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9. ABSTRACT

This volume of eighteen selected papers dealing with industrial pollution is the fourth of five volumes of reading references assembled for use by participants in the IPEAID seminar conducted at the University of North Carolina in March and April of 1975. The subject matters of the five volumes are, respectively: Environmental Planning; Water Quality Management--Solid Wastes; Air Quality Management; Industrial Pollution; Resources and the Environment. The papers in this fourth volume:

Amdur, Mary O. Industrial toxicology.
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Barnes, E. C. Ionizing radiation.
Barnes, G. E. Plating and metal finishing.
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Principles of industrial toxicology.
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INDUSTRIAL POLLUTION

VOLUME 4 OF 5

Assembled By

F. Eugene McJunkin

International Program in Environmental

Aspects of Industrial Development

Department of Environmental Sciences and Engineering

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Chapel Hill, N.C. 27514

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INTERNATIONAL ENVIRONMENTAL PROGRAMS AT THE UNIVERSITY OF NORTH CAROLINA

The Department of Environmental Sciences and Engineering at the University of North Carolina has a long standing interest and involvement in international activities and programs concerned with environmental quality and, in particular, with the environmental problems of developing countries. Departmental activities have included special educational programs, on campus and abroad, long and short term; technical assistance; research and development; information transfer, including publications; and consulting and service activities by faculty and staff. These programs have included the International Program in Sanitary Engineering Design, the AID Engineers' Environmental Program, the International Program in Environmental Aspects of Industrial Development, the publication series Water Supply and Sanitation in Developing Countries, technical assistance to several overseas universities, and numerous technical studies.

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CHAPTER 7

INDUSTRIAL TOXICOLOGY

Mary O. Amdur, Ph.D.

INTRODUCTION

Toxicology is the study of the nature and action of poisons. The term is derived from a Greek word referring to the poison in which arrows were dipped. Mythology, legend and history indicate the growth of toxicological knowledge. The early emphasis was on ways to poison people. The 19th century saw the development of tests for identification of various poisons, such as the Marsh test for arsenic. These found use in legal medicine and criminology, the area known as forensic toxicology. Since about 1900, there has been increasing social concern for the health of workers exposed to a diversity of chemicals. This has led to intensive investigations of the toxicity of these materials in order that proper precautions may be taken in their use. This is the area of industrial toxicology which concerns us here.

Some industrial hazards have been known for centuries. For example, clinical symptoms of lead poisoning were accurately described in the 1st century A.D. The Romans used only slave labor in the great Spanish mercury mines at Almaden, and a sentence to work there was considered equivalent to a sentence of death. French hatters of the 17th century discovered that mercuric nitrate aided greatly in the felting of fur. Such use led to chronic mercury poisoning so widespread among members of that trade that the expression "mad as a hatter" entered our folk language. Exposure to other hazardous substances is an outgrowth of modern technology. In addition to newly developed chemicals, many materials first synthesized in the late 19th century have found widespread industrial use. The hydrides of boron, for example, have been known since 1879, but the first report on their toxicity appeared in 1951 as a series of case histories of people, mostly young chemical engineers, who had been exposed to boron hydrides in the course of their work.

Toxicological research now has its place in assessing the safety of new chemicals prior to the extension of their use beyond exploratory stages. Information on the qualitative and quantitative actions of a chemical in the body can be used to predict tentative safe levels of exposure as well as to predict the signs and symptoms to be watched for as indicative of excessive exposure. An elucidation of the mechanism of action of the chemical can hopefully lead to rational rather than symptomatic therapy in the event of damage from excessive exposure. Both in the application of newer refined research techniques of toxicology and in his communication of knowledge vital to the public health, the toxicologist considers old as well as new hazardous substances. This point was well made by Henry Smyth[1] who said "Most people are careful in handling a new chemical whether or not they have been warned specifically of its possible toxicity. Despite the potential hazards of hundreds of new chemicals each year, most injuries from chemicals are due to those which have been familiar for a generation or more. It is important for the perspective of the toxicologist that he keep this fact well to the forefront of his mind. He must not neglect talking about the hazards of the old standbys, lead, benzene and chlorinated hydrocarbons just because this week he discovered the horrifying action of something brand new. Part of his responsibility is a continuing program of communication aimed at informing everyone of the means required to handle safely any chemical whatsoever."

DISCIPLINES INVOLVED IN INDUSTRIAL TOXICOLOGY

In order to assess the potential hazard of a substance to the health of workers industrial toxicology draws perforce on the expertise of many disciplines.

Chemistry: The chemical properties of a compound can often be one of the main factors in its toxicity. The vapor pressure indicates whether or not a given substance has the potential to pose a hazard from inhalation. The solubility of a substance in aqueous and lipid media is a guiding factor in determining the rate of uptake and excretion of inhaled substances. The toxicologist needs to determine the concentration of toxic agents in air and in body organs and fluids. It is important to know if a substance is, for example, taken up by the liver, stored in the bones, or rapidly excreted. For this, analytical methods are needed which are both sensitive and specific.

Biochemistry: The toxicologist needs knowledge of the pathways of metabolism of foreign compounds in the body. Such information can serve as the basis for monitoring the exposure of workmen, as for example the assessment of benzene exposure by the analysis of phenol in the urine. Differences in metabolic pathways among animal species form one basis for selective toxicity. Such knowledge is useful, for example, in developing compounds that will be maximally toxic to insects and minimally so to other species. Such knowledge can also serve as a guide in the choice of a species of experimental animal with a metabolic pathway similar to that of man for studies which will be extrapolated to predict safe levels for human exposure. Rational therapy for injury from

toxic chemicals has as its basis an understanding of the biochemical lesion they produce. One outstanding example is the development of B.A.L. (British Anti-Lewisite, 1,2-dimercaptopropanol) which arose from studies of the inhibition of sulfhydryl enzymes and the manner of binding of arsenic to these enzymes. This led to the use of B.A.L. in therapy for industrial poisons (such as mercury) which interfere with sulfhydryl enzymes. Studies of the nature of the reaction of organic phosphorus esters with the enzyme acetylcholine esterase led to the development of 2-PAM (2-pyridine aldoxime methiodide) which reverses the inhibition of the enzyme. In conjunction with atropine, 2-PAM provides rational therapy for treatment of poisoning by these compounds. In the important area of joint toxic action, understanding comes from elucidation of biochemical action. If, for example, Compound A induces enzymes which serve to detoxify Compound B, the response to the combination may be less than additive. On the other hand, if Compound A should act to inhibit the enzyme that serves to detoxify Compound B then the response may be more than additive.

Physiology: The toxicologist obviously needs to know something of the normal functioning of organ systems. Modern toxicology is moving more and more towards the search for means to detect reversible physiological changes produced by concentrations of toxic substances too low to produce irreversible histological damage or death in experimental animals. Measurement of increases in pulmonary flow-resistance has proved a sensitive tool for assessing the response to irritant gases and aerosols. Tests of pulmonary function can be used to assess response of workmen to industrial environments. Renal clearance and other kidney function tests can serve to detect renal damage. The effects of exercise or nonspecific stress on the degree of response to toxic chemicals is another important research area in modern toxicology.

Pathology: The toxicologist is concerned with gross and histological damage caused by toxic substances. Most toxicological studies include a thorough pathological examination which may include examination of subcellular structure by electron microscopy.

Immunology and Immunochemistry: It is recognized that immunology and immunochemistry constitute an important area for investigation in industrial toxicology. The response to many chemicals, especially inhaled products of biologic origin, has as its basis the immune reaction.

Physics and Engineering: The toxicologist who is concerned with inhalation as the route of exposure needs some knowledge of physics and engineering in order to establish controlled concentrations of the substances he studies. If the toxic materials are to be administered as airborne particles, knowledge is needed of methods of generation of aerosols and methods of sampling and sizing appropriate to the material studied. Without careful attention to these factors, toxicological studies are of limited value. An understanding of the factors governing penetration, deposition, retention and clearance of particulate material from the respiratory tract requires knowledge of both the physical laws governing aerosol behavior and the anatomy and physiology of the respiratory tract. The growing interest in prolonged exposure to closed atmospheres encountered in manned space travel or deep sea exploration has led to experimental studies involving round-the-clock exposures of experimental animals for long periods. Such studies raise additional engineering problems above and beyond those of maintaining the more conventional exposure chambers.

Statistics: Statistics are used in the analysis of data and in the establishing of an experimental design that will yield the maximum of desired information with the minimum of wasted effort. The toxicologist relies heavily on statistics, as the calculation of the LD_{50} (Lethal Dose — 50% probable) is a statistical calculation. Experimental studies of joint toxicity are planned in accord with established statistical designs.

Communication: The ultimate aim of the toxicologist is (or should be) the prevention of damage to man and the environment by toxic agents. One important function is the distribution of information in such terms that the people in need of the information will understand it. The toxicologist's responsibility does not end with the publication of his research results in a scientific journal for the erudition of his peers. He is called upon to make value judgments in extrapolation of his findings in order to advise governmental agencies and others faced with the problem of setting safe levels, be they air pollution standards or Threshold Limit Values for industrial exposure or tolerance levels of pesticide residues in food. In addition to this, when he makes such value judgments, he should above all be honest with himself and with those he advises, that they are value judgments and as such should be subject to frequent review as new knowledge and experience accumulate.

DOSE-RESPONSE RELATIONSHIPS

Experimental toxicology is in essence biological assay with the concept of a dose-response relationship as its unifying theme. The potential toxicity (harmful action) inherent in a substance is manifest only when that substance comes in contact with a living biological system. A chemical normally thought of as "harmless" will evoke a toxic response if added to a biological system in sufficient amount. For example, the inadvertent inclusion of large amounts of sodium chloride in feeding formulae in a hospital nursery led to infant mortality. Conversely, for a chemical normally thought of as "toxic" there is a minimal concentration which will produce no toxic effect if added to a biological system. The toxic potency of a chemical is thus ultimately defined by the relationship between the dose (the amount) of the chemical and the response that is produced in a biological system.

In preliminary toxicity testing, death of the animals is the response most commonly chosen. Given a compound with no known toxicity data,

the initial step is one of range finding. A dose is administered and, depending on the outcome, is increased or decreased until a critical range is found over which, at the upper end, all animals die and, at the lower end, all animals survive. Between these extremes is the range in which the toxicologist accumulates data which enable him to prepare a dose-response curve relating percent mortality to dose administered.

From the dose-response curve, the dose that will produce death in 50 percent of the animals may be calculated. This value is commonly abbreviated as LD_{50}. It is a statistically obtained value representing the best estimation that can be made from the experimental data at hand. The LD_{50} value should always be accompanied by a statement of the error of the estimated value, such as the probability range or confidence limits. The dose is expressed as amount per unit of body weight. The value should be accompanied by an indication of the species of experimental animal used, the route of administration of the compound, the vehicle used to dissolve or suspend the material if applicable, and the time period over which the animals were observed. For example, a publication might state "For rats, the 24 hr. ip LD_{50} for "X" in corn oil was 66 mg/kg (95% confidence limits 59-74)." This would indicate to the reader that the material was given to rats as an intraperitoneal injection of compound X dissolved or suspended in corn oil and that the investigator had limited his mortality count to 24 hours after administering the compound. If the experiment has involved inhalation as the route of exposure, the dose to the animals is expressed as parts per million, mg/m^3, or some other appropriate expression of concentration of the material in the air of the exposure chamber, and the length of exposure time is specified. In this case the term LC_{50} is used to designate the concentration in air that may be expected to kill 50 percent of the animals exposed for the specified length of time. Various procedures have been recommended for the estimation of the LD_{50} or LC_{50}. For information on the more commonly used techniques, papers such as those of Bliss,[2] Miller and Tainter,[3] Litchfield and Wilcoxon[4] or Weil[5] may be consulted.

The simple determination of the LD_{50} for an unknown compound provides an initial comparative index for the location of the compound in the overall spectrum of toxic potency. Table 7-1 shows an attempt at utilizing LD_{50} and LC_{50} values to set up an approximate classification of toxic substances which was suggested by Hodge and Sterner.[6]

Over and above the specific LD_{50} value, the slope of the dose-response curve provides useful information. It suggests an index of the margin of safety, that is the magnitude of the range of doses involved in going from a non-effective dose to a lethal dose. It is obvious that if the dose-response curve is very steep, this margin of safety is slight. Another situation may arise in which one compound would be rated as "more toxic" than a second compound if the LD_{50} values alone were compared but the reverse assessment of relative toxicity would be reached if the comparison was made of the LD_5 values for the two compounds because the dose-response curve for the second compound had a more gradual slope. It should thus be apparent that the slope of the dose-response curves may be of considerable significance with respect to establishing relative toxicities of compounds. For an excellent non-mathematical discussion of the underlying concepts of dose-response relationships, Chapter 2 of Loomis[7] is well worth reading.

TABLE 7-1
Toxicity Classes

Toxicity Rating	Descriptive Term	LD_{50}-Wt/kg Single oral dose Rats	4 hr Inhalation LC_{50} — PPM Rats
1	Extremely toxic	1 mg or less	<10
2	Highly toxic	1-50 mg	10-100
3	Moderately toxic	50-500 mg	100-1,000
4	Slightly toxic	0.5-5 g	1,000-10,000
5	Practically non-toxic	5-15 g	10,000-100,000
6	Relatively harmless	15 g or more	>100,000

By similar experiments dose-response curves may be obtained using a criterion other than mortality as the response and an ED_{50} value is obtained. This is the dose which produced the chosen response in 50 percent of the treated animals. When the study of a toxic substance progresses to the point at which its action on the organism may be studied as graded response in groups of animals, dose-response curves of a slightly different sort are generally used. One might see for example, a dose-response curve relating the degree of depression of brain choline esterase to the dose of an organic phosphorus ester or a dose-response curve relating the increase in pulmonary flow-resistance to the concentration of sulfur dioxide inhaled.

ROUTES OF EXPOSURE

Toxic chemicals can enter the body by various routes. The most important route of exposure in industry is inhalation. Next in importance is contact with skin and eyes. The response to a given dose of toxic agent may vary markedly depending on the route of entry. A cardinal principle to remember is that *the intensity of toxic action is a function of the concentration of the toxic agent which reaches the site of action.* The route of exposure can obviously have an influence upon the concentration reaching the site of action.

Parenteral: Aside from the obvious use in administration of drugs, injection is considered mainly as a route of exposure of experimental animals. In the case of injection, the dose administered is known with accuracy. Intravenous (iv) injection introduces the material directly into the circulation, hence comparison of the degree of response to iv injection with the response to the dose administered by another route can provide information on the rate of uptake of the material by the alternate route. When a material is administered

by injection, the highest concentration of the toxic material in the body occurs at the time of entrance. The organism receives the initial impact at the maximal concentration without opportunity for a gradual reaction, whereas if the concentration is built up more gradually by some other route of exposure, the organism may have time to develop some resistance or physiological adjustment which could produce a modified response. In experimental studies intraperitoneal (ip) injection of the material into the abdominal fluid is a frequently used technique. The major venous blood circulation from the abdominal contents proceeds via the portal circulation to the liver. A material administered by ip injection is subject to the special metabolic transformation mechanisms of the liver, as well as the possibility of excretion via the bile before it reaches the general circulation. If the LD_{50} of a compound given by ip injection was much higher (i.e., the toxicity is lower) than the LD_{50} by iv injection, this fact would suggest that the material was being detoxified by the liver or that the bile was a major route of excretion of the material. If the values for LD_{50} were very similar for ip and iv injection, it would suggest that neither of these factors played a major role in the handling of that particular compound by that particular species of animal.

Oral: Ingestion occurs as a route of exposure of workmen through eating or smoking with contaminated hands or in contaminated work areas. Ingestion of inhaled material also occurs. One mechanism for the clearance of particles from the respiratory tract is the carrying up of the particles by the action of the ciliated lining of the respiratory tract. These particles are then swallowed and absorption of the material may occur from the gastro-intestinal tract. This situation is most likely to occur with larger size particles (2μ and up)although smaller particles deposited in the alveoli may be carried by phagocytes to the upward moving mucous carpet and eventually be swallowed.

In experimental work, compounds may be administered orally as either a single or multiple dose given by stomach tube or the material may be incorporated in the diet or drinking water for periods varying from several weeks or months up to several years or the lifetime of the animals. In either case, the dose the animals actually receive may be ascertained with considerable accuracy. Except in the case of a substance which has a corrosive action or in some way damages the lining of the gastro-intestinal tract, the response to a substance administered orally will depend upon how readily it is absorbed from the gut. Uranium, for example, is capable of producing kidney damage, but is poorly absorbed from the gut and so oral administration produces only low concentrations at the site of action. On the other hand, ethyl alcohol, which has as a target organ the central nervous system, is very rapidly absorbed and within an hour 90 percent of an ingested dose has been absorbed.

The epithelium of the gastro-intestinal tract is poorly permeable to the ionized form of organic compounds. Absorption of such materials generally occurs by diffusion of the lipid-soluble non-ionized form. Weak acids which are predominately nonionized in the high acidity (pH 1.4) of gastric juice are absorbed from the stomach. The surface of the intestinal mucosa has a pH of 5.3. At this higher pH weak bases are less ionized and more readily absorbed. The pK of a compound (see Chapter 5) thus becomes an important factor in predicting absorption from the gastro-intestinal tract.

Inhalation: Inhalation exposures are of prime importance to the industrial toxicologist. The dose actually received and retained by the animals is not known with the same accuracy as when a compound is given by the routes previously discussed. This depends upon the ventilation rate of the individual. In the case of a gas, it is influenced by solubility and in the case of an aerosol by particle size. The factors that influence the dose of a substance retained in an inhalation exposure will be discussed later. For the moment, suffice it to say that the concentration and time of exposure can be measured accurately and this gives a working estimate of the exposure. Two techniques are sometimes utilized in an attempt to determine the dose with precision and still administer the compound via the lung. One is intratracheal injection which may be used in some experiments in which it is desirable to deliver a known amount of particulate material into the lung. The other is so called "precision gassing." In this technique the animal or experimental subject breathes through a valve system and the volume of exhaled air and the concentration of toxic material in it are determined. A comparison of these data with the concentration in the atmosphere of the exposure chamber gives an indication of the dose retained.

Cutaneous: Cutaneous exposure ranks first in the production of occupational disease, but not necessarily first in severity. The skin and its associated film of lipids and sweat may act as an effective barrier. The chemical may react with the skin surface and cause primary irritation. The agent may penetrate the skin and cause sensitization to repeated exposure. The material may penetrate the skin in an amount sufficient to cause systemic poisoning. In assessing the toxicity of a compound by skin application, a known amount of the material to be studied is placed on the clipped skin of the animal and held in place with a rubber cuff. Some materials such as acids, alkalis and many organic solvents are primary skin irritants and produce skin damage on initial contact. Other materials are sensitizing agents. The initial contact produces no irritant response, but may render the individual sensitive and dermatitis results from future contact. Ethylenediamines and the catechols in the well known members of the Rhus family (poison ivy and poison oak) are examples of such agents. Chapter 34 is devoted to the damaging effects of industrial chemicals on the skin. The physiochemical properties of a material are the main determinant of whether or not a material will be absorbed through the skin. Among the important factors are pH, extent of ionization,

water and lipid solubility and molecular size. Some compounds such as phenol and phenolic derivatives can readily penetrate the skin in amounts sufficient to produce systemic intoxication. If the skin is damaged, the normal protective barrier to absorption of chemicals is lessened and penetration may occur. An example of this is a description of cases of mild lead intoxication that occurred in an operation which involved an inorganic lead salt and also a cutting oil. Inorganic lead salts would not be absorbed through intact skin, but the dermatitis produced by the cutting oil permitted increased absorption.

Ocular: The assessment of possible damage resulting from the exposure of the eyes to toxic chemicals should also be considered. The effects of accidental contamination of the eye can vary from minor irritation to complete loss of vision. In addition to the accidental splashing of substances into the eyes, some mists, vapors and gases produce varying degrees of eye irritation, either acute or chronic. In some instances a chemical which does no damage to the eye can be absorbed in sufficient amount to cause systemic poisoning. The extreme toxicity of fluoroacetate was discovered accidentally in this manner by a group of Polish chemists who tested it for lachrymatory action in a rabbit. They had hoped that fluoroacetate would be as irritating to the eyes as iodoacetic acid. The latter had proved unsuitable for warfare purposes because of the purple cloud of iodine vapor that betrayed its presence when it was exploded in a bomb. Their rabbit showed no signs of eye irritation, but alerted their interest when it had convulsions and died. An excellent reference on ocular effects of toxic chemicals is "Toxicology of the Eye" by Grant.[8]

CRITERIA OF RESPONSE

After the toxic material has been administered by one of the routes of exposure discussed above, there are various criteria the toxicologist uses to evaluate the response. In modern toxicological research, these criteria are oriented whenever possible towards elucidating the mechanisms of action of the material.

Mortality: As has been indicated, the LD_{50} of a substance serves as an initial test to place the compound appropriately in the spectrum of toxic agents. Mortality is also a criterion of response in long term chronic studies. In such studies, the investigator must be certain that the mortality observed was due to the chronic low level of the material he is studying; hence an adequate control group of untreated animals subject to otherwise identical conditions is maintained for the duration of the experiment.

Pathology: By examination of both gross and microscopic pathology of the organs of animals exposed, it is possible to get an idea of the site of action of the toxic agent, the mode of action and the cause of death. Pathological changes are usually observed at dose levels which are below those needed to produce the death of animals. The liver and the kidney are organs particularly sensitive to the action of a variety of toxic agents. In some instances the pathological lesion is typical of the specific toxic agents, for example, the silicotic nodules in the lungs produced by inhalation of free silica or the pattern of liver damage resulting from exposure to carbon tetrachloride and some other hepatotoxins. In other cases the damage may be more diffuse and less specific in nature.

Growth: In chronic studies the effect of the toxic agent on the growth rate of the animals is another criterion of response. Levels of the compound which do not produce death or overt pathology may result in a diminished rate of growth. A record is also made of the food intake. This will indicate whether diminished growth results from lessened food intake or from less efficient use of food ingested. It sometimes happens that when an agent is administered by incorporation into the diet, especially at high levels, the food is unpalatable to the animals and they simply refuse to eat it.

Organ Weight: The weight of various organs, or more specifically the ratio of organ weight to body weight may be used as a criterion of response. In some instances such alterations are specific and explicable, as for example the increase of lung weight to body weight ratio as a measure of the edema produced by irritants such as ozone or oxides of nitrogen. In other instances the increase is a less specific general hypertrophy of the organ, especially of the liver and kidney. In a summary of data from two major industrial toxicology laboratories where a wide variety of compounds had been screened for toxicity,[9] it was pointed out that in using body growth, liver weight and kidney weight as criteria of response, a change in one or more of these was observed at the lowest dose at which any effect was seen in 80 percent of 364 studies. If liver and kidney pathology were included in the list, then a change in one or more criteria was observed at the lowest dose at which any effect was seen in 96 percent of these studies. The other 4 percent included materials with very specific action such as the organophosphorus insecticides which will produce alterations in acetylcholine esterase at very low levels. Such nonspecific increases in organ weight are difficult to interpret and may not of necessity represent a harmful change, but they lower the threshold at which a dose may be termed "no effect."

Physiological Function Tests: Physiological function tests are useful criteria of response both in experimental studies and in assessing the response of exposed workmen. They can be especially useful in chronic studies in that they do not necessitate the killing of the animal and can, if desired, be done at regular intervals throughout the period of study. Tests in common clinical use such as bromsulphalein retention, thymol turbidity, or serum alkaline phosphatase may be used to assess the effect of an agent on liver function. The examination of the renal clearance of various substances helps give an indication of localization of kidney damage. The ability of the kidney (especially in the rat) to produce a concentrated urine may be measured by the osmolality of the urine produced. This has been suggested for the evaluation of alterations in kidney function.[10] Alterations may be detected following inhalation of materials such as chlorotrifluoroethylene at levels of reversi-

ble response. In some instances measurement of blood pressure has proved a sensitive means of evaluating response.[11] Various tests of pulmonary function have been used to evaluate the response of both experimental animals and exposed workmen. These tests include relatively simple tests which are suitable for use in field surveys as well as more complex methods possible only under laboratory conditions. Simple tests include such measurements as peak expiratory flowrate (PEFR), forced vital capacity (FVC), and 1-second forced expiratory volume ($FEV_{1.0}$). More complex procedures include the measurement of pulmonary mechanics (flow-resistance and compliance) and their application in epidemiologic surveys. Information on the effects of various agents on the lungs is discussed in Chapter 33.

Biochemical Studies: The study of biochemical response to toxic agents leads in many instances to an understanding of the mechanism of action. Tests of toxicity developed in animals should be oriented to determination of early response from exposures that are applicable to the industrial scene. Many toxic agents act by inhibiting the action of specific enzymes. This action may be studied *in vitro* and *in vivo*. In the first case, the toxic agent is added to tissue slices or tissue homogenate from normal animals and the degree of inhibition of enzymatic activity is measured by an appropriate technique. In the second case, the toxic agent is administered to the animals; after the desired interval the animals are killed and the degree of enzyme inhibition is measured in the appropriate tissues. A judicious combination of *in vivo* and *in vitro* studies is especially useful when biotransformation to a toxic compound is involved. The classic example of this is the work of Peters[12] on the toxicity of fluoroacetate. This material, which was extremely toxic when administered to animals of various species, did not inhibit any known enzymes *in vitro*. Peters' work demonstrated that fluoroacetate entered the carboxylic acid cycle of metabolism as if it were acetic acid. The product formed was fluorocitrate which was a potent inhibitor of the enzyme aconitase. Biological conversion in the living animal had resulted in the formation of a highly toxic compound. He coined the term "lethal synthesis" to describe such a transformation. An elegant paper by Cremer[13] on the ethyl lead compounds is worth discussing as an example of research techniques in this area. She injected rats with tetra-, tri-, and di-ethyl lead and with lead acetate. Symptoms of excitability, tremors and convulsions were observed in the animals injected with the tetraethyl and triethyl lead but not in the animals injected with diethyl lead or the inorganic lead. The triethyl lead was more potent than the tetraethyl lead, which suggested that perhaps the toxic response resulted from biologically formed triethyl lead. By analytic methods, she was able to demonstrate the presence of triethyl lead in the tissues of animals poisoned with tetraethyl lead. She found *in vitro* that liver preparations were capable of converting tetraethyl lead to triethyl lead. She measured the metabolism of brain slices from animals treated *in vivo* and found that the oxygen consumption was lowered in animals receiving tetraethyl or triethyl lead but not in animals treated with diethyl lead or lead acetate. Turning again to *in vitro* experiments, she measured the oxygen consumption of brain cortex slices from normal animals to which the ethyl lead compounds were added. These experiments showed that tetraethyl lead is without effect and that triethyl lead is the active component.

The fundamentals of the metabolism of toxic compounds are discussed in Chapter 5. The classic reference in the field is *Detoxification Mechanisms* by Williams.[14] The term "biotransformation" is in many ways preferable to "detoxication" for in many instances the toxic moiety may be the metabolic product rather than the compound administered. There are some instances, of course, such as the conversion of cyanide to thiocyanate, which are truly "detoxication" in the strict sense.

Tests for the level of metabolites of toxic agents in the urine have found wide use in industrial toxicology as a means of evaluating exposure of workmen. These are commonly referred to as biologic threshold limits which serve as biologic counterparts to the TLV's. The presence of the metabolic product does not of necessity imply poisoning; indeed the opposite is more commonly the case. Normal values have been established and an increase above these levels indicates that exposure has occurred and thus provides a valuable screening mechanism for the prevention of injury from continued or excessive exposure. Table 7-2 lists some of these metabolic products which have been used to evaluate exposure as well as the agents for which they may be used.

TABLE 7-2
Metabolic Products Useful As Indices Of Exposure

Product in Urine	Toxic Agents
Organic Sulfate	Benzene Phenol Aniline
Hippuric Acid	Toluene Ethyl benzene
Thiocyanate	Cyanate Nitriles
Glucuronates	Phenol Benzene Terpenes
Formic Acid	Methyl alcohol
2, 6, dinitro-4-amino toluene	TNT
p-nitrophenol	Parathion
p-aminophenol	Aniline

There are other instances in which a biochemical alteration produced by the toxic agent is useful as a criterion of evaluating exposure. Lead, for example, interferes in porphyrin metabolism and increased levels of delta aminolevulinic acid may be detected in the urine following lead exposure. Levels of plasma choline esterase may be used to evaluate exposure to organic phosphorus insecticides. Levels of carboxyhemoglobin provide a means of assessing exposure to carbon monoxide. Levels of methemoglobin can be used to evaluate exposure to nitrobenzene or aniline. Hemolysis

Analysis of blood, urine, hair, or nails for various metals is also used to evaluate exposure, though whether these would be termed "biochemical tests" depends somewhat on whether you are speaking with an engineer or a biochemist.

The use of biologic threshold limit values provides a valuable adjunct to the TLV's which are based on air analysis. The analysis of blood, urine, hair, or exhaled air for a toxic material *per se* (e.g., Pb, As) or for a metabolite of the toxic agent (e.g., thiocyanate, phenol) gives an indication of the exposure of an individual worker. These tests represent a very practical application of data from experimental toxicology. Research in industrial toxicology is often oriented towards the search for a test suitable for use as a biologic threshold which will indicate exposure at a level below which damage occurs.

Behavioral Studies: When any toxic agent is administered to experimental animals, the experienced investigator is alert for any signs of abnormal behavior. Such things as altered gait, bizarre positions, aggressive behavior, increased or decreased activity, tremors or convulsions can suggest possible sites of action or mechanisms of action. The ability of an animal to maintain its balance on a rolling bar is a frequently used test of coordination. The loss of learned conditioned reflexes has also been used and by judicious combination of these tests it is possible to determine, for example, that the neurological response to methyl cellosolve differs from the response to ethyl alcohol.[15] Ability to solve problems or make perceptual distinctions has been used on human subjects, especially in an effort to determine the possible effects of low levels of carbon monoxide and other agents which might be expected to interfere with efficient performance of necessary tasks, thus creating a subtle hazard. Effects on neurological variables such as dark adaptation of the eye are much used by Russian investigators in determining threshold limit values.

Reproductive Effects: It is possible that a level of a toxic material can have an effect on either male or female animals which will result in decreased fertility. In fertility studies the chemical is given to males and females in daily doses for the full cycle of oogenesis and spermatogenesis prior to mating. If gestation is established, the fetuses are removed by caesarean section one day prior to delivery. The litter size and viability are compared with untreated groups. The young are then studied to determine possible effects on survival, growth rate and maturation. The tests may be repeated through a second and third litter of the treated animals. If it is considered necessary the test may be extended through the second and third generation.

Teratogenic Effects: Chemicals administered to the pregnant animal may, under certain conditions, produce malformations of the fetus without inducing damage to the mother or killing the fetus. The experience with the birth of many infants with limb anomalies resulting from the use of thalidomide by the mothers during pregnancy alerted the toxicologists to the need for more rigid testing in perhaps in recent times was the teratogenic effect of methyl mercury as demonstrated in the incidents of poisoning in Minamata Bay, Japan. The study of the teratogenic potential poses a very complex toxicological problem. The susceptibility of various species of animal varies greatly in the area of teratogenic effects. The timing of the dose is very critical as a chemical may produce severe malformations of one sort if it reaches the embryo at one period of development and either no malformations or malformations of a completely different character if it is administered at a later or earlier period of embryogenesis. For a discussion of a recommended method of teratogenic testing and a summary of the literature in this area, the paper by Cahen[16] may be consulted.

Carcinogenicity: The study of the carcinogenic effects of a toxic chemical is a complex experimental problem. Such testing involves the use of sizeable groups of animals observed over a period of two years in rats or four to five years in dogs because of the long latent period required for the development of cancer. Efforts to shorten the time lag have led to the use of aging animals. This may reduce the lag period one third to one fourth. Various strains of inbred mice or hamsters are frequently used in such experiments. Quite frequently materials are screened by painting on the skin of experimental animals, especially mice. Industrial experience down through the years has made plain the hazard of cancer from exposure to various chemicals. Among these are many of the polynuclear hydrocarbons, beta-naphylamine which produces bladder cancer, chromates and nickel carbonyl which produce lung cancer. An excellent summary of recent experimental work in the area of the production of lung cancer in experimental animals is given by Kuschner.[17]

The FDA Advisory Committee on Protocols for Safety Evaluation Panel on Carcinogenesis has recently published in the literature their *Report on Cancer Testing in the Safety Evaluation of Food Additives and Pesticides.*[18] The particular emphasis is on testing materials which would come into contact with man principally through the diet, either as food additives or as contaminating residues on food products as in the case of pesticides; however, many fundamental points pertinent to the overall area of experimental testing for carcinogenesis by the toxicologist are raised and thoughtfully discussed. This reference is highly recommended reading. For ubiquitous substances air quality standards must consider contributions from all sources, food and beverages, water, ambient air, and smoking, as well as those from the industrial environment, e.g., asbestos and lead.

FACTORS INFLUENCING INTENSITY OF TOXIC ACTION

Rate of Entry and Route of Exposure: The degree to which a biological system responds to the action of a toxic agent is in many cases markedly influenced by the rate and route of exposure. It has already been indicated that when a substance is administered as an iv injection, the material has maximum opportunity to be carried by the blood

stream throughout the body, whereas other routes of exposure interpose a barrier to distribution of the material. The effectiveness of this barrier will govern the intensity of toxic action of a given amount of toxic agent administered by various routes. Lead, for example, is toxic both by ingestion and by inhalation. An equivalent dose, however, is more readily absorbed from the respiratory tract than from the gastro-intestinal tract and hence produces a greater response.

There is frequently a difference in intensity of response and sometimes a difference even in the nature of the response between the acute and chronic toxicity of a material. If a material is taken into the body at a rate sufficiently slow that the rate of excretion and or detoxification keeps pace with the intake, it is possible that no toxic response will result even though the same total amount of material taken in at a faster rate would result in a concentration of the agent at the site of action sufficient to produce a toxic response. Information of this sort enters into the concept of a threshold limit for safe exposure. Hydrogen sulfide is a good example of a substance which is rapidly lethal at high concentrations as evidenced by the many accidental deaths it has caused. It has an acute action on the nervous system with rapid production of respiratory paralysis unless the victim is promptly removed to fresh air and revived with appropriate artificial respiration. On the other hand, hydrogen sulfide is rapidly oxidized in the plasma to non-toxic substances and many times the lethal dose produces relatively little effect if administered slowly. Benzene is a good example of a material which differs in the nature of response depending on whether the exposure is an acute one to a high concentration or a chronic exposure to a lower level. If one used as criteria the 4 hr LC_{50} for rats of 16,000 ppm which has been reported for benzene, one would conclude (from Table 7-1) that this material would be "practically non-toxic" which, of course, is contrary to fact. The mechanism of acute death is narcosis. Chronic exposure to low levels of benzene on the other hand produces damage to the blood-forming tissue of the bone marrow and chronic benzene intoxication may appear even many years after the actual exposure to benzene has ceased.

Age: It is well known that, in general, infants and the newborn are more sensitive to many toxic agents than are adults of the same species, but this has relatively little bearing on a discussion of industrial toxicology. Older persons or older animals are also often more sensitive to toxic action than are younger adults. With aging comes a diminished reserve capacity in the face of toxic stress. This reserve capacity may be either functional or anatomical. The excess mortality in the older age groups during and immediately following the well known acute air pollution incidents is a case in point. There is experimental evidence from electron microscope studies that younger animals exposed to pollutants have a capacity to repair lung damage which was lost in older animals.[27]

State of Health: Pre-existing disease can result in greater sensitivity to toxic agents. In the case of specific diseases which would contraindicate exposure to specific toxic agents, pre-placement medical examination can prevent possible hazardous exposure. For example, an individual with some degree of pre-existing methemoglobinemia would not be placed in a work situation involving exposure to nitrobenzene. Since it is known that the uptake of manganese parallels the uptake of iron, it would be unwise to employ a person with known iron deficiency anemia as a manganese miner. It has been shown that viral agents will increase the sensitivity of animals to exposure to oxidizing type air pollutants. Nutritional status also affects response to toxic agents.

Previous Exposure: Previous exposure to a toxic agent can lead to either tolerance, increased sensitivity or make no difference in the degree of response. Some toxic agents function by sensitization and the initial exposures produce no observable response, but subsequent exposures will do so. In these cases the individuals who are thus sensitized must be removed from exposure. In other instances if an individual is re-exposed to a substance before complete reversal of the change produced by a previous exposure, the effect may be more dangerous. A case in point would be an exposure to an organophosphorus insecticide which would lower the level of acetylcholine esterase. Given time, the level will be restored to normal. If another exposure occurs prior to this, the enzyme activity may be further reduced to dangerous levels. Previous exposure to low levels of a substance may in some cases protect against subsequent exposure to levels of a toxic agent which would be damaging if given initially. This may come about through the induction of enzymes which detoxify the compound or by other mechanisms often not completely understood. It has been shown, for example, that exposure of mice to low levels of ozone will prevent death from pulmonary edema in subsequent high exposures.[28] There is also a considerable "cross tolerance" among the oxidizing irritants such as ozone and hydrogen peroxide, an exposure to low levels of the one protecting against high levels of the other.

Environmental Factors: Physical factors can also affect the response to toxic agents. In industries such as smelting or steel making, high temperatures are encountered. Pressures different than normal ambient atmospheric pressure can be encountered in caissons or tunnel construction.

Host Factors: For many toxic agents the response varies with the species of animal. There are often differences in the response of males and females to the same agent. Hereditary factors also can be of importance. Genetic defects in metabolism may render certain individuals more sensitive to a given toxic agent.

CLASSIFICATION OF TOXIC MATERIALS

Within the scope of this chapter it is not possible to discuss the specific toxic action of a variety of materials, although where possible specific information has been used to illustrate the principles discussed. It might, however, be useful to consider several ways in which toxic agents may be

classified. No one of these is of itself completely satisfactory. A toxic agent may have its action on the organ with which it comes into first contact. Let us assume for the moment that the agent is inhaled. Materials such as irritant gases or acid mists produce a more or less rapid response from the respiratory tract when present in sufficient concentration. Other agents, such as silica or asbestos, also damage the lungs but the response is seen only after lengthy exposure. Other toxic agents may have no effect upon the organ through which they enter the body, but exert what is called systemic toxic action when they have been absorbed and translocated to the site of biological action. Examples of such agents would be mercury vapor, manganese, lead, chlorinated hydrocarbons and many others which are readily absorbed through the lungs, but produce typical toxic symptoms only in other organ systems.

Physical Classifications: This type of classification is an attempt to base the discussion of toxic agents on the form in which they are present in the air. These are discussed as gases and vapors or as aerosols.

Gases and Vapors: In common industrial hygiene usage the term "gas" is usually applied to a substance which is in the gaseous state at room temperature and pressure and the term "vapor" is applied to the gaseous phase of a material which is ordinarily a solid or a liquid at room temperature and pressure. In considering the toxicity of a gas or vapor, the solubility of the material is of the utmost importance. If the material is an irritant gas, solubility in aqueous media will determine the amount of material that reaches the lung and hence its site of action. A highly soluble gas, such as ammonia, is taken up readily by the mucous membranes of the nose and upper respiratory tract. Sensory response to irritation in these areas provides the individual with warning of the presence of an irritant gas. On the other hand, a relatively insoluble gas such as nitrogen dioxide is not scrubbed out by the upper respiratory tract, but penetrates readily to the lung. Amounts sufficient to lead to pulmonary edema and death may be inhaled by an individual who is not at the time aware of the hazard. The solubility coefficient of a gas or vapor in blood is one of the factors determining rate of uptake and saturation of the body. With a very soluble gas, saturation of the body is slow, is largely dependent upon ventilation of the lungs and is only slightly influenced by changes in circulation. In the case of a slightly soluble gas, saturation is rapid, depends chiefly on the rate of circulation and is little influenced by the rate of breathing. If the vapor has a high fat solubility, it tends to accumulate in the fatty tissues which it reaches carried in the blood. Since fatty tissue often has a meager blood supply, complete saturation of the fatty tissue may take a longer period. It is also of importance whether the vapor or gas is one which is readily metabolized. Conversion to a metabolite would tend to lower the concentration in the blood and shift the equilibrium towards increased uptake. It is also of importance whether such metabolic products are toxic. For a discussion of the interplay of factors relating to the uptake of gases and vapors, Chapter 5 of Henderson and Haggard[21] or Chapter 6 of Patty[22] should be consulted.

Aerosols: An aerosol is composed of solid or liquid particles of microscopic size dispersed in a gaseous medium (for our purposes, air). Special terms are used for indicating certain types of particles. Some of these are: "dust", a dispersion of solid particles usually resulting from the fracture of larger masses of material such as in drilling crushing or grinding operations; "mist", a dispersion of liquid particles, many of which are visible; "fog", visible aerosols of a liquid formed by condensation; "fume", an aerosol of solid particles formed by condensation of vaporized materials; "smoke", aerosols resulting from incomplete combustion which consist mainly of carbon and other combustible materials. The toxic response to an aerosol depends obviously on the nature of the material, which may have as a target organ the respiratory system or may be a systemic toxic agent acting elsewhere in the body. In either case, the toxic potential of a given material dispersed as an aerosol is only partially described by a statement of the concentration of the material in terms of weight per unit volume or number of particles per unit volume. For a proper assessment of the toxic hazard, it is necessary to have information also on the particle size distribution of the material. Understanding of this fact has led to the development of instruments which sample only particles in the respirable size range. Chapters 13 and 14 discuss analytical methods for obtaining the needed data. The particle size of an aerosol is the key factor in determining its site of deposition in the respiratory tract and, as a sequel to this, the clearance mechanisms which will be available for its subsequent removal. The deposition of an aerosol in the respiratory tract depends upon the physical forces of impaction, settling, and diffusion or Brownian movement which apply to the removal of any aerosol from the atmosphere, as well as upon anatomical and physiological factors such as the geometry of the lungs and the air-flow rates and patterns occurring during the respiratory cycle. The interrelationship of these factors has been examined both theoretically and experimentally. The monograph by Hatch and Gross, "Pulmonary Deposition and Retention of Inhaled Aerosols"[23] gives an excellent discussion of the subject and should be required reading for anyone entering the field of environmental toxicology. The most recent theoretical treatment is that of the Task Force on Lung Dynamics[24] which also gives an excellent summary of past work.

In the limited space available only one point will be emphasized here, namely, the toxicological importance of particles below 1 μm in size. Aerosols in the range of 0.2-0.4 μm tend to be fairly stable in the atmosphere. This comes about because they are too small to be effectively removed by forces of settling or impaction and too big to be effectively removed by diffusion. Since these are the forces that lead to deposition in the respiratory tract, it has been predicted theoretically and confirmed experimentally that a lesser *percentage* of these particles is deposited in the respiratory tract.

On the other hand, since they are stable in the atmosphere, there are large numbers of them present to be inhaled, and to dismiss this size range as of minimal importance is an error in toxicological thinking which should be corrected whenever it is encountered. Aerosols in the size range below 0.1μm are also of major toxicological importance. The percentage deposition of these extremely small particles is as great as for 1μm particles and this deposition is alveolar. This fact was predicted theoretically by Findeisen as far back as 1935[25] and has been confirmed experimentally.[26] Particles in the sub-micron range also appear to have greater potential for interaction with irritant gases, a fact which is of importance in air pollution toxicology.

Chemical Classification: Toxic compounds may be classified according to their chemical nature. Volume II of Patty[22] is so structured and is an excellent practical reference. *Industrial Toxicology* by Hamilton and Hardy[27] is also arranged more or less according to the chemical classification. Since both of the authors were distinguished as industrial physicians (the late Dr. Alice Hamilton being one of the pioneers in that area), the book is more oriented to medical signs and symptoms than towards experimental toxicology. Several more specialized works deal with certain types of chemical compounds. Among these may be included Browning's *Toxicity of Industrial Metals*[28] and *Toxicity and Metabolism of Industrial Solvents*[29] and Gerarde's *Toxicology and Biochemistry of Aromatic Hydrocarbons*.[30]

Physiological Classification: Such classification attempts to frame the discussion of toxic materials according to their biological action. Most such systems (including the present one) have as their basis the now classic scheme proposed by Henderson and Haggard.[21]

Irritants: The basis of classifying these materials is their ability to cause inflammation of mucous membranes with which they come in contact. While many irritants are strong acids or alkalis familiar as corrosive to non-living things such as lab coats or bench tops, bear in mind that inflammation is the reaction of a living tissue and is distinct from chemical corrosion. The inflammation of tissue results from concentrations far below those needed to produce corrosion. As was indicated earlier in discussing gases and vapors, solubility is an important factor in determining the site of irritant action in the respiratory tract. Highly soluble materials such as ammonia, alkaline dusts and mists, hydrogen chloride and hydrogen fluoride affect mainly the upper respiratory tract. Other materials of intermediate solubility such as the halogens, ozone, diethyl or dimethyl sulfate and phosphorus chlorides affect both the upper respiratory tract and the pulmonary tissue. Insoluble materials such as nitrogen dioxide, arsenic trichloride, or phosgene affect primarily the lung. There are exceptions to the statement that solubility serves to indicate site of action. One such is ethyl ether and other insoluble compounds that are readily absorbed unaltered from the alveoli and hence do not accumulate in that area. In the upper respiratory passages and bronchi where the material is not readily absorbed, it can accumulate in concentrations sufficient to produce irritation. Another exception is in materials such as bromobenzyl cyanide which is a vapor from a liquid boiling well above room temperature. It is taken up by the eyes and skin as a mist. In initial action, then, it is a powerful lachrymator and upper respiratory irritant, rather than producing a primarily alveolar reaction as would be predicted from its low solubility.

Irritants can also cause changes in the mechanics of respiration such as increased pulmonary flow-resistance or decreased compliance (a measure of elastic behavior of the lungs). One group of irritants among which are sulfur dioxide, acetic acid, formaldehyde, formic acid, sulfuric acid, acrolein and iodine produce a pattern in which the flow-resistance is increased, the compliance is decreased only slightly and at higher concentrations the frequency of breathing is decreased. Another group among which are ozone and oxides of nitrogen have little effect on resistance, produce a decrease in compliance and an increase in respiratory rate. There is evidence that in the case of irritant aerosol, the irritant potency of a given material tends to increase with decreasing particle size[31] as assessed by the increase in flow-resistance. Following respiratory mechanics measurements in cats exposed to irritant aerosols, the histologic sections prepared after rapid freezing of the lungs showed the anatomical sites of constriction.[32] Long term chronic lung impairment may be caused by irritants either as sequelae to a single very severe exposure or as the result of chronic exposure to low concentrations of the irritant. There is evidence in experimental animals that long term exposure to respiratory irritants can lead to increased mucous secretion and a condition resembling the pathology of human chronic bronchitis without the intermediary of infection.[33, 34] The epidemiological assessment of this factor in the health of residents of polluted urban atmospheres is currently a vital area of research.

Irritants are usually further subdivided into primary and secondary irritants. A primary irritant is a material which for all practical purposes exerts no systemic toxic action either because the products formed on the tissues of the respiratory tract are nontoxic or because the irritant action is far in excess of any systemic toxic action. Examples of the first type would be hydrochloric acid or sulfuric acid. Examples of the second type would be materials such as Lewisite or mustard gas, which would be quite toxic on absorption but death from the irritation would result before sufficient amounts to produce systemic poisoning would be absorbed. Secondary irritants are materials which do produce irritant action on mucous membranes, but this effect is overshadowed by systemic effects resulting from absorption. Examples of materials in this category are hydrogen sulfide and many of the aromatic hydrocarbons and other organic compounds. The direct contact of liquid aromatic hydrocarbons with the lung can cause chemical pneumonitis with pulmonary edema, hemorrhage and tissue necrosis. It is for

this reason that in the case of accidental ingestion of these materials the induction of vomiting is contraindicated because of possible aspiration of the hydrocarbon into the lungs.

Asphyxiants: The basis of classifying these materials is their ability to deprive the tissue of oxygen. In the case of severe pulmonary edema caused by an irritant such as nitrogen dioxide or laryngeal spasm caused by a sudden severe exposure to sulfuric acid mist, the death is from asphyxia, but this results from the primary irritant action. The materials we classify here as asphyxiants do not damage the lung. Simple asphyxiants are physiologically inert gases which act when they are present in the atmosphere in sufficient quantity to exclude an adequate oxygen supply. Among these are such substances as nitrogen, nitrous oxide, carbon dioxide, hydrogen, helium and the aliphatic hydrocarbons such as methane and ethane. All of these gases are not chemically unreactive and among them are many materials which pose a major hazard of fire and explosion. Chemical asphyxiants are materials which have as their specific toxic action rendering the body incapable of utilizing an adequate oxygen supply. They are thus active in concentrations far below the level needed for damage from the simple asphyxiants. The two classic examples of chemical asphyxiants are carbon monoxide and cyanides. Carbon monoxide interferes with the transport of oxygen to the tissues by its affinity for hemoglobin. The carboxy-hemoglobin thus formed is unavailable for the transport of oxygen. All aspects of current research on carbon monoxide were the subject of a recent conference of the New York Academy of Sciences and the monograph resulting from this meeting is an excellent reference.[35] Over and above the familiar lethal effects, there is concern about how low level exposures will affect performance of such tasks as automobile driving, etc. In the case of cyanide, there is no interference with the transport of oxygen to the tissues. Cyanide transported to the tissues forms a stable complex with the ferric iron of ferric cytochrome oxidase resulting in inhibition of enzyme action. Since aerobic metabolism is dependent upon this enzyme system, the tissues are unable to utilize the supply of oxygen, and tissue "hypoxia" results. Therapy is directed towards the formation of an inactive complex before the cyanide has a chance to react with the cytochrome. Cyanide will complex with methemoglobin so nitrite is injected to promote the formation of methemoglobin. Thiosulfate is also given as this provides the sulfate needed to promote the enzymatic conversion of cyanide to the less toxic thiocyanate.

Primary Anesthetics: The main toxic action of these materials is their depressant effect upon the central nervous system, particularly the brain. The degree of anesthetic effect depends upon the effective concentration in the brain as well as upon the specific pharmacologic action. Thus, the effectiveness is a balance between solubility (which decreases) and pharmacological potency (which increases) as one moves up a homologous series of compounds of increasing chain length. The anesthetic potency of the simple alcohols also rises with increasing number of carbon atoms through amyl alcohol which is the most powerful of the series. The presence of multiple hydroxyl groups diminishes potency. The presence of carboxyl groups tends to prevent anesthetic activity which is slightly restored in the case of an ester. Thus acetic acid is not anesthetic, ethyl acetate is mildly so. The substitution of a halogen for a hydrogen of the fatty hydrocarbons greatly increases the anesthetic action, but confers toxicity to other organ systems which outweighs the anesthetic action.

Hepatotoxic Agents: These are materials which have as their main toxic action the production of liver damage. Carbon tetrachloride produces severe diffuse central necrosis of the liver. Tetrachloroethane is probably the most toxic of the chlorinated hydrocarbons and produces acute yellow atrophy of the liver. Nitrosamines are capable of producing severe liver damage. There are many compounds of plant origin such as some of the toxic components of the mushroom Amanita phalloides, alkaloids from Senecio, and aflatoxins which are capable of producing severe liver damage and in some instances are powerful hepatocarcinogens.

Nephrotoxic Agents: These are materials which have as their main toxic action the production of kidney damage. Some of the halogenated hydrocarbons produce damage to the kidney as well as to the liver. Uranium produces kidney damage, mostly limited to the distal third of the proximal convoluted tubule.

Neurotoxic Agents: These are materials which in one way or another produce their main toxic symptoms on the nervous system. Among them are metals such as manganese, mercury and thallium. The central nervous system seems particularly sensitive to organometallic compounds, and neurological damage results from such materials as methylmercury and tetraethyl lead. Trialkyl tin compounds may cause edema of the central nervous system. Carbon disulfide acts mainly on the nervous system. The organic phosphorus insecticides lead to an accumulation of acetyl choline because of the inhibition of the enzyme which would normally remove it and hence cause their main symptoms in the nervous system.

Agents which act on the blood or hematopoietic system: Some toxic agents such as nitrites, aniline and toluidine convert hemoglobin to methemoglobin. Nitrobenzene forms methemoglobin and also lowers the blood pressure. Arsine produces hemolysis of the red blood cells. Benzene damages the hematopoietic cells of the bone marrow.

Agents which damage the lung: In this category are materials which produce damage of the pulmonary tissue but not by immediate irritant action. Fibrotic changes are produced by materials such as free silica which produces the typical silicotic nodule. Asbestos also produces a typical damage to lung tissue and there is newly aroused interest in this subject from the point of view of possible effects of low level exposure of individuals who are not asbestos workers. Asbestosis was the subject of a recent conference of the New York Academy of Sciences and the papers in the re-

sulting monograph present the various aspects of current research in the area.[36] Other dusts, such as coal dust, can produce pneumoconiosis which, with or without tuberculosis super-imposed, has been of long concern in mining. Drinker and Hatch[37] is a classic reference in this area and Hunter[38] discusses at length occupational exposures to dusts. Many dusts of organic origin such as those arising in the processing of cotton or wood can cause pathology of the lungs and/or alterations in lung function. The proteolytic enzymes added to laundry products are an occupational hazard of current interest. Toluenediisocyanate (TDI) is another material which can cause impaired lung function at very low concentrations and there is evidence of chronic as well as acute effects.[39] Chapter 33 discusses materials in this category.

References

1. SMYTH, H. F., JR.: "The Communication Lines and Problems of a Toxicology Laboratory Working for Industry." *Arch. Indust. Health, 15*: 269 (1957).
2. BLISS, C. I.: "The Determination of the Dosage-Mortality Curve from Small Numbers." *Quart. J. Pharm. and Pharmacol. 11*: 192 (1938).
3. MILLER, L. C. and M. L. TAINTER: "Estimation of the ED50 and Its Error by Means of Logarithmic-Probit Graph Paper." *Proc. Soc. Exptl. Biol. and Med. 57*: 261 (1944).
4. LITCHFIELD, J. T., JR. and F. WILCOXON: "Simplified Method of Evaluating Dose-Effect Experiments." *J. Pharmacol. 96*: 99 (1949).
5. WEIL, C. S.: "Tables for Convenient Calculation of Median-Effective Dose (LC or ED) and Instruction in Their Use." *Biometrics 8*: 249 (1952).
6. HODGE, H. C. and J. H. STERNER: "Tabulation of Toxicity Classes." *Am. Indust. Hyg. Quart. 10*: 93 (1949).
7. LOOMIS, T. A.: *Essentials of Toxicology*, Chapt. 2, "*Numbers in Toxicology*," Lea and Febiger, Philadelphia (1968).
8. GRANT, W. M.: *Toxicology of the Eye*, Charles C. Thomas, Springfield, Illinois (1962).
9. ROWE, V. K., M. A. WOLF, C. S. WEIL and H. F. SMYTH, JR.: "The Toxicological Basis of Threshold Limit Values. 2. Pathological and Biochemical Criteria." *Am. Indust. Hyg. Assoc. J. 20*: 346 (1959).
10. ZAPP, J. A.: The Toxicological Basis of Threshold Limit Values. 3. Physiological Criteria. *Am. Indust. Hyg. Assoc. J. 20*: 350 (1959).
11. FERRIS, B. G., JR.: "Use of Pulmonary Function Tests in Epidemiologic Surveys." *Bull. Physio-Path. Resp. 6*: 579 (1970).
12. PETERS, R. A.: Lethal Synthesis. *Proc. Royal Soc. B. 139*: 143 (1952).
13. CREMER, J.: "Biochemical Studies on the Toxicity of Tetraethyl Lead and Other Organo-lead Compounds." *Brit. J. Indust. Med. 16*: 191 (1959).
14. WILLIAMS, R. T.: *Detoxication Mechanisms*. John Wiley and Sons, New York, (1959).
15. GOLDBERG, M. E., C. HAHN and H. F. SMYTH, JR.: "Implication of Altered Behavior Induced by an Industrial Vapor." *Tox. Appl. Pharm. 4*: 148 (1962).
16. CAHEN, R. L.: "Evaluation of the Teratogenicity of Drugs." *Clin. Pharmacol. Therap. 5*: 480 (1964).
17. KUSCHNER, M.: The J. Burns Amberson Lecture: "The Causes of Lung Cancer." *Am. Rev. Resp. Dis. 98*: 573 (1968).
18. FOOD AND DRUG ADMINISTRATION ADVISORY COMMITTEE ON PROTOCOLS FOR SAFETY EVALUATION. Panel on Carcinogenesis. "Report on Cancer Testing in the Safety Evaluation of Food Additives and Pesticides." *Tox. Appl. Pharm. 20*: 419 (1971).
19. WAYNE, L. G. and L. A. CHAMBERS: "Biological Effects of Urban Pollution." Arch. Environ. Health 16: 871 (1968).
20. STOKINGER, H. E. and L. D. SCHEEL: "Ozone Toxicity. Immunochemical and Tolerance Producing Aspects." *Arch. Env. Health 4*: 327 (1962).
21. HENDERSON, Y. and H. W. HAGGARD: *Noxious Gases*, Chapter 5, Reinhold, N.Y. (1943).
22. PATTY, F. A.: *Industrial Hygiene and Toxicology*, 2nd Ed. Interscience, N.Y. (1958).
23. HATCH, T. F. and P. GROSS: *Pulmonary Deposition and Retention of Inhaled Aerosols*. Academic Press, N.Y. (1964).
24. TASK GROUP ON LUNG DYNAMICS "Deposition and Retention Models for Internal Dosimetry of the Human Respiratory Tract." Hlth. Physics *12*: 173 (1966).
25. FINDEISEN, W.: "Über das Absetzen Kleiner in der Luft suspendierten Teilchen in der menoshlichen Lunge bei der Atmung." *Arch. Ges. Physiol. 236*: 367 (1935).
26. MORROW, P. E. and F. R. GIBB: "The Deposition of a Submicronic Aerosol in the Respiratory Tract of Dogs." *Am. Indust. Hyg. Assoc. J. 19*: 196 (1958).
27. HAMILTON, A. and H. E. HARDY: *Industrial Toxicology*, 2nd Ed. Hoeber, N.Y. (1949).
28. BROWNING, E.: *Toxicity of Industrial Metals*, Butterworths, London (1961).
29. BROWNING, E.: *Toxicity and Metabolism of Industrial Solvents*, Elsevier, N.Y. (1965).
30. GERARDE, H. W. *Toxicology and Biochemistry of Aromatic Hydrocarbons*, Elsevier, N.Y. (1960).
31. AMDUR, M. O. and M. CORN: "The Irritant Potency of Zinc Ammonium Sulfate of Different Particle Sizes." *Am. Indust. Hyg. Assoc. J. 24*: 326 (1963).
32. NADEL, J. A., M. CORN, S. ZWI, J. FLESCH and P. GRAF: "Location and Mechanism of Airway Constriction After Inhalation of Histamine Aerosol and Inorganic Sulfate Aerosol." *Inhaled Particles and Vapors* II Ed. C. N. Davies Pergamon Press p. 55, Oxford (1967).
33. RIED, L.: "An Experimental Study of Hypersecretion of Mucus in the Bronchial Tree." *Brit. J. Exp. Pathol. 44*: 437 (1963).
34. DAHLHAMN, T.: "Mucous Flow and Ciliary Activity in Trachea of Healthy Rats and Rats Exposed to Respiratory Irritant Gases." *Acta. Physiol. Scand. 36*: Supp. No. 123 (1952).
35. COBURN, R. F. (Editor): "Biological Effects of Carbon Monoxide." *Ann. N.Y. Acad. Sci. 174*: Art. 1, 430 pp. (1970).
36. WHIPPLE, H. E. (Editor): "Biological Effects of Asbestos." *Ann. N.Y. Acad. Sci. 132*: Art. 1, 766 pp. (1965).
37. DRINKER, P. and T. HATCH: *Industrial Dust*, 2nd Ed. McGraw-Hill, N.Y. (1954).
38. HUNTER, D.: *The Diseases of Occupations*, 4th Ed. Little, Brown & Co., Boston (1969).
39. PETERS, J. M.: "Cumulative Pulmonary Effects in Workers Exposed to Toluene Disocyanate." *Proc. Royal Soc. Med. 63*: 372 (1970).

Preferred Reading: Books

1. BOYLAND, E., R. GOULDING, *Modern Trends in Toxicology*, Appleton - Century - Crofts, N. Y. C. (1968).
2. BROWNING, E., *Toxicity of Industrial Metals*, Butterworths, London (1961) and *Toxicity and Metabolism of Industrial Solvents*, Elsevier, N.Y. (1960). Extremely comprehensive and well referenced in their specific areas.

3. *Elsevier Monographs on Toxic Agents.* This series was edited by the late Ethel Browning. They are available in paper back editions. They deal with specific materials i.e., Beryllium, Arsenic, Aromatic Hydrocarbons, Vanadium, Aromatic Amines, etc. A list of the ones in print should be obtainable from Elsevier Publishing Co., 52 Vanderbilt Ave., New York, N.Y.
4. HAMILTON, A. and H. E. HARDY, *Industrial Toxicology*, 2nd Ed., Hoeber, N.Y. (1949).
5. HATCH, T. F. and P. GROSS, *Pulmonary Deposition and Retention of Inhaled Aerosols*, Academic Press, N.Y. (1964). Available in paper back. An excellent reference.
6. LOOMIS, T. A., *Essentials of Toxicology*, Lea & Febiger, Phila. (1968).
7. NIOSH, *Toxic Substance List*, Cincinnati, Ohio (1971).
8. PATTY, F. A., *Industrial Hygiene and Toxicology* Vol. I and II 2nd Ed. Interscience, N.Y. (1958). Probably the best practical reference for industrial toxicology.
9. SUNSHINE, I., *Handbook of Analytic Toxicology*, Ed., Chem. Rubber Co., Cleveland, Ohio (1971).
10. STOKINGER, H., ED., *Beryllium: Its Industrial Hygiene Aspects*, Acad. Press, N.C.Y. (1966).
11. GERARDE, H. W., *Toxicology and Biochemistry of Aromatic Hydrocarbons*, Elsevier, New York (1960).
12. HENDERSON and HAGGARD, *Noxious Gases*, Reinhold, N.Y. (1943).

Journals: (English)

A.M.A. Archives of Environmental Health; American Industrial Hygiene Association Journal and The British Journal of Industrial Medicine have many articles on industrial toxicology.

Journals: (Foreign)

Medicina del Lavoro — Italian

Archives des Maladies Professionelles — French

Gigiena i Sanitariya — Russian (Translation Available)

Pracovni lekarstvi (Czechoslovakian)

Japanese Journal of Labor Science

Abstracts:

Chemical Abstracts

Exerpta Medica Abstracts in Occupational Health and Industrial Medicine

Bulletin of Hygiene (British)

Scientific Reports on Industrial Hygiene and Occupational Diseases in Czechoslovakia (Published Annually by Inst. of Indust. Hyg. & Occ. Diseases in Prague. In English)

Hygienic Guides:

A series of useful pamphlets published by Am. Industrial Hygiene Association, 210 Haddon Ave., Westmont, N.J. 08108.

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ENVIRONMENTAL CONSIDERATION IN THE LOCATION OF INDUSTRY

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Vienna, Austria

Environmental Consideration in the Location of Industry

1. INTRODUCTION

Over the past decade there has been an increasing awareness that there is a vital need for preservation and improvement of the environment in the world in which we live; that with ever increasing population and the corresponding requirements for energy, air, water and living space, planning is essential.

This realization culminated in the Stockholm Conference of 1972 which within the omnibus aim of preservation and improvement of the human environment made 106 recommendations for action. As a result the United Nations formed a body now known as the United Nations Environment Programme (UNEP) to take action on these recommendations. UNEP in conjunction with the other many United Nations Agencies and several interested Governmental and Non-Governmental bodies developed a plan of action in which the recommendations were grouped into eight broad programme areas. (Ref. 1)

Of these eight programme areas three are particularly apt to the context of the location of industry:

Programme Area:
- (a) Human Settlements, Human Health, Habitat and well-being
- (b) Land, Water, and Desertification;
- (c) Trade Economics and Transfer of Technology.

It is of significance that these three programme areas have all been designated as having high priority by the Governing Council of UNEP. The importance of the environmental aspects in location of industry are thus well recognized.

The reason underlying the assignation of high priority is expressed in the Declaration of Principles of the United Nations Conference on the Human Environment in June 1972. Quoting from Principle No. 1: "Man has the funda-

mental right to freedom, equality and adequate condition of life in an environment of quality that permits a life of dignity and well-being and he bears a solemn responsibility to protect and improve the environment for future generations."

Proper consideration given to location of industry can help to achieve both of the goals stated, ensure a life of dignity and well-being, and protection and improvement of the environment.

However, while the former, expressed as the economic requirements of location, have been well recognized, the importance of the latter has not in the past been given the attention it deserves.

During man's evolution to the technological society in industrialized countries of today, the social pressure arising due to population growth was not fully realized and little care was taken to consider the effects on the ecology of the environment of either the technology or location of the industries which are evidence of the development process. Social aspects such as health and overall community well-being were in fact subjugated, or neglected and in some cases deliberately exploited in man's haste to "improve" his living standard. Despite the social pressures and environmental awareness of today, this state of affairs continues to some extent due mainly to lack of criteria to enable a complete overview of the technological process. Such an overview must include not only the narrow aspect of the economics of the industry concerned but also the effect on the overall economy of the region. This is an area in which considerable work needs to be done and in fact UNIDO in conjunction with UNEP have in process projects intended to provide suitable data for decision-making purposes.

2. OVERVIEW OF THE LOCATION PROBLEM

It is important to realize that the broad generalizations which are discussed here must be considered carefully in light of the ecological and economic structure of the ecosystem in which the industry is to be located since the decision on actual location may have far reaching consequences. Nevertheless, these generalities serve to pin-point guidelines for the more detailed studies necessary to provide decisive criteria.

The environmental consideration of location of industry involve more than just the physical aspects of the matter, just as important and in many ways more so, is the desirability of the industry itself. The question which must always be answered is, what are the aims of setting up the industry? To exploit a natural resource? To expand a known market? To create employment? For politico-social reasons? For national prestige? To exploit particular technical or manual skills? To take commercial advantage of proximity to an existing market? To take advantage of geographical location? To attract overseas investment? To absorb excess local capital? All of these are plausible reasons for setting up an industry and each will face its own particular problem, but in every case the common factor is the improvement of living standards in both economic and environmental aspects.

In this connexion it is important to note the interrelationship between relative income and acceptance of poor environmental conditions.

It is reasonable to expect that at the near subsistence level, as occurs in some developing countries, that more importance should be placed by the populace upon the essentials of life, shelter, food and water, than upon atmospheric pollution, destruction of the flora and fauna, etc. However, experience has shown that as economic conditions improve there becomes an increasing awareness of the desirability of a good habitat and social pressure arises for a decrease in environmental pollution. It seems likely that there

is a correlation between living standards and social pressures and studies are in progress to try to express this correlation in quantitative terms. Such information could, if used in the decision-making process, lead to large economic advantages since the cost of adding pollution mitigation equipment to an existing, producing factory or plant is almost certainly higher than if this equipment is included in the initial investment.

In both developed and developing countries there is a tendency towards agglomeration of both urban and industrial areas. This is natural since an industry needs an infrastructure with such facilities as transport, labour market, commercial structure for banking and investment, proximity to raw materials, proximity to markets, etc. Production costs can be saved by adding to a conglomeration in which this infrastructure exists but this narrow view may be wrong when consideration is given to the regional and national economic aspects. The aim in location studies must be to achieve a balance between social and economic profitability which, without consideration of all parameters, may appear as conflicting natural goals. If development were the only criterion of environmental improvement their future agglomeration would be sensible.

It would appear, therefore that dispersion, while possibly desirable from the ecological aspect, may be difficult due to lack of infrastructure. Thus dispersal must be the result of a planning operation which ensures provision of appropriate facilities and takes account of natural or regional development requirements. The question of the optimum size of an agglomoration has not been fully investigated but is worthy of further study taking into account ecological aspects on an equal footing with the economic consideration. The experience of several of the larger cities of the world whose location has been based purely on trade convenience are examples of unplanned siting which it would be preferable not to repeat.

The aim of location studies today must be to allow full industrial development without detrimental socio-ecological effects.

The problem which forms the basic of the paper is therefore to bring into perspective the socio-ecological factors and their relationship to the already well-known economic aspects.

3. FACTORS IN THE LOCATION OF INDUSTRY

(i) Economic Factors

Although not the subject of this paper it is considered worthwhile to list here some of the major economic considerations normally considered as factors and used in mathematical modelling for location studies. Discussion of these factors has been well documented elsewhere and will not be repeated here, but since it is essential to consider all factors in the decision-making process they may serve as a useful reference.

Proximity to Natural Resource
Proximity to Market - local or export
Availability of Transport System
Cost of Transport
Availability of Commercial Infrastructure
Availability of Labour Market
Available Labour Skills
Retraining of Labour
Sectoral Planning Requirements
Availability of Technology
Cost of Land
Viability of Change of Use of Land

The above factors are related to the strictly commercial aspects of the problem only, if the industry is required to also be designed to have a minimum effect on the habitat. The econo-ecological effects of the measures taken also need to be taken in to account.

This is of great importance since the added investment and running cost of pollution mitigation equipment can only be negative factors in the viability calculation if the industry is considered in isolation. The benefits of the community must also be accounted in economic terms.

Typical of these benefits are:-

A. Health

Just the creation of an industry in an undeveloped region may mean the instigation of a hitherto non-existent or improvement of a rudimentary health service. The creation of a non-polluting industry will ensure that this service will be provided at the optimum costs.

B. Workers Compensation

Pollution control in the factory should ensure less compensation payments for industrial deseases and injuries.

C. Working Life

The provision of a pollution free habitat should have a beneficial effect on both working and total life span of the populace, thus reducing training costs and potentially more efficient production.

D. Habitat

The provision of a clean atmosphere, correct water treatment and controlled treatment and disposal of solid wastes will all have the effect of increasing the useful life of buildings, roads, and community amenities.

E. Preservation of Site Aesthetics

All cultures have an aesthetic sense through the dynamics of development becomes of increasing importance as the standard of living rises.

F. Regional Economic Effects

What price can be paid locally to preserve the amenities and perhaps livelihood of the populace downstream of the industry. One portion of the community cannot be allowed to develop to the detriment of another.

4. ENVIRONMENTAL FACTORS

In the quotation from Principle 1, stated above it is evident that there are two components for environmental consideration; improvement and protection.

"Improvement" occurs more frequently in developed countries as is evidenced by the decentralization policies at present being carried out, notably in the U.K. and in Western Germany and by the careful planning which was used in developing the Port of Rotterdam. The advantages of this policy have been among other, prevention of increasing agglomeration and consequent addition of further pollution to already polluted areas, to allow by planning

the utilization of fully integrated systems for energy supply, waste removal sewage, water supply, and the more efficient utilization of existing transport systems by reduction of local traffic volume and planned integration of new systems into the existing network. Not only has this resulted in an improvement of the environment in the subsystem but it seems likely that there has been overall economic advantage.

While dispersion of existing industry and prevention of excessive agglomeration are primarily of importance in industrial countries they are also of relevance in developing countries where industrial systems have been developed during colonial administration.

India with its large concentrations of industrial activity such as Bombay and Calcutta are good examples of this and pose the problem of mobility of labour, regional socio-economic requirements, cultural characteristics and natural resource proximity. There is of course the additional danger in disposal planning, particularly in developing countries, of spreading limited investment resources so thinly that they become ineffective.

Interlinking in a complex fashion with both economic and improvement consideration are the protection requirements.

Given the opportunity to freely make decisions on location, as in a decentralization policy or in the creation of new industries whether in the developed or developing countries, it is imperative to have knowledge of the pollution potential of technology, the effectiveness and investment requirements for pollution mitigation equipment, of tolerable pollution levels and of energy requirements.

While considerable information is available for the techno-economic aspects related to most industries data on the wider external factors is not yet sufficiently well formulated to be of quantitative use.

Thus location studies today are restricted by a knowledge gap, which several organizations are trying to fill.

UNIDO in conjunction with UNEP has a series of projects fitting within the framework of an integrated programme of environmental work which should make a contribution to this field. "Impact" studies of existing plants are in progress to establish the overall effect they have had upon the total environment. Since the UNIDO mandate is to give aid to developing countries the industries chosen are those which are particularly important to such countries, namely leather, rubber, textiles, iron and steel, cement, and basic chemicals. The methodology used in these projects is designed to provide information for inputs to the complex study described later in this paper and to endeavour to discover, through pattern recognition techniques, necessary modification to the initial thoughts upon the subject.

5. MINIMISING POLLUTION THROUGH LOCATION

Because of this paucity of quantitative broad based information considerable thought has been given to ways and means of achieving environmental cleanliness utilizing available knowledge.

It is considered that there are two steps which can be taken now.

1. Minimization of pollution from a given plant or factory;
2. Integrated complexes of industries with minimum pollution.

These will lead, as facts become available, to the sensible location of industrial complexes as a third factor.

It is the second of these factors which is the subject of a major joint UNIDO/UNEP project.

The starting point in pollution mitigation is the realization of the pollution potential of any given industry and the measures which can be taken within the industry itself.

A typical pollution cycle is shown in the block diagram of Figure 1, in which a typical existing system is shown in full line. It should be particularly noted that included in the system are not only the industry itself, but also transport and the consumer who also contributes to the overall pollution.

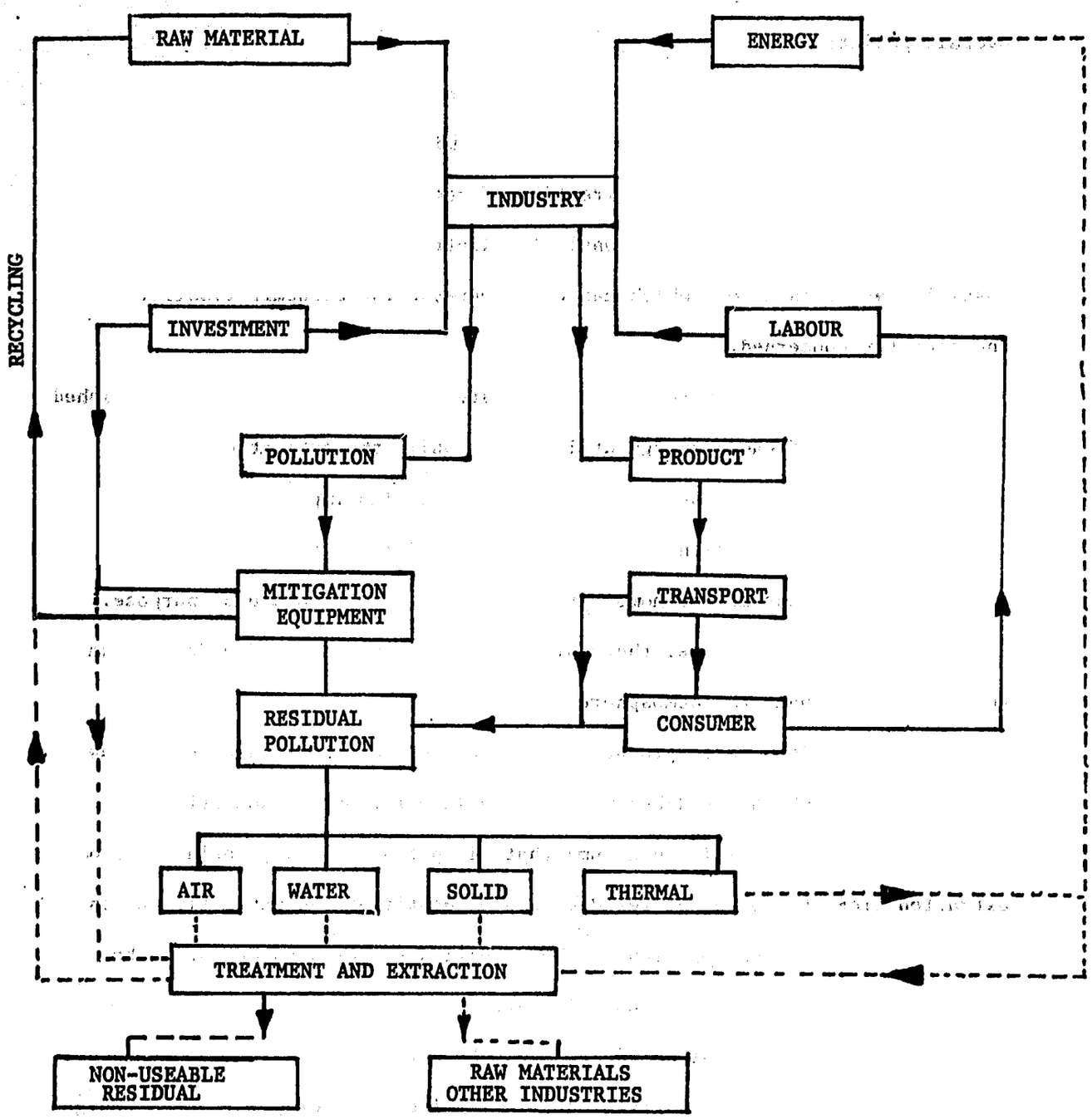
In dotted line are shown modifications to the system which are feasible and which could be added to achieve minimum pollution. All efforts, it should be noted, are in the direction of recycling and utilization of wastes. The removal and or disposal of pollutants from the system without possible re-use is a cost which can only decrease the economic viability of the industry concerned.

Treatments of air, water and solid wastes are reasonably well established but the problem of waste energy utilization, while the subject of a large amount of study, has not been completely solved. Its importance is shown, however, by the realization that the average efficiency of thermal processes is only 35% and that at the moment the remainder serves no useful purpose. In conventional fuels alone, there are 3,900 million tons of fuel per annum serving only to heat the atmosphere.

The other final waste products of the cycle are a non-reusable residue and by-products which could become raw materials for other industries. It is of course not realistic to assume that all potential raw materials can be extracted from the pollutant residues since quantities and extraction costs may make the operation non viable. The modified system does appear to be possible, however, for large scale industries.

The non-reusable waste products would have to be treated by conventional methods, removal of harmful gases, neutralization of water prior to discharge into sewers or water courses and controlled dumping, incineration and composting

Pollution Cycle



TYPICAL EXISTING SYSTEM

MINIMUM POLLUTION SYSTEM

FIGURE 1

of solids. The technology of the latter is still in its infancy, but it is expected that in view of the awakened interests in recycling of materials, that use of the process will increase greatly in the near future.

These deliberations lead to the concept of the integrated industrial complex.

THE INTEGRATED INDUSTRIAL COMPLEX WITH MINIMUM POLLUTION

The objective of this project is to establish criteria for mixing in an industrial estate industries which can either:

1. utilize the product of another industry;
2. utilize raw materials extracted from the waste of another industry;
3. provide a neutralizing medium for the non-reusable waste from another country

The concept can be realized by consideration of the block diagram of Figure 2. Although each of the individual industries shown have a pollution cycle similar to that of in Figure 1., for clarity only simplified cycles are shown here.

In order to achieve viability of the pollution treatment process it has been assumed that the complex would be concentrated around a major industry such as an iron and steel plant or chemical works. Although experience may show that this is not essential.

The major industry A should feed its products as raw materials for ancillary industries B.C.D. It is likely then that pollutants from each of these four industries will have a high degree of commonality and can be fed to a common extraction treatment plant or plants.

The output from the treatment plant provides raw materials for industries F. and E. and gives a pollutant residue which when added to that of industries A. B. C. D., has been designated type +X.

MINIMUM POLLUTION INDUSTRIAL COMPLEX

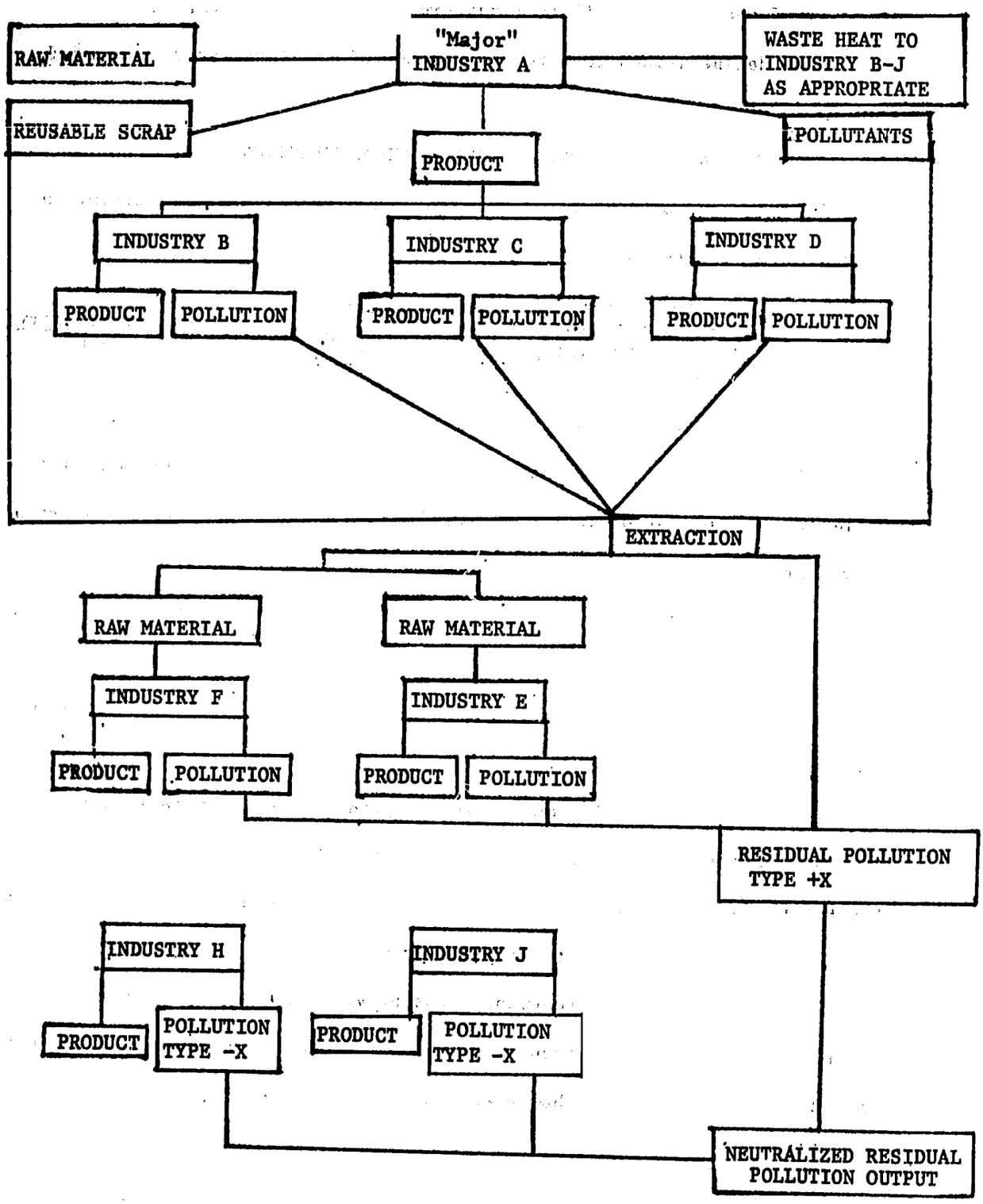


FIGURE 2

Industries H. and J. can be of any type providing a non-reusable residue which has been designated type -X and which wil- neutralize the non-reusable pollutants from plants A. B. C. D. and E.

It must be realized that the concept as described is very much over simplified, but it is expected that by using system analysis techniques that useable results will be achieved from full accounting.

There are bound to be many variations on the above theme and there is no lack of appreciation of the difficulties which are likely to arise. However, the advantages of the ideas even if only partially realized are such as to make the attempt worthwhile.

The main advantages are:

1. Minimum waste of resources;
2. Minimum residual treatment costs.
3. Reduction of transport costs and provided the estate area is not too large, reduction in both traffic volume and pollution by utilization of non-polluting transport.
4. Creation of a commercial infrastructure of planned size and amenity.
5. Because of the wide variety of industries fullest exploitation of the total labour market.

7. CONCLUSION

This paper has not attempted to answer questions but rather to state the problem and inform on steps that are being taken to achieve solutions. The ideas suggested are almost certainly not the only possible solution, nor are they necessarily the best solution, but it is hoped that they will stimulate thoughts on this most important subject.

There is a further question upon which no comment has been made here, that is, where within a region should the industry and complex be located? This, of course, brings in such parameters as geography, meteorology, labour potentials, land use and the overall characteristics of the ecosystem within which it is desired to create an industry. The problem has been neither

forgotten nor neglected, but a scheme for the necessary investigation has not yet been formulated sufficiently firmly to allow discussion in this brief paper.

The sole purpose of UNIDO as an organization is to aid developing countries to formulate and implement programmes of industrial development. It is essential that the information being sought on location problems should become quickly available, therefore, in global environmental terms it is also in the interests of industrialized countries to continue to make available their experience and knowhow on these matters to the developing countries.

It is in these developing countries that the opportunity most often arises to set up industry from grass roots and it is of paramount importance that this process should proceed without hindrance.

We have inherited an essentially restricted environment which we must improve and preserve for posterity.

Source: 'The Industrial Environment--its Evaluation & Control', U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, 1973.

CHAPTER 29

IONIZING RADIATION

Edgar C. Barnes

INTRODUCTION

Definition and General Description

Ionizing radiation, in general, is any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, by interaction with matter. In the specific situation being considered here, the industrial environment — and usually in considering radiation protection matters — that portion of the electromagnetic spectrum having frequencies in the ultraviolet portion and lower is excluded (see Chapter 28). Stated in more explicit terms, the International Commission on Radiation Units and Measurements (ICRU)[1] defines ionizing radiation as: "any radiation consisting of directly or indirectly ionizing particles or a mixture of both. Directly ionizing particles are charged particles (electrons, protons, alpha particles, etc.) having sufficient kinetic energy to produce ionization by collision. Indirectly ionizing particles are uncharged particles (neutrons, photons, etc.) which can liberate directly ionizing particles or can initiate nuclear transformations." Thus, ionizing radiation encompasses consideration both of atomic particles having a variety of physical and electrical characteristics streaming at velocities from nearly zero, to values approaching the speed of light, and of electromagnetic radiations (photons) having a wide range of energies streaming at the speed of light. Photons, which have no mass, are referred to as "particles" for theoretical reasons. In this chapter "radiation" implies "ionizing radiation."

In the industrial environment, the radiations of primary concern are: x, gamma, alpha, beta and neutron. X and gamma radiations may be called x rays and gamma rays. Also, alpha and beta radiations are called alpha and beta particles. Except for very small amounts from natural background radiation, proton and some other kinds of radiation are not of concern unless there is equipment designed to specifically produce them. Research facilities, such as large accelerators, are not discussed in this chapter.

X and gamma radiations both are penetrating electromagnetic radiations having wavelengths much shorter than that of visible light but they are of different origin. X rays originate in the extra nuclear part of the atom, whereas gamma rays are emitted from the nucleus in the process of nuclear transition or during particle annihilation. (Annihilation is the process by which a negative electron and a positive electron, called a positron, combine and disappear with emission of electromagnetic radiation.)

Ordinarily, useful x rays are produced in an evacuated tube by accelerating electrons from a heated filament to a metal target with voltages of 50 to 500 kilovolts (kV). Sometimes much higher or somewhat lower voltages are used. The electrons interact with orbital electrons of atoms in the target causing energy level changes that result in the emission of "characteristic" x rays, and also with the nucleus of the atom to produce electromagnetic radiation having a "continuous" spectrum (called bremsstrahlung).

All radionuclides undergo a spontaneous transformation, called decay, during which radiation is emitted and a new nuclide, called a daughter (or decay product) is formed. The radiations are of a specific type (or types) and energy, or energy distribution, for each species of radionuclide. Tabulated data for many radionuclides are presented in *Radiological Health Handbook*.[2]

Gamma rays are emitted by the nucleus of certain radionuclides during their decay. Each such radionuclide emits one or more gamma rays having a specific energy. Gamma rays also are produced by neutron interactions with nuclei.

Alpha radiation consists of a stream of alpha particles, each particle being physically identical to the helium nucleus — two neutrons and two protons. They are emitted spontaneously during the radioactive decay of certain radionuclides, primarily those of higher molecular weight — bismuth and higher. Because of the comparatively large size and double positive charge of the alpha particles, alpha radiation does not penetrate matter readily. The more energetic radiation is completely stopped by the skin. Inside the body, however, it produces dense ionization in tissues.

Beta radiation consists of a stream of beta particles, which are either electrons of negative charge or electrons of positive charge, called positrons, which have been emitted by an atomic nucleus — or by a neutron in the process of transformation. Radionuclides that spontaneously emit beta particles span the entire range of the elements. These nuclides emit particles having a maximum energy characteristic of that nuclide, along with many other particles of lower energy.

Neutron radiation consists of a stream (flow) of neutrons. Radionuclides do not emit neutrons spontaneously, although a small number of very heavy radionuclides fission spontaneously with the emission of neutrons. Neutron radiation is produced by various nuclear reactions, by nuclear fission and by interactions of alpha or gamma radiation with certain nuclei. Since neutrons are

uncharged, the radiation readily penetrates matter. Neutrons decay into a proton and an electron with a half-life of 11.7 minutes. Neutron energies, expressed in electron volts (eV) or the multiples kiloelectron volts (keV) and megaelectron volts (MeV), span a very wide range of values, and are commonly classified into three general groups — slow, intermediate and fast. The range of energies for each of these general groups is indefinite, different ranges being selected according to specific needs. One such classification is <1 eV, 1 eV to 0.1 MeV and >0.1 MeV, respectively.[3] There are also more specific classes, e.g., thermal, which are those essentially in thermal equilibrium with the medium in which they exist (mean value 0.025 eV at 20°C).

Quantities and Units

In quantitating radioactive materials, a unique situation exists because one property of primary interest is continually changing. As decay takes place, the activity, or number of nuclear disintegrations occurring in a given quantity of material per unit time decreases exponentially. Therefore, a time dependent factor, half-life, becomes part of any quantitative evaluation. Each radionuclide has a definite half-life, however the range of half-lives for different radionuclides is very great, from fractions of a second to billions of years. Since the mass of material does not change significantly during this decay, the quantity of a radionuclide or of a radioactive material is usually specified in terms of its activity, with the exception that mass may be used in some situations (e.g., nuclear fuel manufacturing) where half-lives of the useful radionuclides are very long. Since activity in a given specimen (and the radiation from it) may come from one or more radionuclides, each decaying exponentially, the composition and activity must be specified as of a definite date, the accuracy (year, month, day, minute, second) depending on the relation of the half-lives to previous or subsequent periods of interest. The activity is commonly expressed in curies (or its multiples) although for some measurements, disintegrations per minute (dpm) or per second (dps) are commonly used. One curie equals 3.7×10^{10} disintegrations per second.

Another unique and complex situation exists in quantitating the effect of radiation on living organisms. The different kinds of radiation interact in a wide variety of ways both with living organisms (e.g., body tissues) and inanimate things (e.g., shielding). Furthermore, the interactions may be different for different energies of the same type of radiation; and the spatial distribution of the interaction is not uniform. They all, however, impart energy to matter through which they pass; and for living organisms the absorbed dose — energy imparted in a volume element divided by the mass of irradiated material in that volume element — provides a common base for considering the degree of effect produced by specific amounts of any of the different types of radiation. The unit of absorbed dose is the rad. One rad equals 100 ergs per gram.

The biological effect for equal absorbed doses from different types and energies of radiation, however, is not constant. Therefore dose equivalent, which is the absorbed dose modified by pertinent factors, particularly the "quality factor," is used for radiation protection evaluations to take into account the difference in the biological effect of the different radiations. Values of the quality factor for commonly encountered radiations, suitable for general use, have been determined (see page 391). The special unit of dose equivalent is the rem, which is the product of absorbed dose in rads and the applicable quality factor. For special situations, a factor in addition to the quality factor may be used. Dose-limiting recommendations are expressed as maximum permissible dose equivalent in rems, commonly called "maximum permissible dose (MPD)." A similar concept is expressed as a Radiation Protection Guide (RPG) by the Federal Radiation Council.[4]

In some situations, it may be convenient and sufficiently accurate to express dose-limiting recommendations for x and gamma radiation (or to make related measurements) in terms of ionization in air, at the point of interest. The measure of ionization produced in air by x or gamma radiation is called "exposure," its special unit being the roentgen (R). It is customary, for radiation protection purposes, to consider that one R at the point of interest would be equivalent to a dose equivalent of one rem.

A comprehensive collection of data, graphs and tables will be found in the *Radiological Health Handbook*.[2] It should prove to be a useful adjunct to this chapter, since extensive tables and graphs are not included here.

Glossary

This glossary includes a limited number of terms used in radiation protection practice. These definitions are mostly from reference (3) which contains definitions of other terms. References (2) and (3) also include pertinent definitions.

activity (A). The number of nuclear disintegrations occurring in a given quantity of material per unit time.

body burden. The total quantity of a radionuclide present in the body.

body burden, maximum permissible. That body burden of a radionuclide which, if maintained at a constant level, would produce the maximum permissible dose equivalent in the critical organ.

bremsstrahlung. The electromagnetic radiation associated with the deceleration of charged particles. The term is also applied to the radiation associated with the acceleration of charged particles.

controlled area. A specified area in which exposure of personnel to radiation or radioactive material is controlled and which is under the supervision of a person who has knowledge of the appropriate radiation protection practices, including pertinent regulations, and who has responsibility for applying them.

curie (Ci). The special unit of activity. One curie equals 3.7×10^{10} disintegrations per second exactly. By popular usage, the quantity of any

radioactive material having an activity of one curie.

daughter. A nuclide, stable or radioactive, formed by radioactive decay. A synonym for decay product.

dose. A general term denoting the quantity of radiation or energy absorbed in a specified mass. For special purposes, its meaning should be appropriately stated, e.g., absorbed dose.

dose, absorbed. The energy imparted to matter in a volume element by ionizing radiation divided by the mass of irradiated material in that volume element.

dose equivalent. The product of absorbed dose, quality factor, and other modifying factors necessary to express on a common scale, for all ionizing radiations, the irradiation incurred by exposed persons.

dose equivalent, maximum permissible (MPD). The largest dose equivalent received within a specified period which is permitted by a regulatory agency or other authoritative group on the assumption that receipt of such dose equivalent creates no appreciable somatic or genetic injury. Different levels of MPD may be set for different groups within a population. (By popular usage, dose, maximum permissible, is an accepted synonym.)

exposure. A measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all of the ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in the air, divided by the mass of the air in the volume element.

genetically significant dose (GSD). The dose which, if received by every member of the population, would be expected to produce the same total genetic injury to the population as do the actual doses received by the various individuals.

half-life, radioactive. For a single radioactive decay process, the time required for the activity to decrease to half its value by that process.

half-value layer. The thickness of a specified substance which, when introduced into the path of a given beam of radiation, reduces the value of a specified radiation quantity by one-half. It is sometimes expressed in terms of mass per unit area.

isotopes. Nuclides having the same atomic number but different mass numbers. NOTE: this term is often used inaccurately as a synonym for nuclide.

nuclide. A species of atom characterized by its mass number, atomic number, and energy state of the nucleus, provided that the mean life in that state is long enough to be observable.

quality factor. A linear energy transfer dependent factor by which absorbed doses are to be multiplied to obtain the dose equivalent.

rad. The special unit of absorbed dose. One rad equals 100 ergs per gram.

radiation source. An apparatus or a material emitting or capable of emitting ionizing radiation.

Radiation Protection Guide (RPG). The radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable.

Radioactivity Concentration Guide (RCG). The concentration of radioactivity in the environment which is determined to result in organ doses equal to the Radiation Protection Guide.

roentgen (R). The special unit of exposure. One roentgen equals 2.58×10^{-4} coulomb per kilogram of air.

sealed source. A radioactive source sealed in a container or having a bonded cover, where the container or cover has sufficient mechanical strength to prevent contact with and dispersion of the radioactive material under the conditions of use and wear for which it was designed.

PHYSICAL ASPECTS OF IONIZING RADIATION

Electromagnetic Radiation

In the electromagnetic spectrum, gamma radiation spans an energy range from approximately 8×10^{4} eV to 10^{7} eV, the corresponding frequencies being 2×10^{19} to 2.5×10^{21} hertz. X rays span a somewhat wider range of values although there is no clear break at the lower energy boundary and at higher energies special equipment, such as an accelerator, is used for their production.

A beam of x rays from x-ray equipment encompasses a range of energies. The highest photon energy in the beam corresponds to the electron accelerating voltage, with the median being considerably below this value. The beam will include both photons having energies which are "characteristic" of the target material and photons having a continuous spectrum (bremsstrahlung), the proportion of the latter being greater at higher electron accelerating voltages. The energy spectrum, or quality of the beam, may be expressed either in terms of an "effective energy" or in terms of its half-value layer. The accelerating voltage may be constant or may come from a pulsating generator, which influences the photon energy distribution, the latter being designated in terms of peak voltage (kVp). Ordinarily, x-ray tubes and their housings are arranged so that there is shielding in all directions except for a "window" where the useful beam is emitted. The solid angle and shape of the useful beam is determined by the size of the window and by collimating devices, such as diaphragms and cones, made of shielding materials. Some low energy x rays are absorbed in the target, while others are removed from the useful beam by the material in the tube window and usually also by filters that preferentially absorb the less penetrating radiation. Accelerators used to produce high energy x rays are commonly arranged for beam emission to accomplish a specific purpose.

Sealed sources, consisting of a radionuclide encased in a metal capsule, are a common source of gamma radiation used in industry. They are used in radiography, measuring devices and a number of other special applications. The radionuclides in them are selected to provide radiation of the desired photon energy. Some emit photons of one energy, such as cesium-137 (.66MeV); others a range of energies, such as radium (.047 to 2.4 MeV due to retained daughters).

There are two basic processes by which electromagnetic radiation interacts with matter: scattering, in which the direction of the photon and its energy are altered; and absorption, in which the photon disappears with transfer of its energy to other radiations.

Along the path of a primary beam of photons, there are interactions between the electric fields of these photons and the electrons in the material being penetrated which cause "scattering" of some of the primary beam photons. Further reactions ensue with a resulting 360° angular distribution of scattered photons having a range of energies down to nearly zero. The shape of this angular, and associated energy, distribution is a function of the energy of the original photons. For a mathematical treatment of scattering, see *Principles of Radiation Protection*.[5]

Absorption of photons occurs primarily by three processes — the photoelectric effect, the Compton effect and pair production. These are also treated mathematically in the above book.[5] The photoelectric effect predominates for the lower energy photons, the Compton effect where the energy is greater than approximately 0.5 MeV, and for pair production a minimum of 1.02 MeV is required.

The photoelectric effect involves an interaction between incident photons and the electrons in the shells around the nuclei. Electrons are ejected from the atoms with an energy equal to the difference between the photon energy and the binding energy of the ejected electron. Subsequently, x rays or electrons are emitted as the shell vacancies are corrected, the x rays having a wide range of energies which are higher for the higher atomic number materials. The portion of photons interacting by the photoelectric process increases with increasing atomic number and decreasing energy.

The Compton effect involves interactions of photons incident on orbital electrons. The photon gives up part of its energy to the electron causing it to recoil and the balance of its energy goes into a scattered photon. From conservation of energy and momentum, the angular relationships of the recoil electron, scattered photon and incident photon can be determined. The original photon energy determines the distribution of these angles; at lower energies, the angles at which electrons are scattered is greater.

Pair production occurs by the interaction of a photon with the electric field surrounding a charged particle. The original photon disappears with the formation of an electron-positron pair. The photon energy must exceed 1.02 MeV and it is divided equally between the electron and the positron. The portion of incident photons which interact with a nucleus by pair production increases with increasing atomic number.

As a beam of photons traverses matter, the scattering and absorption of photons by all processes results in attenuation of the beam exponentially. This is expressed by the equation:

$$I = I_o e^{-\mu x} \qquad (1)$$

where I is exposure rate at a depth x

I_o is exposure rate at zero depth

μ is the attenuation coefficient

The value of the attenuation coefficient depends on the photon energy and the absorbing material. This coefficient may be expressed in terms of thickness, as a linear attenuation coefficient (cm^{-1}), or as a mass attenuation coefficient (cm^2/g) obtained by dividing the linear coefficient by the density ρ of the absorbing material. Table 29-1 presents some of these values. More extensive tables are available in reference (2). In matter being traversed by a beam of electromagnetic radiation, there is actually a higher intensity of photons at any point, particularly at great depth,

TABLE 29-1
Mass Attenuation Coefficients

Photon energy	Mass attenuation coefficient in cm^2/g for —				
MeV	Aluminum	Iron	Lead	Water	Concrete
0.01	26.3	173	133	5.18	26.9
0.02	3.41	25.5	85.7	0.775	3.59
0.05	0.369	1.94	7.81	0.227	0.392
0.1	0.171	0.370	5.40	0.171	0.179
0.5	0.0844	0.0840	0.161	0.0968	0.087
1.0	0.0613	0.0599	0.0708	0.0707	0.0637
5.0	0.0284	0.0314	0.0424	0.0303	0.0290
10.0	0.0231	0.0298	0.0484	0.0222	0.0231

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TABLE 29-2

Dose Buildup Factor (B) for a Point Isotropic Source

Material	MeV	μx*						
		1	2	4	7	10	15	20
Water	0.255	3.09	7.14	23.0	72.9	166	456	982
	0.5	2.52	5.14	14.3	38.8	77.6	178	334
	1.0	2.13	3.71	7.68	16.2	27.1	50.4	82.2
	2.0	1.83	2.77	4.88	8.46	12.4	19.5	27.7
	3.0	1.69	2.42	3.91	6.23	8.63	12.8	17.0
	4.0	1.58	2.17	3.34	5.13	6.94	9.97	12.9
	6.0	1.46	1.91	2.76	3.99	5.18	7.09	8.85
	8.0	1.38	1.74	2.40	3.34	4.25	5.66	6.95
	10.0	1.33	1.63	2.19	2.97	3.72	4.90	5.98
Aluminum	0.5	2.37	4.24	9.47	21.5	38.9	80.8	141
	1.0	2.02	3.31	6.57	13.1	21.2	37.9	58.5
	2.0	1.75	2.61	4.62	8.05	11.9	18.7	26.3
	3.0	1.64	2.32	3.78	6.14	8.65	13.0	17.7
	4.0	1.53	2.08	3.22	5.01	6.88	10.1	13.4
	6.0	1.42	1.85	2.70	4.06	5.49	7.97	10.4
	8.0	1.34	1.68	2.37	3.45	4.58	6.56	8.52
	10.0	1.28	1.55	2.12	3.01	3.96	5.63	7.32
Iron	0.5	1.98	3.09	5.98	11.7	19.2	35.4	55.6
	1.0	1.87	2.89	5.39	10.2	16.2	28.3	42.7
	2.0	1.76	2.43	4.13	7.25	10.9	17.6	25.1
	3.0	1.55	2.15	3.51	5.85	8.51	13.5	19.1
	4.0	1.45	1.94	3.03	4.91	7.11	11.2	16.0
	6.0	1.34	1.72	2.58	4.14	6.02	9.89	14.7
	8.0	1.27	1.56	2.23	3.49	5.07	8.50	13.0
	10.0	1.20	1.42	1.95	2.99	4.35	7.54	12.4
Lead	0.5	1.24	1.42	1.69	2.00	2.27	2.65	(2.73)
	1.0	1.37	1.69	2.26	3.02	3.74	4.81	5.86
	2.0	1.39	1.76	2.51	3.66	4.84	6.87	9.00
	3.0	1.34	1.68	2.43	2.75	5.30	8.44	12.3
	4.0	1.27	1.56	2.25	3.61	5.44	9.80	16.3
	5.1097	1.21	1.46	2.08	3.44	5.55	11.7	23.6
	6.0	1.18	1.40	1.97	3.34	5.69	13.8	32.7
	8.0	1.14	1.30	1.74	2.89	5.07	14.1	44.6
	10.0	1.11	1.23	1.58	2.52	4.34	12.5	39.2

* μx = mass absorption coefficient (μ/ρ) × shield thickness (cm) × shield density (g/cm²).

NOTE: For concrete use an average of aluminum and iron: e.g., B(conc) = [B(iron) + B(Al)] ÷ 2.

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than would be predicted solely by attenuation (equation 1) because of the presence of x rays and secondary or scattered photons. This increase in exposure rate, called buildup (B), is not easily calculated. It can be included as a factor B in the attenuation equation $I = BI_0e^{-\mu x}$ and tabulated values of B for one set of conditions is shown in Table 29-2. Additional values appear in reference (2). To assure proper accuracy, it is usually necessary to consider this buildup factor.

Since absorption of energy is the physical quantity used in specifying absorbed dose, a mass energy absorption coefficient similar to the attenuation coefficient is useful.

Table 29-3 presents some of these values. More extensive tables will be found in *Physical Aspects of Irradiation.*[9]

TABLE 29-3
Mass Energy-absorption Coefficients

Photon energy MeV	Mass energy-absorption coefficient in cm^2/g for			
	Water	Air	Bone	Muscle
0.01	4.89	4.66	19.0	4.96
0.02	0.523	0.516	2.51	0.544
0.05	0.0394	0.0384	0.158	0.0409
0.1	0.0252	0.0231	0.0368	0.0252
0.5	0.0330	0.0297	0.0316	0.0327
1.0	0.0311	0.0280	0.0297	0.0308
5.0	0.0190	0.0173	0.0186	0.0188
10.0	0.0155	0.0144	0.0159	0.0154

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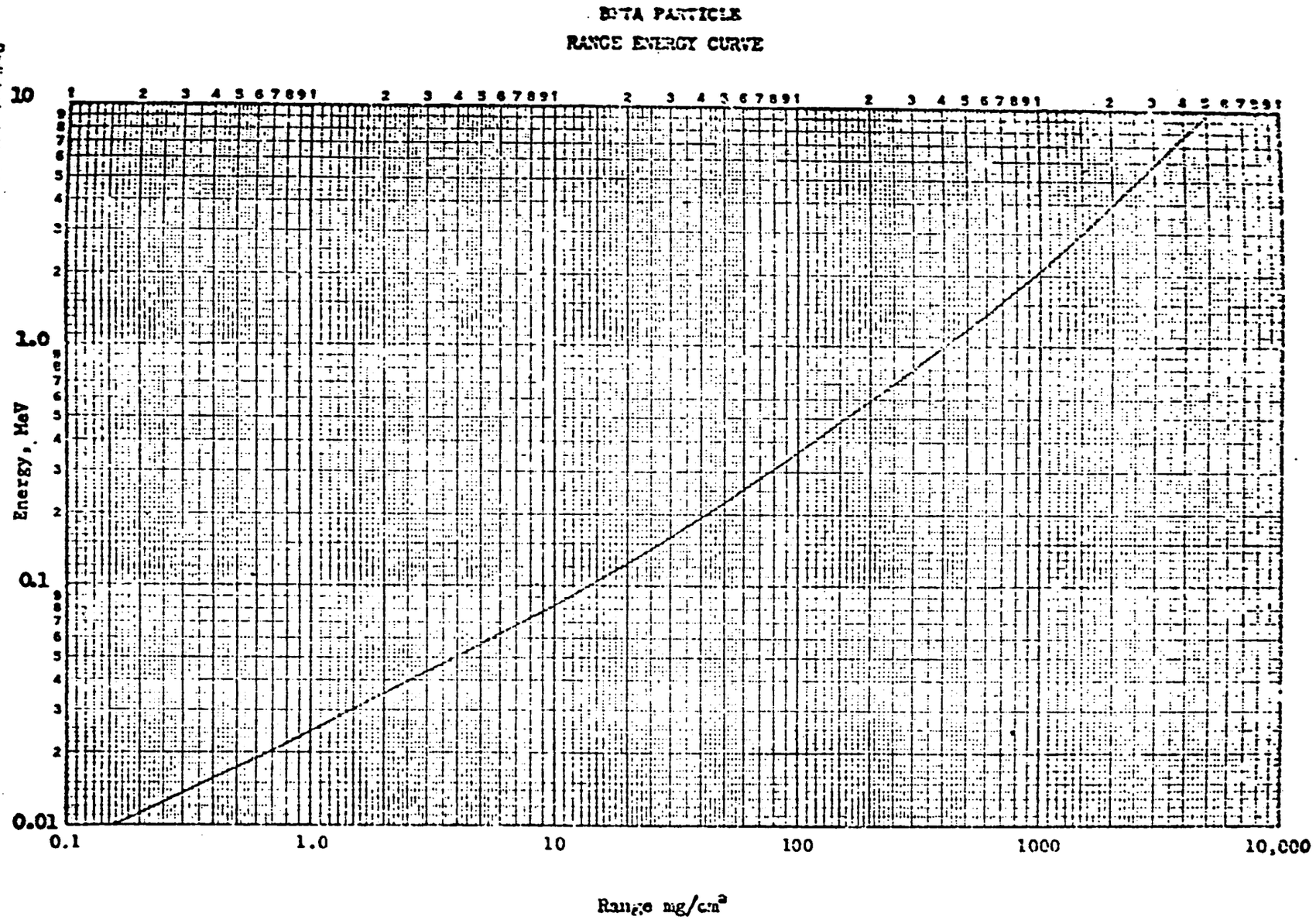
Shielding of radiation sources is commonly provided to reduce the exposure rate in occupied areas. For economy, the shield should be as close as possible to the radiation source. For discrete energies, the attenuation by a shield can be calculated from the attenuation equation, including buildup. In practice, extensive data on attenuation (or transmission), presented in graphic form, is available and used for shielding calculations. This data is presented in a variety of ways and selection of the most useful form will simplify shielding calculations. Because attenuation is exponential, the thickness of a "half-value layer" (HVL) for different shielding materials is a common and convenient form to present such data. A shield thickness of 2 HVL reduces exposure rate by a factor of 4, 3 HVL by a factor of 8, etc. Table 29-4 presents such data for the gamma radiation from several radionuclides, as well as their specific gamma ray constants (exposure rate constants). The latter are useful in determining exposure rate at varying distances, in air, from a point source using the inverse square relationship between exposure rate and distance from the source. Additional values are included in reference (2). Comprehensive shielding data for x rays appear in *Safety Standard for Non-medical X-ray and Sealed Gamma-ray Sources*,[7] and *Medical X-ray and Gamma-ray Protection for Energies up to 10 MeV*.[8]

Particulate Radiation

Beta radiation is emitted by a large percentage of the radionuclides, frequently accompanied by x or gamma radiation. Each nuclide, which decays by beta particle emission, emits beta particles having a maximum energy characteristic of that nuclide along with many other particles of lower energy. The average of these energies is much less than the maximum and for different nuclides the ratios of maximum to average span a wide range of values. For different nuclides, the range of maximum energies is from a few keV to slightly over 4 MeV. In contrast to electromagnetic radiation which is attenuated exponentially, beta radiation has a definite range as it traverses matter, the maximum being determined by its energy and the density of the material. If this distance is divided by density, a graph showing range in mg/cm^2 versus energy in MeV is applicable to all materials. Values for a given energy from the graph in Figure 29-1, divided by the density of the material being traversed (mg/cm^3), gives the thickness of that material (cm) which will completely stop that beta radiation. It should be noted that complete shielding for beta radiation is provided by reasonable thicknesses of commonly available materials. Correspondingly, measuring instruments must be selected which will not significantly impede the beta radiation, this being of particular importance at low energies. As beta radiation traverses matter, the electrons occasionally interact in a manner to produce electromagnetic radiation (bremsstrahlung), the amount of this radiation increasing as the beta energy and atomic number of the absorber increase.

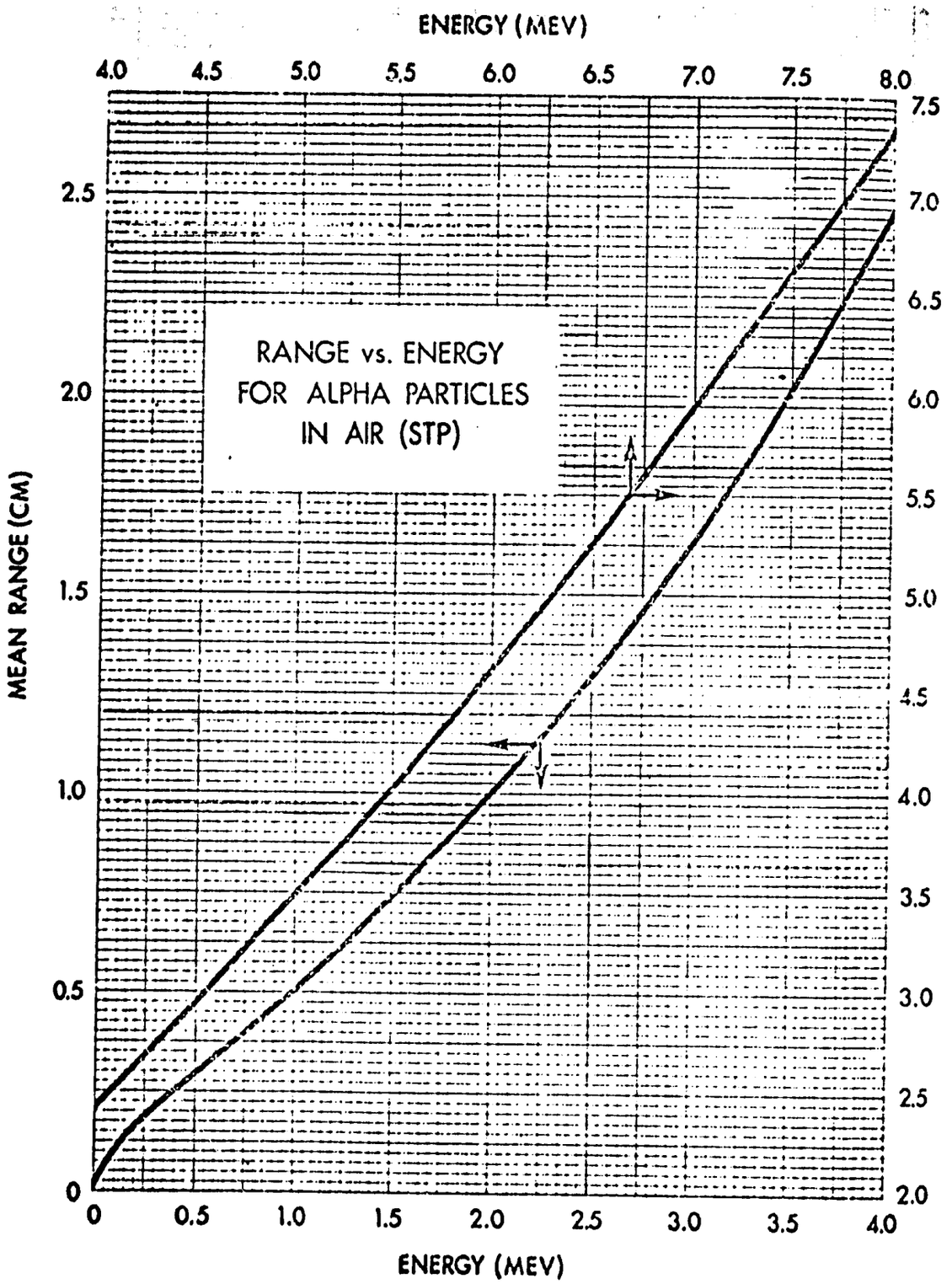
Alpha radiation is emitted primarily by the heavier radionuclides. The alpha particles are emitted at a specific energy characteristic of each nuclide. The energy range of these alpha particles from the different nuclides is predominantly between 4 and 8 MeV. Alpha radiation, like beta, has a definite range in the materials it traverses. The distances traversed, however, are much shorter than for beta. The horny layer of the skin completely stops alpha radiation and air stops it in a few centimeters. Figure 29-2 is a graph showing the range in air for different energy alpha particles.

Although neutrons are not emitted by radionuclides other than by a few that fission spontaneously, there are several types of radioactive neutron sources available and in use. Of course, neutron radiation exists around the core of any nuclear reactor and it will be produced in the event of an accidental nuclear criticality incident. The radioactive neutron sources are sealed sources, normally of relatively small size. Their neutrons are produced by interactions of alpha or gamma radiation with nuclei of appropriate materials (target materials). Alpha emitting radionuclides having a high specific activity are mixed with or alloyed with the target material; and in sources using gamma interactions, the target material usually surrounds the radionuclide. These sources emit neutrons with a maximum energy characteristic of the radionuclide and target material; and many more neutrons at lower energies, with a distinctive energy spectrum. Characteristics of some radioactive neutron sources are shown in Table 29-5. When neutron radiation traverses matter it is attenuated by elastic and inelastic scattering, capture, and induced nuclear reactions. The extent of these processes depends both on the energy (or energy spectrum) of the radiation and the specific nuclides in the matter being traversed. Moderation (slowing down) of the neutrons by elastic collisions progressively changes the energy spectrum. The probability of these interactions taking place is specified in terms of cross-sections,



Radiological Health Handbook. U.S. Dept. of Health, Education and Welfare, Public Health Service, 1970.

Figure 29-1. Beta Particle Energy Range Curve.



Radiological Health Handbook. U.S. Dept. of Health, Education and Welfare, Public Health Service, 1970.

Figure 29-2. Alpha Particle Energy Range Curve.

with their area expressed in units of barns (1 barn = 10^{-24} cm^2). These various interactions result in the production of secondary radiations, particularly gamma rays, which must always be considered when neutron radiation is present. The complexities of neutron interactions with matter do not permit adequate treatment of energy absorption and shielding here (see *Protection Against Neutron Radiation*).[3]

Dosimetry

Dosimetry involves the evaluation of radiation, often complex as to its nature, energy, direction and quantity, in terms related to its effect on biological systems or other matter. Theoretically, it would seem that measurements could be made to completely describe the radiation field itself at any point of interest including time variations, and from this, the dose or other quantity of interest determined. In practice, however, measurements are made at the place of interest in a manner which relates the measurement directly to the quality of interest — usually absorbed dose or dose equivalent. To the maximum possible extent, there is a summation of the quantities of interest. Furthermore, due to the complexity of any biological response to irradiation by various types and quantities of radiation, as well as their measurement, it is customary to utilize environmental measurements for radiation protection purposes, with precise determinations of dose and dose distribution in biological systems limited to situations of special interest — usually abnormal exposures. Thus, dose-limiting recommendations, although specified in terms of dose equivalent in the body, are commonly evaluated by strictly environmental measurements.

There are a variety of detectors, with associated readout devices which are used for radiation monitoring or measurement. The most important are: Geiger-Müller (GM) tubes, ionization chambers, proportional counters, luminescent detectors, scintillation detectors, photographic emulsions, chemical reaction detectors, induced radiation detectors and fissionable materials. None are universally applicable and selection of the most appropriate detector or detectors for each radiation measurement (or type of measurement) becomes a matter of great importance. These detectors, with associated readout equipment, are used to perform two distinctly separate functions — to measure the radiation in the environment (monitoring or surveying); and to determine the activity or kind of radionuclide, or both, in solids or fluids, commonly samples from a larger quantity of material (analysis).

G-M tubes detect ionizing events which take place within their sensitive volume, each event causing an output voltage pulse. These pulses may be counted or summed in various ways, usu-

TABLE 29-4
Data for Gamma-Ray Sources

Radioisotope	Atomic Number	Half Life	Gamma Energy	Half-Value Layer[a]			Tenth-Value Layer[a]			Specific Gamma-Ray Constant
				Conc.	Steel	Lead	Conc.	Steel	Lead	
			MeV	in	in	cm	in	in	cm	R cm^2 m Ci-h[b]
Cesium-137	55	27 y	0.66	1.9	0.64	0.65	6.2	2.1	2.1	3.2
Cobalt-60	27	5.24 y	1.17, 1.33	2.6	0.82	1.20	8.2	2.7	4.0	13.0
Gold-198	79	2.7 d	0.41	1.6	—	0.33	5.3	—	1.1	2.32
Iridium-192	77	74 d	0.13 to 1.06	1.7	0.50	0.60	5.8	1.7	2.0	5.0[c]
Radium-226	38	1622 y	0.047 to 2.4	2.7	0.88	1.66	9.2	2.9	5.5	8.25[d]

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[a] Approximate values obtained with large attenuation.
[b] These values assume that gamma absorption in the source is negligible. Value is R/millicurie-hour at 1 cm can be converted to R/Ci-h at 1 meter by multiplying the number in this column by 0.10.
[c] This value is uncertain.
[d] This value assumes that the source is sealed within a 0.5 mm thick platinum capsule, with units of R/mgh at 1 cm.

TABLE 29-5
Data for Neutron Sources

Source	Half-life	Max. neutron energy MeV	Avg. neutron energy MeV	Yield n/sec. x 10^{-6}/curie
^{210}Po-Be	138.4 d	10.8	4.3	2.5
Ra DEF-Be	19.4 y	10.8	4.5	2.5
^{226}Ra-Be	1622 y	13.2	3.6	15
^{239}Pu-Be	24,400 y	10.6	4.5	2.0

Reprinted from NBS Handbook 85-196, National Bureau of Standards, Washington, D.C.

ally to give a count rate (counts per minute, cpm). Two types of G-M survey meters are in common use. One uses a cylindrical tube encased in a protective metal shield with an opening on one side over which various absorbers can be placed. The other has the opening at one end of the cylinder where the tube has a very thin "window." The output (cpm) is not proportional to exposure or absorbed dose rate for different types and energy of the radiation. Although scales on survey meters are frequently marked "R per hour," these values are only true for the calibrating radiation. Significant errors can occur from use where the radiation is different than the calibrating radiation. When G-M tubes are used for analysis, proper calibration is likewise essential.

Ionization (ion) chambers are commonly used to measure dose or dose rate (or exposure or exposure rate) from beta, gamma and x radiation. Ions formed by the radiation passing through a selected gas in a chamber are measured either by applying voltage continuously with measurement of the extremely low current flow or by using the chamber as a condenser which is first charged, then exposed to the radiation and the amount of discharge determined. The chamber walls, internal components and gas filling are usually either air equivalent or tissue equivalent.

Proportional counters usually consist of a gas filled cylinder (chamber) containing a central wire to which a potential is applied. The potential is selected so that the output voltage signals are proportional to the energy released by the radiation causing the ionization events in the chamber. This permits selective measurement of different radiations. These counters are commonly used to measure alpha or neutron radiation. The gas in the chamber may be either static or flowing. They may be used as survey meters or for analysis, including spectrometric analysis (measurement of radiation intensity as a function of energy). The alpha survey meters have a very thin "window" to minimize absorption of the radiation.

Luminescent detectors are solids in which energy changes produced by radiation are stored so that subsequent processing will cause them to emit a quantity of light proportional to the energy change. Commonly used materials are metaphosphate glass and calcium or lithium fluoride. The glass is processed by irradiation with ultraviolet and the fluorides by heating. The latter, called thermoluminescent dosimeters (TLD), are finding many uses because of good sensitivity with small pieces. They are used for personnel monitoring, including neutron exposure evaluation.

Scintillation detectors use the phenomenon of light production due to interaction of radiation with crystals or other phosphors (solid, liquid or gas). Light pulses from the scintillator are measured with a photomultiplier tube and its associated electronic equipment. Since the light output and in turn the electrical signal is proportional to the radiation energy absorbed in the scintillator, these devices find a wide variety of uses. They are used as survey meters and for analysis, including spectrometric analysis.

Radiation produces a latent image in photographic emulsions, resulting in darkening of the film when developed by usual techniques. Two general types of film are used, one in which the radiation (beta, gamma, x ray) produces a general blackening, and the other in which small tracks are produced by charged particles, usually protons from fast or thermal neutron interactions in the film. The blackening due to gamma and x rays is not proportional to air or tissue absorbed dose at different energies, and various absorbers are placed adjacent to the film to minimize this aberration. Blackening due to beta radiation varies a small amount with energy. A major use of film for dosimetry has been in personnel monitoring badges. Using both shielded and unshielded sections permits measurement of beta as well as gamma and x rays.

Chemical reaction detectors are systems in which radiation produces a chemical change in a material in such a manner that a chemical analysis or indicator will measure the amount of change. An example is a system using a chlorinated hydrocarbon, such as chloroform, with water and a dye indicator to measure the acid formed due to irradiation. These detectors are not used extensively because of their low sensitivity.

Induced radiation detectors are materials in which the radiation interacts to form radionuclides whose radiation can be measured. They are particularly useful for detecting or measuring neutron radiation. A typical example is the use of indium foil for detection of neutron radiation exposures. Proper selection of foil materials permits evaluation of a neutron energy spectrum. Fissionable materials also are useful for neutron radiation detection and measurement.

CATEGORIES OF RADIATION EXPOSURE

Natural Radiation

Individuals continually receive a dose from natural radiation that comes both from sources external to the body and from naturally occurring radionuclides deposited within the body. The external sources are primarily cosmic radiation and gamma radiation from materials naturally present in the ground and in building materials. From foods, drinking water and in the air, several radionuclides are deposited in the body including uranium and its decay products, thorium and its decay products, radiopotassium and radiocarbon. Natural radiation in the United States results in an estimated average annual dose equivalent to individuals of about 125 mrem (100 mrem external and 25 mrem internal). It is unlikely to be less than 100 mrem for any individual and unlikely to be more than 400 mrem for any significant number of people.[9]

Environmental Radiation

In addition to natural radiation, environmental radiation from man-made sources adds a small increment of dose to the population generally. This dose comes from a wide variety and type of sources including: fallout from nuclear weapons testing; effluents from nuclear and other facilities processing or using radionuclides; luminous dial

clocks or watches and signs; and electronic devices, such as television sets, using high voltages. The average annual dose equivalent to the population from these sources is estimated to be only a few percent of natural radiation, probably about five or six mrem per person per year.

Medical Irradiation

The planned exposure of patients to radiation is a category which involves a large percentage of the general population. Occupational exposures received incidentally by physicians and supporting staff are not considered part of this exposure category. Diagnostic and therapeutic procedures involve external irradiation with beta, gamma or x radiation, internal irradiation from ingested or injected radionuclides, and irradiation from implanted sealed sources. Doses to individuals vary over an extremely wide range but usually involve only partial body irradiation. Average annual dose equivalent to the population members from these sources has been estimated to be between 50 and 70 mrem per year.[10] Ordinarily, medical and occupational exposures are considered separately. With the exception of a high dose due to an occupational accident, necessary medical exposures are not restricted because of occupational exposures.

Occupational Irradiation

Occupational radiation exposures arise from practically every type of radiation and radiation source. The major groups of occupationally exposed personnel are medical or para-medical workers and workers in the expanding nuclear energy programs. However, there are many exposures to radiation or radioactive materials throughout industry, in underground mining, and in many types of research. On the basis of occupational radiation exposure records of the U. S. Atomic Energy Commission and its contractors for 1967, the average annual occupational exposure is estimated at about 500 mrem per person to 100,000 adults (95% of them received less than 1 rem each).[10] Assuming a similar dose to other workers, the estimated average annual dose equivalent to the population members is a fraction of a millirem per year.

BIOLOGICAL ASPECTS OF IRRADIATION

Somatic and Genetic Effects

Irradiation of humans produces two types of effect — somatic and genetic. The somatic effect is the effect on tissues, organs or whole body. Independent of any somatic effect, irradiation of the gonads may cause genetic effects since mutations, which are caused by heritable changes in the germ plasm, may occur. Of course, only the irradiation prior to conception can have this influence.

Somatic effects vary over a wide range — from rapid death due to short term whole body exposures of 10,000 Roentgens or greater to slight reddening of the skin due to minimal exposure.

Effects, including those of particular concern —neoplasms, cataracts and life shortening—may also be delayed for long periods. Within the body, cells react with varying degrees of sensitivity. Tissues also respond differently, depending on dose equivalent rate. Dose fractionation has an ameliorating effect and there is repair of tissues and organs when time permits and the change is not irreversible. Partial body irradiation has much less effect than whole body irradiation. Age is a significant factor; for a given dose many effects are less as age increases. For equal absorbed doses, different types (and energies) of radiation do not produce the same degree of response.

In the study of biological effects, the variation due to different kinds of radiation is referred to as "relative biological effectiveness" (RBE) — the ratio of absorbed doses that produce equal effect, with cobalt-60 gamma rays or 200-250 kV x rays used as the reference. This ratio is reflected indirectly in the quality factor used in radiation protection practice. Those somatic effects (e.g., neoplasms) that are delayed for long periods of time may occur only in a small fraction of the exposed individuals — the *probability* of the effect occurring increasing with increased dose equivalent.

Genetic effects are of general concern because radiation-induced mutations are added to the "load" of defective genes present in the population. Because of the presence of defective genes in all members of the population, it is not possible to identify an abnormality in an offspring with possible mutations caused by irradiation of the parent. Thus, genetic effects relate to population groups, not individuals. Because of this, the radiation exposure to the entire population group is the matter of primary concern, and the genetically significant dose (GSD) has been established as a measure of this population exposure. Furthermore only gonadal exposures during the reproductive period of a lifetime have an influence. Thus, the age at which radiation exposures occur, as well as the dose equivalent, is of prime concern in relation to genetic effects.

Acute and Chronic Exposures

Practically all occupational irradiation involves chronic exposures, i.e., small weekly doses (e.g., <100 mrem) occurring over many months and years. Occasionally, due to an accident, an acute exposure may occur, i.e., a high dose (e.g., >25 rem) in a period of a day or less. Somatic response to acute exposure is different from and greater than that for an equal chronic exposure. In a lifetime of occupational exposure without any observable effect, an individual's total dose can be large enough so that an equal dose given in a few hours would be seriously disabling or fatal. Effects of acute exposures may be early, delayed or secondary, and late. Early effects as a result of an acute whole body exposure are shown in Table 29-6. There is less effect for partial body exposures. Delayed effects may occur some time after the early effects have been ameliorated, the extent depending on the dose. In addition to possible loss of hair, one such effect of general concern (often misunderstood) is sterility. Permanent sterility occurs only with absorbed doses to the

TABLE 29-6

Representative Dose-effect Relationships in Man for Whole Body Irradiation

Nature of Effect	Representative absorbed dose of whole body x or gamma radiation (rads)
Minimal dose detectable by chromosome analysis or other specialized analyses, but not by hemogram	5-25
Minimal acute dose readily detectable in a specific individual (e.g., one who presents himself as a possible exposure case)	50-75
Minimal acute dose likely to produce vomiting in about 10% of people so exposed	75-125
Acute dose likely to produce transient disability and clear hematological changes in a majority of people so exposed.	150-200
Median lethal dose for single short exposure	300

The dose entries in this table should be taken as representative compromises only of a surprisingly variable range of values that would be offered by well-qualified observers asked to complete the right hand column. This comes about in part because whole body irradiation is not a uniquely definable entity. Mid-line absorbed doses are used. The data are a mixed derivative of experience from radiation therapy (often associated with "free-air" exposure dosimetry), and a few nuclear industry accident cases (often with more up to date dosimetry). Also, the interpretation of such qualitative terms as "readily detectable" is a function of the conservatism of the reporter.

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gonads of 500-600 rads of x or gamma radiation; and a single dose of 50 rads may induce brief temporary sterility in many men and some women.[10] Late effects as the result of acute exposure, such as leukemia, may occur many years after exposure, their *probability* increasing as dose increases. From chronic exposures, there are no secondary or delayed effects and the possibility of late effects is minimal. If chronic occupational doses are within the NCRP dose limiting recommendations, the probability of any late effect is so small that it has not been possible to establish clearly whether any such somatic effect exists.

Internal and External Radiation Sources

External radiation sources, i.e., those sources which are located external to the body, present an entirely different set of conditions than radionuclides which have gained entrance to the body with their attendant continuous irradiation of the cells and tissues in which they exist. Such radionuclides are called internal radiation sources — sometimes internal emitters.

Entry of internal radiation sources into the body during occupational exposures is principally from breathing air containing particulate or gaseous radionuclides, although ingestion may be a significant mode. Absorption through the skin is significant for some compounds of a few radionuclides, particularly tritium; and implantation under the skin may occur as the result of accidental skin puncture or laceration. Once inside the body, radionuclides are absorbed, metabolized and distributed throughout the tissues and organs according to the chemical properties of the elements and compounds in which they exist. Their effects on organs or tissues depends on the type and energy of the radiation and residence time. Both radioactive decay and biological elimination remove radionuclides from the body and its organs, these removal rates frequently being expressed as half-lives. The net rate is designated as the "effective half-life." While metabolically similar, the degree of effect from different radioactive isotopes of the same element will vary according to the type and energy of the radiation they emit and their radioactive half-life. Acute or early effects do not occur from internal radiation sources, with the possible exception of a very large intake of certain radionuclides.

While radiation measurements can be made in the environment of workers which characterize their dose equivalent from external radiation sources, no comparable environmental radiation measurement will reveal dose equivalent from exposures to internal radiation sources. Instead, evaluation (and control) is based on activity concentrations in air or water, a specific relation between these concentrations and the resulting dose equivalents for each radionuclide having been determined from human experience when available, or from calculations. Thus, practical dose-limiting recommendations are expressed in terms of maximum permissible concentrations (MPC) for inhaled or ingested radionuclides. A similar concept is expressed as a Radioactivity Concentration Guide (RCG) by the Federal Radiation Council.[4] For essentially insoluble gases producing beta or gamma radiation, such as the inert gases argon and krypton, the amount of the radionuclide that becomes an internal radiation source is so small that the external irradiation from an infinite cloud surrounding the individual will produce the greater dose equivalent.

The effect from external radiation sources depends on the penetrating ability of the particular radiation. Thus, alpha radiation is of no concern externally, and beta is stopped in the outer tissues, the depth depending on energy. Very low energy x or gamma radiation is attenuated quite rapidly.

The effect of radiation on any organ or tissue is dependent on the total dose equivalent from both internal and external radiation sources. Thus, the total dose equivalent must be considered when comparisons with the MPD are made. Theoretic-

ally, it should be possible to sum these separate dose equivalents but in practice such quantitation is difficult, if not impossible. Therefore, it is customary to use the two different dose-limiting recommendations conservatively.

Critical Organs and Tissues

The various tissues and organs of the body are not affected equally by equal irradiation. Their responses vary considerably and for radiation protection purposes it is essential that dose equivalent to the most sensitive organs essential to well being be given primary consideration. For uniform whole body irradiation, the blood forming organs (red bone marrow), the lens of the eye, and the gonads are more susceptible to significant effects and these are designated as "critical organs." Of course, for individuals past reproductive age the gonads are not a critical organ. For those internal radiation sources that do not irradiate the body uniformly the distribution and metabolic pattern for each radionuclide will determine which organs and tissues receive the larger dose. Again, for radiation protection purposes, any essential organ or tissue which is likely to be affected the most by the radiation from internal radiation sources is of primary concern and these are also designated as critical organs. These critical organs (and tissues), sometimes designated as limiting organs, are: lung, GI tract, bone, muscle, fatty tissue, thyroid, kidney, spleen, pancreas and prostate.

The total activity (curies) of a radionuclide in the body is designated as the "body burden." Distribution may be inhomogeneous, with a large fraction in one or more organs or tissues. While the activity in the crititcal organ is the limiting factor, the body burden corresponding to the MPD for the critical organ indicates the total activity that should be present in the entire body. It is designated as the maximum permissible body burden.

RADIATION PROTECTION CONSIDERATIONS

Occupational and Public Exposures

Occupational radiation exposures involve a select age group of healthy individuals. Their exposures occur for periods not exceeding approximately eight hours per day and 250 days per year. This group is a very small portion of the general population and they are trained in radiation protection practices. In contrast, the general population necessarily includes the unborn, the very young, the sick or disabled; and their exposures can be continuous — 24 hours per day, 365 days per year. For these, and other reasons, dose-limiting recommendations for the general population are set at lower limits than for occupational exposure, commonly by a factor of 10 or greater. Dose-limiting recommendations applicable to the public are designated frequently as "dose limits," those for occupational exposure as "maximum permissible dose equivalent (MPD)." The Federal Radiation Council designates both as RPG's. Only those individuals whose duties involve exposure to radiation should be classed as "occupationally exposed" and their training in radiation protection should be assured.

Dose Assessment

To accurately determine the true dose equivalent to the critical organs of all occupationally exposed individuals is a desirable objective which in practice becomes impractical, if not impossible. Activities in the workplace are varied in space and time, the energy and frequently the type of radiation varies, parts of the body being irradiated change with time, irradiation may occur from both internal and external radiation sources, and measurement devices have varying degrees of accuracy. Environmental measurements, however, can be made in a manner such that they provide a conservative evaluation of the dose equivalent to the critical organs and in turn assure that dose-limiting recommendations are not exceeded. This is accomplished by a combination of radiation surveys, area monitoring and personnel monitoring. If radiation surveys or other adequate data indicate that external irradiation will be less than one fourth of the applicable dose-limiting recommendation, personnel monitoring devices are not recommended. Above this, suitably selected personnel monitoring devices are required for evaluation of the radiation environment in which the individual works. The dose equivalents indicated by these are normally conservative with respect to any critical organ dose equivalent, and for general control purposes their readings can be compared to the applicable dose-limiting recommendation. Personnel monitoring devices are normally worn on the trunk of the body, but for some types of work they are required on extremities, particularly hands and forearms, as well. The dose-limiting recommendations permit higher doses here. Possible doses from small beams not intercepted by personnel monitoring devices must be evaluated by other means.

For exposures to airborne radioactive materials, the activity concentration in the breathing zone of the worker, averaged over a 40-hour weekly period, is compared with the tabulated values of maximum permissible concentrations (MPC) for the radionuclides of concern (see page 390). These concentrations, if breathed 40 hours per week indefinitely, will produce a dose equivalent in the critical organ equal to the dose-limiting recommendation.

If a valid determination of total dose equivalent to the whole body, the parts of the body, or the critical organ is required, such as after an abnormal exposure or to establish a monitoring procedure, a detailed evaluation based on all pertinent data should be made.

To convert absorbed dose to dose equivalent, the rounded practical values of the quality factor in Table 29-7 may be used. Methods of calculating a quality factor are described in reference (10). If neutron flux density and energy are measured or known, the dose equivalents may be found in Table 29-8.

TABLE 29-7
Practical Quality Factors

Radiation Type	Rounded QF
X rays, gamma rays, electrons or positrons, Energy >0.03 MeV	1
Electrons or positrons, Energy <0.03 MeV	1
Neutrons, Energy <10 keV	3
Neutrons, Energy >10 keV	10
Protons	10
Alpha particles	20
Fission fragments, recoil nuclei	20

TABLE 29-8
Mean quality factors, $\overline{QF}$[a], and values of neutron flux density which in a period of 40 hours results in a maximum dose equivalent of 100 mrem.

Neutron Energy	$\overline{QF}$	Neutron Flux Density
MeV		$cm^{-2}\ s^{-2}$
2.5×10^{-8} (thermal)	2	680
1×10^{-7}	2	680
1×10^{-6}	2	560
1×10^{-5}	2	560
1×10^{-4}	2	580
1×10^{-3}	2	680
1×10^{-2}	2.5	700
1×10^{-1}	7.5	115
5×10^{-1}	11	27
1	11	19
2.5	9	20
5	8	16
7	7	17
10	6.5	17
14	7.5	12
20	8	11
40	7	10
60	5.5	11
1×10^{2}	4	14
2×10^{2}	3.5	13
3×10^{2}	3.5	11
4×10^{2}	3.5	10

[a]Maximum value of $\overline{QF}$ in a 30-cm phantom.

Tables 29-7 and 29-8 reprinted with permission of National Council on Radiation Protection and Measurements, from "NCRP Report No. 39" — (1971) Washington, D.C.

TABLE 29-9
NCRP Dose-limiting Recommendations

Maximum Permissible Dose Equivalent for Occupational Exposure	
Combined whole body occupational exposure	
Prospective annual limit	5 rems in any one year
Retrospective annual limit	10-15 rems in any one year
Long term accumulation to age N years	(N − 18) × 5 rems
Skin	15 rems in any one year
Hands	75 rems in any one year (25/qtr)
Forearms	30 rems in any one year (10/qtr)
Other organs, tissues and organ systems	15 rems in any one year (5/qtr)
Fertile women (with respect to fetus)	0.5 rem in gestation period
Dose Limits for the Public, or Occasionally Exposed Individuals	
Individual or occasional	0.5 rem in any one year
Students	0.1 rem in any one year
Population Dose Limits	
Genetic	0.17 rem average per year
Somatic	0.17 rem average per year
Emergency Dose Limits—Life Saving	
Individual (older than 45 years if possible)	100 rems
Hands and forearms	200 rems, additional (300 rems total)
Emergency Dose Limits—Less Urgent	
Individual	25 rems
Hands and forearms	100 rems, total
Family of Radioactive Patients	
Individual (under age 45)	0.5 rem in any one year
Individual (over age 45)	5 rems in any one year

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The dose to the whole body or to the critical organs from internal radiation sources continues as long as the radionuclide is present. When intake is stopped, the dose decreases with time — frequently exponentially. Where the effective half-life is long, the total dose equivalent is rather large in comparison to that produced during and shortly after the time of exposure. This total dose equivalent, integrated over a lifetime, is designated as the "dose commitment." It is useful in a number of different types of evaluations.

Dose-Limiting Recommendations

The National Council on Radiation Protection and Measurements (NCRP) is generally recognized as an authoritative source of radiation protection information, data and criteria in the United States. NCRP Report No. 39[10] discusses radiation protection criteria in detail and presents their dose-limiting recommendations, which are shown in Table 29-9. The NCRP comment on the occupational limits is: "There will be occasions when the measured or estimated actual dose equivalent exceeds the prospective limit of 5 rems in a year. No deviation from sound protection is implied if the retrospective dose equivalent does not exceed 10 to 12 rems for dose increments well distributed over time or even 15 rems for exceptionally well-distributed increments. Repetition of retrospective dose equivalents in excess of planned limits is controlled by the long-term occupational accumulated dose equivalent." The NCRP recommendations serves as the basis for various regulations and standards in which interpretations are made according to specific needs. Regulations of states, U.S. Atomic Energy Commission and other governmental agencies may not be the same as NCRP recommendations and must be consulted and used as applicable (see Chapter 9 and page 392).

Similarly, NCRP has provided tabulated values of maximum permissible body burdens and maximum permissible concentrations of radionuclides in air and water for occupational exposures. Some of these values are shown in *Radiological Health Handbook*.[9] The complete tabulation is in NCRP Report No. 22[11] and a similar tabulation, with the derivation data and methods, is in a report of the International Commission on Radiation Protection.[12] The various regulations also contain such tabulations, usually including values applicable to the general public.

IRRADIATION BY EXTERNAL RADIATION SOURCES

Exposure Control

A basic concept in radiation protection practice is the establishment of a "controlled area." Access to these areas must be controlled and within them supervision and control of occupational exposures is provided. Emergence of beams and escape of radioactive materials from these areas are also controlled. These areas are identified by use of the standard radiation symbol[13] with associated warning notices. This symbol, a purple trefoil on a yellow background, also identifies any radiation source.

Since the useful beam of x-ray equipment may inflict a year's MPD in minutes or less, the design of industrial x-ray facilities must of necessity give proper consideration to the establishment of a suitably controlled area which will assure proper radiation protection for two groups of individuals — those who operate the equipment (occupationally exposed) and those in the environs, either normally or casually (not occupationally exposed). Where possible, the x-ray equipment should be within a room or other enclosure arranged with controls outside and having interlocks to prevent entry when equipment is energized. Shielding can then be provided so that the exposure rate outside the enclosure will be low enough to insure that the applicable MPD or dose limit will not be exceeded. Small devices or instruments using x rays, such as laboratory equipment, usually can be totally enclosed with adequate shielding, but accessibility to the inside of the shield requires special consideration (interlocks, etc.). Where work requires truly mobile or portable equipment, exposure time and distance from the equipment become the basic method for controlling exposure rates to values which will insure that no individual exceeds the applicable MPD or dose limit. Portable shielding can be an aid. *American National Standard Z54.1-1963*[7] classifies x-ray and sealed gamma-ray source installations into three types: exempt, enclosed and open. Shielding design and operational requirements are given. Although intended for medical installations, *Medical X-ray and Gamma-ray Protection for Energies up to 10 MeV*[8] may provide useful data; shielding data is also presented in reference (2). For accelerators, *American National Standard Radiological Safety in the Design and Operation of Particle Accelerators*[14] establishes safety requirements.

In addition to x-ray equipment, there may be other sources of x rays in industry, such as high voltage (>10kV) electron tubes, which may require shielding or other means of control to assure adequate radiation protection for workers (or the public).

Gamma radiation, usually from a sealed source, is used for a variety of purposes in industry. The larger sources produce beams comparable in exposure rate to x-ray equipment. Detailed descriptions cannot be given here, but rather a few general considerations. Gamma radiation cannot be turned off like x rays. This imposes a severe requirement on retention of the sealed source at a predetermined specific location where exposure control is assured or within appropriate shielding at all times. Procedures and surveys must guarantee this control. The integrity of the encapsulation or bonded cover of the sealed source must be assured at all times to prevent release of the radioactive material into the environment where it could be dispersed and inhaled or ingested. Periodic tests, such as smears of the sealed source or its container, should be made. Appropriate testing of radium sources is particularly important because any failure will release radon gas which, with its daughters, can contaminate the surrounding area. Exposure rates from sealed sources, in air, can be calculated from the specific gamma-ray constant (see page 382). As an approximation, the gamma exposure rate (R/hr) at 1 foot is 6CE, where C is the number of curies and E is the total energy per disintegration in MeV. As for x-ray installations, references (7) and (8) provide useful shielding information.

Beta radiation sources, which are frequently built into some piece of equipment such as a thickness gauge, must be shielded and arranged so that access to the beta radiation is prevented. Of par-

ticular concern is control of exposures during any maintenance procedures. Consideration must be given to any associated gamma radiation; and to the bremsstrahlung exposure rate, particularly for sources of high activity and energy. To permit escape of the beta radiation, the encapsulating material must be relatively thin, at least over the useful area of the source. Damage to this encapsulation will permit release of the radionuclide to the environment where it can be dispersed and inhaled or ingested.

Radioactive neutron sources are commonly small sealed sources of relatively substantial construction. Yield of neutrons is proportional to the activity in the source. See page 385 for neutron source data. Consideration must be given to gamma radiation as well as neutron radiation from them. If the radionuclide in them is radium, the gamma dose equivalent rate is higher than that from neutrons and the possibility of radon leakage must be recognized. Leakage of any of the radionuclides used in these sources presents a hazard of considerable magnitude which necessitates care in use and periodic testing. Commonly used shielding materials are concrete, polyethylene, boronated polyethylene or boron in other materials such as aluminum. Shielding and other useful data will be found in *Physical Aspects of Irradiation*[6] and *Protection Against Neutron Radiation*[9].

External radiation sources involve a wide variety of equipment which cannot be described here. Descriptions and useful data will be found in *Radiation Hygiene Handbook*.[15]

Exposure Evaluation

Applicable regulations (or NCRP recommendations) established the time period during which specific dose equivalents may be given to workers. Currently, most regulations permit a limit of 1.25 rem quarter indefinitely to the whole body, gonads, bloodforming organs and lens of the eye; or, for individuals whose previous radiation history has been established, a limit of 3 rems/quarter* with an overriding yearly limitation of 5(N-18) rems, N being age in years. Separate quarterly and usually yearly limits, with higher values, are specified for extremities and skin. Exposure evaluations therefore must be related to these time periods, no matter whether measurements are made in rems (or R) per hour, per day, per week or per month. Administratively, daily or weekly limits are frequently used for general control.

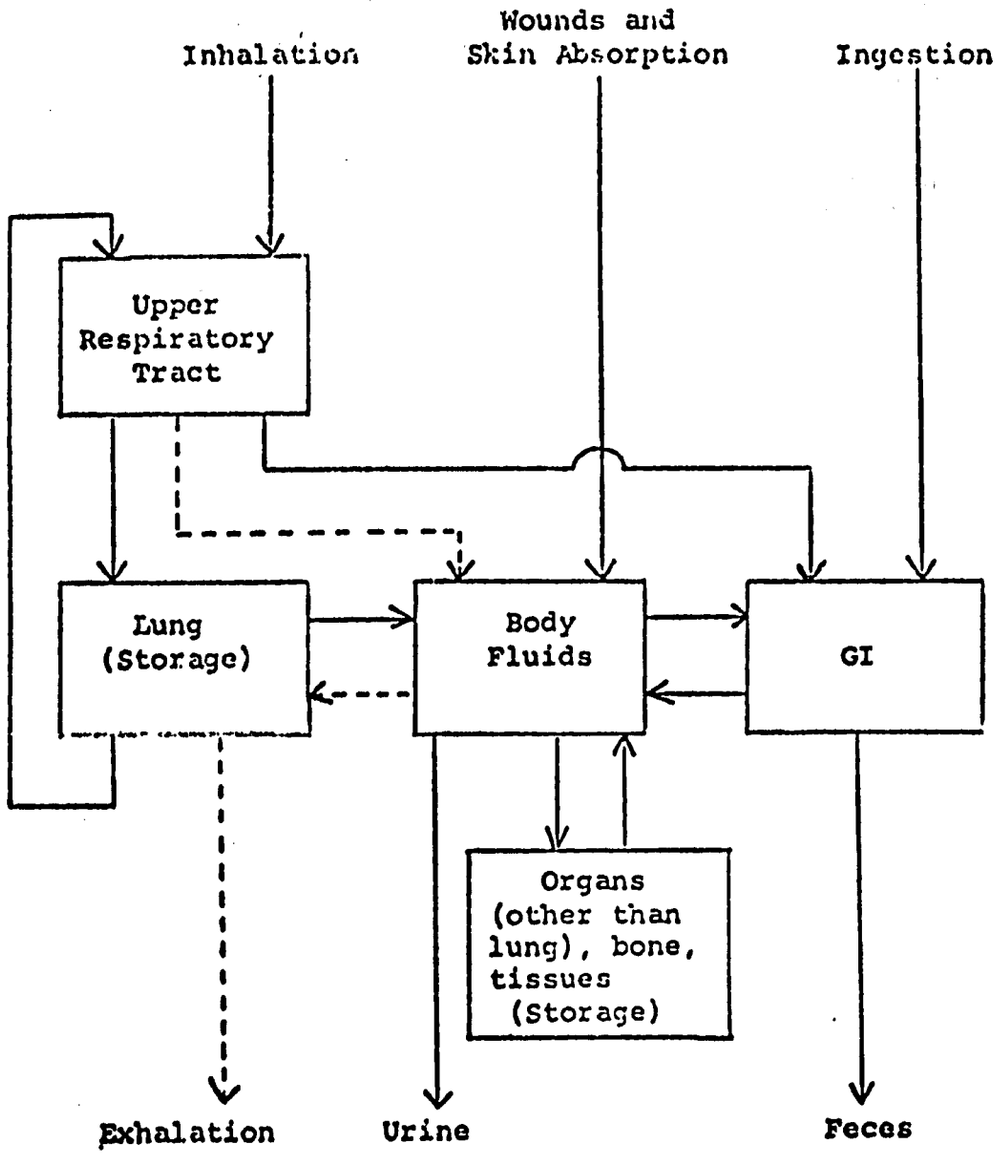
The evaluations to establish dose equivalent from external radiation sources are accomplished by conducting radiation surveys and monitoring the environment in which the individuals work. The radiation survey establishes the parameters that must be measured and depicts whether occasional or essentially continuous surveillance with measuring instruments is required. Proper instruments must be selected for the survey so that all possible types and energies of the radiation will be measured with reasonable accuracy. A wide selection of instruments is available commercially[5, 16, 17] but caution must be exercised to be certain their specified capability will fulfill the required needs. A comprehensive discussion of instrumentation is in *Radiation Protection Instrumentation and Its Application*.[15] Proper calibration for the radiation to be measured is essential. The higher the instantaneous dose rates or potential dose rates in the work area and the greater the complexity of the operations, the greater the need for continuous or frequent surveillance measurements; and correspondingly, closer control over the exposure time of the workers. Where abnormal situations may occur, area monitoring by permanently installed instruments at key locations, with readouts under observation at a central location, will aid in detecting any significant changes of the radiation levels in the general environment. Use of alarms may be indicated in extreme cases.

Except where it can be assured that dose equivalent rates are consistently very low (<25% MPD), personnel monitoring devices must be used to measure the radiation incident on a worker's body (or extremities), integrated over preselected time periods. Film badges, available from commercial services,[16, 17] have been used extensively with time periods usually being from a week to a month. Currently, there is increasing use of thermoluminescent dosimeters (TLD) for these and longer periods. Where dose equivalent rates are high and variable, the dose accumulated during minutes or hours of exposure becomes critical and pocket dosimeters (ionization chambers) provide a convenient means of such measurement. There are two types, those that require an instrument for readout and those that can be read directly. The latter are particularly useful when the worker can read them frequently and limit his work period or procedures accordingly. A film badge or TLD is normally used in addition to the pocket dosimeter to provide a back-up for an off-scale reading. There may be discrepancy between the two readings because of different response characteristics. A pocket-size instrument with an alarm sensitive to either dose or dose rate is available and can be used if operating conditions warrant. Indium foils may be added to film badges or other badges worn by workers if accidentally high neutron exposures may occur, the induced activity permitting a rapid qualitative check for a high neutron exposure.

External irradiation of the body tissues or organs may occur from radionuclides deposited on the skin or in the clothing. To detect (or measure) this requires a very careful probing over the entire body with a suitable instrument. A probe on a flexible cord is desirable; or where the contamination is limited to the hands or shoes, a "hand and foot counter" may be used.

Although periodic medical examinations are desirable for many reasons, they cannot be used as a means of exposure evaluation unless dose equivalents are many times the MPD (see Table 29-6). A relatively new cytogenetic technique involving a determination of chromosome irregu-

*This was a former NCRP recommendation.



Simplified Diagram of
Metabolic Pathways of Radionuclides in the Body

. principal pathways

- - - - - - - supplementary pathways depending on chemical and physical composition

Figure 29-3. Radionuclide Pathways through the Body.

larities found in somatic human blood cells,[19] although nonspecific, can provide a means of measuring dose equivalents slightly above the MPD, but use of this technique is severely limited due to the many man-hours required for each determination.

General administrative practices for radiation monitoring are presented in *American National Standard Guide for Administrative Practices in Radiation Monitoring.*[20]

IRRADIATION BY INTERNAL RADIATION SOURCES

Mode of Entry

Internal radiation sources gain entry to the body by breathing gaseous or particulate airborne radioactive materials, by swallowing radioactive materials that have gotten into the mouth from contaminated lips, hands, foods, or liquids, and by absorption through or implantation under the skin. After entry, a rather complex distribution throughout the body may occur as indicated in Figure 29-3. Although there may be irradiation throughout the body, the organs or tissues where the residence time and concentration are greatest receive most of the dose equivalent from alpha and beta radiation, while gamma dose is more distributed.

When inhaled, a fraction of radioactive gases and particulates are retained and absorbed in accordance with chemical and physical properties (not radioactive properties), the balance being exhaled. The retained material is distributed along all respiratory passages — that deposited in the upper passages being subsequently swallowed after clearance by drainage or ciliary action. Retention of particulates in the several sections of the respiratory tract is a function of the particle size distribution, the larger particles (10 μm dia.) not reaching the lung. Soluble materials, when deposited in the lung, are taken up in the blood stream, their subsequent distribution and excretion being determined by the metabolic pattern for that element. Insoluble materials are retained in the lung with a relatively slow clearance rate (e.g., ~ 120 day half-life). Without specific data, ICRP recommends an assumption that 25% is exhaled, 50% is deposited in the upper respiratory passages and 25% is deposited in the lungs, with all of that in the upper passages and half of that in the lungs being swallowed.

Ingested materials, including those cleared from the respiratory tract, pass through the gastrointestinal tract, with their absorption and excretion being determined by solubility of the particular chemical compound and metabolic pattern of the element.

Embedded materials, unless very soluble, tend to remain in the tissues near the sight of entry with a slow clearance rate from that site. Those few materials which can be absorbed through the skin are promptly distributed throughout the body tissues.

The tabulated values of MPC for air and water take all of these various ramifications into account except for embedded materials, yet for exposure control and exposure evaluation purposes some of the above factors require consideration.

Exposure Control

Work with radioactive materials that are not effectively contained necessitates the establishment of a well defined controlled area. Preferably it should be a room or other totally enclosed area which will prevent atmospheric dispersion of the radioactive materials to outside areas. Exhaust of air from the room through filters may be required. Movement of individuals or materials through the exit (entrance) should be controlled to prevent inadvertent transfer of radioactive materials outside. Any liquids containing radioactive materials should either be retained for safe disposal at an authorized location or be put into a drain which fulfills pertinent requirements for release of radioactive materials to the environment. Only workers, properly trained, or visitors properly controlled, should be permitted entry. The degree of these controls will vary over a wide range for different kinds of work depending on the activity (Ci) involved, the MPC of the radionuclides in air or liquid, the dispersion characteristics of the materials and the size or complexity of the operations.

Within the controlled area, the workers must be protected against breathing radionuclides in concentrations greater than the MPC averaged over a 40 hour week. Where exposure times are less or greater than 40 hours in a week, the tabulated MPC may be adjusted up or down proportionately. Although the MPC's are set for 40 hours per week exposures indefinitely, most regulations require that each week be considered separately. For work with very small amounts of material, e.g., less than the activity in a few maximum permissible body burdens, rather simple exposure controls are required — perhaps gloves and a lab coat. As the activity and dispersibility increase, protective measures progress through ventilated hoods, specially designed exhaust hoods, total enclosures and glove boxes. Some of these are described in reference (15). Use of personal protective equipment such as coveralls, gloves, head covers and shoe covers may be indicated (see Chapter 36). Where the concentration of airborne radioactive materials cannot be adequately controlled by exhaust and enclosures, respiratory protective equipment approved for radioactive materials is required. Where abnormal concentrations may occur, continuous air sampling devices with an alarm may be needed. Contamination of surfaces with radioactive materials throughout the controlled area may require control, such measurements being made by counting smears taken on filter papers from 100 cm^2 areas. Clothing change rooms with shower facilities, located at the exit (entrance) of the controlled area, may be required to prevent spread of radioactive materials from the area and to assure removal of contamination from workers' bodies. Possible remaining contamination is checked with an instrument probe.

For a laboratory, many or all of these factors require consideration. *American National Stand-*

ard Design Guide for a Radio-Isotope Laboratory (Type B)[22] is a general guide to these requirements.

Exposure Evaluation

Except for an accident, internal radiation sources resulting from occupational exposures usually accumulate gradually in the body of workers. Breathing airborne radioactive materials either intermittently or continuously is a prime source. Thus, a knowledge of the radionuclides and their average activity concentration in the air breathed by workers becomes important in any assessment of dose equivalent to critical organs or the corresponding bodily intake in relation to the MPC. Usually it is sufficient to assure that the weekly average airborne radioactivity concentration in the breathing zone of workers is less than the MPC, although other possible modes of entry should be considered. Hence, where dispersible radioactive materials are used, an air sampling program becomes a necessity. This program may vary from an occasional spot check where concentrations are readily maintained at a small fraction of the MPC, to continuous sampling either at or near the breathing zone of workers where exposure may average near the MPC or equipment failures may produce abnormal conditions.

Air sampling techniques and instruments discussed in Chapters 13, 14 and 15 may be used for radioactive materials provided the sample is suitable for radioactivity analysis. Samplers using filter paper or membranes have found general application because the activity measurement can be made readily. For some situations, samplers which provide a size separation are used. The samplers may be portable instruments with a sampling head that can be positioned or held near the breathing zone of workers, or be permanently mounted equipment. *American National Standard Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities*[23] provides a complete guide to sampling airborne radioactive materials.

Radionuclides are removed from the body by excretion in the urine and feces, the rate and partitioning between the two depending on many factors including mode of entry into the body, elemental composition, solubility and rate of intake. For many radionuclides, sufficient knowledge of excretion patterns and rates are available so that measurements of excretion rates can be quantitatively related to intake rates, or activity in the body, or both. Data obtained from analysis of urine or feces — frequently called bioassays — can serve as an assessment of previous and current intake rates to verify air sampling data. By discontinuing current intake for a period, an estimate of the body burden or critical organ burden can be made from such excretion measurements — usually a series of measurements over a period of a week or longer. When used to assess current intake rates it is common practice to establish, for each radionuclide, an "investigation level" or "check point." These are discussed in *Recommendations of the International Commission on Radiological Protection, Report of Committee IV on Evaluation of Radiation Doses to Body Tissues from Internal Contamination Due to Occupational Exposure,*[24] with very conservative values listed. For excretion rates or activity concentrations in the excreta which are below an appropriate investigation level, it is assumed that exposure controls and evaluations have been adequate; but if above these levels, an examination of the adequacy of current practices is made.

A further means of assessing the current status of a worker with respect to intake and retention of radionuclides is an in vivo determination of body burden or critical organ burden by measuring the gamma radiation being emitted from his body (or critical organ). The simplest of these is measurement of radioiodine in the thyroid by placing an instrument adjacent to the thyroid. For most radionuclides, a "whole body counter" is required. It consists of one or more measuring instruments which scan the whole body, usually in a well shielded enclosure to minimize the effect of background radiation.[25] Such measurements require skilled personnel and very sensitive measuring devices, properly calibrated. Such measurements can be made for radionuclides emitting x rays, such as uranium-235, plutonium-239 and americium-241, as well as for radionuclides emitting higher energy gamma radiation.

As with external irradiation, medical examinations cannot be used to evaluate dose equivalent from internal radiation sources when exposures are at or below MPC, and the cytogenetic technique (page 392) may be useful in a qualitative way at slightly higher exposures.

PARTICULAR CONDITIONS

Nuclear Criticality Safety

A few of the heavier radionuclides which are capable of sustaining a nuclear chain reaction require handling and processing techniques which will avoid the possibility of inadvertently forming a critical mass, with the attendant emission of intense radiation. The mass of these fissile materials at any one location or their geometric arrangement must be controlled with a high degree of confidence. Information about the basic limiting parameters used to assure nuclear criticality safety are in *American National Standard N16.1*[26] Additionally, all fissile materials are used under Atomic Energy Commission regulations and license — in which they are designated as "Special Nuclear Materials." The regulations designate the masses of fissile materials below which nuclear criticality safety controls are not required and licenses specify the limiting conditions of use for greater amounts. A standard symbol is used to identify fissile materials and areas in which they are used.[27] It is similar to the radiation symbol with circular bars around it.

Nuclear Reactor Industry

The nuclear reactor industry presents an array of radiation protection problems much too complex to discuss in this Chapter. During mining of uranium ore there are exposures to radon gas and its daughters, as well as to uranium dust;[28] and similar problems occur during the processing to extract the uranium from the ore.[29] The uran-

ium enrichment (in uranium-235) process involves various chemical forms of uranium including uranium hexafluoride, a gas. After enrichment, nuclear criticality safety controls become mandatory for all subsequent handling and processing. Fuel manufacturing[30] involves a chemical conversion process and various treatments of the resulting solids prior to loading into the fuel rods. The fuel rods are sealed and subsequent handling involves no further exposure to airborne radioactive materials. Fuel manufacturing and much of the previous processing involves only relatively minor external irradiation problems. In a nuclear reactor facility, control of exposure to external radiation sources as well as control of fission and corrosion products which may become airborne becomes necessary. Fuel reprocessing plants take spent fuel, which is highly radioactive, and pass it through complex chemical processes to separate the fuel materials (including plutonium) from the fission products, so that both external irradiation and complex airborne radioactive materials, including gases, require control and evaluation. Fuel manufacturing may include fuel elements that contain plutonium — requiring sophisticated controls to prevent release of plutonium. Throughout the industry, control and evaluation of releases of radioactive materials to the environment is essential.

Transportation

Radioactive materials are shipped by all normal transportation methods including the U. S. Postal Service, railroads, airplanes, trucks and ships. There are some limitations on the types and quantities that will be accepted by some of these, particularly the Postal Service. Regulations of the U. S. Department of Transportation (DOT) are applicable to all interstate transport except for the Postal Service. There are separate regulations for the Coast Guard and Federal Aviation Agency, although these conform to the DOT Regulations. Most states have regulations applicable to intrastate transport and a few cities have some regulations. Turnpikes, bridges and tunnels operated by authorities may have separate regulations, limitations and requirements. Packaging of fissile materials and large quantities of radioactive materials are subject to Atomic Energy Commission Regulations, 10 CFR 71 (see Chapter 9). International transport is subject to regulations of the International Atomic Energy Agency.

In all cases the shipper is required to provide packaging which fulfills the requirements of the pertinent regulations except for small quantities that are exempted. For detailed packaging and labelling requirements, the regulations applicable to the mode of shipment should be consulted.[31-32]

Records

Since some diseases and attendant disability that may be caused by exposure to radiation or radioactive materials can occur after many years of exposure or many years after exposure, retention of suitable records relating to exposures and working conditions for long periods of time is desirable and usually required by regulations. Workmen's Compensation Laws usually permit filing claims for radiation injury many years after exposure occurred, and for these adequate records will be required. A comprehensive presentation of information about records and their retention is in *American National Standard N2.2.*[33]

Regulations

The use of radiation and radioactive materials is subject to official regulation by various governmental agencies. Such regulations are discussed in Chapter 9. It is essential that any user of radiation or radioactive materials become intimately familiar with the details of all current rules and regulations applicable to his operations. Licenses, permits or notifications are commonly required. Before preparing a license application the person who will subsequently issue the license should be consulted. Because of the length, detailed provisions and variability of these rules and regulations, only a few general provisions have been mentioned in this chapter.

References

1. *Radiation Quantities and Units* ICRU Report 19, International Commission on Radiation Units and Measurements, Washington, D. C. 20014 (1971).
2. *Radiological Health Handbook* U. S. Dept. of Health, Education and Welfare, Public Health Service. U. S. Govt. Printing Office, Washington, D. C. 20402 (1970).
3. *American National Standard Glossary of Terms in Nuclear Science and Technology* N1.1-1967. American National Standards Institute, New York, N.Y. 10018 (1967).
4. *Background Material for the Development of Radiation Protection Standards*, Report No. 1, Federal Radiation Council. U. S. Govt. Printing Office, Washington, D. C. 20402 (1960).
5. MORGAN, K. Z. and J. E. TURNER. *Principles of Radiation Protection*, John Wiley and Sons, Inc., New York, N.Y. (1967).
6. *Physical Aspects of Irradiation* ICRU Report 10b, National Bureau of Standards Handbook 85, U. S. Govt. Printing Office, Washington, D. C. 20402 (1964).
7. *Safety Standard for Non-medical X-ray and Sealed Gamma-ray Sources*, Part I. General, National Bureau of Standards Handbook 93. U. S. Govt. Printing Office, Washington, D. C. 20402 (1964).
8. *Medical X-ray and Gamma-ray Protection for Energies up to 10 MeV*, Structural Shielding Design and Evaluation, NCRP Report No. 34. National Council on Radiation Protection and Measurements, Washington, D. C. 20008 (1970).
9. *Protection Against Neutron Radiation* NCRP Report No. 38. National Council on Radiation Protection and Measurements, Washington, D. C. 20008 (1971).
10. *Basic Radiation Protection Criteria* NCRP Report No. 39. National Council on Radiation Protection and Measurements, Washington, D. C. 20008 (1971).
11. *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and Water for Occupational Exposure* NCRP Report No. 22. National Bureau of Standards Handbook 69. U. S. Govt. Printing Office, Washington, D. C. 20402 (1959).
12. *Recommendations of the International Commission on Radiological Protection, Report of Committee II on Permissible Dose for Internal Radiation (1959)* ICRP Publication 2, Pergamon Press. *Health Physics 3*:1, P.O. Box 156, East Weymouth, Ma. 02189 (1960).
13. *American National Standard Radiation Symbol*

N2.1-1969. American National Standards Institute, New York, N.Y. 10018.

14. *American National Standard Radiological Safety in the Design and Operation of Particle Accelerators* N43.1-1969. NBS Handbook 107, U.S. Govt. Printing Office, Washington, D. C. 20402 (1969).

15. BLATZ, H. *Radiation Hygiene Handbook*, McGraw-Hill Book Co., Inc., New York, N.Y. (1959).

16. *Guide to Scientific Instruments, Science 174A*:9 (1971).

17. *Nuclear News Buyers Guide 1971*, Supplement to Nuclear News. 14: No. 2, Feb. 1971. American Nuclear Society, Hinsdale, Ill. 60521.

18. *Radiation Protection Instrumentation and Its Application* ICRU Report 20. International Commission on Radiation Units and Measurements, Washington, D. C. 20014 (1971).

19. BENDER, M. A. *Somatic Chromosomal Aberrations, Use in Evaluation of Human Radiation Exposures. Archives of Environmental Health 16*:556, Chicago, Ill. (1968).

20. *American National Standard Guide for Administrative Practices in Radiation Monitoring* N13.2-1969. American National Standards Institute, New York, N.Y. 10018 (1969).

21. U. S. Bureau of Mines, *Procedure for Testing Filter Type Dust, Fume and Mist Respirators for Permissibility* Schedule 21B, June 1969. (30 CFR 14) U. S. Govt. Printing Office, Washington, D. C. 20402 (1969)

22. *American National Standard Design Guide for a Radio-Isotope Laboratory (Type B)* N5.2-1963. American National Standards Institute, New York, N.Y. 10018 (1963).

23. *American National Standard Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities* N13.1-1969. American National Standards Institute, New York N Y (1969).

24. *Recommendations of the International Commission on Radiological Protection, Report of Committee IV on Evaluation of Radiation Doses to Body Tissues from Internal Contamination Due to Occupational Exposure* ICRP Publication 10. Pergamon Press, Long Island City, N.Y. 11101 (1968).

25. *Radioactivity* ICRU Report 10c. National Bureau of Standards Handbook 86. U. S. Govt. Printing Office, Washington, D. C. 20402 (1963).

26. *American National Standard Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors* N16.1-1969. American National Standards Institute, New York, N.Y. 10018 (1969).

27. *American National Standard Fissile Material Symbol* N12.1-1971. American National Standards Institute, New York, N.Y. 10018 (1971).

28. *American National Standard Supplement to Radiation Protection in Uranium Mines and Mills* N7.1a-1969. American National Standards Institute, New York, N.Y. 10018 (1969).

29. *American National Standard Radiation Protection in Uranium Mines and Mills (Concentrators)* N7.1-1960. American National Standards Institute, New York, N.Y. 10018 (1960).

30. *American National Standard Radiation Protection in Nuclear Reactor Fuel Fabrication Plants* N7.2-1963. American National Standards Institute, New York, N.Y. 10018 (1963).

31. *Code of Federal Regulations*. U. S. Govt. Printing Office, Washington, D. C. 20402.
Department of Transportation 49CFR170-179.
Coast Guard 46CFR146.
Federal Aviation Agency 14CFR103.

32. *Radioactive Matter*, Publication No. 6, U. S. Postal Service, U. S. Govt. Printing Office, Washington, D. C. 20402.

33. *American National Standard Practice for Occupational Radiation Exposure Records System* N2.2-1966. American National Standards Institute, New York, N.Y. 10018 (1966).

Preferred Reading

Health Physics, Official Journal of the Health Physics Society. P.O. Box 156, East Weymouth, Mass. 02189.

American Industrial Hygiene Association Journal. 66 South Miller Rd., Akron, Ohio 44313.

Reports (various). National Council on Radiation Protection and Measurements, Washington, D. C. 20008.

American National Standards (various). American National Standards Institute, New York, N.Y. 10018.

Reports (various). U. S. Dept. of Health, Education and Welfare, Public Health Service, Rockville, Maryland 20852.

Barnes, George E.

PLATING AND METAL FINISHING OPERATIONS

The plating shop at Newton Instrument Company was originally designed for only captive plating within the company. However, with growth of the company and changing of its product line and scope of operation, the plating shop has become mainly a job shop, accepting metal finishing jobs by contract from other persons or firms. Operation of the shop will vary from day to day, depending on the contracted workload.

The metal finishing operations consist of four major lines. Surface coatings available are cadmium, chromium, copper, nickel, phosphate, tin and zinc, with chromium conversion coating of cadmium and zinc. The four main lines are:

A. a hoist-operated iron phosphating line capable of treating items 12 feet long;

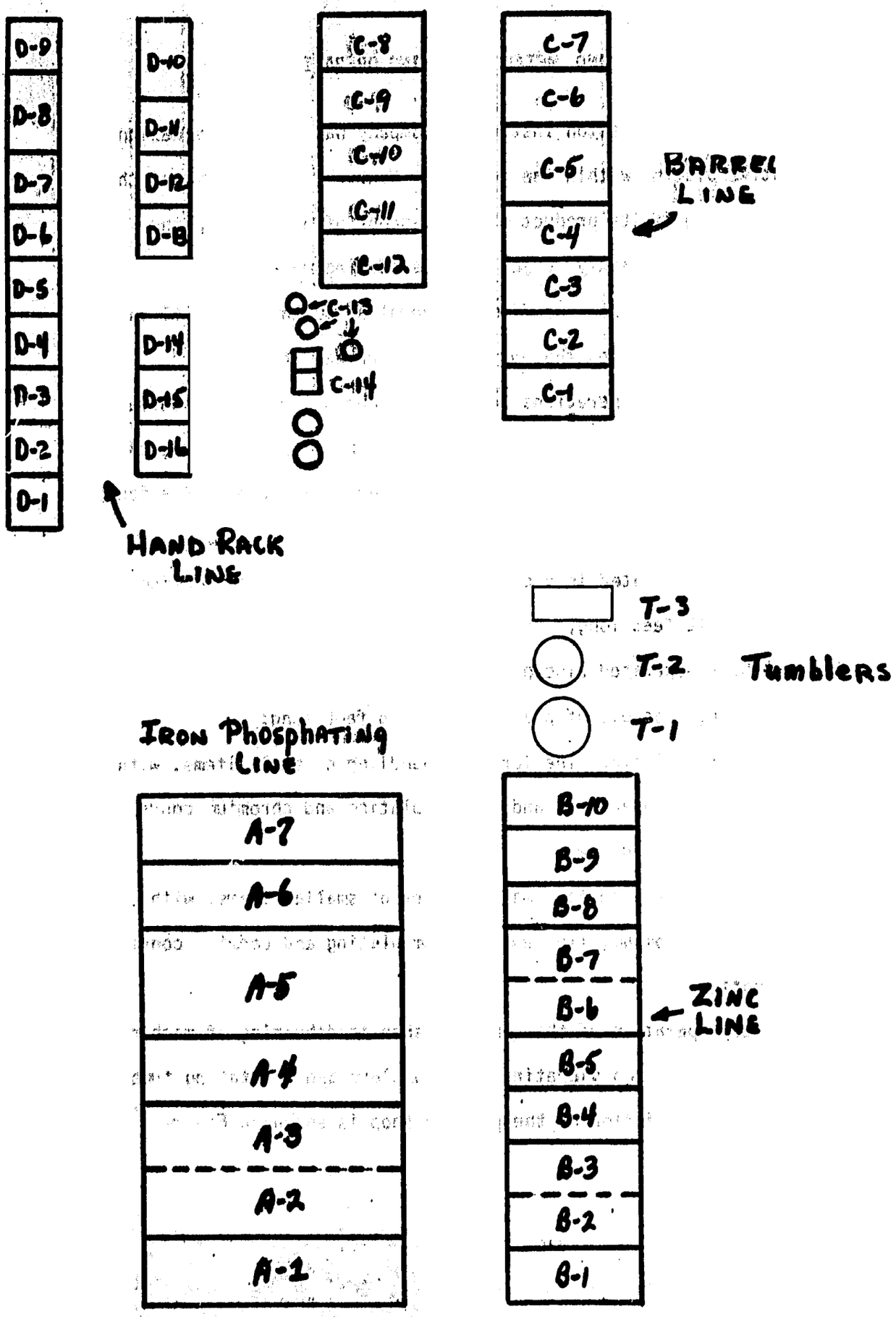
B. A hoist-operated zinc plating line, with chromium conversion coating, capable of plating items 8 feet long;

C. A barrel plating line for bulk handling of small items, with cadmium, copper, tin and nickel plating and chromium conversion coating of cadmium;

D. A hand rack line for small numbers of smaller items, with copper, nickel chromium, tin and cadmium plating and cadmium conversion coating.

An ancillary operation of the plating shop is deburring of machined par This is accomplished by two vibrating rock tumblers and a rotating tumbler.

A layout and description of the plating shop is shown on Figure ___ and in Table ___.


D-9
D-8
D-7
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D-4
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D-11
D-12
D-13
D-14
D-15
D-16
C-8
C-9
C-10
C-11
C-12
C-13
C-14
C-7
C-6
C-5
C-4
C-3
C-2
C-1
BARREL LINE
HAND RACK LINE
T-3
T-2
T-1
Tumblers
IRON PHOSPHATING LINE
A-7
A-6
A-5
A-4
A-3
A-2
A-1
B-10
B-9
B-8
B-7
B-6
B-5
B-4
B-3
B-2
B-1
ZINC LINE

TABLE

NEWTON INSTRUMENT COMPANY PLATING SHOP

Processing Line	Tank No.	Tank Process
Phosphating Line	A-1	Alkaline Cleaner Rinse to A-2, A-3
	A-2, A-3	Rinse tanks, countercurrent
	A-4	Acid Pickle, H_2SO_4 Rinse to A-2, A-3
	A-5	Iron Phosphate Rinse to A-6
	A-6	Spray Rinse
	A-7	Chromium sealer
Zinc Line	B-1	Alkaline cleaner Rinse to B-2, B-3
	B-2, B-3	Rinse tanks, countercurrent
	B-4	Reversing current cleaner, 4% NaCN, Rinse to B-2, B-3
	B-5	Acid Zinc plating tank Rinse to B-6, B-7
	B-6	Rinse
	B-7	Rinse
	B-8	Chromium conversion coating Rinse to B-9
	B-9	Rinse
	B-10	Rinse
Barrel Line	C-1	Alkaline electrocleaner Rinse to C-3
	C-2	Reversing current cleaner, 4% NaCN, Rinse to C-3
	C-3	Rinse
	C-4	Acid Pickle, H_2SO_4, Rinse to C-3
	C-5	Cadmium Cyanide plating tank, Rinse to C-10
	C-6	Copper cyanide plating tank, Rinse to C-7
	C-7	Rinse
	C-8	Tin plating tank Rinse to C-10
	C-9	Nickel plating tank Rinse to C-10
	C-10	Rinse
	C-11	Rinse (not in use)
	C-12	Unloading (Rinse tank not in use)
	C-13	Chromium conversion coatings, Rinse to C-14
	C-14	Rinse tank, 2-stage countercurrent
Hand Rack Line	D-1	Alkaline cleaner Rinse to D-4
	D-2	Reversing current cleaner, 4% NaCN, Rinse to D-4
	D-3	Alkaline electrocleaner Rinse to D-4
	D-4	Rinse
	D-5	Acid Pickle, H_2SO_4, Rinse to D-4, D-6
	D-6	Rinse
	D-7	Copper cyanide plating tank, Rinse to D-6
	D-8	Nickel plating tank, Rinse to D-9
	D-9	Rinse
	D-10	Chromium plating tank, Rinse to D-11, D-12, D-13
	D-11	Chromium dragout recovery tank
	D-12	Rinse
	D-13	Hot Water Rinse
	D-14	Tin Plating tank Rinse to D-16
	D-15	Cadmium cyanide plating tank Rinse to D-16
	D-16	Rinse

The Environment and the Industrial Worker

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THE ENVIRONMENT AND THE INDUSTRIAL WORKER

by D. A. Fraser

Industrial Hygiene has been defined as "The science and art concerned with the recognition, evaluation and control of those hazards to health that arise from the work place". The realization that work may involve certain risks and indeed may result in illness or traumatic injury is not new. Indeed in 400 B.C. Hippocrates described cures of lead poisoning in men engaged in refining metals. And in 600 A.D. Pliny the elder recommended the use of masks made from the bladder of animals to protect workers refining from noxious fumes and mists. An Italian physician Bernardo Ramazzini published the first text on Industrial Medicine entitled "De Moribas Artificum Diatriba" in 1700. It was not until the early 19th century that laws concerned with the well being of workers began to appear in Great Britain: "The Health and Morals of Apprentices" - 1802, "Child Labor Laws" - 1833, "Protection of Health of Workers" - 1901. The Swiss in 1881 enacted a Workman's Compensation Law and were immediately followed by many other European nations. The first such act in the United States was passed in 1911 by the state of Wisconsin and by 1920 42 States had followed this lead. These laws, it should be noted, were concerned only with compensating the worker after an injury occured.

In 1914 the United States Government faced with World War I and the need to conserve manpower in the defense industries created a Division of Occupational Health within the Public Health Service. The activities of this Division were further stimulated by the need for conservation and the control of disease and injury during World War II. Other Federal Laws applying to

particular industries or groups of workers were enacted during this period but the motivation appears to have been principally economic and social conscienceness had not developed to the point of prevention or great concern for the workers. Appart from workmen's compensation the recourse of an injured worker was through a civil suit and the English Common Law defenses of (1) the worker assumed the known risk of the job, (2) the worker's own negligence contributed to the accident, (3) there was negligence on the part of a fellow employee, were perfectly valid defenses. The first industrial hygienists were usually physicians concerned with the diagnosis of strange and exotic diseases and seeking the cause of these illnesses in the work environment. As the causes were found the need to quantitate exposures and to recommend control measures materialized and engineers, chemists and other specialists were needed.

On December 29, 1970 the Occupational Safety and Health Act was signed into law. This act was designed to insure a safe and healthful working environment for American workers. The responsibilities for implementing this Act are divided between the Department of Labor and the Department of Health, Education and Welfare. The Department of Labor is required to: (1) promulgate mandatory occupational safety and health standards, (2) to inspect workplaces and to cite and penalize violations of these standards, (3) to collect and analyse health statistics, (4) to supervise training of employees and employers in occupational safety and health, (5) to administer grants to the States to encourage local programs for implementing the Act. The Department of Health Education and Welfare is to: (1) to conduct research relevant to occupational health, (2) to develop criteria and recommend safe exposure levels for toxic substances, (3) to publish annually a list of all known toxic substances, (4) to conduct investigations at the request of employers or employees, (5) to provide education to ensure a supply of adequately trained personnel to carry

out the provisions of the act. If the provisions of the Occupational Safetv and Health Act are enforced vigorously the effect on American labor and American industry will be profound indeed.

Recognition of Industrial Diseases

An effective program of occupational health differs from other public health activities such as water and air pollution control in several ways. Although its aim is the prevention of illness rather than the treatment of disease the first essential element is the recognition of sickness in the workforce which requires the diagnostic skills of the physician. It is concerned with only that position of the day, or of a mans life that is spent at work. The number of hazards or insults is as diverse as the number of industries and processes. At the same time the number of people exposed to a given hazard may be relatively small and the normal public health surveilance techniques may be inadequate. Once diagnosed, the illness must be differentiated from ordinary community diseases and identified as work related. Something of the exposure which produced the illness must be surmised. Superimpose on this the adaptability of the human body to stress, the natural defenses against disease and the unwillingness of most men to admit to illness and the physician in industry is facing formidible problems. The new and powerful tools of industrial epidemiology and statistics are beginning to be applied to the recognition of industrial diseases but the lack of adequate medical histories, exposure information and the difficulty of locating even death certificates for previous employees makes these studies very expensive and often physically impossible. In spite of this, the alert physician has often recognized an industrial hazard in its early stages and prevented a disaster which may have involved large numbers of workers. Thus, the plant physician for the Goodrich Company in Louisville, Kentucky, in reviewing death certificates of prior employees noted

the second diagnosis of angiosarcoma (cancer of the liver) as a cause of death and was astute enough to search previous records to find a third. Realizing the rarity of this disease, he informed the State Health Service and alerted the world to the potential of vinyl chloride to produce liver cancer. His revalation lead to the immediate reduction of the permissable level of exposure for this substance from 500 ppm to 50 ppm and the subsequent reduction to 1 ppm. thus protecting thousands of future workers in this industry from unnecessary risk of cancer.

While the physician in industry practices medicine and his efforts are directed primarily toward the patient his counterpart and colleque the industrial hygienist addresses himself to the evaluation of the work environment and the design of control systems to reduce exposure to hazardous materials and to maintain a healthful working environment. Between these extremes a variety of specialists contribute their knowledge to make safe processes possible. Among these are the industrial nurse (often a primary contact with the worker and a source of information concerning their responses to changes in work conditions) the analytical chemist, the toxicologist and the physiologist. Thus, the solution of industrial health problems always involves a team of people addressing the common problem, the health of the worker.

Evaluation of the Environment

Early industrial hygients recognized the need for a yardstick by which to judge the safety of exposure to chemicals. In 1920 Warren Cook published a list of 20 substances with which he had some experience and suggested the airborne concentrations of those that he considered safe. That list has now grown to approximately 500 and is published annually as the "Threshold Limit Values" (T.L.V.) by the American Conference of Governmental Industrial Hygienists. This same list was recently published in the Federal Register by the U.S. Department

of Labor and has thus become part of the Federal Regulations. The concentrations listed are considered safe for an 8 hour exposure, 5 days per week for a normal working lifetime. They are designed for the healthly adult male worker and not young children, the elderly or infirm and thus should not be confused with community air quality standards. In setting the limits the committee considers several factors; the hazard in using the substance or the likelihood of producing damage; the comfort or lack of irritation of the worker. Thus these limits do not provide a direct comparison of the relative toxicity of the compounds. The recommended concentrations are usually listed both as parts per million (by volume) and as milligrams per cubic meter of air. Special terms such as millions of paricles per cubic foot of air or number of fibers per cubic centimeter of air are used to refer to numeral dusts or asbestos fibers. Other rules apply when the dust contains more than 1% of free crystaline silica. In the latest (1973) T.L.V. list values or charts are also given for permissible exposures to certain physical agents (heat, stress, noise, microwaves). Sonizing radiation is not invluded since these standards are published by the Atomic Energy Commission.

Armed with this list and suitable sampling techniques the industrial hygienist is prepared to make an estimate of the risk to health in the industrial environment. In the past, every airborne chemical in the environment required a separate analytical method. Modern analytical technology is greatly simplifying these techniques and today most sampling for solvent vapors is done by drawing a known volume of air through a small glass tube filled with charcoal. The charcoal is then extracted with a suitable solvent (CS_2) and the extract analysed by gas chromatography. Portable instruments such as infra red spectrophotometers and light-scattering photometers (for airborne particles) are also available although quite expensive. The Threshold Limit Values are based on time-weighted-average (TWA) concentrations and this may dictate the sampling

and analytical method of choice. Thus if one were interested in "peak" concentrations a "grab" or instantaneous sample might be indicated while to establish the TWA concentration a longer term integrated sample would be better. In any case it is essential that the pump or air moving device be calibrated carefully so that the amount of contaminant can be related to the volume of air from which it was extracted and the concentration calculated correctly.

Control of the Industrial Environment

During an inspection of an industrial premises one of the most obvious, if not sophistacted observations that is made, relates to housekeeping. Sloppy handling of solvents and chemicals must lead to airborne concentrations of vapors or dusts. Most reports will contain either praise for good housekeeping, or recommendations for improvement of the aspect. It is often found that this is a direct reflection of the morale of the workers or the adequacy of the supervision.

Probably the easiest and most economical recommendation that can be made involves the substitution of a less hazardous or toxic substance for one that is being used,for example toluene or stoddard solvent for benzine or perchoroetheylene for carbon tetrachloride. Sometime a process modification is indicated such as welding instead of soldering to eliminate lead exposure or wet drilling instead of dry to reduce dust.

The major remedy available to the industrial hygienist, however, is ventilation. This may be in the form of general room ventilation to reduce odors, humidity or temperature but more often will involve local exhaust ventilation to remove the offending contaminant at the source and to prevent its escape into the room atmosphere. The techniques of local exhaust ventilation are described in a book entitled "Industrial Ventilation" published by the American Conference of Government Industrial Hygienists". An efficiently designed exhaust system will offer protection to the worker and eliminate the need for respirators or

other personal protective devices. Design, installation and testing of such a system should be supervised by a compentant industrial hygienist since few contractors are familiar with the health related objectives of the system and many examples can be found of expensive and technically attractive installations which do not provide adequate protection to the employees.

In the event that none of the above approaches is possible, respirators, cannister guas masks, air line respirators may provide a last resort or temporary solution. Since these devices all depend on voluntary compliance by the worker they may not be reliable. A worker in a hazardous environment who contracts an occupational illness will generally be awarded compensation even though an approved respirator was provided by the company.

The Future Unfolds

Occupational health and the responsibilities of the industrial hygienist cannot be divorced from a changing social climate and increased social conscienceness. Legislation to protect the worker has been provided by the Congress and it can be expected to be implemented. If additional legislation is required it will be provided Labor unions are taking an increasing interest in protecting the health of their members. This is evident in their demand for appropriate legislation and in their willingness to bargain with management for provision for this in their working contracts and indeed to share cooperative programs and faculty sponsored studies with their management and universities. The cost of controls to meet new regulations will lead to process changes which in turn will require evaluation for implications to health. Improved technology and speeding up of old equipment will introduce new problems. The search for new sources of energy will introduce new processes and require novel controls. As men retire from work at an earlier age and at the same time have life extended by medical advances new diseases - some related to their work experience -

will appear. New terms such as ergonomics, social factors, psychological factors are already appearing in the industrial hygienists vocabulary.

Principles of Industrial Toxicology

by

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Principles of Industrial Toxicology

General Considerations

This material has not been designed for physicians or others who have been specially trained in the field of industrial toxicology. Rather it has been prepared for the purpose of providing a certain amount of background for those non-specialists who may be called upon to understand and interpret data which are largely medical in nature.

Toxicology Defined. In simple terms, toxicology may be defined as the study of the action of poisons on the living organism. Industrial toxicology is concerned with the human organism and consequently lies within the broad field of medicine. Since medicine cannot be considered an exact science in the same sense that chemistry, physics or mathematics are so considered, toxicologic phenomena cannot always be predicted with accuracy or explained on the basis of physical or chemical laws. It is this unpredictability which frequently reduces conclusions and decisions to opinion rather than fact.

Poison defined. In attempting to define the term "poison", a major consideration is that of quantity or dosage. A poison may be defined as a substance which causes harm to living tissues when applied in relatively small doses. A clear-cut distinction between poisonous and non-poisonous substances is not always easy to make.

Effective dosage. Generally speaking, industrial toxicology is concerned with the effects of substance which gain entry into some part of the human body. Almost any substance can cause harm when applied directly to the skin. Among the factors which are concerned in effective dosage, the most important are:

1. Quantity or concentration of the material
2. Duration of exposure
3. State of dispersion (size of particle or physical state, e.g. dust, fume, gas, etc.)
4. Affinity for human tissue
5. Solubility in human tissue fluids
6. Sensitivity of human tissues or organs

Obviously there are possibilities for wide variations in any of these factors.

Methods of expressing effective dosage:

Threshold Limit Values (TLV), formerly Maximum Allowable Concentration (M.A.C.).

For gases and vapors the TLV value is usually expressed in parts per million (p.p.m.), that is parts of the gas or vapor per million parts of air.

For fumes and mists, and for some dusts, the TLV is usually given as milligrams per cubic meter (mgm/m^3) or per ten cubic meters of air.

For some dusts, particularly those containing silica the TLV is usually expressed as millions of particles per cubic foot of air (M.P.P.C.F.).

TLV values have gained wide acceptance in industrial toxicology as a means of expressing concentrations of potentially harmful substances. They purport to represent the average amount of a substance to which persons may be exposed for eight hours a day for a period of months or years without danger to health.

Literal acceptance of this concept is fraught with great danger for the following reasons:

a. A great majority of all published TLV values are based either on speculation, opinion or limited experimentation on rats, mice, guinea pigs or other laboratory animals. In very few instances have the values been established firmly on a basis of examinations of human subjects correlated with adequate environmental observations.

b. Concentrations of dangerous materials in any working environment rarely remain constant throughout a work day. The occurrence of "surges" is well known.

c. Industrial exposures frequently involve mixtures rather than single compounds. Very little is known about the effects of mixtures.

d. Individuals vary tremendously in their sensitivity or susceptibility to toxic substances. The factors controlling this variability are not well understood. It is dangerous to assume that conditions which are safe for some individuals will be safe for all.

e. For some substances, concentrations which may be considered "safe" may still result in discomfort or annoyance.

f. A single TLV value is usually given for substances which occur in the form of salts or compounds of different solubility or in different physical states (e.g., lead, mercury).

If these limitations of TLV's are understood and accepted, the published TLV values can be used to great practical advantage. The principal usefulness is found in connection with the design of ventilating equipment. It should not be assumed, however, that attainment of concentrations at or even below the published TLV limits will necessarily prevent all cases of occupational poisoning, nor should it be assumed that concentrations which exceed the given limits will necessarily result in cases of poisoning. The concept known as Haber's Law, which involves the product of concentration and time ($C \times T = K$), expresses an index of the degree of toxic effect. This, too, may be misleading since little is known of the relative effectiveness of large doses over a short period of time as compared with smaller doses over a longer time period.

2. Minimal lethal dose and LD50.

In experimental toxicology it is common practice to determine the quantity of poison per unit of body weight of an experimental animal which will have

a fatal effect. (A scale commonly used is milligrams of poison per kilogram of body weight). That amount per unit of body weight which will kill an experimental animal under certain standard conditions is known as the minimal lethal dose (M.L.D.). A more commonly used figure in experimental industrial toxicology is the amount which will kill one half of a group of experimental animals. This is known as the LD50, representing 50 percent fatalities.

The Manufacturing Chemists Association bases its definition of the term "poison" on the LD50 test. In its publication entitled "Warning Labels" (6th edition, 1961) it states the following: "Poison: A substance or mixture of substances which falls within any of the following categories.

(a) Produces death with 14 days in half or more than half of a group of 10 or more laboratory white rats weighing 200-300 grams at a single dose of 50 milligrams or less per kilogram of body weight, when administered orally; or

(b) Produces death within 14 days in half or more than half of a group of 10 or more laboratory white rats weighing 200-300 grams, when inhaled continuously for a period of one hour or less at an atmospheric concentration of 200 ppm. or 2 milligrams or less per liter of gas, vapor, mist, or dust, provided such concentration is likely to be encountered by man when the substances are used in any reasonable foreseeable manner; or

(c) Produces death within 14 days in half or more than half of a group of 10 or more rabbits tested in a dosage of 200 milligrams or less per kilogram body weight, when administered by continuous contact with the bare skin for 24 hours or less.

"If available data on human experience with any substance in the above named concentrations indicate results different from those obtained on animals, the human data shall take precedence in any classification of a substance as poisonous."

The official U.S. Governmental concept of hazard rating is set forth in Federal Hazardous Substances Labelling Act which became fully effective in 1962. In this act, a substance is considered "highly toxic" if it has the characteristics described above in the Manufacturing Chemists Association definition of a poison. (See above) A toxic substance is defined as follows:

"(1) Any substance that produces death within 14 days in one-half of a group of white rats each weighing between 200 grams and 300 grams, at a single dose of more than 50 milligrams per kilogram but not more than 5 grams per kilogram of body weight, when orally administered.

"(2) Any substance that produces death within 14 days in one-half of a group of white rats each weighing between 200 grams and 300 grams, when inhaled continuously for a period of 1 hour or less at an atmospheric concentration of more than 200 parts per million but not more than 20,000 parts per million by volume of gas or vapor or more than 2 milligrams but not more than 200 milligrams per liter by volume of mist or dust, provided such concentration is likely to be encountered by man when the substance is used in any reasonably foreseeable manner.

"(3) Any substance that produces death within 14 days in one-half of a group of rabbits weighing between 2.3 kilograms and 3.0 kilograms each, tested at a dosage of more than 200 milligrams per kilogram of body weight, when administered by continuous contact with the bare skin for 24 hours.

"The number of animals tested shall be sufficient to give statistically significant results and be in conformity with good pharmacological practice.

"(4) Any substance that is 'toxic' (but not 'highly toxic') on the basis of human experience."

3. "Range Finding" Tests

This approach to determining and expressing the degree of toxicity of chemicals used in industry has been developed primarily by H.F. Smyth, Jr., and his collaborators. Its greatest usefulness is in testing new compounds for which no toxicological information exists. The basis of the test is a comparison of the potency of an unknown compound with that of a more familiar material. This is possible since there are a number of chemicals for which fairly extensive toxicological data are already available. By this technique a certain amount of valuable information can be obtained within a space of about three weeks.

4. Hazard Rating

This term is used in the present notes to indicate in a general way whether a material has high, moderate, or slight toxicity or has no poisonous properties at all. This is obviously a somewhat crude method of expressing toxicity, but it is of value as a rough guide to be followed until further information can be obtained.

The hazard ratings of industrial chemicals are based on an interpretation of all available data, particularly TLV, LD50, and Range Finding data.

5. Maximum Acceptable Concentration used by American Standards Assn. is more restrictive than TLV. It signifies a value which should not be exceeded at any time. (The term "Acceptable Concentration Standard" is now used by the A.S.A.)

Hazard ratings based on acute, single exposure experiments may be misleading since it cannot always be assumed that a large amount of a toxic agent is more dangerous than a small amount. (See below under Individual Susceptibility)

Classes of Toxic Substances

Toxic or harmful substances encountered in industry may be classified in various ways. A simple and useful classification is given below, along with definitions adopted by the American Standards Association.

1. Dusts: Solid particles generated by handling, crushing, grinding, rapid impact, detonation and decrepitation of organic or inorganic materials such as rocks, ore, metal, coal, wood, grain, etc. Dusts do not tend to flocculate except under electrostatic forces, they do not diffuse in air, but settle under the influence of gravity.

2. Fumes: Solid particles generated by condensation from the gaseous state, generally after volatilization from molten metals, etc., and often accompanied by a chemical reaction such as oxidation. Fumes flocculate and sometimes coalesce.

3. Mists: Suspended liquid droplets generated by condensation from the gaseous to the liquid state or by breaking up a liquid into a dispersed state, such as by splashing, foaming, and atomizing.

4. Vapors: The gaseous form of substances which are normally in the solid or liquid state and which can be changed to these states either by increasing the presure or decreasing the temperature alone. Vapors diffuse.

5. Gases: Normally formless fluids which occupy the space of enclosure and which can be changed to the liquid or solid state only by the combined effect of increased pressure and decreased temperature. Gases diffuse.

This classification does not include the obvious categories of solids and liquids which may be harmful nor does it encompass physical agents. The latter, strictly speaking, cannot be considered "substances". Living agents, such as bacteria, molds, and other parasites comprise another group of "substances" that would appear in a comprehensive classification of in-dustrial health hazards.

Routes of Absorption

In the physiologic sense, a material is said to have been absorbed only when it has gained entry into the blood stream and consequently is carried to all parts of the body. Something which is swallowed and which later is excreted more or less unchanged in the feces has not necessarily been absorbed, even though it may have remained within the gastro-intestinal tract for hours or even days. The industrial toxicologist is concerned primarily with three routes of absorption or portals of entry through which materials may enter the blood stream: the skin, the gastro-intestinal tract and the lungs.

Absorption through the skin: Those who are familiar with the history of medicine will recall that before the introduction of modern methods in the treatment of syphilis a part of the standard therapy consisted of mercury injunctions. The effectiveness of this treatment depended on the fact that certain forms of mercury could be absorbed through the intact skin. Today it is recognized that skin absorption may be a significant factor in occupational mercury poisoning as well as in a number of other industrial diseases. In the case of metals other than mercury, entry through the skin is relatively unimportant except for some of the organic compounds such as tetraethyl lead.

Skin absorption attains its greatest importance in connection with the organic solvents. It is generally recognized that significant quantities of these compounds may enter the body through the skin as a result either of direct accidental contamination or indirectly when the material has been spilled on the clothing. An additional source of exposure is found in the fairly common practice of using industrial solvents for removing grease and dirt from the hands and arms, in other words, for washing purposes. This procedure, incidentally, is a fruitful source of cases of dermatitis.

Gastro-intestinal absorption: It has already been suggested that the mere fact that something has been taken into the mouth and swallowed does not necessarily mean that it will be absorbed. Naturally, the less soluble the material is, the less is the likelihood of absorption. In the past it has been common practice to attribute certain cases of occupational poisoning to uncleanly habits on the part of the victim, particularly failure to wash the hands before eating. There is no doubt that some toxic materials used industrially can be absorbed through the intestinal tract but it is now generally believed that with certain notable exceptions this portal of entry if of minor importance. One outstanding exception is the case of the radium dial painters who followed the practice of "pointing" their brushes between their lips, thus ingesting lethal quantities of radio-active material. Accidental swallowing of harmful amounts of poisonous compounds in single large doses has also been known to occur. In general it can be said that intestinal absorption of industrial poisons is of minor importance and that the "dirty hands" theory of poisoning has been pretty well discredited.

Absorption through the lungs: The inhalation of contaminated air is by far the most important means by which occupational poisons gain entry into the body. It seems safe to estimate that at least ninety percent of all

industrial poisoning (exclusive of dermatitis) can be attributed to absorption through the lungs. Harmful substances may be suspended in the air in the form of dust, fume, mist or vapor, and may be mixed with the respired air in the case of true gases. Since an individual under conditions of moderate exertion will breathe about ten cubic meters of air in the course of an ordinary eight hour working day it is readily understood that any poisonous material present in the respired air offers a serious threat.

Fortunately all foreign matter which is inhaled is not necessarily absorbed into the blood. A certain amount, particularly that which is in a very finely divided state, will be immediately exhaled. Another portion of respired particulate matter is trapped by the mucus which lines the air passages and is subsequently brought up in the sputum. (In this connection it might be mentioned that some of the sputum may be consciously or unconsciously swallowed, thus affording an opportunity for intestinal absorption.) Other particles are taken up by "scavenger cells" following which they may enter the blood stream or be deposited in various tissues or organs. True gases will pass directly from the lungs into the blood in the same manner as the oxygen in inspired air. Because of the fact that a great majority of the known industrial poisons may at some time be present as atmospheric contaminants and thus constitute a potential threat to health, programs directed toward the prevention of occupational poisoning generally place major emphasis on some form of ventilation to reduce the hazard.

Storage and Excretion

Relatively little is known about storage depots of industrial chemicals other than that lead tends to accumulate in the bones and inorganic mercury in the kidneys. Transport mechanisms have not been extensively studied. Particulate matter when inhaled can be phagocytosed and remain in the regional lymph nodes where it may have little effect as in the case of coal dust or may produce pathological changes as in the case of silica and beryllium.

Excretion of heavy metals is usually studied only in the urine. This may be due in part to the relative ease of sampling and analysis. Nobody enjoys analysing feces. Sweat, saliva, bile, milk are not easy to collect for analysis. Gases and volatile vapors are commonly excreted via the lungs. This can be used as a measure of earlier absorption.

Acute and Chronic Effects

Industrial toxicology is generally concerned with the effects of low-grade sub-lethal exposures which are continued over a period of months or years. It is, of course, true that toxicological problems are not infrequently presented as a result of accidents which create sudden massive exposure to overwhelming concentrations of toxic compounds. The acute poisoning which results may cause unconsciousness, shock or collapse, severe inflammation of the lungs or even sudden death. An understanding of the nature of the action of the offending agent may be of great value in the treatment of acute poisoning but in some instances the only application of toxicological knowledge will be establishing the cause of death.

The detection of minute amounts of toxic agents in the atmosphere and in body fluids (blood and urine) and the recognition of the effects of exposure to small quantities of poisons is among the principal jobs of the industrial toxicologist. The manifestations of chronic poisoning are often so subtle that the keenest judgment is required in order to detect and interpret them. The most refined techniques of analytical chemistry and of clinical pathology are called into play, involving studies of the working environment and of exposed individuals.

In order to demonstrate that chronic industrial poisoning has taken place or is a possibility it must be shown that an offending agent is present in significant concentrations, that it has been absorbed and that it has produced disturbances in the exposed subject. Significant concentrations are commonly expressed in terms of Threshold Limit Values (TLV). Absorption of a substance may be proven by demonstrating its presence in the blood or urine in concentrations above those found in non-exposed persons, or by finding certain metabolic products in the excreta. To prove that disturbances have occurred in an exposed subject may require the application of all of the diagnostic procedures used in medicine. This includes a medical history, physical examination, blood counts, urinalysis, x-ray studies and other measures.

A few of the more widely used industrial chemicals, notably lead and benzene, will produce changes in the blood in the very early stages of poisoning. Other chemicals, particularly chlorinated hydrocarbons, give no such early evidence of their action. Heavy metals such as mercury and lead produce their chronic harmful effects through what is known as "cumulative action". This means that over a period of time the material which is absorbed is only partially excreted and that increasing amounts accumulate in the body. Eventually the quantity becomes great enough to cause physiologic disturbances. Volatile compounds do not accumulate in the body but probably produce their chronic toxic effects by causing a series of small insults to one or more of the vital organs.

Site of Action of Poisons

Brief mention has already been made of the fact that different poisons act on different parts of the body. Many substances can produce a local or direct action upon the skin. The fumes and mists arising from strong acids, some of the war gases and many other chemicals have a direct irritating effect on the eyes, nose, throat and lower air passages. If they reach the lung they may set up a severe inflammatory reaction called chemical pneumonitis. These local effects are of greatest importance in connection with acute poisoning. More important to the industrial toxicologist are the so-called systemic effects.

Systemic or indirect effects are those which occur when a toxic substance has been absorbed into the blood stream and distributed throughout the body. Some materials such as arsenic, when absorbed in toxic amounts, may cause disturbances in several parts of the body: blood, nervous system, liver, kidneys and skin. Benzene, on the other hand, appears to affect only one organ, namely, the blood-forming bone marrow. Carbon monoxide causes asphyxia by preventing the hemoglobin of the blood from carrying out its normal function of transporting oxygen from the lungs to the tissues of the body. Although oxygen starvation occurs equally in all parts of the body, brain tissue is most sensitive to this insult; consequently the earliest manifestations are those due to damage to the brain. An understanding of what organ or organs can be damaged, and the nature and manifestations of the damage caused by various compounds is among the more important functions of the industrial toxicologist.

At the cellular level, toxic agents may act on the cell surface or within the cell, depending on "receptors" or binding sites. A familiar example is the affinity of arsenic and mercury for sulfhydryl (S-H) groups in biological material.

"Individual Susceptibility"

The term "individual susceptibility" has long been used to express the well known fact that under conditions of like exposure to potentially harmful substances there is usually a marked variability in the manner in which individuals will respond. Some may show no evidence of intoxication whatsoever; others may show signs of mild poisoning while still others may become severely or even fatally poisoned. Comparatively little is known about the factors which are responsible for this variability. It is believed that differences in the anatomical structure of the nose may be concerned with different degrees of efficiency in filtering out harmful dusts in the inspired air. Previous infections of the lungs, particularly tuberculosis, are known to enhance susceptibility to silicosis. Most industrial toxicologists believe that obesity is an important predisposing factor among persons who are subject to occupational exposure to organic solvents and related compounds. Age and sex are also believed to play a part and previous illnesses may be significant.

Other possible factors relating to individual susceptibility are even less well understood than those just mentioned. It has been suggested that different rates of working speed, resulting in variations in respiratory rate, in depth of respiration and in pulse rate may play a part. The action of the cilia, those tiny hairs which are present in the cells which line the air passages, may have some importance. The permeability of the lungs may influence absorption and the efficiency of the kidneys may govern the rate at which toxic materials are excreted, but the underlying nature of these possible variations is not at all known.

There is considerable literature purporting to show that nutritional factors may have something to do with susceptibility to occupational poisoning. Most of the published material is rather unscientific and unconvincing but a few reports recently published strongly suggest that there actually exists a relationship between the nature of the diet and susceptibility to poisoning. There is as yet no substantial evidence that the addition of vitamin concentrates or special foods will have protective value, but when diets are deficient in some of the essential nutritional elements it appears that poisoning is more likely to occur. There is considerable evidence that indulgence in ethyl alcohol will significantly increase the possibility of occupational poisoning occurring, particularly from organic solvents.

Other "host factors" that may play a role in "individual susceptibility" are endocrine status, genetic make-up (heredity), intestinal flora and personal hygiene.

Toxicity by Analogy

Because of the paucity of toxicological information on many chemical compounds used in industry there frequently is a tendency to assume that compounds which are closely related chemically will have similar toxic properties. While this may be true for a limited number of substances it is by no means universally true.

As mentioned elsewhere, many chemical compounds, when absorbed by the body, undergo a series of changes (detoxication processes) before they are excreted. The intermediary products depend largely on the chemical structure of the original material, and minor differences in structure may result in totally different intermediary and end products. This principle is well illustrated in the case of benzene and toluene, which are closely related chemically but whose metabolism is dissimilar. The degree of toxicity of the two is also very different. For some chemicals, e.g. methanol, metabolic intermediates may be responsible for important toxic effects.

When a person is exposed to a mixture of chemicals, there is always the possibility of combined action. This may enhance or diminish toxic response.

Absorption vs. Poisoning

As mentioned above, with the exception of external irritants, toxic substances generally must be absorbed into the body and distributed through the body by means of the blood stream in order for poisoning to occur. In other words, poisoning ordinarily does not occur without absorption. On the other hand, absorption does not necessarily or always result in poisoning. The human body is provided with an elaborate system of protective mechanisms and is able to tolerate to an amazing degree the presence of many toxic materials. Some foreign materials are excreted unchanged through the urine and feces. Toxic gases, following absorption, may be given off through the lungs. Some chemical compounds go through processes of metabolism and are excreted in an altered form. Some of these processes are known as detoxication (or detoxification) mechanisms. In some instances the intermediary products in a detoxication process may be more toxic than the original substance, e.g. formic acid and formaldehyde from methyl alcohol.

Since absorption must precede poisoning, the question often arises as to where the dividing line between absorption and poisoning is to be drawn. An answer to this question frequently entails considerable difficulty. There is no doubt that when absorption reaches a point where it causes impairment of health, poisoning has occurred. Impaired health manifests itself by the presence of altered structure, altered function, or a combination of the two. These impairments, in turn, result in abnormal symptoms, abnormal physical or laboratory findings, or combinations of these.

When absorption has produced both abnormal symptoms and abnormal objective findings there is no question that poisoning has occurred. In the opinion of the writer, absorption which produces objective evidence of altered structure or function should also be called poisoning, even though there may be no abnormal subjective symptoms. When subjective symptoms constitute the only basis for distinguishing between absorption and poisoning, the distinction becomes a matter of medical opinion requiring individual evaluation.

Causal Relationship and Competent Producing Cause

The industrial toxicologist frequently becomes involved in medico-legal problems, since actual or suspected cases of occupational disease often result in workmen's compensation claims or negligence suits. A successful legal action on the part of a claimant or plaintiff depends upon his ability to demonstrate, usually through medical or other expert testimony, that occupational exposure caused harm to his health.

A competent producing cause is one which conceivably could have produced the harmful effect. It involves possibility.

Causal relationship exists when a competent producing cause actually did produce the harmful effect. It involves probability.

Medico-legal cases are usually adjudicated on the basis of opinion, because of the fact that medicine is not an exact science. It has been said, and truthfully, that in medicine anything can happen. Decisions then, must be made on the basis of the most probable explanation of a set of circumstances. Medical opinion, to be convincing, must be based on actual facts or observations, but the same set of facts or observations may be subject to more than one interpretation. Hence the importance of opinion.

Workmen's compensation laws are usually written or interpreted in such a way that in cases of doubt (sometimes reasonable doubt) a decision is rendered in favor of the claimant. Socially this is probably correct, at least in theory. This practice, however, tends to place the burden of proof on the defendant rather than on the claimant. Competent producing cause is all too often considered to be synonymous with causal relationship. Often it devolves upon a defendant to attempt to prove that a competent producing cause was in fact not the actual cause of an illness. Obviously this may entail considerable difficulty. It is not sufficient for the defendant merely to deny the existence of causal relationship. Successful defense requires an opinion (diagnosis) other than that of an occupational disease which will provide a more convincing explanation of the observed facts. Often this requires the highest degree of diagnostic acumen as well as the most astute legal procedure.

Principles of Prevention

Any effective program for the prevention of occupational poisoning depends on teamwork. Key members of the preventive team are the industrial physician with his knowledge of toxicology, the industrial hygiene engineer with his understanding of control measures, and the chemist who provides basic analytical data. The industrial nurse because of her intimate contact with employed personnel, often provides the first clue to the existence of a potentially dangerous situation. Safety men and supervisors also play an important part, while a well-informed working force, instructed to recognize danger signs, constitutes an additional safeguard.

It was pointed out above that an understanding of the basic principles of industrial toxicology is fundamental in any program of prevention. One must know what materials can cause poisoning and the relative toxicity of various compounds and groups of compounds. Another essential is an understanding of how toxic substances are absorbed, and the relative importance of the various routes of absorption. Realization of the fact that inhalation is the principal mode of entry means that preventive measures will be directed mainly toward reducing atmospheric contamination. For protection against chemicals that can be absorbed through the skin, suitable impervious gloves and work clothing can be provided.

Although very little is known about "individual susceptibility", the few facts which are available may be helpful in selectively placing certain persons in jobs where their age, sex, state of nutrition or previous illnesses will not constitute any extra threat to their well-being. Thorough familiarity with the so-called maximum allowable concentrations, their interpretation and applications is essential for the engineer who is called upon to design ventilation systems. All who are concerned with a preventive program must know that months or years of exposure may elapse beofre toxic manifestations appear, and the physicial in particular must be prepared to detect and recognize the earliest evidences of poisoning. Failure to apply these few fundamentals may be costly not only in terms of lost production and lost income but also in terms of health and even of life.

Preventive procedures are often spoken of as falling into two major categories: (1) medical control and (2) engineering control.

1. <u>Medical control</u>. This term is used to describe those procedures which are applied to the employed person. It includes:
   a. Preplacement physical examinations. One purpose of these examinations is to protect workers with unknown susceptibility against any potentially harmful exposure. An individual found to have healed pulmonary tuberculosis, for example, should not be placed in a job entailing exposure to silica dust nor should one with former liver disease be exposed to chlorinated hydrocarbons.

   b. Periodic examinations. A major purpose of these is to detect any existing evidence of poisoning at an early stage when corrective measures can be expected to result in complete recovery. Correction

may call for improved industrial hygiene practices, for temporary or permanent change of job assignments or both of these.

c. Education. The purpose of this is, to inform workers and supervisory personnel of the nature of any potentially harmful materials with which they may come in contact. An informed working force may be expected to accept and observe recommended precautionary measures.

d. Personal protective devices. With few exceptions, personal protective devices should be relied upon only when the application of engineering measures offers insurmountable difficulties. Protective clothing is usually worn to prevent injuries and so will not be discussed.

Protective masks have been widely used, (or rather misused) to reduce the inhalation of potentially harmful dusts, fumes, vapors, mists and gases. In general it can be said that reliance on masks is justified only when exposures are of short duration (minutes) and low frequency (10-20 times daily).

Protective masks or respirators obviously should be properly selected for the purpose for which they are intended. To be effective they must be individually fitted to the user In the filter or canister types the filtering units must be replaced regularly and with adequate frequency. A program of regular cleaning, repairing and replacing of worn out parts is highly desirable. Those who are obliged to wear respirators or masks should be fully instructed as to proper use and maintenance. Unless these rules are followed it cannot be said that masks and respirators are being properly used and it might be preferable not to use them at all.

2. Engineering Control.

In this category are included those procedures which are applied to the working environment rather than to the individual. The most important engineering control measures are:

a. Substitution of a less toxic in place of a more toxic material, when this is possible technologically. Common examples of this approach are the use of steel shot in place of silica sand in sand blasting.

b. Enclosure of a process. This has its widest application in the chemical industries where frequently it is possible and practicable to design totally enclosed systems for carrying out the manufacture or processing of chemical compounds.

c. Segregation, which may be accomplished by confining a potentially dangerous process to a segregated or enclosed area to prevent contamination of adjacent work spaces. In some situations segregation can be accomplished by locating a process in an opem shed or even completely out of doors.

d. Ventilation, which is perhaps the most important engineering control measure. Ventilation may be general or local. General ventilation consists in rapid dilution of contaminated air with fresh air usually

by fans located in windows or overhead in work areas. Fans or blowers may operate by bringing fresh air into a space, thus forcing contaminated air out through natural openings such as doors and windows, or by drawing off contaminated air thus creating a partial vacuum which is filled by the entry of fresh air. Unpleasant drafts of air, particularly near open doors and windows, are sometimes produced when natural ventilation is produced in large volume.

Local ventilation usually consists in providing air suction close to the point where potentially harmful dusts, fumes, vapors, mists or gases are generated. This permits removal of the contaminants with relatively small quantities of air and prevents contamination of adjacent work spaces. Collection and disposal of contaminants removed by local exhaust ventialtion sometimes presents a major engineering problem. In some processes, especially those involving the use of volatile chemicals, it is common practice to install a recovery system as part of the ventilating equipment. This may result in savings sufficient to defray the cost of installing and operating the ventilating system.

e. Wetting. The use of water to limit the dispersal of atmospheric contaminants finds its chief application in the control of dust. This procedure is widely used in rock-drilling and it is also useful when sweeping is done in a dusty work-room.

f. Neutralization or inactivation of chemical compounds is sometimes useful in connection with local exhaust ventilation and in cleaning up contaminated areas.

g. General housekeeping procedures, while perhaps the simplest of all control measures, is none-the-less extremely important and valuable. Regular clean-up schedules, particularly where dust is a problem, are essential in any control program.

In addition to the specific procedures just enumerated, it is often important to condust regular appraisals of the working environment by means of dust counts, air analyses and similar tests, thereby checking on the effectiveness of the preventive measures.

Reference Books

1. Occupation and Health. Geneva: International Labour Office, 1930. Vol. 1, 1934, Vol. II., supplements 1938, 1939, 1940, 1944. Detailed data on history, industrial processes, statistics, legislation. Second Edition, 1971-1972.
2. Analytical Toxicology of Industrial Inorganic Poisons. By Morris B. Jacobs. New York: Interscience Publishers, Inc., 1967.
3. Industrial Toxicology. By Lawrence Fairhall. Williams and Williams, Second Edition, 1957. A useful reference book with a good bibliography.
4. Industrial Hygiene and Toxicology. Edited by Frank Patty. Interscience Publishers. Two volumes, very comprehensive with empahsis on engineering phases. Second edition. Vol. I, 1958, Vol. II, 1963.
5. The Chemistry of Industrial Toxicology. By Hervey B. Elkins. John Wiley and Sons, Second Edition, 1959.
6. Industrial Health Engineering. By A. D. Brandt. John Wiley & Sons, 1948.
7. Occupational Diseases and Industrial Medicine. By R. T. Johnstone and S. E. Miller. Philadelphia: W. B. Saunders Co., 1960. Part I for administration.
8. The Diseases of Occupation. By Donald Hunter (England). Boston: Little, Brown, and Company, 3rd or 4th Edition, 1962 or 1969. Rich in historical material and quite comprehensive. Available in paperback.
9. Dangerous Properties of Industrial Materials. N. Irving Sax, Editor. New York: Reinhold Publishing Corp., Third Edition, 1968. An encyclopedic work listing over 10,000 materials.
10. Clinical Toxicology of Commercial Products. By Gleason, Gosselin and Hodge. Baltimore: Williams and Williams, Third Edition 1968. Detailed data on pesticides. Lists over 15,000 trade names of products.
11. The Merck Index. Eighth Edition, 1968. Contains a wealth of toxicological and other information.
12. Elsevier Monograph Series: Arsenic, Mercury, Thallium, Vanadium, Aromatic Hydrocarbons, Aliphatic Fluorines, Aromatic Amines, Plastics.
13. Occupational Diseases: A Guide to their Recognition. Public Health Service Publication No. 1097, 1964. Govt. Printing Office. A real bargain at $ 2.25 from Supt. of Documents. (OUT OF PRINT)
14. Fundamentals of Industrial Hygiene. Edited by J. B. Olishifski and F. E. McElroy. National Safety Council, Chicago, 1971. $ 10.00.

Journals

1. Archives of Environmental Health. Editorial Office: 3300 Henry Avenue, Philadelphia 29, Pa. Began July 1960. Successor to A.M.A. Archives of Industrial Health. Published Monthly. Subscription Price: $ 12.00 per year.
2. Industrial Hygiene Journal. Official Publication of the American Industrial Hygiene Association. Monthly (formerly quarterly). Editorial Office: 1014 Broadway, Cincinnati 2, Ohio.
3. Journal of Occupational Medicine. Began January 1959 as official publication of the Industrial Medical Association, 28 E. Jackson Blvd., Chicago 4, Ill. Subscription: $ 10.00 per year.

The World Bank, Industrial Development, and the Environment

Introductior

The World Bank Group--the single largest economic development institution in the world--follows a policy that calls for every project proposed to it for financing in developing countries to be examined for its environmental implications and to have appropriate safeguard measures incorporated. Industrial projects undergo a searching evaluation of their pollution potential; that story, in brief, is presented below following a description of the World Bank Group as an institution.

THE WORLD BANK GROUP AND POLLUTION CONTROL IN DEVELOPING COUNTRIES

The World Bank Group provides financial and technical help for the development of poor countries.

The Group consists of the World Bank (International Bank for Reconstruction and Development), IDA (International Development Association) and IFC (International Finance Corporation).

The Bank and IDA are now lending more than $3,400 million a year to help raise the standard of living in developing countries. This is well over one-fourth of the total from all official sources outside the developing countries themselves. The IFC has the same purpose, but its role is more specialized; helping to stimulate growth in the private sector, particularly industry. It is now

investing nearly $150 million a year.

Both the Bank and IDA have expanded rapidly in the last five years as shown in the following tables:

Table 1: Bank and IDA lending to current borrowers[1] 1964-73
(US$ millions. Fiscal years.)

Number of Countries in ( )	Average 1964-68	Average 1969-73	1973
Bank only (33)	$ 516	$ 1,154	$1,241
IDA only (25)	16	205	384
Bank/IDA (35)			
Bank	223	629	810
IDA	251	582	973
Totals	$ 1,006	$ 2,570	$3,408

[1] Member countries which have borrowed since fiscal 1968 or which are included in the fiscal 1974 lending program.

Table 2: Bank and IDA lending to current borrowers by principal sectors, 1964-73 (US$ millions. Fiscal years.)

	1964-68		1969-73		1973	
	Amount	%	Amount	%	Amount	%
Agriculture	$ 124	12	$ 518	20	$ 938	28
Education	31	3	145	6	276	8
Industry[1]	120	12	364	14	377	11
Population Planning	-	-	13	1	22	1
Public Utilities[2]	346	34	706	27	849	25
Tourism	-	-	16	1	-	-
Transportation	293	29	651	25	682	20
Urban Projects[3]	-	-	10	-	36	1
Non-project[4]	91	9	146	6	229	7
Totals	$1,006		$2,570		$3,408	

[1]Including development finance companies.

[2]Communications, power, water supply and sewerage.

[3]Specifically to help with the "urbanization" problem.

[4]Industrial imports, reconstruction and rehabilitation, technical assistance, project preparation, planning.

In fiscal 1973, the Bank provided more than twice as much and IDA nearly four times as much financial help to developing countries as in any year before 1969. These funds are helping to support a wide variety of projects, large and small, public and private chiefly in the following fields: agriculture, education, electric power, industry, population planning, tourism, transportation, telecommunications, urban development, water supply and sewerage.

The Bank Group has also committed itself to helping its 122 member countries with their many intractable development problems, including questions of income distribution, rural poverty, unemployment, excessive population growth, rapid urbanization and, of late, environmental rehabilitation.

Although legally and financially distinct, the Bank, IDA, and IFC are a closely integrated unit. Using funds from different sources and lending on different terms and arrangements, they have become a highly flexible instrument for giving both financial and technical assistance to developing member countries at virtually all stages of economic and social growth. Together, they constitute a true development institution.

On a global scale, the World Bank was the first institution to be established with the explicit purpose of helping less developed countries raise their living standards.

Along with the International Monetary Fund (IMF), the Bank was founded in 1944 at a United Nations Monetary and Financial Conference of 44 governments at Bretton Woods, New Hampshire, U.S.A. It began operations in June 1946. Membership in the Bank is open to all members of the IMF, and 122 have joined. The Bank is owned and controlled by its member governments.

The Bank's charter spells out certain basic rules which govern its operations. It must lend only for productive purposes, and only if there are reasonable prospects of repayment. Each loan must be guaranteed by the government concerned. Except in "special circumstances," loans must be for specific projects. The Bank must assure itself that the necessary funds are unavailable from other sources on reasonable terms. The use of loans cannot be restricted to purchases in any particular member country or countries. And the Bank's decisions must be based only on economic considerations.

A unique feature of the Bank as an intergovernmental organization is the fact that it relies mainly on private investors for its financial resources. Most of the money it lends comes from the Bank's own borrowings in various

capital markets. Although a total of $25,197 million of its authorized capital of $27,000 million has been subscribed, members pay in only 10%. The remaining 90% serves as a gurantee of the Bank's debt. It can be used only if required to meet obligations to investors in Bank securities.

Thus, investors who might otherwise never become involved in the financing of projects in developing countries are contributing to their economic growth. The Bank has borrowed a cumulative total of $15,764 million, of which $8,882 million is outstanding in 15 different currencies.

Since the Bank obtains most of its funds on commercial terms, it must charge its own borrowers a commensurate rate of interest. On average, Bank loans are repaid over about 20 years, and the current rate of interest is 8 percent. Table 1 shows how Bank loans are used along with IDA credits, on unusually favorable terms, to help meet the needs of many of the poorest countries.

Aside from borrowings, paid-in capital subscriptions and charges on its loans, the Bank has two other principal sources of funds it can lend. Most important is the flow of repayments on previous loans. These have amounted to $5,316 million. In addition, it often sells portions of its loans to other investors, chiefly commercial banks, and

uses these funds to make additional loans. By this means, it has been able to raise $2,500 million.

The Bank earns a profit on its operations, but it has never paid a dividend, since all shareholders agree that earnings should be used to help developing countries. Part of the Bank's net earnings have been placed in reserves which strengthen its ability to borrow and most of which are also available for lending. Beginning in 1964, the balance each year has been given to IDA, increasing its ability to help the poorest countries. These grants to IDA have totaled $705 million, and net earnings applied to reserves have amounted to $1,750 million.

IDA

Unlike the Bank, IDA gets virtually all of its funds in the form of contributions. This makes it possible for the Bank Group to help countries that are too poor to borrow from the Bank at all, and to ease the average terms of lending to others that can afford to borrow only a part of their legitimate needs on conventional terms.

Nearly all IDA "credits," as they are called, have been for a period of 50 years, without interest except for a small charge to cover administrative costs. Repayment of principal does not begin until after 10 years of grace.

The need for lending to many poor countries on much easier terms than the Bank alone could give became apparent

during the 1950s. On the initiative of the United States, endorsed by other members of the Bank and by the United Nations General Assembly, IDA was established in 1960 to help meet this need. It was made an affiliate of the Bank, to be administered in accordance with the Bank's own standards of efficiency.

All members of the Bank are eligible for membership in IDA, and 112 have joined. Nineteen of the wealthier members have contributed 87% of all funds that have been available for the Association's use, or $6,094 million. Out of its net earnings, the Bank has contributed $705 million, or 10%, including $3 million earmarked for agricultural research grants. About $78 million has been contributed or otherwise made available by developing countries.

The annual amount IDA can lend has increased by more than 400% over the last five years. During the period 1964-68, the Association was able to lend an average of only $267 million a year. In fiscal 1973 its credits totaled nearly $1,360 million.

These funds are carefully rationed for use in the poorer countries. There are four main criteria that a country must meet in order to borrow from IDA:

1. It must be very poor. The "poverty ceiling" varies from time to time, depending on circumstances; it is

now roughly $375 a year of income per capita.

2. It must have sufficient economic, financial and political stability to warrant long term development lending.

3. It must have an unusually difficult balance of payments problem, and little prospect of earning enough foreign exchange to justify borrowing all it needs on conventional terms.

4. It must have a genuine commitment to development, reflected in its policies.

About 70 countries would now be eligible under the first criterion. They include nearly four fifths of the population of the 96 countries that are current borrowers from the Bank, IDA or both. About 70% of them live in Asia, 24% in Africa, 3% in Europe (Turkey), and 4% in Latin America and the Caribbean area.

Under the second criterion, four of these countries have not been in a position to borrow from either the Bank or IDA. For various reasons related to other criteria, another six have borrowed from the Bank but not from IDA. Twenty five of the poorest have borrowed only from IDA. And a "blend" of Bank loans and IDA credits has been provided to another 35.

To the poorer countries, the importance of IDA as an integral part of the Bank Group can be seen in the record

of lending, as shown in Table 1. Without funds on IDA terms, any significant help to the group of 25 very poor countries might well have been impossible. Without the ability to reduce the average debt burden by combining its loans with a rising volume of IDA credits, the Bank could not have increased its own support to the 35 "blend" countries to the degree it has.

Thus the scope and flexibility of Bank Group help to the poorest of the poor depend upon the volume of IDA's resources. This is determined chiefly by the level of contributions agreed to from time to time by the wealthier member countries. The amount from this source is now about $800 million a year.

Operating Methods

Whether large or small, every project financed by the Bank or IDA is considered in the light of the country's total needs, capabilities and policies. This is essential from the point of view of the Bank and IDA, to assure the most efficient use of their own resources. It is even more important to the people of the borrowing country, whose hope for a better standard of life depends upon the efficient mobilization and allocation of all resources available.

The first step in response to each country's request for assistance, therefore, is the conduct of a compre-

hensive study of its economy. The resulting "country economic report" is used by both the Government and the Bank, and is kept up-to-date. It provides a basis for the Bank's own decisions on both financial and technical assistance. It often serves also as a planning tool for the Government, and as a basic document for the use of other national and international lending agencies.

The report describes and analyzes the entire economy and the country's development policies, organization and principal problems. On the basis of objective analysis, it outlines a general order of development priorities among the various sectors. Whenever necessary, the country study is supplemented by more detailed analyses of individual sectors and relationships between them, which help to throw light on the relative importance of alternative projects in achieving the country's development goals.

Chiefly on the basis of the economic report, and after consultation with the Government, a program of Bank/IDA operations in the country is drawn up for a five-year period. This is reviewed and revised annually. It takes into account the likely availability of other external finance, as well as the country's own resources. The program provides a framework for concrete proprosals for action to help the country carry out an agreed strategy of development. Each individual project is then considered

within this framework.

There is no "application form" for Bank or IDA financing. Sometimes a formal request is made by letter, perhaps to the President of the Bank. Sometimes Bank staff members or missions identify specific project possibilities, discuss them with the Government and, in some cases, help with the detailed work required to describe and document them. More often, project proposals arise out of the joint efforts of Government and Bank staff members in their search for solutions to common problems. No matter how a proposal originates, however, the project is subjected to careful analysis, including its environmental aspects, and a detailed agreement is worked out with the borrower before a loan or credit is approved.

Assume, for example, that technical staffs of the Government and the Bank agree that improvements in the road system are a priority need for attainment of the country's development goals. Often in such a case, the Bank will recommend that consulting engineers be hired to draw up detailed plans. After this preparatory work is completed, the Bank will send a staff mission to make a thorough appraisal of all aspects of the project.

When agreement is reached on details of the proposed project and on financing requirements, a formal loan or credit agreement is negotiated. If this is satisfactory,

the President presents the proposal to the Executive Directors, who represent all member countries, for their approval.

The approval of a loan does not end the Bank's involvement, nor does the borrower walk away with cash in his pocket. In most cases, the borrower seeks bids, on the basis of international competition, for the goods and services required. The Bank releases money only as needed to meet verified expenditures on the project. Goods and services paid for by Bank loans or IDA credits may be obtained from any member country or Switzerland. The Bank pays in whatever currency is required, and the borrower repays in the currency used by the Bank.

Bank involvement continues throughout the life of the project. The borrower provides periodic progress reports and Bank staff members visit the site from time to time, helping to anticipate and overcome difficulties and to assure that the project's intended benefits to the country are realized. This close supervision is facilitated by the fact that the borrowing country is a part owner of the Bank and shares in the control of its policies and operations. As a cooperative multinational institution, the object of the Bank is to see that each project is carried out at the least possible cost and that it makes its full contribution to the country's development.

Table 2 shows how much has been lent to the current borrowers for different purposes during the last 10 years, and how the emphasis has been changing. Shifts in the geographical distribution of lending are reflected in Table 3 as follows:

Table 3: Bank and IDA lending to current borrowers by region, 1964-73
(US$ millions. Fiscal years.)

	1964-68		1969-73		1973	
	Amount	%	Amount	%	Amount	%
Eastern Africa	$ 71	7	$ 214	8	$ 342	10
Western Africa	60	6	178	7	177	5
Asia	387	38	866	34	1,292	38
Europe, Middle East, No. Africa	178	18	606	24	913	27
Latin America, Caribbean	310	31	706	27	685	20
Totals	$1,006		$2,570		$3,408	

IFC

The International Finance Corporation (IFC), established in 1956, is the member of the World Bank Group that encourages the growth of productive private enterprise in the developing countries, especially in the industrial

sector.

Membership in IFC is open to all governments which are members of the World Bank. On June 30, 1973, the Corporation had 98 member countries.

IFC has total resources of approximately $616 million. That amount is made up of the Corporation's capital of $107 million, subscribed by its member countries, accumulated earnings of some $76 million, ability to borrow up to $428 million from the World Bank and a $5 million loan from the Netherlands. These resources are augmented through repayments on IFC loans, which as of June 30, 1973, totaled $66 million, and sales by IFC of its own investments to other investors.

IFC can offer other resources to local and foreign entrepreneurs, sponsors, technical partners and similar investors associated with its projects. For example, the Corporation has expert knowledge on financial, legal, technical and related aspects of private enterprise in developing countries. IFC can also draw on the World Bank's wide experience, as well as on its own contacts with financial institutions, business concerns, economic development agencies and governmental organizations.

The Corporation encourages private enterprise in the developing countries principally by itself investing projects that either establish new businesses, or expand,

modernize or diversify existing businesses.

Besides making its own investments IFC can recruit capital from other sources, local and foreign, and obtain managerial and technical support for a project.

As of June 30, 1973. IFC had made 285 commitments totaling $848 million to 203 private enterprises, located in 51 developing countries. Other investors had invested approximately $3,372 million in these projects--making a total of over $4,200 million.

In addition to making its own direct investments IFC invests in regional and local development finance companies which, in turn, make smaller investments in the private sector in the developing countries than it is practicable for IFC itself to do.

The World Bank Group and the Environment

As stated earlier, the basic function of the World Bank Group is to prepare and finance projects for economic development in the developing countries of the world.

That purpose is paramount today; it will remain so tomorrow. It is also the policy of the Bank Group that careful and studied attention must be given, in the planning and execution of its development projects, for the consequences to the environment and to the health and welfare of affected peoples.

Though the Bank Group had, prior to 1971, concerned

itself with the environmental implications of its developmental activities, no systematic procedure existed to identify and examine those effects. More importantly, methods to prevent or mitigate adverse environmental consequences had not, in all instances, been devised.

Such an unsystematic approach was clearly seen as inadequate in light of scientific data that has come to light in recent years about the specific and collective effects of unplanned development on environmental systems; and, the rapid growth of control technologies.

In late 1970, the post of Environmental Adviser was established and given a strong mandate to review and evaluate every investment project from the standpoint of its potential effects on the environment. That solo post has now grown into an Office of Environmental Affairs which oversees the Bank Group's environmental activities, including especially, ensuring that projects proposed for financing are examined for their ecological, health, and sociocultural effects, and appropriate measures taken to prevent or mitigate seriously adverse consequences.

Important to this task has been the Bank Group's handbook, Environmental, Health, and Human Ecologic Considerations in Economic Development Projects. Prepared for use by its own staff, the handbook has found widespread use throughout the developing world, including government

planners, borrowing entities, engineering and construction firms, consultant organizations, universities, etc. As environmental considerations have more and more become a fixed part of Bank Group operations, these guidelines and criteria now cover many different kinds of project possibilities and settings and are used in the evaluation of environmental impacts of virtually all projects.

Experience in environmental evaluations within the Bank Group has given rise to a series of operations which are now being followed for each project believed to have significant environmental/health/human ecologic impacts.

In brief these include:

In-house study of the proposed project utilizing the Bank Group's technical staff.

On-site "environmental reconnaissance" to determine likely impact of the project; the problems, if any, likely to result; recommendations for preventing or mitigating such problems; or recommendations for in-depth studies of particular environmental responses.

In-depth studies are the subject of multi-disciplinary investigations conducted under terms of reference carefully tailored to the conditions and requirements surrounding the particular project, or component thereof.

Projects of such a nature that their environmental impacts are of unique importance to a regional or global audience, and wherein singularly unique and important environmental values are involved must, of necessity, be the object of comprehensive and detailed studies to determine how or if the project can proceed.

Projects for which environmental safeguards or controls are to be included are examined during the construction and pre-operation stages to determine their adequacy and sufficiency in light of any changes which may have occurred subsequent to final appraisal.

Projects in operation are examined periodically to determine the continuing adequacy of environmental safeguards, and the need, if any, for new or improved controls.

Projects involving important ecological systems are subjected to "environmental post-audits" at appropriate points in their implementation to determine the accuracy of the pre-project impact assessment, and the actual consequences for such systems.

In each and every project subjected to one or more of the steps cited above, the environmental safeguards which may be indicated are the object of cost/benefit analysis.

Efforts are continuing to develop a more suitable methodology for identifying and quantifying the diseconomies, social and opportunity costs, and benefits to be anticipated. The difficulties experienced in this regard are many, and are the subject of increased research.

The environmental studies seen as being requisite to financing a project are, in most instances, financed by the borrowing entity, in much the same manner as other aspects of project preparation, such as engineering, geology, marketing, etc. In some cases involving poor countries, the Bank Group may finance the required studies. Increasingly, the borrowing entity is encouraged to make the necessary studies, while the Bank Group reserves the right to approve the terms of reference and the qualifications of those employed in their conduct. The Bank Group does assist, where appropriate, in preparing the terms of reference and in defining the disciplines to be used in the studies. In some instances, the Bank Group will conduct the required studies being financed by the borrower. In any event, findings of environmental studies are shared jointly with the borrower, member country government, and the Bank Group.

Thus, while no formal "impact statement" on the environmental consequences of a development project is strictly required, the Bank Group does require that major adverse

effects be avoided or mitigated and as indicated, has established systematic procedures for accomplishing this. To date, all projects requiring safeguard measures have been successfully negotiated with the borrower and member country.

Industrial Projects

The guidelines for industrial projects given in the Bank Group's handbook follow a progression of check points designed to accomplish two main purposes: the prevention of deterioration of natural resources so that they can continue to provide the basis for further and sustained economic development; and, the provision of adequate warning of the side effects of project development which may incur costs not identified in ordinary review procedures.

The first purpose, protection of the resource base for future development, aims to identify opportunities in project design which will facilitate the full utilization and renewal of resources where possible or, the conversion of resource sites to alternate subsequent uses where renewal is not possible. The guidelines also seek avoidance of depletion and destruction in the sense of leaving areas with no future uses or in a condition to do harm to other related resources.

The second purpose, to call attention to undesirable side effects, aims to bring external effects or social

costs not ordinarily calculated into the overall project evaluation. In this case, the rate of return on the project and the economic return to society may be different so that the total expected costs have to be weighed against total expected benefits.

The objectives require a compilation of information in a frame of reference of sufficient breadth of scope and time to identify the relevant context for project evaluation. Nine different steps are outlined; they serve to link the particular project first to the natural resource origin of the raw material to be handled and finally to its eventual resting place in a disposal area. The steps call attention to the place of the project being appraised in the context of the cycle from extraction to disposition.

A second feature limits the concern of the analyst. In order to incorporate environmental considerations into the concerns of economics, the environment has to be treated as an economic entity. It must be demonstrated to have scarcity, priorities, and alternatives for action. Without an awareness of these three characteristics, environmental evaluation reduces to assertions which cannot be handled through economic analysis. Whether or not these economic characteristics of the environment are quantitatively expressed is not the only issue. Analysis can proceed as long as there is a sense of scarcity, priorities and

alternatives.

Environmental considerations have often been excluded from economic analysis because they could not be handled with current analytical tools. The development of necessary concepts is still in the early stages and the criteria articulated here are minimally necessary to proceed.

The state of the art of incorporating environmental criteria is not only complicated by conceptual difficulties, but also by an absence or relative paucity of both the data necessary to assess effects and the dynamic predictive models which employ the data. Thus, the need to make difficult judgments, in order to assess the risk of uncertainty of prediction as well as weigh the costs and benefits. The difficulty is compounded by the fact that many environmental judgments do not have to deal with the imperatives of survival, but with differences in values of substance and timing. Thus, poor men may value jobs more than aesthetics and may be willing to make short term gains now and hope to repair the damage later. The guidelines point the way to making these choices consciously, but they cannot make the choices themselves. They are guides rather than absolute prohibitions or assertions of certain fact.

Environmental Guidelines*

The environmental guidelines for project appraisal include a broad array of concerns designed to assess costs leading to impairment of future productivity of a country's natural resource base and the side effects of investments. As indicated in the nine steps of analysis (presented below) the impact of investments on the human environment requires a systematic and integrated view of projects which links them to materials flow within production processes and throughout the economy and society. This widening of the scope of concern is justified because incremental change in particular cases has led to a broader impact.

Proceeding through the nine steps from natural resource linkage to optimization calls attention to the interrelation of choice of process with recycling and reuse potantial, of plant location with urbanization issues, of waste management with process design, and other such connections which make the integrated project design sensitive to environmental needs.

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*Excerpts from Chapter 9, Guidelines for Estimating Industrial Environmental Impact of the the World Bank 1973 publication Environmental, Health and Human Ecologic Considerations in Economic Development Projects.

There will be considerable variation of opportunity to make an integrated appraisal for there is variation in the degree and timing involvement by the economic development institution. There will be variation in economics, natural conditions, and interests in the issues addressed. Over time, it is increasingly likely that the full range of interests expressed here. and perhaps others, will play a significant role. The following outline of environmentally sensitive target areas in current industrial projects lending is intended to call attention to relevant factors.

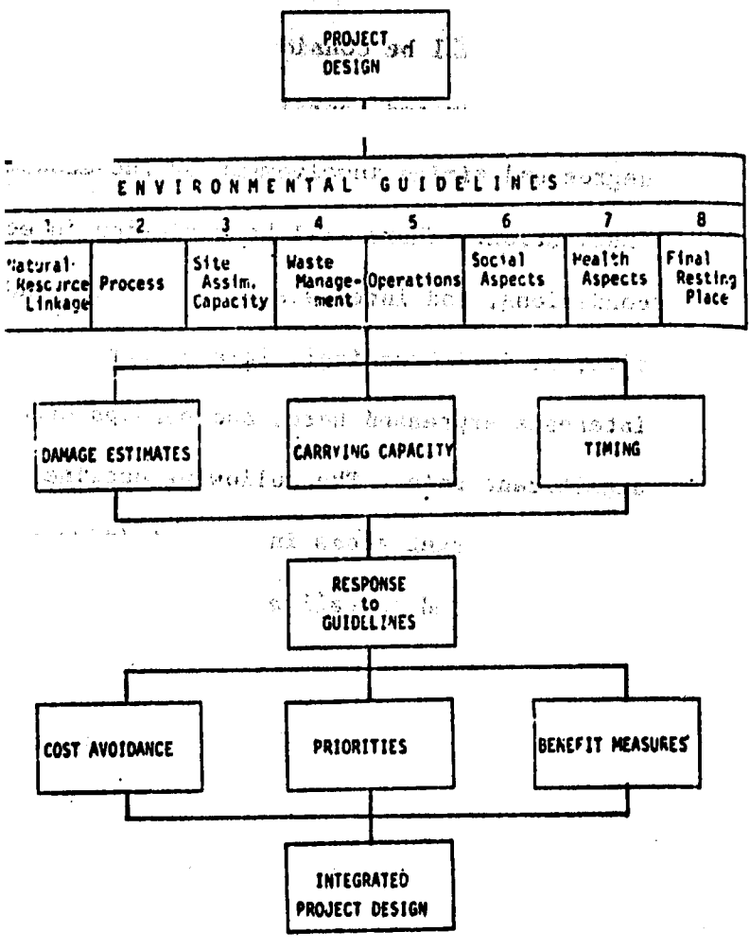

Figure 1: OPTIMIZATION PROCEDURE

9-20

Step 1. Natural Resource Linkage: This step includes environmental considerations from the original extraction of the ore or other resource to the time it enters the projected plant. If the material is an import the linkage may start with its arrival in the country. The natural resources would include (a) all organic material such as liquid, solid, and gas fossil fuels and other organics not used for fuel including crude oil; (b) all inorganic ores leading to the fields of fertilizer, ceramics and cements, and other basic chemicals; (c) all metallic ores whether complex or native metal; and (d) all primary and reusable materials including agricultural and marine products for food and industry.

An example of this linkage can be seen in a decision to fund a naphtha cracker to produce feedstock for polyethylene. The linkage would begin with the drilling of a well or with the arrival of the crude at the seaport, go through the refining process to separate the naphtha fraction by distillation, and then follow on to the actual building of the cracker, the project under consideration. The particular problems to be considered in this linkage would be oil spillage, oil storage and transportation, and the refinery operations. The refinery would produce a range of gases, liquids, and solids, of which the naphtha feedstock would be only a small part. Plans for the full

range of waste materials should be formulated at the same time.

Step 2. Process: This step includes the decisions on basic processes to be used in the projected plant, the source(s) of energy for power and heat, and the supply of air and water. The environmental aspects of any projected plant start with the decision to use a particular process. An environmentally sensitive decision includes a consideration of by-products and wastes and their abilities to be either reused or assimilated. The source of energy considers available materials in the area besides the traditional supplies, whether there be waste gases or liquids, or perhaps tree bark or other solids with potential heat content.

Air and water can be thought of as chemical inputs to the system, their purity after use to be considered as carefully as before use. To ensure more complete materials utilization, the raw materials in each step can be chosen from the possibilities in the area including by-products and wastes which might be available but often are excluded by a centralized designing source. The selection of the process or processes can be made from a collection of all these facts.

Copper extraction suggests an example of an environmentally sensitive decision. Although most copper is

extracted from its ore by smelting and then electrolytic refining, there are alternatives. Depending on the particular ore to be processed, there are roast and leach techniques or just leaching itself. The leaching approach avoids the formation of sulfur dioxide and instead produces a waste liquor which can regenerate the leaching solution. This process can provide an alternative to the formation of sulfur dioxide and subsequent production of by-product sulfuric acid by extracting sulfur when this is a more convenient by-product.

A similar line of reasoning can be made for flash smelting. In this process the sulfur dioxide gas will be richer, thus allowing a more profitable operation of a by-product sulfuric acid plant for those cases where there is a sufficient acid market. Oxygen enrichment is another method of increasing the sulfur dioxide content of the off gas and thus increasing the sulfuric acid recovery or allowing the production of liquid sulfur dioxide, another marketable chemical.

The decision to use one process instead of another is made by considering the by-products as well as the product. In this way, economic gains through reuse or resale of these wastes can be made greater and environmental degradation through waste disposal can be minimized.

Step 3. Site Assimilative Capacity: The purpose of

this guideline is to analyze and interpret a proposed site's natural resource characteristics for its ability to sustain an industrial project's environmental impact. It is assumed probable industrial project stresses on the biophysical environment (scope of impact) will be delineated during Step 2 project process guideline assessment. Environmental parameters relating to water, land and air should be inventoried and interpreted to identify those implicit and explicit characteristics indicative of project impact/stress on the fragility of the local ecosystem. Direct and indirect effects should be assessed within this guideline framework to ensure least cost in natural resource degradation to the local site as well as direct or indirect effects over time to the regional environment.

Site assimilative capacity should not necessarily be constrained only to the environmental impact of an industrial project. Local and regional natural resource characteristics should be assessed for land use assimilative capacity. Proposed settlement patterns generated by an industrial project should be compatible with the land and its related resource characteristics; e.g., basic infrastructure such as water supply, sewage and solid waste disposal, road layout and design, land stability for housing construction and other land use settlement criteria should be considered as part of the site assimilative capacity

guideline.

The choice of site does not only imply constraints, but also opportunities. Through the application of density controls for land use, the costs of abatement technology might be eliminated where the assimilative capacity is not exceeded and standards can be maintained.

A proposed coal mining operation site exemplifies site assimilation guideline application. A major environmental pollution problem is created by acid mine drainage occurring when pyrites--iron sulfides usually found in coal deposits--are exposed to air and water. The pyrites--oxidized to sulfuric acid and ferrous sulfate--leach through natural drainage waters and trickle into streams creating major pollution problems. The sulfuric acid not neutralized by receiving waters destroys vegetation, fish and other water biota rendering streams useless for recreation, water and food supply. Therefore, attention should be given to the hydrographic character of groundwater movements and gradients in the vicinity of operations to determine the natural capacity to neutralize drainage waters. Where site conditions might lead to water pollution, alternative abatement tactics should be considered. The alternatives for coal mining include: (1) closing the mine to oxygen after use by filling with an inert substance such as sand or by sealing, (2) neutralizing the waste liquor after

it is formed by means of lime or limestone, (3) treating and recycling the chemicals in the liquor.

Step 4. Waste Management: The most important consideration in waste management is that the alternatives be planned to fit with the process or processes and the site. Emphasis should be placed on use or reuse of the materials whenever possible, and assimilation back to the natural ecosystem as a last resort. In this way treatment is not the complete pollution solution, rather it is a part of the solution in making the material(s) fit for reuse or for assimilation.

Step 5. Operation and Control: The objective of this guideline is to develop and maintain a project administrative framework capable of monitoring a facility within constraints indicated by previous guidelines--especially the performance of process and control devices. As a minimum, staff structuring might include expertise in environmental engineering applicable to the proposed industrial project. Environmental functions include monitoring systems applicable to materials flow from raw material input to final product output to ensure that tolerances are maintained according to design specifications. In-house research and development might be considered to ensure project efficiency and conservation of materials. Data compilation over time can be analyzed to monitor deviation from

baseline (starting) conditions and the approaching threat of exceeding thresholds of ecological carrying capacity. An environmental engineering staff can serve in evaluating a change in process technology or industrial project expansion. Where feasible, simulation models can be developed and projected effects analyzed for project efficiency and environmental impact. Project quality control criteria could then include an active assessment of accumulative effects of waste streams.

Step 6. Social Aspects: This step previews social implications for the environment generated by industrial project investments. Social aspects, especially of those industrial projects employing a large labor force, influence in-migration of populations thus affecting land use patterns.

Locational requirements attendant to the in-migration of a labor force and its families' impact on land use patterns should be evaluated in the light of available food, water, shelter and accessible transportation systems, based on localized institutions, mores and customs. Medical and other public services should be available or accessible.

The social implications of product output consider effects on local land use patterns, e.g., cement manufacturing's effect on localized construction or a fertilizer plant's influence on agricultural techniques and the

attendant changes in social, economic and land use structures. The guideline can consider such broad issues as the desirability of labor intensive technologies to aid in fulfilling employment and income distribution goals. Consideration might also be given to the impact of population movements on rural life.

Guideline assessments should generally preview the land and its related resources, identifying the ability of the area to sustain development pressures generated by habitation patterns characteristic of local cultural preferences. Attention to these potential problems can lead to desirable social cohesion and minimal social disruption. The effects on the push-pull of urban-rural migrations need attention, for the instabilities of urban life can be aggravated by adding industries to cities where the fixed capital of the infrastructure cannot effectively handle increased population loads and the tax base can tolerate little or no expansion.

Cost calculations of social aspects might include many different aspects: some quantitative, such as the cost of the provision of adequate worker housing; some qualitative, such as cultural change induced by relocating families or social tensions induced by crowded conditions. The assessment of social costs is not a simple engineering assessment and needs to be done in the light of broader qualitative

criteria than are traditionally considered in project appraisal. This broadening of the definition of environmental assessment leads to linking project design with overall economic development goals and may or may not be done at the project level. However, specific project design in terms of location and physical layout can be affected by the more qualitative judgments, and attention would be usefully paid to dealing with the social issues somewhere in the appraisal effort.

Step 7. Health Aspects: This step calls attention to the need to monitor and consider maintaining the health and welfare of project employees and local and regional populations adjacent to the project facility. In-house safety procedures can be designed through employee education and clear and concise management policy statements pertaining to operations. Job specifications can be communicated to ensure efficiency and safety operations. Product safety hazards, implicit and explicit, should be clearly defined for consumer protection, notably in export industries to countries with high environmental standards. Attention needs to be paid where chemicals, petro-chemicals, fertilizers and other products for consumer use with possible cumulative concentrations have effects on human health and welfare. Pollution vectors--water, land and air transport--should be closed or minimized where local and

regional health is affected by the transport of disease.

Public health standards should be set and maintained through regional or local institutions based upon ecological, economic and human susceptibility criteria. Water quality, ambient air, sewage and other waste water, land use and other standards as they relate to human health, can be implemented with appropriate flexibility to prevent environmental conditions capable of sustaining the growth and cumulative concentrations of germs, viruses, particulate matter, toxic chemical emissions, haphazard land disposal of toxic wastes, etc. For instance, air quality criteria are affected where meteorological conditions are conducive to inversions, such as in river valleys which trap emissions with probable effects on human health and welfare; e.g., increased prevalence of chronic bronchitis and emphysema in adults, diminished pulmonary function, increased frequency of common colds and minor respiratory ailments.

An attempt to quantify health aspects which simply assesses the economics of worker-days lost through absenteeism, or the costs of medical clinics to provide cures would miss the most important cost of human discomfort. An assessment of this cost would have to be traded off against the illnesses associated with non-productive economies having poor levels of health due to poverty. The net cost

calculated on this basis would then be more inclusive, even though it was not associated with dollar value.

Step 8. Final Resting Place: This step is considered in the overall evaluation in a manner similar to the natural resource linkage, in order to complete the natural cycles. Everything ends up someplace, there is no such thing as ultimate disposal. The step can be as complicated as a mercury flow chart locating every gram of the metal, or it can be as general as a paper discussion showing the amount to be recycled into pulp, the amount to be saved, and the amount to be dumped. The step must be included, however, for every disposal technique has a cost associated with it. In some cases, the cost may be high because it is a non-degradable substance, or because it has an intermediary or final product which is toxic. All these costs require evaluation.

A plant producing poly vinyl chloride can serve as an example. This is a non-biodegradable material which is resistant to compaction and large amounts could not be handled in sanitary land fills or compost heaps. Alternative means of disposal such as salvage or high temperature incineration would have to be considered. Not only do the solid, liquid and gaseous wastes from the project itself have to be considered, but the costs of disposal of the product after use should be included. In the case of poly

vinyl chloride. it may necessitate a higher-priced method of disposal.

It is not possible to identify the range of dollar costs precisely because the cost of collection, the cost of the land for disposal and the capacity to recover valuables from generalized waste varies considerably according to the character of materials in an economy.

Step 9. Optimization: The analysis of costs of the various alternatives for protecting environmental values and for protecting natural resources will have to augment traditional costing procedures in order to accomplish overall optimum project design. The previous eight steps have called attention to information requirements which are reviewed in the last step. Choices of industrial processes or choices of techniques for mining and harvesting forest products will all be associated with different costs. There will be considerable variation from project to project in terms of amounts and kinds of costs, and the aim in this guideline is to establish concepts which guide the judgments to be rendered. Environmental cost analysis can be conceived as having two parts. The first deals with who bears the costs and the second deals with determining amounts of costs.

There is already a body of literature on who bears the costs and economists have made a convenient distinction

between those internal costs borne by the firm, which may affect the financial rate of return, and those external costs absorbed by the society, which may affect the economic rate of return. Guidelines cannot determine who will bear the costs, for proper assignation of costs is dependent on circumstances which vary from society to society. However, the guidelines do need to consciously examine total costs to avoid overlooking the full range of requirements for project design and evaluation.

It would require a substantial theoretical treatment to examine the alternative modes of assessing costs, for environmental costing techniques are not as well developed as other economic guidelines. However, as a general rule, the information gathered in the first eight steps should suffice to bring to mind such factors as public health effects. For example, some of the costs of air pollution from sulfur dioxide levels which exceed the threshold of human tolerances can be noted in terms of man days lost from work as well as public health facilities to effect cures, as well as the qualitative judgment of the tolerability of respiratory illness.

For another example, the costs of river pollution, may be the cost of a water treatment plant downstream to render water potable, or the opportunity cost of using the ecological carrying capacity of the river for a more

productive enterprise, or for public recreation, or for tourism or fishing. For another example, forest management techniques used in a pulp mill project might result in erosion and can severely limit the life of a downstream dam through siltation, causing earlier amortization than projected. Erosion can also deny a second use of the land such as agriculture or can deny possible multiple uses of the land which could help defray overhead costs. Forestry cutting procedures create opportunity costs in terms of later benefits to be derived such as satisfying a projected demand for construction materials for public housing.

In each case the costs can be identified from calling attention to the information from the guidelines. Whether these costs are borne by the project or by the society is a matter for discussion and negotiation in each case. It may often be the case that the social benefits from a project will outweigh the social costs so that the net judgment for the project is positive and the assignation of the costs is accepted by the society. Historically, this has often been true, but recent changes in public values and strategies of economic development require a reassessment of the position.

A framework for determining costs will evolve from experience. Before the environment can be handled by the tools of economists, it must at least have the characteristics of scarcity, priorities, and alternatives. The

guidelines have been designed to satisfy these needs with information bearing on each. Scarcity arises from the fact that environmental assets such as clean water and air, have a limited capacity to absorb materials before they change state. The change of state may be through destruction of water bodies due to excessive nutrients which support plant life in water. The cost may be aesthetic, such as the loss of a lake, or it can be directly economic for such water chokes intake filters and cooling mechanisms of machinery. The change of state is due to the scarcity of carrying capacity for pollutants which represent materials outside of natural cyclical patterns. Such scarcity is the reason why the guidelines have called attention to monitoring and standard setting in order to know how much room for assimilation of materials is left before adverse changes of state must be borne. This scarcity of assimilative or carrying capacity also has led to emphasis on recycling and efficient use of natural resources in Steps 1, 2, 3 and 8.

Nature is constantly changing state, with or without the intervention of man, but industrial activity can hasten these changes and can send them in unfavorable directions with resulting counterproductive costs. That is why priorities need to be established. Whether or not changes of natural state are tolerable depends on priorities in economic development strategy. Global survival may take first

place and environmental damage which threatens man as a species would therefore be intolerable. However, the evidence that survival is at stake needs further development and anything less than that is a relative matter subject to ordering of priorities. Thus, whether or not developing countries want to repeat the public health costs borne by the developed countries is a matter of priorities and trade offs. The guidelines will indicate what the costs are, but how they are weighed is a relative matter. Economic development includes a mixed set of goals and the values of the environment impinge on many of them.

In the sense that other non-economic decisions are taken as parameters by growth economists, the environment is no different than employment goals, or income distribution goals, or political stability. The qualitative mix of economic development priorities will just include one more element. This element will have to seek its place in the priority schemes of planners, for allocating assets for the future is their task.

To help determine the place of the priorities for environmental and resource protection, alternative solutions have to be sought. One of the major alternatives which may be open to project designers is time. One can mortgage the environmental future by destroying now and hoping it possible to clean up later. This argument will have much

currency in that it is the path which developed countries have taken. However, cost analysis will have to include some assessment of how much time is available before diseconomies set in and how much the cost of reversibility will be. In some cases reversibility will be so costly, or biologically impossible, that there will be no choice. The guidelines for site assimilative capacity in Step 3 include information on threshold values and the possibility of reversibility.

There are other alternatives besides time. Process selection as indicated in Step 2 is specifically designed to evaluate alternative methods of achieving the economic goals without incurring costs which must be paid, how or in the future. There are different techniques for foresting on slopes which will forestall erosion and avoid costs. Once again, however, whether or not the costs are deemed to be serious or are outweighed by the benefits, as indicated in pricing mechanisms is a matter of relative priorities.

Some Case Studies

For illustrative purposes extracts of five selected case histories are presented below. These project cases are drawn from the period during which the Bank Group has made special efforts to enlarge its project analysis; that is, early 1971 to the present.

Case Study No. 1: Iron Ore Project

The project provided for the exploitation of large quantities of high grade iron ore, and its rail transportation from the country's interior to a marine terminal to be constructed on an island located within the boundaries of a largely unspoiled estuary. At the terminal site in the bay, large (300,000 - 500,000 tons) combination oil/ore boats would load the ore for distant world markets.

The Bank's announced policy to pursue economic development with studied regard for environmental quality was put to a test by this large project which presented a number of apparent potential environmental problems. Expressions of concern were also received in letters addressed to the Bank from individuals who conceived of potential impairment of their respective interests. The bay's aesthetic beauty and recreational opportunities caused the population to swell from about 3000 permanent residents to some 15,000 during the summer months. It also supported an important shellfish and fin fish industry. The apparent threats therefore called for an immediate on-site study and the Bank Group accordingly dispatched a multi-disciplined team of consultants (marine biologist, fisheries and shellfish expert, and oceanographer/marine ecologist) to identify likely problems and recommend measures for their solutions.

The studies revealed inter alia a poor circulation pattern around the island that would prohibit efficient dispersal of any future waterborne waste emanating from the ore terminal. The extensive biological sampling program carried out throughout the bay established the major biotic communities as benchmarks against which any future changes may be related.

The tourism potential of the area was evaluated, as was the environmental impact at the mine site, along the rail transportation route, the rail trestle crossing the bay to the island, and the terminal site on the island proper.

The plans for the island terminal, as approved, involved construction of the railway access bridge, conveyor trestle and pier, ferry and tug dock, dredging, water and electrical systems and facilities to handle oil slops. The national law provided stiff penalties for dumping slops into coastal waters but protection for the bay in this regard was weak. The Borrower therefore agreed to prepare plans for dealing with slops at the terminal, for disposal of solid waste and sewage originating at the terminal and transferred from ships using the terminal, and to develop contingency plans and maintain standby equipment to minimize the effect of accidental spills at, or in the vicinity of, the terminal.

Standards for air and water pollution and details of the port regulations issued by the Borrower to govern ships using the terminal facility were determined on the merits and needs of the case at higher levels than existing local regulations would demand.

It was agreed that the Borrower would take all steps to preserve the ecological integrity of the part of the island not being used for the marine terminal and would preserve in its entirety a smaller island located between the terminal site and the mainland, and would terrace, landscape and otherwise provide for the visual amenities at the terminal site, prohibit the erection of advertising billboard signs on the island or adjacent mainland, and arrange for continuing studies of the impact of the project on the environment. Blending colors would be used for painting of facilities, and the trestle designed to serve as a catwalk for fishermen and tourists.

At the mine, conventional open-pit mining methods were already in use for ore extraction. Practices there demonstrated the Borrower's own interest in environmental protection. The new ore preparation plant would consist of primary crushing, screening, secondary crushing, final screening and washing, and hydraulic classification facilities. Drills for blasting will be equipped with dust collectors. Dust on haul roads will be minimized by

sprinkling. The crushing plant will be equipped with dust collectors connected to hoods at the feeder and crusher. Water sprays will be used to control dust on open piles of ore stored after crushing, and tailings or a slurry of fine hematite sand and slime from the processing will be thickened by passing through a cyclone, and the reclaimed water will be returned to the process plant. The final slurry and natural runoff will be stored in a pond formed by an earthen dam in a valley behind the plant. Pond water also will be recycled to the plant after treatment with a synthetic polyelectrolyte flocculant to clarify the water.

Erosion in the mining and processing areas is to be minimized by various means including lined ditches at the top levels to carry off water. Reforestation will be applied to control erosion at the mining site and to minimize the visual impact of land stripping. Sanitary wastes from the facilities will be treated in an aerated sewage treatment plant.

Only limited solutions were found for the problems of safety, noise and dust on the rail line for transport of ore to the terminal. Heavily loaded ore trains will move frequently and the rail line will pass through several populated areas.

The joint effort by the Bank Group and Borrower looking to the conservation of the ambient region of the

terminal for the future set an example in applied environmental policy and provided a practical demonstration of the relatively low cost, about 1.5 percent of total project cost, and slight delay involved in devising measures to avoid or minimize pollution and landscape defacement. The foreign exchange component financed by the Bank, $96 million, constituted 34 percent of the total project cost.

The values of prevention were in this case very large for the community and the nation because of aesthetic worth and because of avoidance of losses that would be critical for the smaller industries of tourism and the significant shell and fin fishery. Protection also was afforded for an estuarine nursery ground for important coastal fish stocks. The eventual fate of the estuary is uncertain for the long-term in view of other planned and potential industrial activities. Another industrial project on the bay, however, which has been financed in part by the International Finance Corporation (IFC) has received similar treatment to protect the local environment and offered an opportunity to reinforce the Bank Group's views of the need for long-term, integrated environmental planning.

Case Study No. 2: Mining and Infrastructure Project

The project, located in a country which became independent in the 1960s and is at the bare beginning of industrial development, comprises an open-pit mine for

extraction of copper and nickel, a smelter, coal-fueled steam power plant, 40 miles of rail and road connections, and a new township. The township is to include buildings for public administration, health care and four schools, housing suitable to the cultural requirements of the 2000 employees, water supply, and sanitary waste disposal.

Several international agencies participated in this project in which the Bank financed $37.5 million out of a total capital cost of $185.5 million. The Borrower was the national government.

Under the terms of the loan agreement with the World Bank Group, the Government agreed to take all action, including enactment of legislation and regulations, to ensure that the operation of the mining project and infrastructure would be conducted with due regard to public health and the natural ecosystem. The government will cause the mining company to comply with the laws and regulations and will consult with the Bank Group before making any changes in them. The government also will act to control pollution in the construction stages and ongoing life of the project. To assist in fulfilling these requirements, the Bank Group provided an expert environmental consultant. Consultants also were engaged directly by the government and by the mining company.

The principal environmental hazards are atmospheric

pollution caused by sulfur content in gaseous emissions from the power and smelter operations, and water pollution from the mining operation.

The distance between the smelter and power station and the future town is two miles, probably not sufficient for full protection from occasional exposure to exhaust gases and dust, although the prevailing winds were taken into consideration when determining the township location. The government recognized the need to examine the potential effect of gases and dust on the health of the human and animal population, fauna and vegetation of the area, and engaged a consultant through the British Ministry of Overseas Development, to investigate and report measures necessary to keep all aspects of pollution from the mining plant and power station to acceptable levels.

The principle protective measures against SO_2 atmospheric pollution focused on the height of the smelter and power station stacks which, it was determined, should be 525 and 250 feet respectively. The government is establishing a system for monitoring ground level SO_2 concentration and has the responsibility for taking necessary action if it exceeds acceptable limits. Enforcement will entail reduction or shutdown of mine operations until acceptable air quality is restored. Laboratory equipment has been acquired and a training program instituted.

The mining company will provide for treatment of liquid waste effluents from ore reduction so as to prevent discharge into nearby surface waters and injury to downstream users. Effluents will be conducted to a tailings dam where suspended materials will settle. Further treatment may be instituted as required. The company also is responsible for occupational health and safety measures including dust control at the mining faces, safety equipment and training, and periodic physical examination of miners.

Most of the solid wastes of the mining operation will be returned to the cavities left, in a rotating excavation and filling process. Wastes to be incinerated will have proper fly ash and particulate controls.

The project provides an example of international collaboration in aid to an incipient industrial development in a remote and inexperienced country. It involves the issue of environmental protection in all its broad aspects including basic legislation, regulatory and monitoring systems, care for preservation of the natural ecosystem, health and socio-cultural considerations from the long-term point of view, in addition to the immediate concerns regarding industrial pollution of air, soil and water.

The best of planning by the most farsighted experts, however, does not always keep ahead of the human factor.

This project overlooked the overnight appearance of a squatter town, which sprang up with great suddenness in anticipation of project opportunities. Unplanned, unforeseen, patched together from mud, matting, cardboard, corrugated sheeting or almost any waste or salvage material, totally without water and sewage services, as picturesque as they are squalid and unwholesome, such "towns" are inhabited by the people who come to seek work, accompanied by wives, children and camp followers. The one embarrassing this project's wholesome new town project was no exception to any of these characteristics.

The government acted quickly to promote order in this case by appointing headmen to supervise and guide the squatters. The government proposes establishing a site and service area near the coal mine and encouraging the migrants to move there. Such a service area was in fact originally recommended in the consultants' Township Report as a means of avoiding slum developments on the fringes of the new township, but planning and costing were not carried out. The cost of taking up the recommendation at this later stage was about US$50,000. The total additional project costs resulting from environmental/health considerations was estimated at approximately $1.6 million.

The case study illustrates what is found to be true generally, i.e. that even with the addition of overlooked

and unforeseen items, the costs of building environmental protection into industrial development, including consultant service, changes from proposed to alternative choices of site, purchase and installation of special equipment, and training programs, are monetarily small in comparison with the overall investment. They are beyond that, much smaller still in comparison with the probable magnitude and scope of the unquantifiable values attained in terms of the physical and social health of nations and conservation of the health of the biosphere.

Case Study No. 3: Expansion of Steel Production

The project entailed the expansion of production facilities at a large plant located in a semi-arid, relatively isolated region adjacent to the Black Sea. At the end of the project in 1976 the manufacturing facilities will have doubled and will produce 900,000 tons of flat products, 300,000 tons of billets, 60,000 tons of ingots, and 180,000 tons of pig iron.

The loan requested from the World Bank Group was US$76 million, and the cost estimates for recommended pollution control equipment were $5 million, or 1.72 percent of total project cost.

The project includes a second blast furnace, a third oxygen vessel, a billet caster and a semi-continuous hot strip mill, an expanded cold reduction mill, and added

auxiliary equipment. Each of the separate plants has specific environmental impact and pollution potential associated with it.

A first review showed that little or no provision had been made for control of the liquid and gaseous effluents which would be released into the environment in relatively large quantities. Of particular concern was the possible effect of air pollution on public health and on livestock and vegetation in and around the project site. Further, the liquid wastes containing toxic ingredients were to be released directly into the off-shore waters of a sea shared with neighboring countries. This important body of water is now showing signs of heavy pollution and the United Nations Food and Agriculture Organization (FAO) has called attention to its seriously deteriorating condition.

Ecology in the country concerned is a new or unaccustomed subject to many, but both the government and the private interest were responsive to environmental recommendations from the World Bank. In close cooperation with them, an on-site ecological study was made by expert industrial pollution control consultants engaged by the Bank who recommended appropriate control technology. During discussions held with various Ministries involved, the interest of the national government was stimulated to the extent that a scientific and research center of the country was

directed to determine the air, water and noise pollution of the entire plant and establish the minimum requirements for control. The government is expected to follow the present international trend of progressively widening the scope of its environmental controls.

The specific recommendations for this project were based on the consideration that within the useful lifetime of the facilities to be constructed, it will be necessary to establish standards on the basis of available technology while the selection of treatment processes and the layout and installation of major production facilities should be compatible with additions which may be required in future to meet more stringent limitations on effluents.

Air pollution effects observed by the consultants were mainly aesthetic, consisting of visible smoke and dust emissions, sufficient, however, to require corrective action. This will include automatic equipment to contain gaseous emissions and stacks of adequate height. Smoke, gas and dust emission at the coke plant will be reduced through the use of design improvements such as self-sealing doors, quenching tower baffles, improved charging system, aspirators and smoke seal boxes.

The Company has agreed to present a specific plan acceptable to the Government and the Bank Group for dealing with air and water pollution, and to implement the specific

plan to be followed will be based on the recommendations of the professional ecologists previously hired by the Bank.

Case Study No. 4: Integrated Pulp and Paper Mill

The International Finance Corporation (IFC) has assisted the financing of an integrated pulp and paper mill in a sub-tropical location.

The environmental considerations have been the subject of concern and intensive studies on the part of the national government, company management, IFC, and the Bank Group's Office of Environmental Affairs. The mill effluents flow into a river which is the source of an important local commercial fishery and flows eventually into an important international body of water. About 30,000 people are dependent on the main river below the mill site.

On the basis of an ecological survey of the area done in 1971 by UNESCO, the national government established detailed standards for the mill's liquid effluent. The plant's waste treatment system was designed to meet those standards. Process water from the mill will be collected and discharged to a clarifier followed by aerated lagoons for BOD removal. Sewage will be treated in a separate oxydation pond. The final effluent will be discharged via a diffusion pipe into the river.

If the river flow in the dry season should not prove sufficient to ensure adequate dilution of the mill waste,

possible oxygen depletion below levels required for aquatic life could cause problems. The UNESCO report, however, shows river flows even during the dry seasons to be sufficient to ensure adequate dilution of waste treatment plant effluents.

Odors emanating from pulp mills are obnoxious but maximum ground level concentrations were not expected to cause problems.

Despite the treatment to be given the effluent of this plant at an estimated cost of $1.8 million, or 3% of total capital project cost, the remaining effluvia, when combined with those from other sources existing and planned, can be expected to have unfavorable effects on the river biota and water quality.

The Bank Group has held meetings with the national government and the company to impress upon them the importance of this possibility and the government and the company have agreed to undertake monitoring of the environmental and human parameters likely to be affected, with a view to taking additional appropriate action should any problems arise. The Bank Group also has reminded the government and management of the importance of training. In this case special importance attaches to training personnel to manage the treatment and discharge facilities, including monitoring and the responsible authorities have also been reminded that

training should include making this personnel aware of the great responsibility they have for protecting the river's biota and the many downstream users from the effects of pollution.

Case Study No. 5: Expansion of Metal Production

A 1973 plan for expanding existing copper mining operations entails an investment of US$644 million and will produce 186,000 tons of mineral annually. Part of the financing (about 2%), was sought from the International Finance Corporation (IFC). The project involves a new open-pit mine, new concentrator, and expansion of smelting and supplementary infrastructure facilities.

The location is a sparsely inhabited, arid plateau near the Pacific seacoast. The expansion would cause effluents and emissions created by mining and smelting operations now in existence at the same location to be doubled in volume: 30 million tons of tailings would be discharged and 600,000 tons of sulfur oxides would be released annually. Productive agriculture in neighboring coastal valleys, offshore fishery, and public health in a port city of 15,000 inhabitants would be endangered by air and water pollution from the project, in the absence of protective measures.

The disposal of concentrator tailings is by gravity directly into the ocean using a series of dry canyons where there is very little rainfall. Sewage from the mine and

concentrator infrastructure is turned into the tailings. The disposal of tailings occurs in part in a valley where one of the few rivers on that coast having a flow of fresh water throughout the year has its course. The large amounts of SO_2 emissions, much of which also eventually end in the ocean, may have possible transnational effects.

The project is one of exceptional significance because of the environmental concern, especially in contrast with practices formerly traditional in the region, which has yielded minerals for world industry in quantity over a long period of time. Disregard of environmental effects was the practice in the past. The environmental factor has now been incorporated in planning on advice of the World Bank Group and demand from other sectors of the national economy. (The Borrower is a consortium of U.S. private corporations licensed by the national government. Proposals have been made for further internationalization by arranging for investment in the equity by European and Japanese corporations which have a trade interest.)

An industrial/environmental pollution control expert employed by the Bank Group in his assessment also stressed the economic and social benefits that the proposed expansion of mining operations could be expected to contribute to the national economy as adequately balancing the possible adverseenvironmental/health effects. Based in part on

the consultants ecological reconnaissance, the Bank Group's Office of Environmental Affairs and the International Finance Corporation (IFC) recommended that more extensive air quality and tailing disposal impact studies must be a prerequisite for World Bank Group participation.

No alternatives were found by the Borrower to disposing of tailings in the sea; and, fisheries apparently have not been adversely affected thus far. An agreement was reached between the World Bank Group and the Borrower, however, which provides for IFC financing on the condition that the Borrower will implement environmental controls as recommended after further extensive, in-depth studies by qualified consultants acceptable both to the IFC and the Borrower. The scope of the studies has been outlined in detail and additional assistance has been offered through the World Bank Group.

The Borrower will install and maintain a telemetric system of air quality monitors to record on a determined periodicity the SO_2 and SO_3 and other air components as indicated by the consultants. The data will be made available to the IFC and the national government. The air quality monitoring system will be used to alert plant officials when pollutant levels can be expected to have adverse effects on public health and other interests. Plant operations will be reduced or suspended until the quality of the

air is restored to acceptable condition. If the cumulative record of data indicates that it is necessary, the Borrower in consultation with the IFC will take further steps required to control emissions.

Studies also will be made without delay of the distribution, dispersal and ultimate disposition of tailings entering the sea, taking into account surface and subsurface currents, tidal and wave action, chemical and physical interactions of the tailing particles with the water and bottom sediments and other factors. The exploration will include changes and potential benefits likely to result from alternative deep water disposal below the euphotic zone of significant trophic activity. Studies will be made of the effects of tailings on the marine biota, including the effects of untreated sewage carried with the tailings.

The Borrower presently is in compliance with national and local legislation regarding effluent standards and conditions for disposal of tailings and will continue to comply should they be made more stringent. The detailed and extensive agreements made with the Borrower regarding its operations and their environmental aspects is illustrative of the Bank Group's attitude and efforts in these matters. Its contribution to the total cost of project expansion is indeed very small, but among the consortium of private corporations involved the Bank Group alone has insisted

on an environmental assessment. Whether or not, and to what extent, such pollution control measures should be taken is quite uncertain, but an agreement with the Borrower to undertake in-depth studies and later adapt to recommendations resulting therefrom seems entirely appropriate and represents a significant departure from past practices.

The case studies summaries as presented illustrate and indicate some of the accomplishments and difficulties encountered during the Bank Group's first years of experience and adaptation to the desired goal of continued economic development which is environmentally sound as well. Exact data on environmental expenditures are not easily furnished for several reasons.

Environmental measures are often productive, and it is questionable whether a project's environmental dimension gainfully should be separated out. Project components are all intimately related, as is the project itself to other projects, the external environment and the society at large. The Bank Group operates under a broad definition of what is environmental, and seeks to incorporate a project's internal environment and its public health and socio-cultural aspects in its evaluations. This mode of operation calls for improvement of human ecologic conditions frequently not conceived of as environmental, while at the

same time attempting to circumvent or mitigate errors made through development on the patterns of the past. The idea that well defined anti-pollution measures are to be added to a project as a cost is not seen as especially productive or desirable. Frequently this is still the only solution available for industry, but often, and more so in the future, pollution is, and will be, overcome through redesign, recirculation, product changes, etc.; a style of planning and production in which steps taken specifically for reasons of environmental protection will be indistinguishable from, and will be a true part of the entire process. The Bank Group, furtheremore, does not ordinarily separate out environmental expenditures as such on projects it finances; it frequently pays for part of studies undertaken and subsequently finances the foreign exchange component of a project, or parts thereof, alone or in cooperation with others. In other instances environmental expenditures relating to a project are financed from other sources entirely. At the time of project appraisal only estimates are made of expenditures to be incurred regarding resettlement, cost of land at new locations, training, occupational health measures, medical facilities, water supply and sewerage, landscaping, studies on how best to minimize industrial pollution, and subsequent cost of treatment facilities and final disposal. Additional money may

time be transferred for these and related environmental purposes or vice versa, depending on progress made toward project realization.

All projects are years in the making and none have yet been completed. In the case of the copper mining project [where] an estimated $500,000 will be spent on initial studies of potential impact on Pacific coastal waters and biota. The eventual expenditures which in the future may be incurred for pollution control are presently unknown altogether and may range from insignificant to a very substantial amount.

Source: 'The Industrial Environment--its Evaluation & Control', U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, 1973.

CHAPTER 2

THE SIGNIFICANCE OF THE OCCUPATIONAL ENVIRONMENT AS A PART OF THE TOTAL ECOLOGICAL SYSTEM

Don D. Irish, Ph.D.

OCCUPATIONAL AREA IS PART OF THE WHOLE

The occupational ecological system is a significant part of the total ecological system. Since it can be measured, we can exert some control over it and make contributions to the health and well-being of the people in the occupational ecological system. These contributions can favorably affect the impact of the total system on our population since a worker may spend one-fourth of his time in the occupational area, and workers are a significant part of the total population.

The purpose of this chapter is to examine the relation of the occupational environment to the total ecological system, to observe the significance of this relationship to the work of the industrial hygienist, and to recognize the favorable effect that his work in the occupational environment could have on the total system.

Nonoccupational exposure is an exceedingly complex and variable factor. Recognition of such exposure is necessary to an understanding of the overall environmental impact on man. The man who drove to work in heavy traffic or walked down a busy street received much greater exposure to carbon monoxide from automobile exhaust than he would have in an acceptable work area. Similarly, a worker who smokes one pack or more of cigarettes per day will be exposed to many times the amount of carbon monoxide that he would be exposed to in an acceptable work environment. This smoker would also be exposed to many times the amount of particulate matter from his smoking than he would contact in an acceptable work area.

There are many other nonoccupational exposures but these examples serve to illustrate two obvious areas of excessive exposure in the nonoccupational area. Such exposures cannot be ignored by those responsible for the health and well-being of people even if their responsibility is primarily in the occupational area.

OCCUPATIONAL INTERACTION WITH NONOCCUPATIONAL

In considering the occupational area one must recognize the interaction with the nonoccupational area and the significance of this interaction to the health and well-being of the individual.

We learned a long time ago that a man who drinks a lot of alcoholic beverages is much more susceptible to injury from exposure to carbon tetrachloride; also, that a man with excessive exposure to silica dust is more susceptible to tuberculosis. Such possible interactions should be kept in mind.

The following illustration demonstrates a different kind of interaction. We were studying the blood bromide concentration of men exposed to low concentrations of methyl bromide in their work. The environmental exposure in their operating area was carefully measured. The exposure was well within acceptable limits. Clinical studies verified this fact. It was valuable to establish a relationship between exposure and blood bromide at exposures within acceptable limits, as this would be useful in the future as a clinical check on the workmen.

One day a workman from this group was found to have a blood bromide concentration sufficiently high to be of concern if it had come from exposure to methyl bromide. Investigation revealed that he had been taking inorganic bromide medication which accounted for the high blood bromide.

Workmen may be brought to the clinic for regular preventive checkups. Biochemical measurements on these workmen may be exceedingly valuable to verify acceptable exposure, also to catch any indication of fluctuations in operating conditions and allow correction before significant exposure can occur. This is a very useful system, but we must be sure we have all the facts before we conclude what caused any observable biochemical changes.

THE INDIVIDUAL AS PART OF THE ECOLOGICAL SYSTEM

Ecology is defined in Webster's dictionary (1971) as "The science of the totality or pattern of relations between organisms and their environment." I prefer to call ecology the science of the interaction of *everything* with *everything else*. The ecological system is the system within which these interactions take place.

The ecological system is not exactly synonymous with the environment. My environment includes everything around me. The ecological system *includes* me. The individual person is a highly significant factor in the control of the environment in the interest of the health and well-being of the person.

A freight elevator was installed with all the usual safety devices. It was approved by state inspectors. A switch on the door made it necessary to close the door before the hand switch would operate the elevator. A tall lanky lad found that he could get his toe to operate the switch closed by the elevator door, and with contortion he could

still reach the operating switch. It would have been easier to close the front door, but it was a challenge. He was that rarity, a man with the reach to do it. No one knows how many times he operated the elevator this way, but one day he left his other foot over the edge of the elevator and seriously injured that foot when the elevator passed the next floor. Yes, fools can be very ingenious in overcoming "foolproof" engineering.

Misoperational problems are not limited to mechanical injury. There was the individual who liked a window wide open. Under certain wind conditions the air from the window blew across the face of a hood so as to allow volatile chemicals to escape from the face of the hood into the work area around the hood.

There was also the man who liked to "sniff" perchloroethylene. He arranged his work so that he could be "high" on perchloroethylene a large part of his work day.

The individual is a significant part of the occupational ecological system. His understanding and cooperation are essential to attaining a healthful work environment. We hope this understanding will carry over to some degree to the nonoccupational ecological system.

PEOPLE IN THE ENVIRONMENT

An important factor in the environment of an individual is "people." People in both the occupational and the nonoccupational environments are of significance to the health and well-being of that individual.

One day the psychologist in our personnel department asked me if we were having any complaints of noise from a certain operation. I told him we were, but we could find no justification for the complaints based on noise measurements made in the area. He commented, "You won't; the workers just don't like the foreman."

In another instance we found it desirable to coordinate a careful study of the environment with a concurrent clinical study of the workmen in the area. One group of older, experienced workmen refused to cooperate. They liked the foreman and their work and were afraid we might make some changes. With friendly understanding, the purpose was explained and they were reassured. You are always dealing with people in the occupational environment.

Another illustration introduces a different problem. Joe came into the clinic with a mashed thumb. The physician tried to get an understanding of the reason for the accident. He asked, "What happened, Joe?" "Oh, I got my thumb in between a couple of drums." "You have a good record, Joe, why did this occur?" "I was thinkin'." "What were you thinking about, Joe?" "Oh, I was thinkin' about my wife's sister." Knowing that health or financial problems in the family may worry people, the physician asked, "What's wrong with your wife's sister?" Joe answered with ecstatic fervor, "Doc, there just *ain't nothin' wrong* with my wife's sister."

We should recognize that people in the *nonoccupational* environment may have an effect which may result in misoperation. Such misoperation can lead to exposure to chemical substances, physical energies, or mechanical injury. This can occur either on or off the job.

The problem of people in the environment is not measured by any analytical instrument, though the instrument may measure a misoperation caused by people. The problem of people is not controlled by preventive engineering alone, though it can help. Effective operation requires a good understanding of people and the ability to get their understanding and cooperation. This is an obligation of the industrial hygienist, the physician and other persons responsible for control of the environment in the interest of the health and well-being of the workmen.

CHEMICALS, ENERGIES AND ORGANISMS

The usual considerations in the occupational environment are more measurable than people. Chemical substances are a concern of the industrial hygienist. Physical energies include: ionizing radiation, a concern of the health physicist; heat, light and noise, a concern of the industrial hygienist; and mechanical injury, a concern of the safety engineer. Then there are biological organisms (other than man) which are a concern of the sanitary engineer.

These are part of the environment both on and off the job. These can be controlled in the occupational environment by good engineering and good operating procedures attained with the understanding and cooperation of the employees. Yes, people are also very important here.

We observed that men from a specific operation were reporting to the clinic with mild complaints which seemed similar to complaints that would be expected from an over-exposure to a solvent used in the operation. Careful analysis by the industrial hygienist, in many locations and at many different times, did not show enough solvent in the air to cause the trouble. A continuous recording analytical instrument was devised in the research laboratory and installed in the operating area. Through its use we found that when either the supervisor or the industrial hygienist was not around, the operator was inclined to leave a leak or spill to be cleaned up by the next shift operator. The men named this instrument the "Squealer" as it was telling us of their misoperation. They began to work with an eye on the recorder. They realized that when the "Squealer" did not squeal they felt better. They changed the name of the instrument to the "Stink clock." The supervisor told us he saved the price of the instrument by reduced solvent loss, and that the overall operation by the men greatly improved. We had their understanding and their cooperation. They realized that we were interested in their health and well-being.

During regular preventive observation of the men in the clinic, lack of adverse effects may show that exposures to chemical substances in the environment have not been excessive. It should not be taken to mean that excessive exposures are impossible or unlikely under other circumstances of use.

For example, a supplier assured his customer that there was no hazard from skin contact asso-

ciated with a particular material because there had been frequent skin contacts with the material in their own operations with no adverse effects. They neglected to indicate how they handled the material, or that contacts were always followed by immediate decontamination of the skin. In use by the customer, the material was spilled on a man's skin. He was several miles out in the "bush" in northern Canada in the winter with the temperature below zero Fahrenheit, and with no water available for decontamination. The man died from poisoning due to skin absorption of the material. Simple experiments on animals in the toxicological laboratory showed that the material was very toxic when absorbed through the skin. When a supplier indicates that no problems have been encountered in handling a particular material, ask how they handle it. Ask them what toxicological information they have on the material.

In controlling the occupational environment in the interest of health and well-being, established acceptable exposure limits for a healthful environment are very useful. These acceptable exposures are expressed as "acceptable concentrations" by the American National Standards Institute and as "threshold limit values" by the American Conference of Governmental Hygienists (such standards are discussed in detail in Chapter 8). These limits are not exacting scientific thresholds of response. They are the judgments of people with knowledge and experience. The intelligent use of these limits depends on the understanding and judgment of the man who must control the occupational environment.

We must recognize that the industrial hygienist usually deals with a variable exposure. Enough analyses are needed to clearly define the probable fluctuations and to establish a significant time weighted average. Maximum concentrations must be determined as well as duration and frequency of peaks of exposure. The summation of this information to define the exposure situation requires the good judgment of a knowledgeable industrial hygienist. The application of the established acceptable limits for a healthful environment also requires the good judgment of a knowledgeable industrial hygienist. Acceptable limits cannot be used effectively as just a routine check point.

Those people responsible for suggesting acceptable limits or for using acceptable limits are part of the ecological system — the industrial hygienist, the physician, the toxicologist and all the other environmental control people. The effectiveness of their operation can have a very significant effect on the occupational ecological system.

When an injury does occur, clinical observation of the victim can provide very valuable information and should be reported in the literature. As was discussed in the previous section, the exposure can be variable. Most important, be sure you know all of the chemical substances or physical energies to which the victim was exposed and, hopefully, quantitation of exposure.

During the early development of 2,4 dichlorophenoxy acetic acid (2,4 D), careful toxicological studies were made on animals in the toxicological laboratory. It was concluded that the material at the high dilution used in the field as a weedkiller was not a significant hazard. After years of use there was a report of a death in Canada from 2,4 D. The man drank a glass full of the diluted solution from the spray tank with suicidal intent. The physician who observed the man in the clinic and the manager of the contract spray company where the solution had been mixed, both confirmed that it was, in fact, 2.4 D. Calculating from the toxicological information, I did not think this was possible. An agricultural scientist was going to visit the area where this death occurred so I asked him to investigate. He asked the foreman of the spray crew, "What did you use as a weedkiller before you used 2,4 D?" "Oh, we used sodium arsenite." "Then you stopped using sodium arsenite?" "No, we just added 2,4 D to the sodium arsenite."

The man who died had drunk enough sodium arsenite to have killed ten people. When you draw a conclusion from that first clinical case, be sure you know all of the materials to which the victim was exposed. This serves as a reminder that people are involved, people between you and the actual circumstances of the incident.

As previously stated valuable information on the nature and amount of exposure can be obtained by biochemical measurements on a person suspected of exposure. This depends on the absorption, transport, metabolism and excretion of the material. Blood, urine or exhaled air analysis can give valuable clues to the nature of certain of the materials to which the person was exposed. The analysis used depends on the way the body handles the material in question. Many volatile organic materials are exhaled in the breath. Infrared analysis can give an indication of the nature of the material and some indication of the amount of exposure.

To illustrate, a man came into the clinic and reported that he had been exposed to a certain volatile solvent. Infrared analysis of his exhaled air showed that he had not been exposed to the solvent he indicated but to a very different solvent. Had the clinic proceeded on the basis of his report of exposure, the handling of the case would have been in error. Some biochemical measurements can be very useful when wisely used.

COMPLEXITY OF THE WHOLE

The ecological picture as a whole is too complex to understand or to control when considered in its entirety (both occupational and nonoccupational). Yet, those who are responsible for the health and well-being of people in the system must keep the total picture in mind.

That total picture includes the chemical substances, physical energies and biological organisms in the occupational area which we can measure and over which we can have some control. As previously discussed. the exposures can be variable. Levels of concentration alone are not enough. One must know the frequency and duration of exposures. There is no simple mathematical procedure which will give a specific numerical answer. One can determine the time weighted average and the maximum concentration, duration and fre-

quency of peak concentrations. These are meaningful if one has sufficient analytical data which represent the actual exposure conditions. These exposure conditions can then be related to the acceptable limits proposed by various organizations. This comparison gives some understanding of the significance of possible exposures in the area studied. In addition, however, one must keep in mind the complexity of the whole. The final decision requires judgment of the whole based on available knowledge and experience.

Comparable factors are in the nonoccupational area where we have little control. Hopefully, we may have some effect by carry-over of experience from the occupational area. In both the occupational and nonoccupational area the individual is an important factor. The people in the environment of the individual both on and off the job have a significant effect.

OBTAINING UNDERSTANDING AND COOPERATION

Obtaining the understanding and cooperation of people in the environment of concern is critical to effective control of that environment. This statement has been made several times in this chapter. It was a significant factor in many of the illustrations used. This is such an important part of effective control that it justifies summation here for emphasis. Without understanding and cooperation all the most careful measurements and careful engineering of an operation may be ineffective. We repeat — fools are most ingenious in overcoming "foolproof" engineering.

It is simple to state "Get their understanding and cooperation." *Getting* it is not always that simple. How does one get it? The method will vary with the industrial hygienist and with the people in the operation of concern. The following methods are suggested as having been successful under many circumstances. What you will do depends on your judgment of the particular circumstances with which you are concerned at a particular time and the people with whom you are concerned.

Previous mention was made of the value of a careful environmental survey and concurrent clinical study of the men involved as a preventive control. Before such a study is made, it is valuable to get all the men in the operation together. A regular safety meeting can be used; it should include all the people — supervisors as well as laborers. Explain what is intended and why. Invite questions from the group. Answers and explanations should be in simple, direct language which they can understand.

During the survey of the environment, the workers' interest and understanding may be helpful. You can obtain a lot of information on the operation from the individual workmen. When the survey is complete, it should be reported to the whole group. Tell them basically what was found, in language they can understand. Indicate what should be done, if anything, to assure a good work environment. When they understand that you have a sincere interest in the workers' health and well-being, it increases their cooperation in effectively controlling the operation.

When you are checking the environment of an operation, talk with the individual workmen. Ask them for information and suggestions. Including them in control efforts will result in more effective cooperation. Take every opportunity to inform all the people who may be concerned with your area of operation. Discussion at safety meetings is useful in getting information to a group. Also look for a chance for discussion with individuals, — all individuals — executives, supervisors, engineers, operators, janitors.

You should also be concerned with the design of a new production unit. Your cooperation with the engineers in design and construction can aid in giving consideration to control of the evironment. Inclusion of good environmental control principles in the design and in the construction of a new production unit is essential. It can save a lot of reconstruction later. It also can make the control of the environment in the interest of health and well-being a much more effective operation.

When talking with groups at a safety meeting or with individual workmen, take every opportunity to discuss also the application of their understanding of healthful working conditions to their off-the-job activities. Through the understanding and cooperation of the employees, we may also have a significantly favorable effect on the nonoccupational ecological system as well as the occupational; hopefully, some of the "understanding" will be carried over by the workmen to their off-the-job activities.

PRACTICAL CONTROL

Yes, the total picture is complex, yet there are a lot of practical things that can be done. We can measure the chemical substances, physical energies and biological organisms in the occupational environment. We can control them through good engineering and good operation. We can and must obtain the understanding and cooperation of the employee in order that our environmental control may be effective. We can compare our findings with the acceptable limits suggested by various groups. With an understanding of the basis of these limits and the significance of our findings, we can judge the effectiveness of our control. We must recognize the possible impact of both occupational and nonoccupational factors.

The most effective use of our present knowledge should be made. We need to make an effort to increase that knowledge through toxicological, environmental and clinical research. We should recognize the complexity of the whole ecological system. This complexity should not discourage us from the effective application of the good practical knowledge which is available. With the practical application of all the factors discussed and the understanding and cooperation of the workers, our efforts can have a very favorable effect on health and well-being.

BIBLIOGRAPHY ON INDUSTRIAL WASTES

1974

Liquid Waste of Industry - Theories, Practices and Treatment," by Nelson L. Nemerow, Addison-Wesley Publishing Co., Inc., Reading, Mass. (1971).

Treatment and Disposal of Industrial Waste Waters, by B. A. Southgate, His Majesty's Stationery Office, London, (1948, Reprinted 1950).

The Treatment of Trade-Waste Waters and the Prevention of River Pollution, The Proceedings of a Course held in the Department of Civil Engineering, King's College, Newcastle upon Tyne, 1-12 April 1957, edited by Peter C. G. Isaac, Contractors; Record Ltd., Lennox House, Norfolk Street, London, W. C. 2 (1957, Reprinted 1960).

Industrial Waste Disposal, edited by R. D. Ross, Reinhold Book Corporation, New York (1968).

The Treatment of Industrial Wastes, by Edmund B. Besselievre, McGraw-Hill Book Company, New York (1969).

Industrial Wastes - Their Disposal and Treatment, edited by Willem Rudolfs, American Chemical Series, Monograph Series No. 118, Reinhold Publishing Corporation, 330 W. 42nd Street, New York (1953).

Industrial Water Pollution Control, by W. Wesley Eckenfelder, Jr., McGraw-Hill Book Company, New York (1966).

Radioactive Wastes - Their Treatment and Disposal, General Editor: J. C. Collins, John Wiley & Sons Inc., 440 Fourth Avenue, New York (1960).

Principles of Industrial Waste Treatment, by C. Fred Gurnham, John Wiley & Sons, Inc., New York and Chapman & Hall, Limited, London, England (1955).

Industrial Waste Treatment Practice, by E. F. Eldridge, McGraw-Hill Book Company, Inc., New York and London (1942).

Industrial Wastewater Control, A Textbook and Reference Work, edited by C. Fred Gurnham, Academic Press, New York and London, (1965).

Theories and Practices of Industrial Waste Treatment, by Nelson Leonard Nemerow, Addison-Wesley Publishing Company, Inc., Reading, Mass. (1963).

Aqueous Wastes from Petroleum and Petrochemical Plants, by Milton R. Beychok, John Wiley and Sons, New York (1967).

Industrial Pollution Control Handbook, by Herbert F. Lund, McGraw-Hill Book Company, New York (1971).

Handbook for Monitoring Industrial Wastewater, U. S. Environmental Protection Agency, Technology Transfer (Aug., 1973).

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GUIDELINES FOR THE CONTROL OF INDUSTRIAL WASTES

3. CANE-SUGAR INDUSTRY WASTES

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Preface

The satisfactory disposal of industrial effluents is a major problem causing growing concern to public health authorities. Direct discharge of wastes into water courses may deplete dissolved oxygen, destroy aquatic life, and make the stream unfit for community water supply and other beneficial uses. On the other hand, the discharge of some industrial effluents into municipal sewers may have damaging effects on sewers or overload the sewage treatment works. Public health authorities are also aware of possible long-term physiological effects of some new organic chemicals which are found in industrial effluents, many of which are not removed by conventional treatment processes. Highly persistent detergents, pesticides and other toxic wastes have become serious problems in developed countries and will in time present a similar threat to developing countries.

In the developing countries the situation is particularly serious in view of the scarcity of qualified professional personnel (sanitary engineers, chemists and biologists), analytical laboratories, and finances for planning and operating industrial-wastes control programmes. It is important to consider the problem not only as it is at present, but also in the light of expected population increase, and of urban and industrial growth. Early government action is required for determining the extent of the problem and for planning and implementing efficient measures for the control of industrial wastes discharges.

This is one of a series of documents prepared by the World Health Organization covering the most prevalent industries in developing countries. The objective of these guidelines is to assist the responsible staff of health agencies and of other regulatory authorities to carry out surveys, interpret laboratory findings, advise industries on inplant remedial measures and disposal of wastes, and make recommendations concerning acceptance of wastes into municipal sewers. The first document in this series described the problem in general terms, and advised on how to carry out surveys and institute programmes of industrial wastes control.[1] The guidelines dealing with wastes from specific industries cover a description of the manufacturing process, with flowchart, the quantity and characteristics of wastes including health hazards, reclamation and recycling practices, methods of treating and disposing of wastes, suggestions for surveying and appraising existing facilities, and selected references to the literature.

It is planned to revise and update the documents from time to time by including information on new processes and procedures with special reference to experience in developing countries. Information and suggestions in this connexion will be welcomed by the Organization.

[1] Document WHO/WD/70.6.

1. Introduction

Most of the world supply of sugar is obtained from two types of raw material sources - sugar cane and sugar beets. The cane is a giant grass which grows 10-20 feet (3.5-7.0 m) high and 1-3 in (2.5-7.5 cm) in diameter, averaging about 15 per cent. fibre and 85 per cent. water and soluble solids, including sugar (sucrose) equivalent to 10-12 per cent. of the cane weight.

Sugar cane is cultivated throughout the world in 56 countries located within a belt between 30° North and South latitudes. Some of the important sugar-producing regions are in Brazil, China, Colombia, Cuba, Dominican Republic, Hawaii, India, Mexico, Nicaragua, Peru, the Philippines, Puerto Rico, the United States of America and the Virgin Islands, (Jenser, 1965; Keller & Huckabay, 1960). World production of cane-sugar in 1962 was estimated (Guzman, 1962) at 30 million tons annually, manufactured in about 6000 factories varying in size over a range of 1-20 000 tons of cane processed per day. Obviously, such facilities also will vary widely in processing techniques and efficiencies.

Although the exact periods for harvesting differ among the regions, this seasonal operation generally lasts three to six months. Milling of the cane to produce raw sugar must be accomplished during the harvesting season, as promptly as possible to avoid serious loss in quality and quantity of sugar. Subsequent refining of raw sugar to produce various market products may be accomplished on a year-around basis, through storage of raw sugar for processing later and, perhaps, elsewhere.

2. Manufacturing process

A simplified flow sheet for production of raw sugar from cane is shown in Fig. 1, but one must recognize that the processes vary considerably depending upon location, size and age of mill, and local resources, labour and customs. Washing of the cane before grinding may not be necessary where it is harvested manually with reasonable care to exclude dirt and impurities. Recent trends in many areas have been towards mechanical harvesting, because of increasing labour costs. Data from Lousiana and Hawaii indicate increases in extraneous material from less than five per cent. with manual harvesting to five to 50 per cent. after adoption of mechanical harvesting (Keller, 1959). Also, mechanical handling results in more damage to the cane and consequently an increased loss of sugar to the wash-water used to clean the cane at the mill before cutting and grinding.

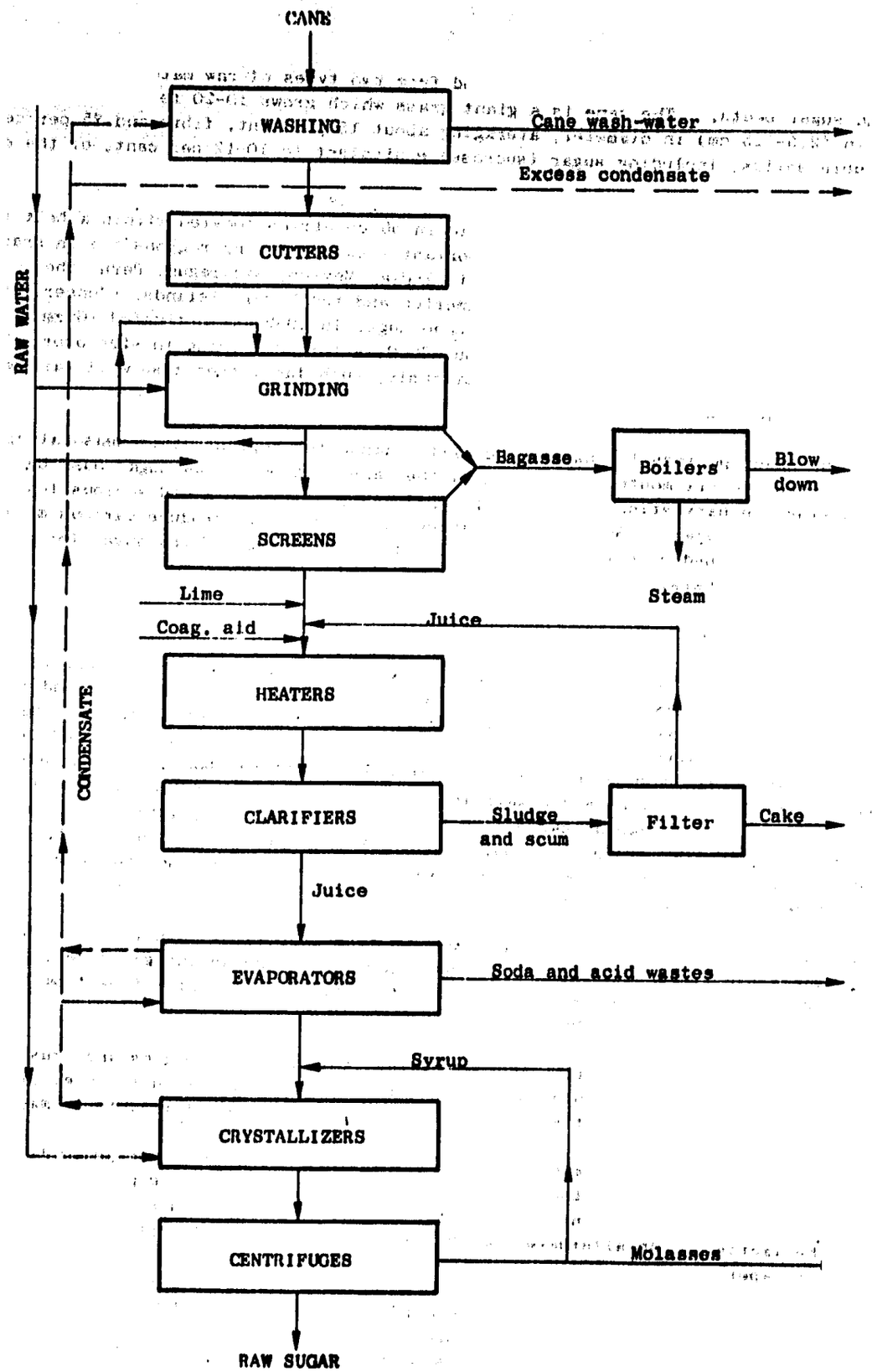
Water which has been used for condensing vapours from evaporators usually is re-used for cane washing, where practiced, thereby conserving water and taking advantage of heat available in the flow. Effluent from this operation represents a major waste-water flow from the plant and will be referred to as "cane wash-water".

Sugar juice is extracted from the cane by cutting it into short lengths and crushing between roller mills in series. Some juice from this process is returned to inlet of the grinding operation to improve effectiveness of water use, a process referred to as maceration.

Fibrous residue from grinding and screening of particles from the sugar juice is called "bagasse" and normally amounts to about 30 per cent. by weight of the cane processed. This usually is burned in the boiler plant for generation of steam and provides enough fuel for operation of the factory. An alternate use for bagasse is as a raw material for production of fibreboard or paper.

The screened juice is treated with lime to a pH above 8.0, to prevent inversion of the sucrose, and enters heaters where the temperature is raised to about 215°F (102°C). Thence it flows into tanks called "clarifiers", where some insoluble compounds settle as a sludge and others rise to form a scum. Both underflow and overflow pass to vacuum filters, from which juice is returned to the process, and filter cake is disposed of on land.

FIG. 1. CANE-SUGAR PROCESS



Adapted from Biaggi, 1968; Guzman, 1962; Jensen, 1965; Keller, 1959; Keller & Huckabay, 1960; Stone, 1951.

Clarified juice from the centre of the unit is withdrawn for concentration in multiple-effect evaporators, producing a syrup containing 60-70 per cent. solids. Water content is further reduced and crystallization accomplished in single-effect vacuum pans, causing formation of a dense mixture of crystals and syrup called "massecuite". This is centrifuged for separation of the crystals as "raw sugar". The remaining "molasses" is returned to the vacuum pans for further crystallization and ultimately the spent molasses is removed from the process for use in alcoholic fermentation, hog-feeding, or for other purposes.

Most raw water entering the plant is used for condensing vapours in the barometric condensers. Some also may be used in the boiler plant, although that often operates on condensate instead. Condenser waters subsequently are used for washing incoming cane and excess flow is discharged as waste water.

Major sources of water pollutants from the process include: (1) cane wash-water, (2) floor washings and boiler blowdown, (3) soda and acid wastes, and (4) excess condenser waters.

3. Quantity and characteristics of wastes

Waste-water flows and characteristics vary widely depending upon local conditions and methods of plant operation. Generally, where sources of fresh water are abundant water consumption is high, but in water-short areas factories practice extensive re-use, reducing water-supply requirements and volumes of waste-water discharges. An extreme example of successful operation with very limited water resources has been reported for a factory in the West Indies faced with a total supply of only about one million gallons available at the beginning of each season (Keller, 1959). About 60 per cent. by weight of cane entering the process may be recovered by condensation of water evaporated from the juices. Conservation of this water makes it possible to operate the plant for extended periods with condensers maintained on a closed circuit through using a cooling tower or pond.

A survey of 103 cane-sugar factories in North India (Bhaskaran et al. 1963) indicated an average production of 290 UK gal (1320 l) of waste water per ton of cane, with a five-day BOD of 570 mg/l (1.4 lb BOD/ton of cane). A subsequent publication (Bhaskaran & Chakrabarty, 1966) reports that waste waters from manufacture of cane sugar in India vary widely because of differences in processes used in the mills, but are reported to have BOD values ranging from 300-2000 mg/l. Table 1 shows characteristics reported in that paper for specific cane-sugar wastes which were studied in pilot plant investigations.

Table 2 shows quantities of wastes reported for raw cane-sugar production in Puerto Rico. Table 3 summarizes sugar balances reported for 17 mills in Puerto Rico, and pollutional characteristics of cooling and condenser waters from those mills are presented in Table 4. Average effluent BOD was 97 mg/l in a flow of 3.8 mgd. This yields a "population equivalent" for a 4200 ton/day plant of 52 000, an average BOD loading of 2.2 lb (1 kg) per ton of cane and flow of 2500 gal (9500 l) per ton of cane. These data were interpreted by the author (Biaggi, 1968) as "clear evidence" that too much sugar was being lost through entrainment into cooling and condenser waters.

Table 5 summarizes waste-water characteristics from raw sugar production in Louisiana, United States of America, based on a mill handling 2400 tons of cane per day without re-use of condenser water. BOD load of plant effluent was calculated to be 5.3 lb (2.4 kg) of BOD per ton of cane processed, 64 per cent. of which was in the cane wash-water, leaving 1.9 lb (.86 kg) BOD per ton of cane in other flows, principally condenser waters.

3.1 Cane wash-water

As indicated earlier, this step is a major source of pollutants, but may not be necessary in installations processing cane harvested manually with care to exclude dirt and extraneous

matter. Where mechanical harvesting is employed, cane washing is necessary and very large volumes of water are used. Rates of flow for such plants in Louisiana have been reported at 500-5000, averaging 1000 gal/min (63 l/s).

As shown in Table 5, the cane wash-water contains high concentrations of suspended solids (typically over 2000 mg/l). Much of the suspended material is colloidal or finely divided and may be stabilized by organic compounds acting as protective colloids. This makes the liquid very difficult to clarify through conventional coagulation with ordinary chemicals.

Because of damage which the cane suffers during mechanical harvesting, the cane wash-water may contain substantial concentrations of sugar, leading to BOD values of 300-1000 mg/l. From the point of view of total BOD contribution, this flow constitutes a most serious source, as reflected in data of Table 5 showing 64 per cent. of the plant total to be in the cane wash-water.

3.2 Floor washings and boiler blowdown

Occasional spills, leaks in piping and general carelessness in operation require frequent floor washings. Boilers for production of steam may be operated on raw water or condenser waters. Blowdown may contain substantial concentrations of various chemicals used to treat the boiler water and organics used for treatment or introduced with the condenser water.

Flow rates of combined wastes from floor washing and boiler blowdown may vary radically in strength from time to time and plant to plant, depending on the nature of facilities and care exerted in their operation. Floor washings may contribute major loadings when the plant is cleaned thoroughly and equipment emptied for weekend shutdowns. Data in Table 5 indicate that, nevertheless these wastes represent a relatively small portion of total BOD discharged from the manufacturing operation.

3.3 Soda and acid wastes

At intervals ranging from weekly to as long as three weeks it is necessary to clean heating surfaces throughout the plant to remove accumulations of scale. This is accomplished usually by rinsing the equipment with water, boiling for several hours with caustic soda, rinsing again, boiling with inhibited dilute hydrochloric acid and giving final rinses to remove acid residues.

Cleaning solutions and rinse waters contribute additional pollutional materials in rather small flow but may have very objectionable characteristics, principally because of inorganic constituents rather than BOD. Wastes from this operation usually are accumulated in an impoundment and released at low rates of flow over extended periods of time.

3.4 Condenser waters

As indicated in Tables 4 and 5, condenser waters represent a major source of pollution from the manufacturing process, second only to cane wash-water. Where cane is not washed, condenser waters represent the bulk of organic pollution from the process. The BOD load can be attributed principally to carryover of sugar into the condensate of evaporators through excessive foaming, or improper control of the evaporators and entrainment of liquid in the vapours.

Characteristics of condenser waters may vary from virtually pure water at temperatures of 35-50°C to solutions containing sufficient organics to produce BOD as high as 300-600 mg/l. Because of the variable nature of condensate and its dependence upon operating care, this represents a strategic location for applying in-plant controls to reduce pollutional loads, as will be discussed subsequently.

3.5 Other sources of wastes

Generally, highly concentrated wastes from the plant are not allowed to enter the liqui waste-water system but occasionally this may occur. One such waste is bagasse, usually use as a fuel in the boiler plant or recovered as raw material for manufacture of paper products.

Filter cake amounts to three to four per cent. of the weight of cane processed and has a high BOD (8000-25 000 mg/l), total solids (40 000-100 000 mg/l) and 0.21 per cent. sucrose (Biaggi, 1968). For convenience in some older plants, the cake has been slurried and discharged to streams or lagoons. This is not considered desirable practice from the point of view of water pollution control and it is highly preferable that it be discarded to the land as a fertilizer.

Spent molasses from the process has an exceedingly high BOD (400 000-900 000 mg/l) and should not be discharged to receiving streams (Biaggi, 1968; Stone, 1951). Normally, it is recovered and may be used for conversion into alcohol or fed directly to cattle.

4. Reclamation and recycling

Pollutional materials from sugar-cane processing plants may be summarized as (a) extraneous substances adhering to cane upon arrival at the mill, (b) cane residues separated from the sugar, (c) chemicals used in cleaning equipment, and (d) sugar lost during processing. It should be evident that lost sugar is undesirable for two reasons - the waste of valuable food material, and creation of water pollution problems.

Sugar balances for Puerto Rican factories in Table 3 indicate total sugar losses averaging 2.468 per cent. by weight of cane processed (22.5 per cent. of sugar entering the mill) and variations in those losses of 1.66-3.08 per cent. of cane weight. When viewed fro the aspect of water pollution, this indicates a ratio of sugar loss between the worst and bes mills of about 2:1. An even greater range in pollutional discharges from various mills is indicated by the lb/BOD/ton of cane reported in Table 4. All of the data suggest possibilities for reduction of water pollution problems from cane-sugar mills through application of in-plant controls.

As indicated earlier, some of the highly concentrated wastes from manufacturing operatio include bagasse, filter cake, and spent molasses. Proper controls should be included to ensure that these materials do not escape with waste-water flow under any circumstances.

Improved housekeeping, operating techniques and plant maintenance can have a significant effect on discharges of pollutional materials in floor washings and other cleanup waste waters. Because they are highly variable in character these flows usually are impounded and released after storage for sufficient time to attain stabilization. Reduction of spills to minimize necessity for washing and institution of reasonable controls on volumes of wash-waters used for that purpose can reduce volume of the flow substantially, making it easier and more economical to impound the waste water for extensive periods. Where cane washing is employed, floor washings frequently are combined with cane wash-waters for treatment and disposal.

For economic reasons and the reduction of water pollution, recovery of alkali from cleaning heat-exchange equipment frequently is practised. This can be accomplished by adding new alkali to the spent solution and settling for removal of suspended material. Careful design and operation to ensure thorough draining of equipment is desirable because it minimizes quantities of alkali discharged in rinse-waters. These waste waters usually are retained in separate basins for discharge over a fairly long period of time to minimize pollutional impact.

As indicated earlier, the cane wash-water represents a major source of pollution from this type of factory and quantities of pollutants discharged depend upon cane-harvesting methods employed. Any steps which reasonably could be taken to leave dirt and trash in the fields instead of delivering them to the mill with the cane would have a favourable impact on characteristics of cane wash-water discharges. Also, pollutional characteristics of this flow may be improved substantially by taking steps to minimize damage to the cane which can cause increased loss of sugar during washing. In those instances where economics still permit manual cane harvesting, it frequently is unnecessary to wash the cane, as already indicated earlier. Thus, avoiding mechanical harvesting and continuing careful manual harvesting where economically feasible, could offer one approach for minimizing pollution from cane sugar mills. In regions where manual harvesting now is practiced, the possibility for changing to mechanical methods should be viewed with caution, and where both techniques are employed it might be reasonable for mills to scale payments for cane depending upon cleanliness. After all, cleaner cane can offer reduced pollution control problems, thereby yielding lower operating costs.

Volumes of waste waters from cane washing may be reduced substantially through adoption of counter-current washing techniques, which may include settling of water re-used in the process (Keller, 1959). However, this may not have significant effect on organic loads which depend upon impurities and sugar removed from cane during washing, not on volume of flow. Nevertheless, reduction in volume can have a beneficial effect where impoundment or other treatment of the waste waters may require construction of detention basins.

Sugar losses in condenser cooling waters represent a major source of pollution and are amenable to control through careful design and operation, as reflected by the observation (Keller, 1959) that BOD values reported for condenser waters in Louisiana plants range from 2-600 mg/l. In two instances (Keller & Huckabay, 1960) installation of efficient entrainment separators reduced BOD in condenser waters from several thousand to 20-30 mg/l, resulting in product savings of about $ 2500 per day. In Puerto Rico, Guzman (1962) reported BOD discharges of 14 lb per ton (6.36 kg) of cane processed in one factory, reflecting excessive loss of sugar through entrainment. Replacement of old separators by modern ones reduced BOD of cooling and condenser waters to 2.8 lb per ton (1.27 kg) of cane. Further investigation indicated that multiple-effect evaporators and vacuum pans were being operated at excessively high levels of syrup, causing sugar loss through entrainment. Marks placed on sides of the units to indicate maximum syrup levels reduced effluent BOD to 30 mg/l, totalling only 0.86 lb per ton (0.39 kg) of cane processed.

Guzman (1962) also indicates that recirculation of cooling and condenser waters reduced volumes of these flows and produced higher concentrations of organic pollutants than in once-through systems. He indicates that the total organic load generally is reduced somewhat where this practice is followed.

Sugar losses in condenser waters should be evaluated frequently by analysing condensates for sugar (Jensen, 1965; Keller, 1959). Also, separators should be examined weekly to ensure good mechanical condition and open lines. With good control and maintenance of equipment, disposal of condenser waters should not create problems. Where problems arise, much or all of the solution may lie in reducing sources of contamination within the plant, instead of resorting to treatment of excess condensate.

It is worthwhile to emphasize the importance of distinguishing carefully between flow reductions and changes in organic loadings attending reclamation and recycling operations. Accurate evaluations require consideration of both aspects of the question because very different unit water flows may be used for the same purpose under different circumstances. As indicated earlier, quantities of water used often reflect availability more than process needs. Thus, it is virtually impossible to evaluate pollutional loads, or the impact of reclamation and recycling, through considering BOD concentrations only.

Stone (1951) indicates that intelligently-designed and operated cane-sugar mills ideally should not have water pollution problems because wastes from production of sugar can and should be employed for fuel, fertilizer, byproducts, or irrigation water and that "sugar cane waste pollution is the result of poor plant engineering and/or bad mill operation".

5. Treatment and disposal of wastes

About one-half of the total solids in cane wash-water (Table 5) may be removed by plain sedimentation. However, the large amounts of organic materials in the flow, some of which may serve as protective colloids, create difficulties with coagulation and chemical oxidation (Keller, 1959; Keller & Huckabay, 1960).

Although several studies have been conducted to evaluate treatment systems for waste waters from cane sugar processing, most of those actually in operation employ some type of lagooning (Jensen, 1965). Studies in Louisiana have indicated that a multi-basin system appears promising and suggest division of available space into three basins. The first should have a detention of two to three days and incorporate aeration to decrease the BOD to, perhaps, 100 mg/l. Effluent from that unit passes successively through two more lagoons for further reduction before discharge at a concentration of 50-60 mg/l BOD (Keller, 1959). Pre-settling is considered important to prevent accumulations of settleable solids on bottoms of the basins, which could retard stabilization substantially by reducing basin volumes and increasing organic loading.

Puerto Rican engineers have observed (Guzman, 1962) that high concentrations of carbohydrates make it difficult to treat concentrated wastes because their degradation may produce sufficient volatile acids to overcome the buffer capacity of the waste water and reduce pH enough to inhibit growth of micro-organisms. This problem can be reduced by enhancing buffer capacity through addition of enough lime or other inexpensive alkali to neutralize the acids produced.

Bottle digester experiments were conducted to evaluate feasibility of anaerobic decomposition (Guzman, 1962). In eight days at a temperature of 29°C, BOD was reduced by 78 per cent. at an average loading of 0.020 lb BOD/day ft^3 (0.32 kg/m^3). It was concluded that the many difficulties encountered with conventional treatment made it desirable to consider other approaches, such as anaerobic decomposition in lagoons - a simple process requiring no equipment, but utilizing more land. Several basins were constructed adjacent to a sugar factory and a waste-water survey performed to minimize flow rates in order to reduce land requirements. Production of volatile acids initially reduced pH to 4.3 in the first lagoon, but after two or three days detention decomposition proceeded at a rapid rate in the second basin. Eventually, stabilization rates decrease when BOD reaches 100 mg/l or less. The author concurs with results reported in Louisiana (Keller, 1959) to the effect that stabilization proceeds faster if space available for lagooning is divided into several basins.

In India, Bhaskaran et al. (1963) report that waste waters from sugar-cane factories can be treated by oxidation ponds to an effluent BOD of 20-95 mg/l. Subsequently, studies are described (Bhaskaran & Chakrabarty, 1966) leading to a conclusion that trickling filters are not effective for treating the waste because of nitrogen deficiency. Pilot plant studies conducted over extensive periods showed the waste water to be amenable to treatment by anaerobic digestion, followed by aerobic oxidation ponds. This type of approach produced over-all efficiencies approximating 90 per cent. BOD removal. Anaerobic digestion can produce BOD reductions of 60-70 per cent. in seven days in open, unheated basins, or in two days in a closed digestor maintained at 37°C.

6. Survey and appraisal

Evaluation of pollution problems in a sugar factory should include careful attention to in-plant controls for minimizing waste discharges through good housekeeping, efficient process operation, and equipment maintenance. Frequent or even continuous sampling is preferred over

intermittent (Keller, 1959) because faulty equipment or entrainment may occur erratically and grab samples may not indicate true extent of losses.

Samples of condenser or other waters may be checked for traces of sugar by using an alcoholic solution of alpha-naphthol, but sometimes this analytical technique is not reliable because of other organic substances in the water. Frequently, the permanganate oxygen consumed test has been used for this purpose, but is not specific for sugar.

A more quantitative method is based on use of ammonium-phosphomolybdate for sugar analysis. This technique produces a blue colour in the presence of sugar, the colour intensity being related directly to concentration of sugar. Colour standards for this analytical technique must be prepared frequently to ensure accurate results.

TABLE 1. CHARACTERISTICS OF CANE-SUGAR WASTES, AS REPORTED IN INDIAN STUDIES

Characteristic	Range of values
pH	4.6 - 7.1
Total solids (mg/l)	868-3500
Suspended solids (mg/l)	220-800
Volatile solids (mg/l)	400-2196
5-day, 20°C BOD (mg/l)	303-1966
COD (dichromate method) (mg/l)	607-4380
Total nitrogen, mg/l	10-40

From Bhaskaran & Chakrabarty (1966) p. 1161.

TABLE 2. QUANTITIES OF CANE-SUGAR WASTES REPORTED FOR PUERTO RICO

Waste	lb (kg)/ton of cane	Gal (l)/ton of sugar
Bagasse fibre	240 (109)	
Filter cake	60 (27)	
Condenser waters		30 000 (113 550)
Concentrated wastes[a]		Unknown

[a] Floor washings, soda and acid wastes, tank washings, spills. Adapted from Biaggi (1968) p. 1427.

TABLE 3. SUMMARY OF SUGAR BALANCES FOR 17 PUERTO RICO FACTORIES (EXPRESSED AS PER CENT. OF CANE WEIGHT)

Source	Minimum	Average	Maximum
Total sucrose	9.274	10.948 (100)	12.797
Sucrose recovered	7.199	8.479 (77.45)	10.040
Losses in:			
Bagasse	0.719	1.01 (9.23)	1.336
Molasses	0.817	1.122 (10.25)	1.337
Filter cake	0.095	0.212 (1.94)	0.483
Miscellaneous	0.077	0.123 (1.13)	0.525
Total losses	1.663	2.468 (22.55)	3.081

Figures in parentheses represent averages expressed as per cent. of total sucrose.

Adapted from Biaggi (1968) p. 1429.

TABLE 4. POLLUTIONAL CHARACTERISTICS OF CONDENSER WATERS IN PUERTO RICO

Cane processed tons/day	Flow mgd	Solids, mg/l Total	Solids, mg/l Suspended	5-day, 20°C BOD mg/l	5-day, 20°C BOD lbs/day	5-day, 20°C BOD lbs/ton of cane
4 000	17.0	180	56	70	9 900	2.47
1 500	2.0	190	13	72	1 200	0.80
4 000	15.8	250	0	130	17 100	1.28
2 400	7.2	260	43	69	4 100	1.73
5 400	5.7	310	96	32	1 500	0.28
7 000	31.7	-	-	90	23 800	3.41
1 800	12.9	200	20	79	8 500	4.72
3 600	Recirculated	690	84	-	-	-
5 000	12.9	525	45	59	6 400	1.27
3 400	12.0	190	20	90	9 000	2.65
6 000	Recirculated	360	20	-	-	-
3 000	10.0	280	43	185	15 400	5.14
1 800	7.2	995	20	147	8 800	4.91
4 200	12.5	-	-	90	9 400	2.23
700	4.3	700	100	183	6 600	9.38
3 750	8.0	-	-	75	5 000	1.33
1 450	4.4	770	230	-	-	-
4 214	10.8	421	56	97	9 050	
4 000	10.0	335	43	84.5	8 750	

Note: Average BOD of water entering mills for cooling purposes was 8.06 mg/l (range = 0.9 to >25).

Adapted from Biaggi (1968) p. 1430.

TABLE 5. VOLUME AND CHARACTER OF WASTES FROM CANE-SUGAR PRODUCTION IN LOUISIANA (BASED ON 2400 TONS/DAY CANE)

Waste water	Flow gal/min	l/s	5-day BOD mg/l	BOD load lb/day	kg/d	Solids, mg/l Total	Solids, mg/l Suspended	Solids, mg/l Settleable
Cane wash-water	1 000 (500-5000)	63 (31.5-315)	680 (300-1000)	8 157	3 703.28	2 900	2 104	1 722
Floor washings and boiler blowdown	100	6.3	378	453	205.66	-	-	-
Soda and acid wastes	10	0.63	-*	-*	-	-	-	-
Condenser waters**	5 000	315	69 (2-600)	4 138	1 878.65	-	-	-
Totals (rounded) BOD/ton of cane	6 100	384		12 750 5.31	5 788			

* Principal pollutants are NaOH, NaCl, HCl.

** Assumes once-through operation. Temperature = 110-130°F (43.3 - 54.5°C).

Adapted from Keller (1959) p. 8.

REFERENCES

Bhaskaran, T. R. et al. (1961) Treatment and disposal of sugar factory effluents, New Delhi Indian Council of Medical Research (Special report series No. 39) Sug. Ind. Abstr., 1963, 25, 57

Bhaskaran, T. R. & Chakrabarty, R. M. (1966) Pilot plant for treatment of cane-sugar waste, J. Wat. Pollut. Control Fed., 38, 1160-1169

Biaggi, N. (1968) The sugar industry in Puerto Rico and its relation to the industrial waste problem, J. Wat. Pollut. Control Fed., 40. 1423-1433

Guzman, R. M. (1962) Control of cane sugar wastes in Puerto Rico, J. Wat. Pollut. Control Fed., 34, 1213-1218

Jensen, L. T. (1965) Sugar. In: Gurnham, C. F. ed. Industrial wastewater control, New York, Academic Press, pp. 133-145

Keller, A. G. (1959) An industrial waste guide to the cane sugar industry, Washington, D.C., Govt. Printing Office (U.S. Public Health Service Publication No. 691)

Keller, A. G. & Huckabay, H. K. (1960) Pollution abatement in the sugar industry of Louisiana, J. Wat. Pollut. Control Fed., 32, 755-760

Stone, R. (1951) Sugar cane process wastes, Sewage Ind. Wastes, 23, 1025-1028

SELECT BIBLIOGRAPHY

Anon (1952) Cane sugar bagasse offers new source for newsprint, Chem. Engrg News, 30, 2708

Biglane, K. E. (1958) Some current waste treatment practices in Louisiana industry. In: Proceedings of the 13th Industrial Waste Conference, Purdue University, Lafayette, Indiana, pp. 12-20

Chakrabarty, R. N. (1964) Cane sugar wastes and their disposal, Environ. Hlth (Nagpur), 6, 265-273

Chakrabarty, R. N. et al. (1963) Treatment of cane sugar wastes in stabilization ponds. In: Proceedings of Symposium on Waste Treatment by Oxidation Ponds, Nagpur, October 1963, Nagpur, Central Public Health Engineering Research Institute

Duvall, A. R. (1967) Hawaii's hydroseparator systems transform cane-cleaner effluent, Sug. Azuc., 62, No. 10, 31-33, Wat. Pollut. Abstr., 1968, 41, Abstr. No. 2354

Edeline, F. & Leclerc, E. (1957) Study on some installations for the sedimentation of waste waters from sugar refineries, Trib. CEBEDEAU, 36, 135, Wat. Pollut. Abstr., 1959, 32, Abstr. No. 519

Gibbons, M. M. (1960) The treatment of cane sugar mill wastes, Revista del Colegio de Ingenieros de Puerto Rico, 10, 123

Godchaux, W. (1954) Sugar refinery waste problems. In: Proceedings 3rd Annual Water Symposium on Water Pollution, Louisiana State University Engineering Experiment Station, Bulletin No. 43

Isacks, A. J. (1946) Nature and disposal of cane sugar factory wastes in Louisiana. In: Water Conference. Stream Control Commission, Baton Rouge, Louisiana, pp. 37-39

Keller, A. G. (1953) Water usage and conservation in the Louisiana sugar industry. In: Proceedings 2nd Annual Symposium on Water Conservation and Industrial Development, Louisiana State University, Engineering Experiment Station, Bulletin No. 38

Lafleur, R. A. (1961) The sugar factory pollution abatement in Louisiana - The case history of a drainage basin. In: Proceedings of the 16th Industrial Waste Conference, Purdue University, Lafayette, Indiana, pp. 212-216

Wheeler, J. E. (1955) Water pollution and the sugar industry. In: Proceedings 4th Annual Water Symposium, Louisiana State University Engineering Experiment Station, Bulletin No. 51

Wheeler, J. E. & Keller, A. G. (1956) Pollution abatement in the Louisiana sugar industry. In: Proceedings 5th Annual Water Symposium, Louisiana State University Engineering Experiment Station, Bulletin No. 55, pp. 31-45

Wheeler, J. E. & Keller, A. G. (1956) Water pollution and the sugar industry. Sug. J. (April) pp. 20-23

Yarbrough, M. V. (1946) Water quality and quantity requirements for cane sugar manufacture in Louisiana. In: Water Conference, Stream Control Commission, Baton Rouge, Louisiana, pp. 29-36

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GUIDELINES FOR THE CONTROL OF INDUSTRIAL WASTES

4. LIVESTOCK WASTES

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PREFACE

The satisfactory disposal of industrial effluents is a major problem causing growing concern to public health authorities. Direct discharge of wastes into watercourses may deplete dissolved oxygen, destroy aquatic life, and make the stream unfit for community water supply and other beneficial uses. On the other hand, the discharge of some industrial effluents into municipal sewers may have damaging effects on sewers or overload the sewage treatment works. Public health authorities are also aware of possible long-term physiological effects of some new organic chemicals which are found in industrial effluents, many of which are not removed by conventional treatment processes. Highly persistent detergents, pesticides and other toxic wastes have become serious problems in developed countries and will in time present a similar threat to developing countries.

In the developing countries the situation is particularly serious in view of the scarcity of qualified professional personnel (sanitary engineers, chemists and biologists), analytical laboratories, and finances for planning and operating industrial wastes control programmes. It is important to consider the problem not only as it is at present, but also in the light of

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expected population increase, and of urban and industrial growth. Early government action is required for determining the extent of the problem and for planning and implementing efficient measures for the control of industrial wastes discharges.

This is one of a series of documents prepared by the World Health Organization covering the most prevalent industries in developing countries. The objective of these guidelines is to assist the responsible staff of health agencies and of other regulatory authorities to carry out surveys, interpret laboratory findings, advise industries on inplant remedial measures and disposal of wastes, and make recommendations concerning acceptance of wastes into municipal sewers. The first document in this series described the problem in general terms, and advised on how to carry out surveys and institute programmes of industrial wastes control.[1] The guidelines dealing with wastes from specific industries cover a description of the manufacturing process, with flowchart, the quantity and characteristics of wastes including health hazards, reclamation and recycling practices, methods of treating and disposing of wastes, suggestions for surveying and appraising existing facilities, and selected references to the literature.

It is planned to revise and update the documents from time to time by including information on new processes and procedures with special reference to experience in developing countries. Information and suggestions in this connexion will be welcomed by the Organization.

1. INTRODUCTION

Any discussion of water pollution problems arising from livestock production activities must proceed with caution to avoid the possibility of seriously misleading the reader. This can be attributed to the fact that there are radical variations in wastes characteristics among different types of livestock operations, and even greater differences in actual water pollution impacts and potential beneficial values of the wastes under different local circumstances.

It has been pointed out (Loehr, 1969) that animal wastes often have been recycled to the soil with minimum release to the aquatic environment. In its simplest form, livestock production can be based upon allowing animals to obtain their food supply from fields and discharging their wastes directly on to the land. With relatively low livestock population densities, little or no waste escapes the land to enter receiving streams and the water pollution potential is very low, or zero. At the other extreme, confinement of thousands of animals in a feedlot for final fattening before slaughter causes production of livestock wastes far in excess of amounts which can be absorbed by the small land area. Under these circumstances very serious stream pollution problems may be caused by discharge of the animal wastes, especially in heavy rainfalls.

In many areas of the world, accumulations of livestock manure are a valuable resource of humus and fertilizer and are carefully spread on land to increase crop production. In other areas, high labour costs make it unattractive to distribute manure on land because requirements can be satisfied more economically with chemical fertilizers.

These extremes illustrate that it is difficult, if not impossible, to make sweeping generalizations about livestock wastes. Also, they may help the reader understand the risk involved in attempting to assess the water pollution impact of animal wastes through examining total production of various types of farm animals and unit loadings expected from each to give a total pollution load from this industry. It has been pointed out (U.S. Federal Water Pollution Control Administration, 1970) that in many reports that approach has produced gross figures for animal waste production of startling magnitudes, which may serve no real purpose and actually mislead the reader. This could produce an adverse reaction by causing the reader to conclude that the data are too absurd to warrant serious consideration.

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[1] Document WHO/WD/70.6.

Another important point related to interpretation of data and development of solutions for animal waste disposal problems is that too seldom has it been recognized that these wastes differ from each other and from various types of municipal and industrial wastes for which treatment technology has been developed. Thus, some efforts to solve the problems have failed because wrong approaches were utilized, or wrong design parameters applied to what might have been the correct approach.

2. LIVESTOCK PRODUCTION

The types of livestock production activities, their organization, and magnitude vary radically among the many countries of the world, but some general types of production are common to many regions. The major categories might be considered profitably by viewing, briefly, components of livestock industry as presented by authors of a recent United States of America report (U.S. Federal Water Pollution Control Administration, 1970) and summarized in Table 1. The livestock industry in the United States of America is considered to consist principally of production of four major types of animals - cattle, poultry, swine and sheep, some of which should be sub-divided in evaluating water pollution potential.

The "beef cow" group is that segment of the cattle industry devoted principally to production of calves on range land. Because the success of this type of operation depends upon an adequate supply of grass, the animal population is retained at a density ensuring good utilization of the land, but low enough to avoid damage to the grass crop. The low animal density and tendency of grasslands to retain their wastes result in a very low water pollution potential by this type of operation.

Cattle for human consumption usually are fattened either by grass feeding or on feed concentrates, such as corn and other products with minerals and various components added to the animal's ration to produce a high rate of weight gain. Those fattened on grass under range conditions have very little water pollution potential, as noted above for beef cow production, because animal population densities are maintained low enough to preclude damage to the grass crop. This density level also usually precludes significant discharges of pollutants into streams.

Accordingly, many cattle make little or no contribution to stream pollution. Those which contribute usually do so because of high population densities in fattening operations, commonly carried out using concentrated foods with animals confined in feedlots. In the United States of America, these operations are numerous (208 596 in the year 1968) and caused serious water, land, and air pollution problems by the 23 million head of cattle handled in 1968. It is this category of United States of America beef cattle operation which attracts the greatest attention and which will require the greatest effort for solution. Parallel situations can be found in some regions of most other countries of the world.

The dairy cattle industry, of course, is concerned with the same general type of animal but has somewhat different water pollution potential and operating criteria. Dairy cattle have very different geographic distributions throughout the country and feeding programmes for these animals differ from those for fattening beef cows. Also, criteria relative to the products are very different fundamentally. Accordingly, there are many similarities, but also several differences, in character of waste handling operations in the dairy industry.

Many cow milking operations employ water-flush systems, used for washing down animals before milking and to clean up after milking. Wastes derived from these operations usually include flows used to clean utensils, pipes, and other equipment, whether or not water-flushing systems are employed for carrying away wastes from stalls in which the cows are kept. In some installations, the animals are confined on sloping concrete floors arranged to ensure that wastes will be dropped where they can be readily flushed away. This flow can produce very severe pollution loads if discharged untreated from large dairy operations into watercourses.

Water-flushing systems also are readily adaptable to swine-raising facilities. Frequently, the barns may be equipped for direct drainage of floors into collecting gutters during flushing operations, making the general character of problems arising from swine barns very similar to those encountered in the dairy industry, except for differences in waste water quality characteristics.

Many sheep are raised on ranges. Accordingly, there may be relatively little water pollution problems arising from production of these animals. Little information has been collected concerning water pollution impact of sheep raising operations in the United States of America (U.S. Federal Water Pollution Control Administration, 1970).

Waste production and handling problems arising from chickens grown as broilers or layers (egg producers) are similar. Many poultry enterprises have water carriage systems to remove wastes from cages or pens in which the birds are raised. These were devised to minimize labour required to clean the pens and may create serious water pollution problems. In arid areas, a system based on taking advantage of natural drying conditions may be preferable to water carriage Currently, several water management techniques are applied to wastes from poultry enterprises.

The production of ducks may present problems of very different complexion because, typically, the birds are raised near flowing water which aids in development of desirable feathers and carriage of wastes discharged directly into the stream. In addition to more or less uniform discharge of wastes by the ducks directly into the watercourse, slug discharges also are encountered during rainstorms. Although duck-raising enterprises do not represent a major national problem in the United States of America, there are very serious local problems arising from this type of operation.

3. QUANTITY AND CHARACTERISTICS OF WASTE WATERS

In those few operations using water flushing systems for management of animal wastes, it is feasible to establish a meaningful estimate of expected flows. For example, flushing operations for carrying manure and debris from dairy barns may use as much as 50-60 US gallons (190-230 l) of water per day per cow, or as little as 20 gallons (75 l) per day per cow where special care is exerted to minimize usage. However, the origin of these wastes indicates that such instances are the exception rather than the rule. More frequently, the wastes do not enter the water cycle at all but are removed and disposed in dry or semi-solid form, using techniques appropriate to solid waste systems instead of waste waters.

Waste waters reaching streams may be due to rainfall and run-off from areas receiving discarded solid wastes or from feedlots directly. In this type of situation, the pollution potential of a livestock production operation is influenced heavily by its location relative to watercourses, the type of terrain on which the operation takes place, and local climate, especially rainfall. The amount of flow involved is of relatively less importance because the critical factors are suspended materials, organics, nutrients, and other pollutants carried into the stream, which are not directly due to rainfall.

Accordingly, it is clear that it is not feasible to relate pollutional potential of livestock wastes with flows as is frequently done for municipal sewage, in which substantially all of certain wastes from the tributary population are carried in the system. For this reason, and because of differences in wastes from various types of animals, livestock wastes usually are reported, summarized, and discussed in terms of unit loadings for each type of animal.

Differences in wastes among the various types of animal may be attributed to ranges in size, diet, and metabolism. Swine have single stomachs and tend to produce faeces and urine similar to those from humans. The types of diet consumed by swine and poultry are much more digestible than those of some other types of livestock, causing relatively small amounts of

excreta. On the other hand, ruminants, such as cattle, have digestive systems capable of utilizing cellulose. Because some compounds accompanying cullulose consumed by the animals (such as lignin) are difficult to digest, these types of animals produce relatively large amounts of wastes having very different composition from those produced by the single stomach species. Thus, one must not assume that data collected for one type of livestock will apply to other species, or that studies relating to human wastes would apply to animal wastes as well (Loehr, 1969).

It has been demonstrated (Mills & Parker, 1967) that wastes from different classes of animals may have very different characteristics. The composition of animal manure depends upon digestibility, protein, and fibre content of the feed, environment of the animal, and feed additives. Generally, those receiving concentrated foods for fattening or work may have a higher pollution potential than wastes from grass-fed animals. Twenty to 30 per cent. of the solid wastes consists of undigested food and bacterial cells. Over 25 per cent. of the organic manure is humus, similar to that in soil (Loehr, 1969).

Variations in character of wastes with types of animals, their environment and type and quantity of feed indicate that waste discharges per unit of production should vary radically in different areas of the world, and even under different circumstances in the same country. Loehr (1969) states that it is difficult to correlate published data because investigators use different units and do not measure the same parameters in all studies. Tables 2-6 summarize data abstracted by him from publications of several investigators concerning physical and chemical characteristics of various types of animal wastes.

Many authors have used such data to calculate waste loadings from various types of animals in terms of human population equivalents. This approach is valid where it is desired to evaluate impact of livestock waste from a "point source", such as a dairy or swine barn with water-carriage system. Loehr (1969) has summarized "population equivalents", based on BOD, total solids, and nitrogen for chickens, swine, dairy cattle and beef cattle. He points out that use of these values to estimate overall stream pollution by livestock is questionable because most animal wastes are discarded on land directly by the animal or through spreading. Also, substantial variations exist in "population equivalents" of any specific type of animals under different conditions of feed, environment, etc.

Livestock wastes may create a wide variety of water pollution problems, depending upon circumstances attending their disposal. Examination of data especially in Tables 6 and 7 indicates that the wastes can carry very substantial contributions of organic substances capable of causing oxygen depletion in streams. Also, they may contain high concentrations of coliform bacteria, suspended solids, and nutrients. In some areas of the United States of America, for example, high coliform concentrations have made it necessary to prohibit taking shellfish from beds near duck farms (Davis et al., 1966). Also livestock operations have caused undesirable aesthetic effects and objectionable growths of algae and aquatic plants because of nutrient contributions.

Run-off from cattle feedlots has caused serious pollution of streams, by high concentrations of bacteria, BOD, suspended solids, and ammonia nitrogen, and has led to large fish kills. For example, Miner et al. (1966) reported concentrations in feedlot run-off of 1.0-140 mg/l ammonia, 1400-12 000 mg/l suspended solids and COD levels of 3000-16 000 mg/l. Other investigators have reported even higher concentrations (Loehr, 1967, 1969).

Many infectious diseases are common to man and other animals and it has been stated that over 100 diseases of animals may be transmitted to man (Decker & Steele, 1966). The same author reports that the most significant pathogens include several types of salmonella; bacteria causing staphylococcal and streptococcal infections, tetanus, tuberculosis, brucellosis, leptospirosis; pathogenic fungi, and the rickettsia causing Q fever. Diseases which have been considered of great importance include anthrax, salmonellosis, which may be conveyed by water, tuberculosis, brucellosis, leptospirosis, and tularaemia. The parasitic disease

trichinosis has been a problem in many areas of the world. In several countries its incidence has been reduced by eliminating the practice of feeding raw garbage to swine and by improved cooking of pork. The role of animal wastes in transmission of viral diseases is less well understood than for bacterial diseases, but their importance in reproduction of insects which are vectors of many viral diseases is wellknown (Gibson, 1966, 1967; Hibbs & Foltz, 1964).

A very bothersome aspect of bacterial pollution by animal wastes is related to high coliform concentrations frequently present in such discharges. Coliform bacteria are used as an index of water quality. Thus, discharge of large numbers into watercourses from livestock wastes could create serious problems in evaluating downstream water quality because coliforms from these wastes do not carry the same implications for health as do coliforms originating in sanitary sewage. Because the quality of water, its suitability for a potable supply, and the degree and type of treatment required must be determined to a significant extent on concentration of these organisms, presence of large numbers of coliforms from livestock operations could lead to erroneous interpretation of water quality data (Geldrich et al., 1962).

Other problems associated with animal wastes include production of large numbers of flies and, sometimes, intensive odour problems. Waste waters from livestock operations also may be highly coloured, causing problems for downstream users (Loehr, 1969; Anderson, 1966).

4. RECLAMATION AND RECYCLING

When the population density of cattle can be maintained at a low level on grasslands, their wastes are returned to the soil directly in a most elementary form of reclamation and recycling. In other instances, it often is feasible to collect animal wastes in dry or semi-solid form and to distribute them on land manually or with the aid of mechanical spreaders. This involves a substantial amount of labour and is losing favour in many industrialized regions of the world where labour costs are high and chemical fertilizers of equivalent strength may be applied much more economically. On the other hand, in many countries it remains the most reasonable method for solving animal waste problems and, further, the wastes constitute a valuable resource for improving productivity of the land.

It should be noted here that where pollution control is being pushed vigorously, the additional cost of treating liquid livestock wastes before release should be considered in evaluating economic feasibility of land disposal, whether of dry or liquid wastes.

Since characteristics of animal wastes depend heavily upon the type and quantity of feed consumed, it might be desirable, from a waste abatement point of view, to reduce quantities of non-digestible materials in animal feeds, as well as excess feed which may be supplied for rapid gain of weight. This approach has not received major attention and, undoubtedly, would meet with resistance from many livestock producers who usually are concerned principally with obtaining maximum weight gain in the shortest possible period of time.

In summary, reclamation and recycling in this industry sometimes may be approached through keeping animal population densities low enough to ensure assimilation of wastes discharged directly on to the land. Obviously, this is not always feasible because frequently the animals must be concentrated into small areas to enhance economy of feeding operations or to hold animals for killing or milking. Under those circumstances, water pollution problems may be minimized by avoiding water carriage of wastes, if local economics permit. Removal of dry wastes for application to land, taking care to minimize removal by run-off into watercourses, often is desirable as a means for reducing water pollution problems.

Another method for recycling which has received considerable attention involves the re-use of some animal wastes as part of the feed for other animals of the same species, or different types of livestock. For example, chicken faeces, which are highly concentrated, have been proposed as part of the feed for chickens, dairy cattle, beef animals, and sheep. Investigations indicate that the milk or meat produced is not significantly different, as long

as the material is properly dried and represents only part of the diet (Anthony, 1966; Fontenot et al., 1966; Loehr, 1969).

5. TREATMENT AND DISPOSAL OF WASTE WATERS

The first line of defence against water pollution problems arising from animal wastes lies in prevention by minimizing contact between the wastes and water. Another method for accomplishing this is to cover feedlots to reduce run-off. This has proven feasible in many operations involving dairies or production of hogs or chickens. As pressures for more rigorous stream pollution control increase, the number of facilities in which it will become feasible to resort to covering feedlots to reduce pollution problems, as contrasted with treatment and disposal of liquid wastes, should increase sharply.

Under circumstances where animal wastes must be handled in liquid form many treatment processes can be considered, but few have been evaluated rigorously to determine appropriate loading criteria or performance. It must be emphasized that criteria applied for treatment of municipal waste waters will not necessarily be appropriate for livestock wastes.

Processes which have been investigated include anaerobic digestion of wastes containing high concentrations of solids and BOD. This technique often could be used successfully with several types of animal wastes, but the effluent usually would require further treatment before discharge into receiving waters. In some investigations, difficulties have been encountered which are not normally observed in anaerobic digestion of sewage sludge and caution must be exercised in applying the process to some types of livestock wastes.

Aerobic treatment of wastes can be applied, if adequate oxygen transfer into solution is provided. This usually requires detention periods of many days, because of high strength of the wastes. This approach also has been extended to further treatment of effluent from anaerobic treatment units (Scheltinga, 1966).

Oxidation ponds may be employed at loadings of 30-50 pounds of BOD per acre per day (Loehr, 1969). However, the very high BOD of livestock wastes indicate that extremely large areas would be required. Loehr (1969) gives an example of a unit for 1000 head of beef cattle which would require 20 acres of pond. Other approaches which have been investigated include aerated lagoons and Pasveer, or oxidation, ditches (Scheltinga, 1969).

Anaerobic lagoons are potentially promising for treating concentrated animal wastes because of high BOD and the fact that this type of unit can provide treatment and simultaneously help in controlling run-off from feedlot areas or serve as a holding basin prior to land disposal. Effluent quality from an anaerobic lagoon receiving livestock wastes usually is poor (300-1500 mg/l BOD and high in solids and nitrogen). Thus, additional treatment probably would be required in most instances before discharge to a receiving stream (Curtis, 1966; Loehr, 1969).

Spreading on land has been the usual method for disposing of solid wastes and also frequently is appropriate for liquid livestock wastes, with care to avoid run-off from the disposal area into receiving streams. This approach also allows recovery of nutrient content of the waste waters. Land disposal systems usually are based on using liquid holding units for equalization of waste flows and for storage during periods of adverse weather. It has been suggested that the lagoons or holding tanks provide at least two months capacity, although that design parameter obviously would be subject to local circumstances (Tietjen, 1966; Loehr, 1969).

Other approaches which have been suggested and investigated, but not used extensively, include incineration, drying, composting, vacuum filtration to reduce the volume of dilute poultry manure, dewatering of slurries from dairy operations on drying beds, use of lime and chlorine for treatment of hog wastes, and trickling filters (Loehr, 1969; Sobel & Ludington, 1966).

6. SURVEY AND APPRAISAL

Loehr (1969) has pointed out that some of the traditional analytical techniques, such as BOD, COD, and suspended solids, commonly used to evaluate pollution potential of waste waters are of less value with animal wastes. The latter are highly concentrated and require many dilutions before the standard waste water analytical techniques can be applied. Also, many livestock wastes may contain antibiotics and metals fed to optimize growth and minimize losses of animals. Those constituents can interfere with some of the analytical techniques. Another problem is that representative sampling of the wastes is very difficult because they are highly concentrated, often solid, and heterogeneous in nature.

Several problems concerned with evaluating the water pollution impact of these wastes have been discussed. Basic characteristics vary considerably from species to species of animal and also show extensive variability within each species, depending upon nature of feed, quantity of feed, environmental conditions, and other factors such as local climate which may lead to variations in run-off. Under some circumstances wastes from livestock operations can have exceedingly great pollution impact, while under other conditions there may be virtually no water pollution.

Even without detailed information to that effect, it is certain that water pollution impact by livestock wastes varies radically in different countries of the world, and among many regions of any given country. In the opinion of this writer, it would be even more risky than with most industrial wastes to attempt to generalize on the pollution impact of these wastes or on the types of treatment processes best suited for solving livestock wastes problems in different countries.

These circumstances indicate clearly the desirability of surveying and evaluating individual problems independently, as may be appropriate. To that end, data or other information in current literature will be valuable principally as aids in designing the programme and to identify specific types of investigations which should be conducted in each individual instance.

TABLE 1

MAJOR COMPONENTS OF LIVESTOCK INDUSTRY
(After: U.S. Federal Water Pollution Control Administration, 1970)

1. Cattle
   - A. Beef cows (calf production)
   - B. Cattle fattening
     - (1) Grass fattened
     - (2) Concentrate fattened (feedlots)
   - C. Dairy cattle
2. Poultry
   - A. Chickens
     - (1) Broilers
     - (2) Layers
   - B. Ducks
   - C. Turkeys
3. Swine
4. Sheep

TABLE 2

CHARACTERISTICS OF ANIMAL WASTES
(Taiganides & Hazen, 1966)

Item	Chickens	Hogs	Cattle
Animal size, in pounds	4-5	100	1000
Wet manure, in pounds per day	0.12-0.39	2.8-9.5	38.5-74.0
Total solids, percentage, wet basis	25-48	12-28	13-27
Total solids, in pounds per day	0.05-0.10	0.8-1.6	9.5-11.4
Volatile solids, percentage, dry basis	74-79	83-87	-
Nitrogen, in pounds per day	0.0012-0.0057	0.042-0.060	0.35-0.44
P_2O_5, in pounds per day	0.0010-0.0045	0.029-0.032	0.11-0.12
K_2O, in pounds per day	0.0005-0.0019	0.034-0.062	0.27-0.34

Note: approximately 2.2 lb = 1 kg

TABLE 3

CHARACTERISTICS OF LIVESTOCK WASTE*
(Hart, 1960)

Parameter	Dairy cattle	Beef cattle	Poultry	Swine	Sheep
Animal weight, in pounds (kg)	1400 (635)	950 (431)	5 (2.3)	200 (91)	100 (45)
Manure production, in cubic feet (dm^3) per day	1.3 (36.8)	1.0 (0.3)	0.0062 (0.175)	0.28 (7.93)	0.11 (3.11)
Manure density, in pounds per cubic feet (kg/dm^3)	62 (0.98)	60 (0.96)	60 (0.96)	62 (0.98)	65 (1.04)
Moisture, as a percentage	85	85	72	82	77
Nitrogen, as a per cent. of dry solids	3.5	3.1	5.4	3.3	5.4

* Fresh mixed manure and urine.

TABLE 4

NUTRIENTS IN ANIMAL WASTES
(Baines, 1964)

Parameter as % of slurry	Dairy cattle	Beef cattle	Hogs	Poultry
Nitrogen (as N)	0.13-0.42	0.24-0.60	0.3-0.9	0.41-1.7
Phosphorus (as P)	0.06-0.09	0.09-0.25	0.2-0.6	0.30-1.5
Potassium (as K)	0.13-0.30	0.14-0.28	0.2-0.4	0.13-1.25

Parameter as % of dry solids	Cattle	Hog	Sheep	Horse	Hen
N	0.3-1.3	0.2-0.9	0.9	0.66	1.8-5.9
P_2O_5	0.15-0.5	0.14-0.83	0.34	0.23	1.0-6.6
K_2O	0.13-0.92	0.18-0.52	1.0	0.68	0.8-3.3

TABLE 5

CHARACTERISTICS OF ANIMAL MANURES
(Benne et al., 1961)

Animal	Moisture, as a percentage	Pounds per ton of manure								
		N	P	K	S	Ca	Fe	Mg	Volatile solids	Fat
Dairy cattle	79	11.2	2.0	10.0	1.0	5.6	0.08	2.2	322	7
Fattening cattle	80	14.0	4.0	9.0	1.7	2.4	0.08	2.0	395	7
Hog	75	10.0	2.8	7.6	2.7	11.4	0.56	1.6	399	9
Horse	60	13.8	2.0	12.0	1.4	15.7	0.27	2.8	386	6
Sheep	65	28.0	4.2	20.0	1.8	11.7	0.32	3.7	567	14

TABLE 6

POLLUTIONAL CHARACTERISTICS OF ANIMAL WASTES[a]
(Loehr, 1969)

Total solids,[b] pounds per day per animal	Volatile solids,[b] pounds per day	BOD		COD		Nitrogen		P_2O_5, pounds per day
		pounds per day	pounds per pounds of volatile solids	pounds per day	pounds per pound of volatile solids	Total, pounds per day	Ammonia, pounds per day	
CHICKENS (4-5 lb)								
	0.035			0.033	0.93			
0.063	0.044	0.015	0.34	0.050	1.14	0.0030	0.0006	0.0026
0.066	0.051	0.015	0.29	0.057	1.11	0.0036	0.0023	
0.057-0.084		0.015-0.032						
		0.006-0.010						
SWINE (100 lb)								
0.80	0.62	0.20	0.32	0.75	1.20	0.032	0.024	0.025
0.97	0.80	0.43	0.54	0.96	1.20	0.064		
0.50	0.35			0.47				
			0.30		1.56			
		0.25						
		0.22				0.07		
0.71		0.56						
DAIRY CATTLE (1000 lb)								
		1.53	0.13		1.57			
10.4	8.3	1.53	0.18	8.4	1.00	0.38		0.12
6.8	5.7	1.32	0.23	5.8	1.02	0.37	0.23	
7.5		0.44				0.49		
BEEF CATTLE (1000 lb)								
3.62	3.17	1.02	0.32	3.26	1.03	0.26	0.11	
9.00			0.28		1.15	0.26		
DUCKS								
0.16		0.02-0.04				0.08		0.006-0.01[c]

[a] Multiple entries in each category represent data reported by different investigators.

[b] Dry solids.

[c] As PO_4.

TABLE 7

AVERAGE ANIMAL WASTES CHARACTERISTICS
(Loehr, 1969)

Species	Pounds per animal per day			Per capita equivalent,[a,b]		
	BOD_5	Total dry solids	Total nitrogen[c]	BOD_5	Total dry solids	Total nitrogen
Chickens	0.015	0.06	0.003	0.11	0.09	0.11
Swine	0.30	0.90	0.05	1.7	1.7	1.5
Dairy cattle	1.0	10	0.40	8	18	12
Beef cattle	1.0	10	0.30	6	18	9

[a] Based on average characteristics in municipal sewage: 0.17 pounds BOD_5 per capita per day, 0.55 lb total solids per capita per day, and 0.033 lb total nitrogen per capita per day.

[b] Number of people equivalent to one animal.

[c] Total Kjeldahl nitrogen.

REFERENCES

Anderson, J. R. (1966) Biological interrelationships between feces and flies. In: Proceedings of the National Symposium on Animal Waste Management, St. Joseph, Mich., American Society of Agricultural Engineers (ASAE Publication No. SP-0366), pp. 20-23

Anthony, W. B. (1966) Utilization of animal wastes as feed for ruminants. In: Proceedings of the National Symposium on Animal Waste Management, St. Joseph, Mich., American Society of Agricultural Engineers (ASAE Publication No. SP-0366), pp. 109-112

Baines, S. (1964) Some aspects of the disposal and utilization of farm wastes, Inst. Sewage Purif. J., pp. 578-588

Benne, E. J., Hogland, C. R., Longnecker, E. D. & Cook, R. L. (1961) Animal manures - what are they worth today? Michigan State University, Agricultural Experiment Station, Lansing, Mich. (Bulletin No. 231)

Curtis, D. R. (1966) Design criteria for anaerobic lagoons for swine manure disposal. In: Proceedings of the National Symposium on Animal Waste Management, St. Joseph, Mich., American Society of Agricultural Engineers (ASAE Publication No. SP-0366), pp. 75-80

Davis, R. V., Cooley, C. E. & Hadder, A. W. (1966) Treatment of duck wastes and their effects on water quality. In: Proceedings of the National Symposium on Animal Waste Management, St. Joseph, Mich., American Society of Agricultural Engineers (ASAE Publication No. SP-0366), pp. 98-105

Decker, W. M. & Steele, J. H. (1966) Health aspects and vector control associated with animal wastes. In: Proceedings of the National Symposium on Animal Waste Management, St. Joseph, Mich., American Society of Agricultural Engineers (ASAE Publication No. SP-0366), pp. 18-20

Fontenot, J. P., Bhattacharya, A. N., Drake, C. L. & McClure, W. H. (1966) Value of broiler litter as feed for ruminants. In: Proceedings of the National Symposium on Animal Waste Management, St. Joseph, Mich., American Society of Agricultural Engineers (ASAE Publication No. SP-0366), pp. 105-108

Geldrich, E. E., Bordner, R. H., Huff, C. B., Clark, H. F. & Kabler, P. W. (1962) Type distribution of coliform bacteria in the feces of warm blooded animals, J. Wat. Pollut. Control Fed., 34, 295-301

Gibson, E. A. (1966) Salmonellosis in cattle, Agriculture, 73, 213-216

Gibson, E. A. (1967) Disposal of farm effluent - animal health, Agriculture, 74, 183-192

Hart, S. A. (1960) The management of livestock manure, Trans. Amer. Soc. Agric. Engrs, 3, 78-80

Hibbs, C. M. & Foltz, V. D. (1964) Bovine salmonellosis associated with contaminated creek water and human infection, Veterinary Medicine/Small Animal Clinic (U.S.A.), 59, 1153-1155

Loehr, R. C. (1967) Effluent quality from anaerobic lagoons treating feedlot wastes, J. Wat. Pollut. Control Fed., 39, 384-391

Loehr, R. C. (1969) Animal wastes - a national problem, J. Sanit. Engng Div., Proc. Amer. Soc. Civ. Engrs, 95, No. SA2, pp. 189-221

Mills, K. C. & Parker, B. F. (1967) Some effects of composition of feed on the biochemical oxygen demand of the excreta produced from this feed (paper presented at winter meeting of American Society of Agricultural Engineers, Detroit, Mich.)

Miner, J. R., Lipper, R. I., Fina, L. R. & Funk, J. W. (1966) Cattle feedlot runoff - its nature and variation, J. Wat. Pollut. Control Fed., 38, 1582-1591

Sobel, A. T. & Ludington, D. C. (1966) Destruction of chicken manure by incineration. In: Proceedings of the National Symposium on Animal Waste Management, St. Joseph, Mich., American Society of Agricultural Engineers (ASAE Publication No. SP-0366), pp. 95-98

Taiganides, E. P. & Hazen, T. E. (1966) Properties of farm animal excreta, Trans. Amer. Soc. Agric. Engrs, 9, 374-376

Tietjen, C. (1966) Plant response to manure nutrients and processing of organic wastes. In: Proceedings of the National Symposium on Animal Waste Management, St. Joseph, Mich., American Society of Agricultural Engineers (ASAE Publication No. SP-0366)

U.S. Federal Water Pollution Control Administration (1970) The economics of clean water. Vol. II. Animal wastes profile, Washington, D.C., Govt Printing Office

SELECT BIBLIOGRAPHY

Agnew, R. W. & Loehr, R. C. (1966) Cattle-manure techniques. In: Proceedings of the National Symposium on Animal Waste Management, St. Joseph, Mich., American Society of Agricultural Engineers (ASAE Publication No. SP-0366), pp. 81-84

Allred, E. R. (1966) Farm-waste management trends in Northern Europe. In: Proceedings of the National Symposium on Animal Waste Management, St. Joseph, Mich., American Society of Agricultural Engineers (ASAE Publication No. SP-0366), pp. 133-136

Cassell, E. A., Warner, A. F. & Jacobs, G. B. (1966) Dewatering chicken manures by vacuum filtration. In: Proceedings of the National Symposium on Animal Waste Management, St. Joseph, Mich., American Society of Agricultural Engineers (ASAE Publication No. SP-0366), pp. 85-91

Centre belge d'Etude et de Documentation des Eaux (1966) Livre de l'eau. Liège, CEBEDOC. Vol. 5 pp. 313-315: "Eaux usées provenant d'exploitations agricoles"

Cornell University Conference on Agricultural Waste Management (1969) Animal waste management. Proceedings . . . Syracuse, New York, January 1969

Culpin, C. (1964) Equipment for disposal of agricultural effluents, Chem. and Ind. (Feb. 29), pp. 350-353

Dornbush, J. N. & Anderson, J. R. (1964) Lagooning of livestock in South Dakota. In: Proceedings of the 19th Industrial Waste Conference, Purdue University, Lafayette, Ind. (Engineering Extension Series No. 117), pp. 317-325

Great Britain, Department of Scientific and Industrial Research (1964) Some further observations of waste waters from farms, Notes Wat. Pollut., No. 24

Forsyth, R. J. (1965) The collection of manure from housed livestock, J. Proc. Instn Agric. Engrs, 21, 124-134

Hart, S. A. & Turner, M. E. (1965) Lagoons for livestock manure, J. Wat. Pollut. Control Fed., 37, 1578-1596

Institute of Water Pollution Control (1970) Proceedings of Symposium on Farm Wastes, Newcastle-upon-Tyne, London

Jackson, S. W., Langlois, B. E. & Johnson, T. H. (1970) Growth of micro-organisms in fresh chicken manure under aerobic and anaerobic conditions, Poult. Sci., 49, 1749-1750

Karlgren, L. (1966) Der Einfluss von Jauche und Siloabwässer auf die Gewässer, Föd. Europ. Gewässersch., Inform.-Bl., No. 13, 33

Leuthier, H. (1963) Das Jauche- und Abwasserproblem im landwirtschaftlichen Grossbetrieb, Wasserwirtschaft-Wassertechnik, 13, 14-18

Liebmann, H. (1963) Der Einfluss von Jauche auf Kleinkläranlagen in Landgemeinden, Münch. Beitr. z. Abw.-, Fischerei- u. Flussbiol., Bd. 10, 205-208

Little, F. J. (1966) Agriculture and the prevention of river pollution as experienced in the West of Scotland, Inst. Sewage Purif. J., pp. 452-454

Loehr, R. C. (1969) Animal wastes - a national problem, J. sanit. Engng Div., Proc. Am. Soc. civ. Engrs. 95, No. SA2, 189-221

Meinck, F., Stooff, H. & Kohlschütter, H. (1968) Industrie-Abwässer. 4., verb. und erw. Aufl. von Nr 6 der "Schriftenreihe des Vereins für Wasser-, Boden- und Lufthygiene, Berlin-Dahlem". Stuttgart, Geo. Fischer. pp. 420-426 "Abwässer landwirtschaftlicher Betriebe"

Poelma, H. R. (1966) The biological breakdown of pig urine, Wageningen, Netherlands, Institut for Farm Buildings (Bulletin No. 18)

Reed, C. H. (1966) Disposal of poultry manure by plow-furrow-cover method. In: Proceedings of the National Symposium on Animal Waste Management, St. Joseph, Mich., American Society of Agricultural Engineers (ASAE Publication No. SP-0366), pp. 52-53

Rundle, W. T. A. (1965) Effluent disposal - still a major problem, J. Proc. Instn Agric. Engrs, 21, 134-139

Smith, S. M. & Miner, J. R. (1964) Stream pollution from feedlot runoff. In: Transactions 14th Annual Conference on Sanitary Engineering, University of Kansas, pp. 18-25

Symposium on Agricultural Wastewaters (1966) Proceedings . . . University of California, Davis, April 1966 (Water Resources Center Report No. 10)

Viehl, K. & Kollatsch, D. (1967) Die Abläufe der landwirtschaftlichen Betriebe ein neues Abwasserproblem, Wasser u. Boden, 19, H. 9

Weiss, C. M. et al. (1971) A review of the 1970 literature on wastewater and water pollution control, J. Wat. Pollut. Control Fed., 43, No. 6, pp. 991-998 "Livestock wastes"

Wheatland, A. B. & Borne, B. J. (1963) Le traitement des effluents des fermes, Trib. CEBEDEAU 16

Witzel, S. A., McCoy, E., Polkowski, L. B., Attoe, O. J. & Nichols, M. S. (1966) Physical, chemical and bacteriological properties of farm wastes (bovine animals). In: Proceedings of the National Symposium on Animal Wastes Management, St. Joseph, Mich., American Society of Agricultural Engineers (ASAE Publication No. SP-0366), pp. 10-14

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GUIDELINES FOR THE CONTROL OF INDUSTRIAL WASTES

5. PULP AND PAPER MANUFACTURING WASTES

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PREFACE

The satisfactory disposal of industrial effluents is a major problem causing growing concern to public health authorities. Direct discharge of wastes into water courses may deplete dissolved oxygen, destroy aquatic life, and make the stream unfit for community water supply and other beneficial uses. On the other hand, the discharge of some industrial effluents into municipal sewers may have damaging effects on sewers or overload the sewage treatment works. Public health authorities are also aware of possible long-term physiologic effects of some new organic chemicals which are found in industrial effluents, many of which are not removed by conventional treatment processes. Highly persistent detergents, pesticides and other toxic wastes have become serious problems in developed countries and will in time present a similar threat to developing countries.

In the developing countries the situation is particularly serious in view of the scarcity of qualified professional personnel (sanitary engineers, chemists and biologists), analytical laboratories, and finances for planning and operating industrial wastes control programmes. It is important to consider the problem not only as it is at present, but also in the light of expected population increase, and of urban and industrial growth. Early government action is required for determining the extent of the problem and for planning and implementing efficient measures for the control of industrial wastes discharges.

This is one of a series of documents prepared by the World Health Organization covering the most prevalent industries in developing countries. The objective of these guidelines is to assist the responsible staff of health agencies and of other regulatory authorities to carry out surveys, interpret laboratory findings, advise industries on inplant remedial measur and disposal of wastes, and make recommendations concerning acceptance of wastes into municipa sewers. The first document in this series described the problem in general terms, and advise on how to carry out surveys and institute programmes of industrial wastes control.[1] The guide lines dealing with wastes from specific industries cover a description of the manufacturing process, with flowchart, the quantity and characteristics of wastes including health hazards, reclamation and recycling practices, methods of treating and disposing of wastes, suggestions for surveying and appraising existing facilities, and selected references to the literature.

It is planned to revise and update the documents from time to time by including informati on new processes and procedures with special reference to experience in developing countries. Information and suggestions in this connexion will be welcomed by the Organization.

1. INTRODUCTION

Pulp and paper manufacturing is one of the largest industries in the world and has exhibited rapid and steady growth. Increased need for the wide variety of materials produced by this industry and continued development of many new products and uses for them promise extensive further growth over many years into the future.

Products supplied by the pulp and paper industry have been classified into four major categories: fine papers, coarse papers, tissues, and specialties (Gehm, 1965). The fine papers include writing materials, papers used in many types of quality publications, and white papers in general. Coarse papers comprise newsprint, wrapping papers, boards used to manufacture containers and many types of building products. Tissues consist of special wrapping papers, utility tissues and glassine. The specialty products encompass a wide variety of materials, including: electrical insulation, cigarette papers, photographic stock, cards and papers used for printing money.

Manufacture of the wide variety of items produced by this industry involves an extensive array of processes, each of which has been developed to permit economical manufacture of one

[1] Document WHO/WD/70.6.

or more products meeting certain specific performance and appearance criteria. As expected, the application of many types of manufacturing processes to a variety of raw materials to produce substantially different end products leads to great diversity in characteristics and effects of waste-water discharges from those operations. In general, however, water usages are high in pulp and paper industries because water is a basic raw material used for many purposes including transportation of raw and intermediate materials, preparation of chemical solvents and additives, and removal of undesirable constituents and by-products.

Accordingly, water pollution problems in the pulp and paper industry are varied and frequently reach major proportions. Pollution problems and methods for their solution long have been the subject of extensive investigations by many segments of the pulp and paper industry and other interested organizations.

2. MANUFACTURING PROCESSES

2.1 Generalized flow sheet

Pulp and paper manufacturing operations conveniently can be divided into steps related to the (1) production of pulp from wood or other raw materials, (2) further treatment of the pulp, and (3) manufacture of the paper product. Raw materials most commonly used for pulping inclu wood, flax, cotton, rag, straw, hemp, esparto, jute, bagasse, and waste paper.

Some mills may execute only part of the operations involved in manufacuring a finished product. For example, some specialize in conversion of various types of raw materials to pul which subsequently may be shipped elsewhere for production of the final paper in other mills. Many manufacturing processes could be used for each step of the operation depending upon the nature of the raw materials and specifications for the product. Because of the number of variables involved and limited scope of this paper, it is not feasible to review all or even most combinations here. Fig. 1 presents a generalized flow sheet for a typical integrated mill in which all of the basic operations are executed, as practised at many locations today. The major steps outlined for preparation of paper, beginning with wood as the raw material, consist of: (1) wood preparation, (2) the pulping process, (3) bleaching of the pulp and (4) manufacture of the paper product.

2.2 Wood preparation

Wood preparation includes steps involved in the transportation and preparation of wood for pulping. This often is based on moving wood by water carriage in flumes, washing and debarking. Water used in these operations may accumulate extensive concentrations of bark particles, wood slivers and silt, as well as solids dissolved in the water by leaching sap and other materials from the wood.

Usually most of the bark is separated as a solid waste and may be disposed of through dumping, incineration, composting or recovery for manufacture of by-products.

If the wood is to be pulped through chemical action, it is chipped to produce uniformly-sized particles small enough to facilitate chemical digestion. This step may be unnecessary in the groundwood pulp process where the wood is mechanically ground.

2.3 Pulping processes

The several types of pulp most commonly produced include groundwood (mechanical pulp), chemi-groundwood, kraft (sulfate), sulfite, neutral sulfite and semi-chemical pulp.

In mechanical pulping, pieces of the log are pressed against revolving grindstones in the presence of water. This type of operation is used to manufacture newsprint, low-grade sanitary tissue and paperboard. In the chemi-groundwood process, the log is cooked before grinding, producing a pulp which drains more rapidly and has greater strength than groundwood pulp.

Kraft pulping uses an alkaline sulfate solution to dissolve lignin and other constituents of the wood which bind the cellulose fibres together. This action releases the fibres for use in manufacture of the paper product. The technique offers the advantage of producing a higher quality pulp which often is used for making brown wrapping paper and similar materials.

The acid sulfite process is based on digestion of wood chips in an aqueous solution of calcium bisulfite and sulfur dioxide. In new mills, more stringent pollution control regulations have led to selection of magnesium, ammonium, or sodium bisulfite instead of calcium bisulfite because of the possibility for producing a waste liquor more amenable to chemical recovery.

The semi-chemical process uses relatively mild chemical treatment to soften the chips, which subsequently are separated mechanically. This approach produces a higher yield of pulp.

After cooking, contents of the digestor are released into a blow tank for separation of vapours and spent liquor from the stock. The crude pulp from this operation is screened and washed to separate coarse from fine fibres and to remove dirt, residual chemicals, and foreign matter. The purified pulp then is thickened, often by use of vacuum filters, before bleaching.

2.4 Bleaching

Bleaching is necessary where it is desired to brighten the pulp, the specific type of bleaching operation depending on character of the pulp and desired end-product. Chemicals most often employed for bleaching are oxidizing agents, including chlorine, chlorine dioxide, hypochlorites, peroxides, and hydrosulfites. Often the bleaching operation may involve several stages with water used for washing and leaching of extractable materials after each step.

2.5 Paper manufacture

In stock preparation, the pulp is prepared for forming into a sheet of paper, often with addition of chemicals to produce a product of desired characteristics and finish. Operations in this phase may include beating and refining, mixing, addition of fillers, sizing, wet-strength resins and colouring materials.

The pulp is converted into a sheet on the paper machine by formation of a wet web, removal of water by pressing, and removal of additional water by heat. Frequently, this is accomplished by flowing the slurry of fibres in water on to a moving 4-denier wire screen to form the wet sheet, excess water being removed by passage through the wire. The wire and sheet then pass through a series of press rolls for removal of additional water and the sheet travels through steel smoothing rolls. Finally, the sheet is carried through a series of dry rollers heated by steam.

Finishing and converting operations prepare the paper for shipment and may include improvement of the surface finish, rewinding, cutting into sheets, or other similar operations. Most of these are basically dry in character and little liquid waste originates here, except for clean-up and occasional spills.

3. QUANTITY AND CHARACTERISTICS OF WASTE WATERS

Pulping blowdown liquor represents a major source of pollutional materials from pulp and paper mills. These waste waters generally are high in BOD and in colour caused by lignin derivatives, and other decomposition products of wood, formed and released during the cooking process. The flows generally are relatively small in volume but highly concentrated in chemical constituents, providing a high proportion of all pollutants in the plant effluent. Accordingly, major impact on character of the overall plant effluent can be realized through recovery or separate disposal of the blowdown liquors. Wastes from bleaching operations also contain very high concentrations of BOD and dissolved constituents. Waste waters from

the paper machine generally are more dilute and contain fibres and fillers. Using saveallsl, most of this water can be recycled within the machine and excess flow used to dilute stock or to satisfy other needs in the mill.

Table 1 summarizes the current range of effluent flows which may be expected in the United States of America from manufacture of various types of pulp and paper products (Gehm, 1965). The quantities of waste water discharged differ radically among the several manufacturing processes and also may vary widely from plant to plant of the same type. These variations often are a function of age of the plants, newer ones usually using less water per ton of product because of growing pressures for water conservation and pollution control.

Table 2 summarizes suspended solids and BOD loadings for various types of pulp and paper manufacturing plants (Gehm, 1965). The same author points out that BOD in effluents from pulping operations, without considering recovery, vary inversely with pulp yield of the process. Accordingly, mechanical pulping plants which yield pulp representing a high proportion of wood used have relatively low discharge BOD per ton of pulp. Chemical pulping processes produce substantially lower yield but higher quality pulp and may discharge two to three times as much BOD per ton of product.

Table 3 presents a more detailed listing of waste water discharges and pollutional loadings from various types of pulp and paper operations, as reported in an extensive waste water profile for pulp and paper industry in the United States of America (Anon., 1967). Table 4 has been calculated from average values for integrated pulp and paper mills in Table 3 to illustrate the magnitude of waste water flows and pollutants in this flows as revealed by that survey. Total flows, loadings, and population equivalents were calculated for a 300-ton per day mill and show the major potential impacts of such facilities. It should be noted that the impact actually could be much larger by a mill practising less than normal care in water conservation and inplant pollution control efforts.

4. RECLAMATION AND RECYCLING

Waste reduction practices in the pulp and paper industry are of major importance in influencing quantities and characteristics of waste water discharged. Techniques which have been employed successfully include water re-use, chemical recovery, fibre and solids recovery and many types of manufacturing process improvements. Table 5 shows the extent to which various process modifications could reduce waste water discharges from processes often found in "older" types of mills. In each instance, the potential estimated reduction in waste water is given relative to conditions which could be expected under "before" conditions as indicated in each section of the Table (Anon., 1967). The potential impact of water re-use or other inplant modifications is shown to be drastic in many instances and the importance of this approach to pollution control in the pulp and paper industry should be evident.

It is estimated that about 80-90% reduction in waste loads and 70% reduction in waste water flow from wood preparation processes could be attained through water re-use. Adoption of the "long log" preparation method could reduce waste loadings as much as 95% and flows up to 85%.

Re-use of water in pulping processes can reduce waste water loads significantly and recovery of cooking liquors can result in reductions of 60-90%. Waste reductions of 20-60% from the pulp screening process may be obtained currently by partial water re-use, but complet elimination of this flow could be attained in the future with additional inplant recycle.

Recirculation in multi-stage bleaching operation reduces waste water loads by 30-80%. Fibre recovery and white water re-use in paper machine operations can reduce waste loads by 20-60% and flows by 60-80%.

By-product recovery from certain spent liquors in the pulp and paper industry has been successful for turpentine and tall oil. Some small mills manufacture other by-products

including lignin sulfonates, acetic acid, formic acid, yeast and alcohols (Anon., 1967; Gehm, 1965). About 10 mills in the United States of America produce by-products, accounting for 10-15% of the liquor produced, but the market for these materials is limited and several of the products can be produced more economically from other materials. Two papers provide excellent information on this subject (Anon., 1963; Wiley & Holderby, 1960). Other by-products which have been investigated or actually produced for market from pulp and paper wastes include roofing felts, heating insulation, and cheap paper manufactured from bark. Spent sulfite liquor has been utilized in production of emulsions for insecticides, scaling inhibitors, tanning agents, fertilizers, flotation agents, well-drilling lubricants, additives for storage batteries, reinforcing agents for rubber, and road binders.

In spite of major activity in this area, the production and sale of by-products from pulp and paper waste water flows does not appear to be attractive and the general trend is towards installation of recovery systems and substitution of pulping processes offering better possibilities for chemical recovery.

5. TREATMENT AND DISPOSAL OF WASTE WATERS

The treatment systems most commonly applied to pulp and paper waste waters are similar in principle to those used for many other types of wastes, including municipal sewage, care being exerted to develop and use design parameters appropriate to the specific waste water in question. Table 6 summarizes levels of performance which may be expected in pulp and paper waste water treatment systems incorporating various types of elements. Primary treatment consists of sedimentation or flotation for removal of suspended matter and may attain 50-95% removal of suspended solids and 10-50% removal of BOD. Secondary treatment is based on biological processes to remove biodegradable materials and, depending upon type and design, can attain 30-95% BOD removal.

Suspended solids in pulp and paper mill wastes include fibres, clays, other filling and coating materials and debris. Usually, most of these materials are removed from machine waters by some type of saveall and returned to the system for re-use. Where further treatment is necessary, the most common approach is sedimentation in mechanically cleaned clarifiers similar to those used for many other types of industrial and municipal waste waters. Some mills use multiple earthen basins, arranged to permit intermittent excavation of solids, but sometimes odour problems have resulted. Where higher removals of suspended solids are required, coagulants such as alum, activated silica, and polyelectrolytes may be used to improve performance to 90% removal or higher. Clarifiers commonly are designed for overflow rates of 600-1000 US gal/ft^2 of surface area per day (25 000-40 000 l/m^2/day).

Activated sludge systems can attain very high BOD removals when properly designed and operated. Where land is moderate in cost many pulp and paper mills have adopted aerated lagoons, which are similar in principle to activated sludge but have no return sludge or final settling facilities, with much longer aeration periods - usually 3-10 days. Where land is cheap, stabilization basins offer additional advantages because the long detention periods minimize process upsets, and operating costs are minimal because the system requires little attention. Design of oxidation pond for pulp and paper wastes is similar to municipal sewage treatment practice, with units 3-5 ft (0.90-1.50 m) deep loaded at about 50 pounds of BOD per acre per day (23 kg/ha/day).

Although trickling filters have been applied to a few pulp and paper mill waste waters, presence of fibres occasionally has caused plugging of stone media (Anon., 1967; Gehm, 1965; Waldmeyer, 1957). Systems with plastic media have been used successfully in several installations as roughing filters for partial removal of BOD, sometimes before further treatment or discharge into municipal systems. This approach also offers the advantage of waste cooling before further treatment, which occasionally is desirable.

Properly designed irrigation systems can be used successfully for treatment and disposal of these waste waters. Application rates vary from 10 000 to 100 000 gal per acre per day (93 500-935 000 l/ha/day) and loadings should be less than 200 lb of BOD per acre (225 kg/ha) per day. Land requirements for this approach are high (40-50 acres per m.g.d. of effluent) (4.3-5.3 ha per 1000 m^3/day) offering serious economic disadvantages in many areas. Also the potential for groundwater contamination must be recognized, especially when highly coloured pulping liquors are applied to the soil. The potential for disposing of waste waters by this technique usually is maximum during drought periods, when stream assimilative capacities are minimum and demand for irrigation water is maximum. On the other hand, this approach may offer disadvantages in hilly terrain or in freezing climates.

Sludges withdrawn from the primary clarifier and biological treatment system usually mus be thickened before disposal. Techniques which have been employed include gravity thickenin of mixed primary and secondary sludges, air flotation, centrifugation and vacuum filtration. Ultimate sludge disposal has been accomplished by land filling and lagooning with other waste materials such as bark, grit, ashes and other debris. Where high land costs and regulations have justified more expensive approaches, incineration has been employed. Techniques which have been considered for separate disposal of strong wastes include recovery of chemicals and deep well disposal.

Other treatment systems which have been investigated extensively for possible future application to pulp and paper waste waters include filtration for removal of BOD and COD, chlorination or ozonation for removal of bacteria, activated carbon adsorption, mass lime treatment for colour removal, and separation of inorganics by electrodialysis, reverse osmosi and ion exchange. These approaches have not yet been employed to a significant extent in practice, except for experimental purposes.

6. SURVEY AND APPRAISAL

The importance of inplant operations and controls in solving pulp and paper waste water problems has been indicated earlier. Serious consideration should be given to recovery of chemicals and separate collection, treatment and disposal of concentrated cooking liquors. In many instances, this approach may include modifying of the cooking process to use chemicals more amenable to subsequent recovery.

Survey of waste water pollution problems in pulp and paper mills should include careful evaluation of water use and re-use patterns in the installation. Major reductions in waste water discharges and pollution loads often can be attained through economical inplant modifications. Now it is common practice to provide savealls for recovery of fibres and other raw materials within the manufacturing process and opportunities for reduction in waste water discharges by this technique should be given careful consideration.

Great care should be exercised in sampling waste water streams to ensure accurate flow metering and collection of samples truly representative of the discharges. Blowdown from cooking processes usually are intermittent and without careful evaluation could lead to grossly erroneous conclusions about overall characteristics of the mill effluent. Discharges from paper machines are less variable but offer difficulties with respect to continuous sampling because of suspended solids content.

Analytical measurements should be conducted in accordance with proven procedures. Suspended solids and BOD determinations usually do not offer special difficulties. Determination of dissolved oxygen in mill effluents and in streams receiving such discharges may suffer from interferences by waste water constituents. One approach which has been proposed to circumvent this type of problem is the use of membrane-covered oxygen electrodes.

Usually, use of the dichromate COD test to predict BOD values in raw and treated waste waters has proven rather unsatisfactory. However, some mills have found reasonable correlation between certain non-standard COD tests and BOD. In particular, some employ a version of a permanganate COD test in preference to the dichromate method.

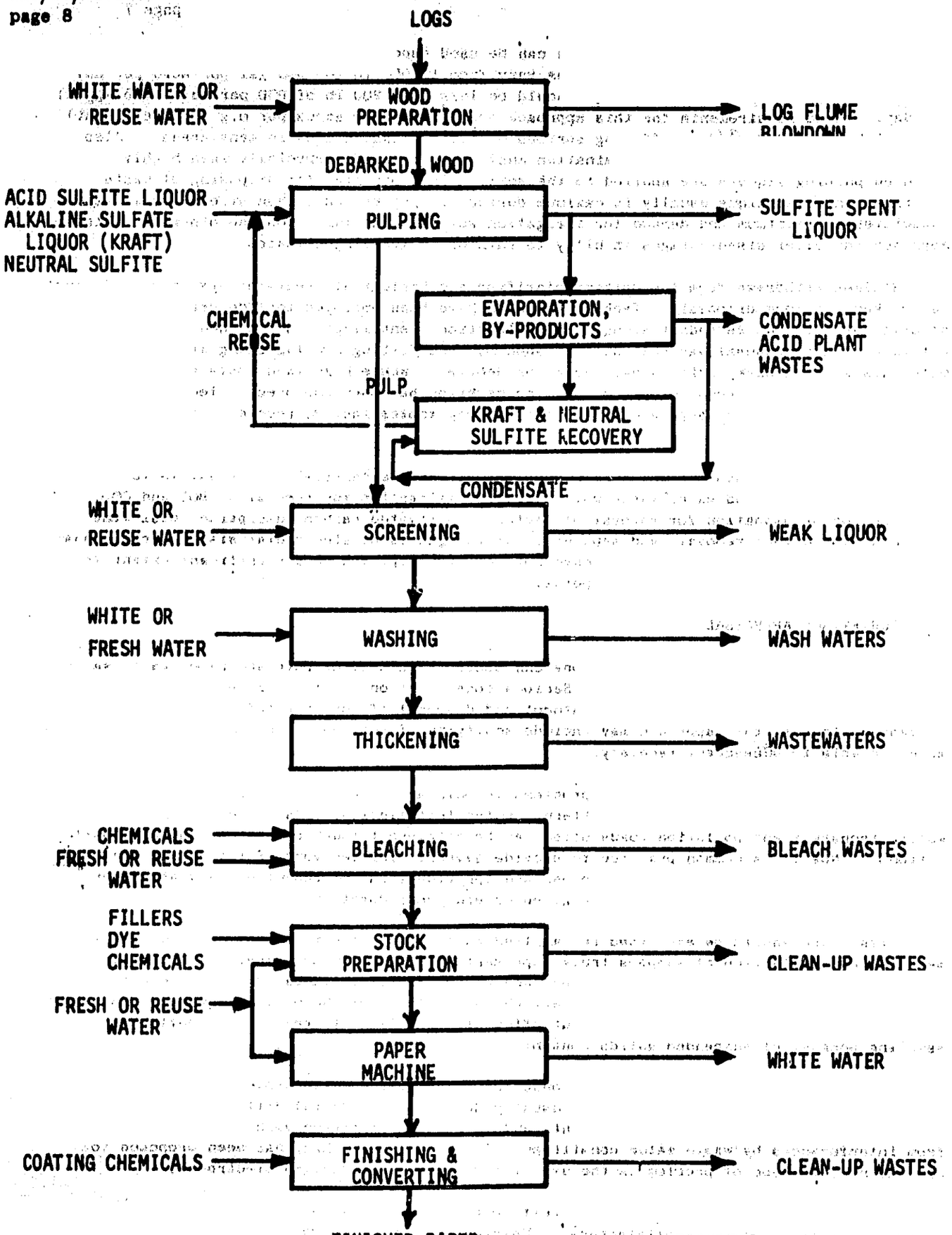

FIGURE 1
GENERALIZED FLOW SHEET FOR AN INTEGRATED PULP AND PAPER OPERATION (After: Anon., 1967)

TABLE 1. EFFLUENT FLOWS FROM MANUFACTURE OF PULP AND PAPER PRODUCTS

Process	US gal per ton*
Pulp manufacture	
Kraft and soda pulps	15 000 - 35 000
Sulfite pulp	40 000 - 60 000
Semi-chemical pulp	30 000 - 40 000
Groundwood pulp	4 000 - 10 000
Deinked pulp	20 000 - 35 000
Pulp bleaching	
Kraft and soda pulp	15 000 - 60 000
Sulfite pulp	30 000 - 50 000
Neutral sulfite pulp	40 000 - 60 000
Paper manufacture	
White papers	20 000 - 40 000
Tissues	8 000 - 35 000
Kraft papers	2 000 - 10 000
Paperboard	2 000 - 15 000
Specialty papers	20 000 - 100 000

* 1 US gal per ton = 4.17 litres per metric ton.

TABLE 2. EFFLUENT LOADS FROM PULP AND PAPER MILLS

(Gehm, 1965) p. 363

Effluent	lb per ton of product*	
	Suspended solids	5-day BOD
Kraft and soda pulp	20 - 30	25 - 50
Groundwood pulp	40 - 80	15 - 25
Sulfite pulp (no liquor recovery)	20 - 40	400 - 600
Neutral sulfite semi-chemical pulp	100 - 180	250 - 450
Textile fibre pulps	300 - 500	200 - 300
Straw pulp	400 - 500	400 - 500
Bleaching	6 - 35	12 - 200
Deinked pulp	500 - 800	100 - 130
Fine papers		
Tissue	50 - 100	15 - 30
Bond, mimeo, and printing	50 - 100	20 - 40
Glassine	10 - 15	15 - 25
Coarse papers		
Boxboard	50 - 70	20 - 40
Corrugating board	50 - 70	25 - 60
Kraft wrapping	15 - 25	5 - 15
Newsprint	20 - 60	10 - 20
Specialty papers		
Fibre	200 - 300	140 - 170
Asbestos	300 - 400	20 - 40
Roofing felt	50 - 100	40 - 60
Insulating board	50 - 100	150 - 250

* 1 lb per ton = 0.50 kg per metric ton.

TABLE 3

WASTEWATER LOADINGS AND FLOWS FROM TYPICAL PULP AND PAPER OPERATIONS

(From: Anon., 1967)

Processes	Wasteload, in lbs/ton of Product * Suspended Solids Range[1]	Suspended Solids Mean[2]	Total Solids Range[1]	Total Solids Mean[2]	BOD Range[1]	BOD Mean[2]	pH Range[1]	Wastewater Quantities ** in gallons/ton Range[1]	Wastewater Quantities ** in gallons/ton Mean[2]
A. Wood Preparation	1.9-40	9	4-50	13	2-10	3	6.5-8.0	1,000-10,000	3,400
B. Pulping									
Groundwood		--		--		--			--
Sulfate (Kraft)									
Blow Tower	(3.7)	4	(21.0)	21	(1.3)	1	(12)	(1,000)	1,000
Dirty Condensate	0-0.5	0.1	6-11	7	6.5-9.0	8	9.5-10	950-1,900	1,200
Evaporator Ejector	0.06-0.2	0.1	1-3	2	1.6-4.5	3	9-10	290-640	300
Causticizing Waste	2.2-5.7	5	46-240	101	8.0-10.5	9	9-11.0	600-9,600	2,500
Green Drag	(1.0)	1	(22)	22	(1.0)	1	(12)	(200)	200
Floor Drain	0.5-10	6	11.0-11.5	11	0.3-1.7	1	11.6-12	340-580	400
Sub-total		17		164		23	9.5-12.0		5,600
Sulfite									
Blow Tower	0.42-1.9	1	36-348	247	29-194	116	2.2-2.9	1,840-1,950	1,900
Condensate	0.05-0.2	0.1	18-67	47	48-71	66	2.3-3.1	750-1,700	1,100
Uncollected Liquor	0.3-43	21	50-515	105	50-61	53	2.2-2.6	2,000-10,000	7,500
Acid Plant Wastes	(5)	5	(10)	10		--	(1.2)	(300)	300
Boiler Blowdown	(2)	2	(22)	22	(0.05)	0.05		(100)	100
Sub-total		29		411		235	1.2-2.9		10,900
Semichemical									
Blow Tower	(2)	2	(8)	8	(1)	1		(1,000)	1,000
Condensate	(0.1)	0.1	(2)	2	(3)	3		(2,000)	2,000
Recovery system	(9)	9	(150)	150	(8)	8		(2,000)	2,000
Uncollected Liquor	(11)	11	(40)	40	(18)	18		(2,000)	2,000
Sub-total	(22)	22		200		30	2.5-4.0		7,000
Deinking									
All sources[3]				--	11-25	--		9,700-36,000	--
C. Pulp Screening									
Groundwood		--		--		--			--
Sulfate (Kraft)	5-8.0	4	60-63	62	10-18	14	9-10	900-9,600	3,600
Sulfite	1.7014	8		27	22-10.7	8	5.4-5.7	1,700-14,300	6,000
Semichemicals		--		--		--			--
Deinking		--		--		--			--
D. Pulp Washing & Thickening									
Groundwood (No Washing)	9-14	11	51-107	75	22-46	33	5.0-6.25	4,800-10,000	7,500
Sulfate (Kraft)	10-30	15	94-180	142	10-35	25	8.9-9.4	3,000-11,000	7,000
Sulfite	6.5-9.0	8	68-1037	131	7.4-34.0	18	2.4-3.9	1,800-15,000	7,500
Semichemical	0.9-6.0	3	42-141	93	10-42	24	7.0-7.9	2,400-7,800	5,400
Deinking		--		--		--			--
E. Bleaching									
Groundwood		--		--		--			4,000
Sulfate (Kraft)	14-124	60	216-294	240	8-88	30		12,000-32,000	19,000
Sulfite	4-44	15	131-415	220	17-44	25	2.9-6.8	9,000-30,000	15,000
Semichemical	--	--	--	--	--	--	--	--	--
Deinking	--	6	--	125	--	12	--	--	5,500
F. Paper Making[4]									
General	10-166	46	31-591	119	3-80	16	4.3-6.9	5,700-40,000	13,000
Products Related:									
Newsprint	20-60	40	--	--	10-20	15	--	37,000	--
Uncoated Groundwood	--	--	--	--	--	--	--	--	--
Coated Printing Paper	--	--	--	--	--	--	--	--	--
Uncoated Book Paper	--	30	--	116	--	16	--	8,000-28,000	14,000
Fine Paper	47-100	73	--	153	15-40	20	--	9,000-40,000	18,000
Coarse Paper	10-30	20	--	--	10-25	15		2,000-29,000	10,000
Special Industrial Paper	200-400	300	--	--	140-170	155	--	20,000-100,000	--
Sanitary & Tissue Paper	50-100	50	--	200	15-30	22	--	8,000-37,000	14,000
G. Total Mill Effluent (Integrated Pulp & Paper Mills)									
Bleached Sulfate & Paper	50-200	170	200-1300	810	30-220	120	--	39,000-54,000	45,000
Bleached Sulfite & Paper	40-100	100	600-1700	1140	235-430	330	--	40,000-70,000	900

1 Single pieces of data are entered under the "Range" column with parenthesis.
2 The mean values shown are not truly statistical average; they are considered to be probable average values based on the available data.
3 Deinking process includes pulping, screening, washing, and thickening.
4 Wastewaters from papermaking include those from stock preparation, paper machine, and finishing and converting operations.

* 1 lb per ton = 0.50 kg per metric ton
** 1 US gal per ton = 4.17 litre per metric ton

1. ILLUSTRATIVE FLOWS AND LOADINGS FROM HYPOTHETICAL 300 TON/DAY INTEGRATED PULP AND PAPER MILLS, BASED ON DATA "G" TABLE 3

Characteristic	Bleached sulfate and paper	Bleached sulfite and paper
Flows:		
Average, m.g.d.	14	17
Range, m.g.d.	12 - 16	12 - 21
BOD:		
Average, lb/day	36 000	99 000
Range, lb/day	9 000 - 66 000	70 000 - 129 000
Average, mg/l	320	720
Suspended solids:		
Average, lb/day	51 000	30 000
Range, lb/day	15 000 - 60 000	12 000 - 30 000
Average, mg/l	435	210
Population equivalent*	216 000	594 000

* Based on 1/6 lb (0.075 kg) BOD_5 per day per capita.

TABLE 5

POTENTIAL WASTE REDUCTION EFFICIENCIES OF VARIOUS PROCESS MODIFICATIONS

(From Amon., 1967)

Processes and Alternative Subprocesses	Waste Reduction Efficiency (per cent.)				
	Suspended Solids	Dissolved Solids	Total Solids	BOD_5	Waste Water Volume
A. Wood Preparation (No Water Reuse)	0	--	--	0	0
With Water Reuse	77	--	--	93	72
Long Log Preparation	95	--	--	99	86
B. Pulping					
Mechanical Pulping					
Groundwood	0	0	0	0	0
Refining Mechanical Pulp	46	89	85	37	71
Sulfate (Kraft) Pulping (Batch, no Reuse)	0	0	0	0	0
Batch Process With Water Reuse	37	-4	-1	56	72
Continuous Process	89	42	47	60	77
Sulfite Pulping (Ca Base, no Reuse)	0	0	0	0	0
Calcium Base with Water Reuse	24	84	83	35	29
Soluble Bases with Liquor Recovery	71	84	87	80	57
Semichemical Pulping (NSSC Batch Process)	0	0	0	0	0
NSSC Kraft Batch Process with Water Reuse	53	-28	-29	30	32
Deinking (Cooking and Washing Without Reuse)	--	--	--	--	0
Cooking and Washing with Water Reuse	--	--	--	--	66
C. Pulp Screening					
Sulfate (Kraft) Pulp (Screening Without Reuse)	0	0	0	0	0
Screening with Partial Water Reuse	55	18	23	22	62
Screening and Cleaning With Water Reuse	(100)	(100)	(100)	(100)	(100)
Sulfite (Screening Without Reuse)	0	0	0	0	0
Screening with Partial Water Reuse	43	9	23	38	34
Screening and Cleaning With Water Reuse	(100)	(100)	(100)	(100)	(100)
D. Pulp Washing and Thickening					
Mechanical Pulp (Thickening and Cleaning With Decker)	0	0	0	0	0
Thickening with Vacuum Filtration	21	52	30	30	25
Thickening and Cleaning With V. F.	57	77	75	79	81
Sulfate (Kraft) Pulp (Diffuser Washing With Decker Thickening)	0	0	0	0	0
Vacuum Filter Washing and Thickening	17	21	20	40	72
Multistage V.F. Washing and Thickening	17	78	72	81	80
Sulfite Pulp (Diffuser Washing With Decker Thickening)	0	0	0	0	0
Vacuum Filter Washing and Thickening	72	50	52	52	62
Multistage V.F. Washing and Thickening	79	75	75	71	90
E. Bleaching					
Sulfate (Kraft) Pulp (Bleaching Without Reuse)	--	--	0	--	0
Bleaching With Low Degree of Water Reuse	--	--	40	--	58
Bleaching With High Degree of Water Reuse	--	--	69	--	74
Sulfite Pulp (Bleaching Without Reuse)	0	0	0	0	0
Bleaching With Low Degree of Water Reuse	50	32	34	37	67
Bleaching With High Degree of Water Reuse	80	80	80	72	86
F. Paper Making (Without White Water Recovery)	0	0	0	0	0
With White Water Recovery	34	27	25	20	60
With Improved White Water Recovery	50	60	56	50	77

TABLE 6. WASTE REMOVAL EFFICIENCIES OF VARIOUS PROCESSES APPLIED TO TYPICAL PULP AND PAPER WASTE WATERS

(From: Anon., 1967)

Removal method	Per cent. of gross waste load removed			
	Suspended solids	BOD_5	COD[1]	Colour[2,1]
Primary treatment				
Sedimentation basin	50 - 90	10 - 40	10 - 30	-
Gravity clarifier[3]	60 - 90	10 - 40	10 - 30	0 - 10
Dissolved air flotation	70 - 95	20 - 50	10 - 40	-
Secondary treatment				
Oxidation pond	0 - 90	30 - 50	-	0 - 10
Trickling filter	-	30 - 70	20 - 50	0 - 15
Aerated lagoon	-	40 - 85	30 - 60	0 - 10
Activated sludge	-	75 - 95	30 - 70	10 - 30
Irrigation	-	60 - 95	-	-
Sedimentation basin[4]	60 - 95	-	-	-
Secondary clarifier[4]	70 - 98	-	-	-

[1] Estimated.

[2] "True" colour (dissolved).

[3] With or without chemical addition and/or flocculation.

[4] As used to remove biological solids in secondary treatment.

REFERENCES

Anon. (1963) Chemicals from the other half of the tree, Chemical Engineering News (USA), No. 6, 83-89

Anon. (1967) Paper mills - industry wastewater profile. The cost of clean water, Vol. III, Washington, D.C., United States Federal Water Pollution Control Administration (Publicatio I.W.P.-3)

Gehm, H. W. (1965) Pulp and paper. In: Gurnham, C. F., ed. Industrial wastewater control, New York, Academic Press, pp. 357-373

Waldmeyer, T. (1957) The treatment of papermill wastes. In: The treatment of trade-waste waters and the prevention of river pollution, London, Contractors' Record Ltd., pp. 215-22

Wiley, A. J. & Holderby, J. M. (1960) Pulp and Paper Magazine of Canada, 61, pp. T212-T217

SELECT BIBLIOGRAPHY

Altieri, A. M. & Wendell, T. W. (1967) De-inking of wastepaper (Tappi Monograph Series, No. 31), Technical Association of the Pulp and Paper Industry (USA)

Amberg, H. R. (1965) By-product recovery and methods of handling spent sulfite liquor, J. Wat. Pollut. Control Fed., 37, 228

Amberg, H. R., Pritchard, J. H. & Wise, P. W. (1964) Supplemental aeration of oxidation lagoons with surface aerators, Tappi, 47, 27A

Anon. (1966) Scottish paper mill avoids polluting local waters, Wat. Waste Treat. J., 11, 132-134 and 136

Banford, R. A. (1964) Centrifugal dewatering of paper mill waste, Tappi, 47, 187A

Berger, H. F. (1966) Evaluating water reclamation against rising costs of water and effluent treatment, Tappi, 49, 79A

Blosser, R. O. (1958) BOD removal from de-inking wastes. In: Proceedings of the 13th Industrial Waste Conference, Purdue University, Lafayette, Ind., pp. 630-639

Blosser, R. O. & Caron, A. L. (1965) Recent progress in land disposal of mill effluents, Tappi, 48, 43A

Blosser, R. O. (1966) Practice in handling barker effluents in mills in the United States, New York, National Council for Stream Improvement, (Tech. Bull. No. 194)

Bolger, J. C., Tate, D. C. & Hopfenberg, H. B. (1967) A new process for improved recovery of tall oil from sulfate liquor, Tappi, 50, 231-237

Brown, R. W. & Spalding, C. W. (1966) Deep-well disposal of spent hardwood pulping liquors, J. Wat. Pollut. Control Fed., 38, 1916-1924

Burns, O. B., jr & Mancini, J. R. (1967) Disposal system for mixed primary and secondary sludges, Tappi, 50, 99A

Central Public Health Engineering Research Institute (1972) Pulp and paper mill wastes, Techn. Dig. (Nagpur), No. 25

Coogan, F. J. & Stovall, J. R. (1965) Incineration of sludges from kraft pulp mill effluents, Tappi, 48, 49A

Copeland, C. G. (1964) Water re-use and black liquor oxidation by the Container-Copeland Process. In: Proceedings of the 19th Industrial Waste Conference, Purdue University, Lafayette, Ind. (Engineering Extension Series No. 117) pp. 391-401

DeHass, G. G. & Amos, L. C. (1967) Recovery systems for mixed kraft and sulfite liquors, Tappi, 50, 75A-78A

Dhaneshwar, R. S. et al. (1970) Characteristics of wastes from pulp and paper mills in the Hoogly estuary, Environ. Hlth (Nagpur), 12, 9-23

Economic Commission for Europe (1967) Economic aspects of treatment and disposal of certain industrial effluents. New York, United Nations (Wat.Pollut./Econ./6). Vol. II. Ca studies of techniques and costs of treatment and disposal of effluents from the pulp, paper and board industries in ECE countries

Erdman, A., jr (1967) Application of fluidized bed processing to spent sulfite liquor combin tion, Tappi, 50, 110A-112A

Follet, R. & Gehm, H. W. (1966) Manual of practice for sludge handling in the pulp and paper industry, New York, National Council for Stream Improvement (Tech. Bull. No. 190)

Foster, J. H. (1963) Fundamentals of primary treatment, Tappi, 46, 155A

Gehm, H. W. (1963) The application of stabilization ponds in the purification of pulp and pa mill wastes, J. Wat. Pollut. Control Fed., 35, 1174-1180

Gehm, H. W. & Gellman, I. (1965) Practice, research, and development in biological oxidation of pulp and papermill effluents, J. Wat. Pollut. Control Fed., 37, 1392-1398

Gellman, I. (1965) Aerated stabilization basin treatment of mill effluents, Tappi, 48, 106A

Hall, H. R. (1963) Paper coating additives (Tappi Monograph Series, No. 25), Technical Association of the Pulp and Paper Industry (USA)

Haynes, D. C. (1966) Water reuse - a survey of pulp and paper industry, Tappi, 49, 51A-52A

Holderby, J. M. & Moggio, W. A. (1960) Utilization of spent sulfite liquor, J. Wat. Pollut. Control Fed., 32, 171-181

Jansson, L. B. (1967) Turpentine recovery systems for continuous digesters, Tappi, 50, 114A-116A

Knapp, C. A., Coughlan, F. P. & Baffa, J. J. (1964) Sedimentation practices for paper industr wastes, J. Sanit. Engng Div., Proc. Amer. Soc. Civ. Engrs, 90, No. SA6, pp. 41-49

Makkonen, O. A. P. (1956) Wastes from paper and pulp mills; a problem of the Northern European countries, with special reference to Finland, Bull. Wld. Hlth Org., 14, 1079-1C

Martin, W. C. (1962) Paper mill and de-inking effluent treatment. In: Proceedings of the 17th Industrial Waste Conference, Purdue University, Lafayette, Ind., p. 211

Meinck, F., Stooff, H. & Kohlschütter, H. (1968) Industrie-Abwässer. 4., verb. und erw. Aufl. von Nr 6 der "Schriftenreihe des Vereins für Wasser-, Boden- und Lufthygiene, Berlin-Dahlem". Stuttgart, Geo. Fischer., pp. 517-550 "Abwässer der Zellstoff- und Papier-industrie"

National Council for Stream Improvement (1961) Recent developments in the application of the activated sludge process for the treatment of pulp and paper mill wastes, New York (Tech Bull. No. 138)

National Council for Stream Improvement (1963) Bibliography of biological oxidation as applied to pulp and papermill effluents, New York (Tech. Bull. No. 161)

Nemerow, N. L. (1963) Theories and practices of industrial waste treatment, Reading, Mass., Addison-Wesley

Nemerow, N. L. (1971) Liquid waste of industry - theories, practices and treatment, Reading, Mass., Addison-Wesley

Quirk, T. P., Olson, R. C. & Richardson, G. H. (1963) Bio-oxidation of concentrated board machine effluents. In: Proceedings of the 18th Industrial Waste Conference, Purdue University, Lafayette, Ind. (Engineering Extension Series No. 115) pp. 655-673

Rayet, R. (1965) L'épuration des eaux usées des papeteries et le traitement des boues, Trib. CEBEDEAU, 18, 386-391

loss, E. N. (1964) Reuse and reduction of paper mill wastes, Tappi, 47, 180A

Screenivasan, A. & Raj, R. S. (1967) Effects of certain wastes on the water quality and fisheries of rivers Cauvery and Bhavani, Environ. Hlth (Nagpur), 9, 13-21

Spalding, C. W., Halko, D. L. & Carpenter, H. S., jr (1965) Deep well disposal of spent pulping liquors, Tappi, 48, 68A

Van Horn, W. M. (1964) Multiple water use for the pulp and paper industry, Tappi, 47, 50A

Varner, H. L. & Miller, B. C. (1963) Water pollution control by in-plant measures, Tappi, 46, 260-266

Weiss, C. M. et al. (1971) A review of the 1970 literature on wastewater and water pollution control, J. Wat. Pollut. Control Fed., 43, No. 6, pp. 956-983 "Paper and allied products"

Westenhouse, R. (1963) Irrigation disposal of wastes, Tappi, 46, 160A

Whisler, R. C. (1964) A tight white water system, its operation and problems, Tappi, 47, 181A

White, M. T. (1965) Surface aeration as a secondary treatment system, Tappi, 48, 128A

WORLD HEALTH ORGANIZATION
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GUIDELINES FOR THE CONTROL OF INDUSTRIAL WASTES

6. METAL FINISHING WASTES

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PREFACE

The satisfactory disposal of industrial effluents is a major problem causing growing concern to public health authorities. Direct discharge of wastes into water courses may deplete dissolved oxygen, destroy aquatic life, and make the stream unfit for community water supply and other beneficial uses. On the other hand, the discharge of some industrial effluents into municipal sewers may have damaging effects on sewers or overload the sewage treatment works. Public health authorities are also aware of possible long-term physiological effects of some new organic chemicals which are found in industrial effluents, many of which are not removed by conventional treatment processes. Highly persistent detergents, pesticides and other toxic wastes have become serious problems in developed countries and will in time present a similar threat to developing countries.

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In the developing countries the situation is particularly serious in view of the scarcit of qualified professional personnel (sanitary engineers, chemists and biologists), analytical laboratories, and finances for planning and operating industrial-wastes control programmes. It is important to consider the problem not only as it is at present, but also in the light o expected population increase, and of urban and industrial growth. Early government action i required for determining the extent of the problem and for planning and implementing efficien measures for the control of industrial wastes discharges.

This is one of a series of documents prepared by the World Health Organization covering the most prevalent industries in developing countries. The objective of these guidelines is to assist the responsible staff of health agencies and of other regulatory authorities to car out surveys, interpret laboratory findings, advise industries on in-plant remedial measures an disposal of wastes, and make recommendations concerning acceptance of wastes into municipal sewers. The first document in this series described the problem in general ter s, and advis on how to carry out surveys and institute programmes of industrial wastes control.[1] The guidelines dealing with wastes from specific industries cover a description of the manufacturi process, with flowchart, the quantity and characteristics of wastes including health hazards, reclamation and recycling practices, methods of treating and disposing of wastes, suggestions for surveying and appraising existing facilities, and selected references to the literature.

It is planned to revise and update the documents from time to time by including informati on new processes and procedures with special reference to experience in developing countries. Information and suggestions in this connexion will be welcomed by the Organization.

1. INTRODUCTION

Many uses of metal products require finishing to enhance appearance and protect against corrosion. The total number of metal finishing facilities in the world is unknown, but one author (Foulke, 1965) has estimated that there are 15 000-20 000 in the United States of Ameri alone. These range in size from thousands of small shops to very large facilities which may be associated with manufacturing concerns requiring the finished metal components or end-produc

Activities in the metal finishing industry have been divided into three categories: (a) cleaning and conversion coatings, (b) organic coatings, and (c) plating and anodizing (Foulke, 1965). A universal requirement in this industry is an adequate supply of water of appropriate quality, the most important use of which is rinsing after cleaning, plating, or other operations. The water may accumulate substantial quantities of metals or other chemica from cleaning and plating baths and many of the constituents could have serious environmental impact, if discharged without proper controls.

None of the waste waters discharged from metal finishing operations present problems whic cannot be solved through recognized in-plant control techniques or existing treatment processe because ample technology has been developed for this purpose over the past several years. Nevertheless, it should be recognized that a special problem exists in this industry because a high proportion of metal finishing shops are small. This situation often renders impractical many otherwise highly acceptable control or treatment procedures because of relatively high capital costs in small installations or lack of practical methods for their day-to-day operatic (Battelle Memorial Institute, 1968). Accordingly, many small plants discharge waste waters wi little or no treatment directly into receiving waters or, more frequently, into municipal sewerage systems. Often small flows may be diluted sufficiently by other waste waters or the receiving stream to eliminate serious problems. On the other hand, large metal finishing installations, or smaller facilities in areas where many are located, may require extensive waste water controls.

[1] Document WHO/WD/70.6.

2. QUANTITY AND CHARACTERISTICS OF WASTE WATERS

Most of the flow from a metal finishing plant consists of rinse waters from plating, cleaning, or other surface finishing operations. Rinses are used between processing steps to reduce contamination of solutions and to remove residual chemicals from the metal upon completi of the finishing operation. It has been estimated that 1-25 US gallons (about 4-100 litres) of rinse water is used daily for each gallon of plating solution (Foulke, 1963). However, the flows vary widely from plant to plant, because of different processes and prctices, covering a range extending from as low as 25% of the plating solution to as much as 50 times that volume

In addition to wide flow variations, there may be radical differences in chemical losses because of the range of practices employed in metal finishing plants. Waste waters may have pH as low as 1.0 and up to almost 14 and may contain many types of toxic metals, depending upon processes employed, including: chromium, copper, zinc, cadmium, nickel, iron, barium, precious metals, and others. Also they may contain high concentrations of cyanides, cyanates, oils, ketones, solvents, sludges, phosphates, carbonates, silicates, and other potential pollutants. One author illustrates the wide ranges of waste water character by giving "typical" rinse water analysis from general plating operations as, perhaps, 2-76 mg/l hexavalent chromium, 0.5-32 mg/ copper, 0.1-2 mg/l nickel, and 12-68 mg/l zinc. Tables 1-4 contain data selected from article by two authors (Foulke, 1963; Lowe, 1970) giving "typical" concentrations in effluents from metal finishing plants.

The highly variable flows and concentrations of constituents in waste waters from metal finishing shops suggest strongly the impossibility of accurate generalizations about quantities and characteristics of waste waters from these types of operations. Thus, in the metal plating industry it is especially important to survey each facility carefully before attempting to arrive at final judgement concerning magnitude of problems caused by the facility and method best suited for their solution.

Most attention in control of metal plating wastes is directed towards rinse waters because of their large volumes. However, it must not be overlooked that serious pollution sometimes results from periodic or accidental dumping of concentrated plating or cleaning solutions. Spills or leaks of concentrated baths, waste waters from clean-up operations, sludges, filter cakes, and ion exchange regenerants may cause serious difficulties if handled in haphazard fashion. Normally these wastes should not be discharged directly into the disposal system but should be hauled away or treated batch-wise, using procedures adapted from techniques used for treating rinse waters.

Concern for control of most metal finishing waste waters is based on the presence of acids alkalies, heavy metals and cyanides. Generally, BOD-causing constituents are present only in relatively small quantities and are not of major interest.

3. POLLUTIONAL IMPACT OF WASTE WATERS

Waste waters from metal finishing operations may have serious direct effects on the environment through action of corrosive or toxic constituents which can interfere directly with aquatic life, or other beneficial uses of watercourses. Although discharges from these facilities seldom, if ever, create oxygen-demand problems directly, many constituents of metal finishing waste waters may interfere seriously with performance of biological systems used to treat municipal and industrial waste waters. Thus, their discharge into municipal systems could lead indirectly to oxygen-demand problems downstream even without significant addition of BOD-causing materials.

Discharge of acid waste waters in quantity sufficient to depress pH significantly may have serious corrosive effects on concrete, steel and cast iron pipes and other structures in municipal sewerage systems, treatment plants, and downstream facilities.

Plating wastes containing cyanides may create serious health hazards to sewer workers under certain conditions. Experiments have demonstrated that in sewage containing 50 mg/l cyanide, the presence of acid conditions could lead to release of lethal concentrations of the gas into the sewerage system. Investigators have suggested that cyanide concentrations in sewers should be maintained below 10-20 mg/l (Battelle Memorial Institute, 1968).

Release of volatile solvents from these waste waters into sewerage systems may create serious health hazards to workers because of excessive concentration of toxic constituents in the atmosphere. Sometimes solvents may lead to serious explosion hazards within sewerage systems or at treatment plants receiving the waste-water flows.

Adverse effects on biological processes used for treating municipal sewage may be serious. In particular, heavy metals and cyanides can interfere with biological processes, including activated sludge, trickling filters, oxidation ponds, and sludge digestion. Aerobic organisms may become acclimatized to low concentrations of cyanides and can even decompose them under certain circumstances, but slug discharges of cyanides have been observed to cause serious disruptions of aerobic and anaerobic (sludge digestion) processes. Considering the health implications of cyanides and to avoid possibility of interference with treatment processes, many municipalities limit cyanide concentrations to low levels, usually approximating 1-2 mg/l (Battelle Memorial Institute, 1968).

Metallic waste-water constituents can exert toxic effects on bacteria and other organisms in biological treatment processes. Many heavy metals may precipitate and accumulate in the plant to levels several times those in incoming waste water, leading to very high concentration in aerobic systems and in sludges discharged to anaerobic digesters. Accordingly, in reviewin observations on heavy metals in biological treatment processes, it is necessary to distinguish carefully between allowable concentrations in incoming sewage and those which actually may be attained in the treatment process.

Partly because of this situation, evaluation of concentrations at which various heavy metals become objectionable in biological treatment plants has been the subject of extensive controversy. Until only a few years ago, it generally was considered that toxic thresholds in sewage for chromium, copper, cadmium, zinc, nickel and several other metals ranged from less than 1 mg/l to, perhaps, 5 mg/l. More recent work indicates that toxic thresholds of most metals in aerobic processes are substantially higher and today many individuals suggest that allowable concentration in waste waters undergoing biological treatment may be increased safely to, perhaps, 5-10 times the levels previously considered to be acceptable. Specific data summarizing toxic effects of metals on various treatment processes may be found in many references (Bailey et al. 1970; Battelle Memorial Institute, 1968; Jackson & Brown, 1970; McKee & Wolf, 1963; US Department of Health, Education, and Welfare, 1965).

Adverse effects of cyanides and metals in receiving streams usually are manifested through toxicity to fish and many other types of aquatic life. Lethal concentrations of many constituents of metal finishing waste waters to fish are summarized in numerous publications (Battelle Memorial Institute, 1968; Jackson & Brown, 1970; McKee & Wolf, 1963; US National Technical Advisory Committee on Water Quality Criteria, 1968). Table 5 summarizes concentrations which have been reported to be fatal to fish, but it must be noted that values reported by different investigators vary widely both above and below those in Table 5 (Pickerin & Henderson, 1966). Allowable concentrations in a receiving stream in which it is desired to protect fish life obviously must be below the lethal concentration. Standards published by various agencies usually permit metals in streams not exceeding 1/10 to 1/100 of the LD_{50} - that concentration which kills half of the test fish during the bioassay test.

An effect of toxicants on fish life which has been ignored all too often is impact which the material may have on fish-food organisms. These adverse effects may be related simply to destruction of fish food, thereby having an obvious harmful effect on productivity. An alternate type of impact may be found in accumulation of metals in organisms comprising the food chain, ultimately leading to destruction of fish through toxicity of its food supply, as contrasted with direct toxic effects from constituents dissolved in the water.

Waste waters from metal plating operations also may be important because of adverse effects on other beneficial uses of the watercourse. For example, many incidents have been reported where plating waste waters caused death of livestock using the receiving stream for watering. Also, some constituents of waste waters may exert serious adverse effects on agricultural utility of the water because of toxicity to the crop being grown or accumulation of objectionable materials in harvested produce. Also, biological accumulation may cause objectionable concentrations of metallic constituents in fish taken from streams receiving metal finishing wastes, making them unsafe for human consumption.

An exceedingly important potential impact of metal finishing waste waters may be found in instances where the receiving stream is used subsequently as a public water supply. The important health effects of cyanides and numberous metals on persons consuming water has been well documented. This is illustrated by existence of recommended or required limitations on concentrations of those constituents in potable water standards of the World Health Organization (1970, 1971), the US Department of Health, Education, and Welfare (1962), and of many other countries. Some of the requirements are summarized in Table 6.

4. IN-PLANT CONTROLS

In the metal finishing industry, as in few others, costs for treating and disposing of waste waters may be influenced radically by relatively simple in-plant controls applied to the processing operations. These measures are directed towards reducing the volume of flow and losses of objectionable constituents and, if pursued with sufficient diligence, ultimately could result in virtual elimination of major waste-water flows and pollution problems.

Much of the pollutional load from metal finishing plants results from drag-out of plating solutions from processing baths into rinse tanks and any approach which reduces drag-out will reduce discharges of potential pollutants. Some steps commonly incorporated into processing operations to reduce drag-out include provision of facilities for increasing time in which the treated objects can drain before passing into the next bath or rinse, installation of dripboards or tanks, air jetting, tumbling, or vibrating the pieces to facilitate removal of liquid. All of these help reduce losses of processing chemicals, which represent the bulk of pollutants discharged from plating facilities.

Recovery of chemicals sometimes may be practised successfully, but this requires very sharp reductions in water usage to allow concentration of rinses to volumes small enough to permit their return to the plating bath. Several techniques reported to give major reductions in rinse water requirements include: installation of multiple rinse tanks through which the work passes in series, adoption of counter-current rinsing techniques to reduce water consumption even further, increased care in control of water flows through rinse tanks, use of sprays for rinsing, adoption of improved techniques for supporting work parts, and good maintenance of racks and tanks to reduce opportunities for drag-out, drips and leaks (Battelle Memorial Institute, 1968; Chalmers, 1970; Foulke, 1963).

Another step which has been reported as helpful in reducing waste-water discharges and facilitating treatment of waste waters is to provide tanks for impounding possible spills. Occasionally, segregation of waste waters may be accomplished into a non-toxic flow which can be dischaged without treatment and other flows requiring treatment. Also, sometimes it is desirable to segregate wastes requiring different types of treatment into separate collection systems, each leading to treatment units most appropriate for that flow.

Many waste-disposal problems in even the smallest shop could be reduced radically through adopting many of the measures which have been outlined (Battelle Memorial Institute, 1968). However, space requirements and costs of installing equipment to accomplish all of these steps may preclude their use in many small metal finishing shops and their operation may be too complex and expensive to be justifiable based on potential savings.

5. METHODS OF TREATMENT AND DISPOSA

Metal finishing waste waters may contain several materials with potential for causing pollution problems, but space limitations here do not allow detailed discussion of the many types of constituents and appropriate treatment processes. Accordingly, waste-water treatment will be reviewed briefly only for two of the most common categories of potential pollutants - (1) processes useful for removal of metallic constituents, and (2) those often used for destruction of cyanides.

5.1 Treatment for metals removal

Most of the metallic constituents in metal plating waste waters may be removed by precipitation at pH 8-10 with lime, followed by settling. An exception is hexavalent chromium, which occurs in waste waters from chromium plating as chromic acid or chromates. Chromium rinse waters and concentrated baths have to be kept separate for treatment because hexavalent chromium does not precipitate readily, it first is reduced to chromic acid (trivalent chromium), which precipitates at pH 8-9. Reducing agents commonly used for this operation include sulfur dioxide, sodium bisulfite, metabisulfite, and ferrous sulfate. In large plating facilities, the approach most often followed involves reduction of chromium with sulfur dioxide at a pH of 2.0-3.0;

$$SO_2 + H_2O \longrightarrow H_2SO_3$$

$$2CrO_3 + 3H_2SO_3 \longrightarrow Cr_2(SO_4)_3 + 3H_2O.$$

This reaction usually requires about 1 lb (0.45 kg) of sulfur dioxide for each pound of chromic acid (CrO_3). Sulfur dioxide may be purchased or waste flue gas in boiler plants may be used by installing scrubbers to absorb the sulfur dioxide into the chromium waste water. If reduction of the chromium is not complete, sodium bisulfite or some other reducing agent may be added to complete the reactions. Sodium bisulfite or sodium metabisulfite could be used to accomplish all of the reduction with similar effects.

Ferrous sulfate may be used but usually is practical only if a plentiful supply of waste ferrous sulfate is available nearby. Even so, use of this material frequently is questionable because of very large volumes of sludge generated when the iron precipitates, in addition to sludge produced by precipitation of chromium after the pH is raised with lime.

After reduction has been completed, the acidic solution is neutralized to a pH of 8-9 through addition of lime, sodium hydroxide, or alkaline waste waters such as treated cyanide wastes. Hydroxides of most heavy metals precipitate and may be removed by settling and dewatering for separate disposal. Effluent from this type of process usually will contain relatively low concentrations of metals, but sometimes may require additional treatment, such as filtration, for removing the last traces of precipitate before discharge.

Several other methods have been proposed for removing chromium from waste waters (Battelle Memorial Institute, 1968, 1971). One of these is based on precipitation of hexavalent chromium with barium salts but this requires addition of a highly toxic chemical which must be controlled rigorously. Further, sludges produced in the process may cause serious disposal problems because of potential toxicity. Dialysis and reverse osmosis have been proposed for purifying chromium and cyanide rinse waters. Also, electrolytic reduction of hexavalent chromium, using scrap metal, has been suggested.

Ion exchange has been used to recover chromium from diluted metal plating rinse waters, concentrated rinses from counter-current operations, and to regenerate plating baths. This may involve use of cation exchangers to remove iron and trivalent chromium from contaminated baths, cation exchangers to recover chromic acid from rinse water and removal of chromium using both cation and anion exchangers to remove trivalent and hexavalent forms. Sometimes evaporation may be used to concentrate solutions in such recovery schemes.

5.2 Treatment of cyanide waste wa

Of the many approaches proposed for treating cyanide-containing waste waters, that most commonly used today involves destruction of the cyanide by alkaline chlorination to produce nitrogen gas and carbonate:

$$2\ NaCN + 5\ Cl_2 + 12\ NaOH \longrightarrow N_2 + 2\ Na_2CO_3 + 10\ NaCl + 6\ H_2O.$$

The reactions actually occur in two steps, with the cyanide first oxidized to cyanate which is much less toxic. That reaction is substantially complete within a few minutes and theoretica requires 2.7 lb (1.23 kg) of chlorine and 3.1 lb (1.41 kg) of sodium hydroxide for each pound of cyanide (CN) destroyed. The second reaction completes destruction of the cyanide and may require 1-24 hours, with theoretical chemical requirements of 6.8 lb (3.09 kg) of chlorine and 7.3 lb (3.31 kg) of sodium hydroxide for each pound of cyanide. In practice, about 8 lb (3.63 kg) of chlorine usually is required per pound of cyanide.

Although either step may be carried out on batch or continuous-flow systems, the most common approach involves use of multiple tanks for batch treatment. This offers the advantag of permitting testing of plant effluent to ensure satisfactory treatment before discharge, without necessity for relying on the sophisticated automatic control equipment required for safe operation in a continuous-flow installation. Because the process is carried out under alkaline conditions, most heavy metals accompanying the cyanide precipitate, producing sludge which may require separate dewatering and disposal.

It is important to note that caution must be applied in operating this process because it is necessary to handle chlorine, a relatively dangerous chemical, to treat cyanide, another dangerous chemical. It is of critical importance that proper alkalinity be maintained in the solution to prevent formation and evolution of highly poisonous cyanogen chloride (Battelle Memorial Institute, 1968).

The same type of reaction, exactly, may be accomplished using hypochlorites instead of chlorine. This approach is relatively simple because it may be based on adding hypochlorite directly to the rinse water, often without requirements for additional alkalis. With any of the chemicals, however, good agitation is necessary to insure proper mixing and complete reaction. Use of hypochlorite is suggested, especially, for treatment of waste waters from small metal finishing facilities.

Ozone also may be used to oxidize cyanide to cyanate. Economic studies indicate that this approach is more expensive than chlorination, but future changes in cost of equipment and power for producing ozone could alter that situation. In a few facilities, cyanide has been removed from waste water by acidifying and stripping the volatile cyanide gas. This must be done only with greatest caution because hydrogen cyanide is extremely toxic. The approach requires dilution with large volumes of air and discharge through a high stack, or absorption in caustic solution.

Another approach which has been suggested for treating cyanide waste waters is based on conversion of cyanide to ferrocyanide by adding ferrous sulfate or pickling liquor. Where waste ferrous sulfate is available, this technique could be relatively inexpensive, but produc large quantities of sludge and strongly coloured effluent. There is some evidence that ferrocyanides may decompose under the influence of sunlight in receiving streams to release cyanide to the water. This method has not been accepted in the United States of America, but is used in Europe.

Other oxidizing agents which have been suggested for destruction of cyanides include potassium permanganate and hydrogen peroxide. Also cyanides may be complexed through adding nickel salts to form very stable nickle-cyanide compounds. It has been found that cyanides may be destroyed biologically in trickling filter and activated sludge plants, provided the organisms are properly acclimatized and cyanide concentrations do not reach toxic thresholds.

Reverse osmosis and dialysis are being considered today for purifying cyanide rinse waters. Laboratory and pilot work have indicated that ion exchange can be used to treat cyanide rinse waters but that the process may be subject to "poisoning" of the resin through irreversible absorption of complex metal cyanides. Also, passage through cation exchange units, producing an acid effluent, could lead to production of hydrogen cyanide within the equipment.

6. SURVEYS AND EVALUATIONS

It has been pointed out earlier that the flows, constituents, and concentrations of metal finishing waste waters may vary radically depending upon many factors related to the type of establishment, its operating efficiency, and size. Accordingly, each facility must be studied independently if potential problems which could be caused by that installation are to be evaluated accurately.

Evaluation of waste-water discharges from a metal finishing plant will require careful flow metering, interpretation of production schedules to select proper times to measure flows and sample, and development of carefully designed programmes to ensure collection of samples which are representative of effluent actually discharged from the installation. Usually, grab sample will mean little unless many are collected in a carefully designed programme which permits the investigator to combine the results mathematically to arrive at average and extreme values for waste-water discharges and concentrations.

Analytical measurements most likely to be appropriate for analysing the samples include appropriate metals (exact types depending upon processing undertaken at the facility), pH and cyanide determinations. Metals analyses, in particular, can be very tedious using conventional wet methods. If available, a highly desirable approach is based on using atomic absorption, which expedites such analyses greatly and usually enhances their accuracy. If this type of equipment is not available in water pollution control laboratories, it would be worth while to investigate to determine whether it might be available in local medical, food, chemical or industrial laboratories or to consider shipping the samples elsewhere for analyses.

Composite samples of the waste water are likely to be of little value unless collected in a fashion to ensure that they are weighted to flow, because great variations in flow from metal finishing installations often may distort results obtained from such samples. Where baths are dumped periodically, care should be taken to analyse them separately and to consider them individually in evaluating potential pollutional effects of the discharge.

TABLE 1. TYPICAL RINSE WATER COMPOSITION (FOULKE, 1963), p. 149

Constituent	Average mg/l	Range, mg/l
Cyanide (CN)	25	10-500
Chromate (CrO_3)	50	10-500
Nickel (Ni)	20	10-200

TABLE 2. TYPICAL EFFLUENT FROM AUTOMATIC PLANT FOR COPPER, NICKEL, AND CHROMIUM PLATING OF ZINC-BASE DIECASTINGS (LOWE, 1970), p. 279

Constituent	Concentration-mg/l
Active alkalinity as Na_2O	10-20
Hydrofluoric acid (HF)	5-10
Sulfuric acid (H_2SO_4)	60-70
Total cyanide as CN	30-40
Copper as Cu	20-30
Nickel as Ni	45-55
Zinc as Zn	3-8
Chromate as Cr	5-10

TABLE 3. TYPICAL EFFLUENT FROM AN AUTOMATIC BARREL ZINC AND CADMIUM PLATING AND PASSIVATING PLANT (LOWE, 1970), p. 280

Constituent	Concentration-mg/l
Active alkalinity as Na_2O	70-95
Hydrochloric acid (HCl)	160-200
Nitric acid (HNO_3)	0-10
Chromates as Cr	2-25
Zinc as Zn	20-30
Cadmium as Cd	10-15

TABLE 4. TYPICAL EFFLUENT FROM A MIXED MANUALLY-OPERATED BARREL AND RACK PLATING PLANT (LOWE, 1970), p. 280

Constituent	Concentration-mg/l
Active alkalinity as Na_2O	50-100
Hydrochloric acid (HCl)	140-190
Sulfuric acid (H_2SO_4)	420-470
Nitric acid (HNO_3)	140-190
Phosphoric acid (H_3PO_4)	200-270
Chromate as Cr	15-25
Cyanide as CN	40-50
Copper as Cu	3-8
Nickel as Ni	15-25
Zinc as Zn	5-10
Cadmium as Cd	7-12
Tin as Sn	1-2
Silver as Ag	0.03-0.07
Gold as Au	Trace or nil

TABLE 5. EFFECTS OF PLATING WASTES COMPONENTS ON FISH LIFE (BATTELLE MEMORIAL INSTITUTE, 1968; PICKERING & HENDERSON, 1966)

Component	Levels of concentration fatal to some fish, mg/l
Hexavalent chromium	5
Trivalent chromium	about 5
Cyanide	0.05
Ferrocyanide	1.45
Copper	0.02
Zinc	0.3
Cadmium	0.6
Nickel	5

TABLE 6. SOME CHEMICAL CONSTITUENTS IN DRINKING-WATER STANDARDS OF THE WORLD HEALTH ORGANIZATION (1970, 1971) AND THE U.S. PUBLIC HEALTH SERVICE (1962)

Chemical constituent	Concentrations in milligrams per litre						
	WHO International (1971)			WHO European (1970)		U.S.P.H.S. (1962)	
	Highest desirable level	Maximum permissible level	Upper limit of concentration	Approx. level above which trouble may arise	Upper limit of concentration	Recommended limit	Maximum allowable
Arsenic (as As)			0.05		0.05	0.01	0.05
Barium		-					1.0
Cadmium		-	0.01		0.01		0.01
Chloride (as Cl)	200	600		200		250	
Chromium (hexavalent)					0.05		0.05
Copper (as Cu)	0.05	1.5		3.0*		1.0	
Cyanide (as CN)			0.05		0.05	0.01	0.2
Iron (total as Fe)	0.1	1.0		0.1		0.3	
Lead (as Pb)			0.1		0.1		0.05
Mercury (total as Hg)			0.001				
Selenium (as Se)			0.01		0.01		0.01
Silver							0.05
Sulfate (as SO4)	200	400		250		250	
Total Solids	500	1500				500	
Zinc (as Zn)	5.0	15		5.0		5.0	

* After 16 hours' contact with new pipes; but water at pumping station should have less than 0.05 mg/l of copper.

REFERENCES

Bailey, D. A., Dorrell, J. J. & Robinson, K. S. (1970) The influence of trivalent chromium on the biological treatment of domestic sewage, Wat. Pollut. Control, 69, 100-110

Barnes, G. E. (1966) Disposal and recovery of electroplating wastes, Plating, September, pp. 1115-1121

Battelle Memorial Institute (1968) A state-of-the-art review of metal finishing waste treatment, Washington, D.C. (US Department of the Interior, Federal Water Quality Administration, Report No. 12010 EIE 11/68)
Note: A 28-page "Bibliography of foreign literature on cyanide and hexavalent chromium wastewater treatment and analysis" is appended to the report.

Battelle Memorial Institute (1971) An investigation of techniques for removal of chromium from electroplating wastes, Washington, D.C. (US Environmental Protection Agency, Water Quality Office, Water Pollution Control Research Series, Report No. 12010 EIE 03/71)

Chalmers, R. K. (1970) Pretreatment of toxic wastes, Wat. Pollut. Control, 69, 281-291

Foulke, D. G. (1963) The economic use of water in the electroplating industry. In: International Union of Pure and Applied Chemistry, Re-use of water in industry, London Butterworths, pp. 147-163

Foulke, D. G. (1965) Metal finishing products. In: Gurnham, C. F., ed. Industrial wastewater control, New York, Academic Press, pp. 339-356

Jackson, S. & Brown, V. M. (1970) Effect of toxic wastes on treatment processes and watercourses, Wat. Pollut. Control, 69, 292-303

Lowe, W. (1970) The origin and characteristics of toxic wastes, with particular reference to the metal industries, Wat. Pollut. Control, 69, 270-280

McKee, J. E. & Wolf, H. W., eds. (1963) Water quality criteria, 2nd ed., Sacramento, Resources Agency of California, State Water Quality Control Board (Publication No. 3-A)

Pickering, Q. H. & Henderson, C. (1966) The acute toxicity of some heavy metals to different species of warm water fishes; Air Wat. Pollut. Int. J., 10, 453-463; Trans. Am. Fish. Soc., 91, 175-184

US Department of Health, Education, and Welfare (1962) Public Health Service Drinking Water Standards, 1962, Washington, D.C. (US Public Health Service Publication No. 956)

US Department of Health, Education, and Welfare (1965) Interaction of heavy metals and biological sewage treatment processes, Cincinnati, Ohio (US Public Health Service Publication No. 999-WP-22)

US National Technical Advisory Committee on Water Quality Criteria (1968) Water quality criteria; report . . . to the Secretary of the Interior, Washington, D.C., Federal Water Pollution Control Administration

World Health Organization (1970) European standards for drinking-water, 2nd ed., Geneva

World Health Organization (1971) International standards for drinking-water, 3rd ed., Geneva

Table 5-9 *Summary of industrial waste: its origin, character, and treatment*

Industries producing wastes	Origin of major wastes	Major characteristics	Major treatment and disposal methods
		Food and drugs	
Canned goods	Trimming, culling, juicing, and blanching of fruits and vegetables	High in suspended solids, colloidal and dissolved organic matter	Screening, lagooning, soil absorption or spray irrigation
Dairy products	Dilutions of whole milk, separated milk, buttermilk, and whey	High in dissolved organic matter, mainly protein, fat, and lactose	Biological treatment, aeration, trickling filtration, activated sludge
Brewed and distilled beverages	Steeping and pressing of grain, residue from distillation of alcohol, condensate from stillage evaporation	High in dissolved organic solids, containing nitrogen and fermented starches or their products	Recovery, concentration by centrifugation and evaporation, trickling filtration; use in feeds
Meat and poultry products	Stockyards, slaughtering of animals, rendering of bones and fats, residues in condensates, grease and wash water, picking of chickens	High in dissolved and suspended organic matter, blood, other proteins, and fats	Screening, settling and/or flotation, trickling filtration
Beet sugar	Transfer, screening and juicing waters, draining from lime sludge, condensates after evaporator, juice, extracted sugar	High in dissolved and suspended organic matter, containing sugar and protein	Reuse of wastes, coagulation, and lagooning
Pharmaceutical products	Mycelium, spent filtrate, and wash waters	High in suspended and dissolved organic matter, including vitamins	Evaporation and drying, feeds
Yeast	Residue from yeast filtration	High in solids (mainly organic) and BOD	Anaerobic digestion, trickling filtration
Pickles	Lime water; brine, alum and turmeric, syrup, seeds and pieces of cucumber	Variable pH, high suspended solids, color, and organic matter	Good housekeeping, screening, equalization
Coffee	Pulping and fermenting of coffee bean	High BOD and suspended solids	Screening, settling, and trickling filtration
Fish	Rejects from centrifuge, pressed fish, evaporator and other wash water wastes	Very high BOD, total organic solids, and odor	Evaporation of total waste, barge remainder to sea
Rice	Soaking, cooking, and washing of rice	High in BOD, total and suspended solids (mainly starch)	Lime coagulation, digestion
Soft drinks	Bottle washing, floor and equipment cleaning, syrup-storage-tank drains	High pH, suspended solids and BOD	Screening, plus discharge to municipal sewer
		Apparel	
Textiles	Cooking of fibers, desizing of fabric	Highly alkaline, colored, high BOD and temperature, high suspended solids	Neutralization, chemical precipitation, biological treatment, aeration and/or trickling filtration

Table 5-9 *Summary of industrial waste: its origin, character, and treatment (Continued)*

Industries producing wastes	Origin of major wastes	Major characteristics	Major treatment and disposal methods
		Apparel (Continued)	
Leather goods	Unhairing, soaking, deliming and bating of hides	High total solids, hardness, salt, sulfides, chromium, pH precipitated lime and BOD	Equalization, sedimentation, and biological treatment
Laundry trades	Washing of fabrics	High turbidity, alkalinity, and organic solids	Screening, chemical precipitation, flotation, and adsorption
		Chemicals	
Acids	Dilute wash waters; many varied dilute acids	Low pH, low organic content	Upflow or straight neutralization, burning when some organic matter is present
Detergents	Washing and purifying soaps and detergents	High in BOD and saponified soaps	Flotation and skimming, precipitation with $CaCl_2$
Cornstarch	Evaporator condensate, syrup from final washes, wastes from "bottling up" process	High BOD and dissolved organic matter; mainly starch and related material	Equalization, biological filtration
Explosives	Washing TNT and guncotton for purification, washing and pickling of cartridges	TNT, colored, acid, odorous, and contains organic acids and alcohol from powder and cotton, metal, acid, oils, and soaps	Flotation, chemical precipitation, biological treatment, aeration, chlorination of TNT, neutralization
Insecticides	Washing and purification products such as 2,4-D and DDT	High organic matter, benzene ring structure, toxic to bacteria and fish, acid	Dilution, storage, activated carbon adsorption, alkaline chlorination
Phosphate and phosphorus	Washing, screening, floating rock, condenser bleed-off from phosphate reduction plant	Clays, slimes and tall oils, low pH, high suspended solids, phosphorus, silica, and fluoride	Lagooning, mechanical clarification, coagulation and settling of refined waste
Formaldehyde	Residues from manufacturing synthetic resins, and from dyeing synthetic fibers	Normally has high BOD and HCHO, toxic to bacteria in high concentrations	Trickling filtration, adsorption on activated charcoal
		Materials	
Pulp and paper	Cooking, refining, washing of fibers, screening of paper pulp	High or low pH; colored; high suspended, colloidal, and dissolved solids; inorganic fillers	Settling, lagooning, biological treatment, aeration, recovery of byproducts
Photographic products	Spent solutions of developer and fixer	Alkaline, contains various organic and inorganic reducing agents	Recovery of silver, plus discharge of wastes into municipal sewer
Steel	Coking of coal, washing of blast-furnace flue gases, and pickling of steel	Low pH, acids, cyanogen, phenol, ore, coke, limestone, alkali, oils, mill scale, and fine suspended solids	Neutralization, recovery and reuse, chemical coagulation
Metal-plated products	Stripping of oxides, cleaning and plating of metals	Acid, metals, toxic, low volume, mainly mineral matter	Alkaline chlorination of cyanide, reduction and precipitation of chromium, and lime precipitation of other metals

ıble 5-9 *Summary of industrial ıste: its origin, character, and ıtment (Continued)*

Industries producing wastes	Origin of major wastes	Major characteristics	Major treatment and disposal methods
		Materials (Continued)	
ron-foundry ıroducts	Wasting of used sand by hydraulic discharge	High suspended solids, mainly sand; some clay and coal	Selective screening, drying of reclaimed sand
)il	Drilling muds, salt, oil, and some natural gas, acid sludges and miscellaneous oils from refining	High dissolved salts from field, high BOD, odor, phenol, and sulfur compounds from refinery	Diversion, recovery, injection of salts; acidification and burning of alkaline sludges
ℓubber	Washing of latex, coagulated rubber, exuded impurities from crude rubber	High BOD and odor, high suspended solids, variable pH, high chlorides	Aeration, chlorination, sulfonation, biological treatment
;lass	Polishing and cleaning of glass	Red color, alkaline non-settleable suspended solids	Calcium chloride precipitation
Naval stores	Washing of stumps, drop solution, solvent recovery, and oil recovery water	Acid, high BOD	Byproduct recovery, equalization, recirculation and reuse, trickling filtration
		Energy	
Steam power	Cooling water, boiler blowdown, coal drainage	Hot, high volume, high inorganic and dissolved solids	Cooling by aeration, storage o ashes, neutralization of excess acid wastes
Coal processing	Cleaning and classification of coal, leaching of sulfur strata with water	High suspended solids, mainly coal; low pH, high H_2SO_4 and $FeSO_4$	Settling, froth flotation, drainage control, and sealing of mines
Nuclear power and radioactive materials	Processing ores, laundering of contaminated clothes, research-lab wastes, processing of fuel, powerplant cooling waters	Radioactive elements; can be very acid and "hot"	Concentration and containing, or dilution and dispersion

Source: McGauhey, P. H.; "Engineering Management of Water Quality," McGraw-Hill Book Co. (1968).
Originally from: Nemerow, Nelson L.; "Liquid Waste of Industry," Addison-Wesley Publishing Co (1971).

Table 5-6 *Sign[illegible]ificant chemicals in industrial waste waters*

Chemical	Industry
Acetic acid	Acetate rayon, pickle and beetroot manufacture
Alkalies	Cotton and straw kiering, cotton manufacture, mercerizing, wool scouring, laundries
Ammonia	Gas and coke manufacture, chemical manufacture
Arsenic	Sheep-dipping, fell mongering
Chlorine	Laundries, paper mills, textile bleaching
Chromium	Plating, chrome tanning, aluminum anodizing
Cadmium	Plating
Citric acid	Soft drinks and citrus fruit processing
Copper	Plating, pickling, rayon manufacture
Cyanides	Plating, metal cleaning, case-hardening, gas manufacture
Fats, oils, grease	Wool scouring, laundries, textiles, oil refineries
Fluorides	Gas and coke manufacture, chemical manufacture fertilizer plants, transistor manufacture, metal refining, ceramic plants, glass etching
Formalin	Manufacture of synthetic resins and penicillin
Hydrocarbons	Petrochemical and rubber factories
Hydrogen peroxide	Textile bleaching, rocket motor testing
Lead	Battery manufacture, lead mining, paint manufacture, gasoline manufacture
Mercaptans	Oil refining, pulp mills
Mineral acids	Chemical manufacture, mines, Fe and Cu pickling, DDT manufacture, brewing, textiles, photo-engraving, battery manufacture
Nickel	Plating
Nitro compounds	Explosives and chemical works
Organic acids	Distilleries and fermentation plants
Phenols	Gas and coke manufacture; synthetic resin manufacture; textiles; tanneries; tar, chemical, and dye manufacture; sheep-dipping
Silver	Plating, photography
Starch	Food, textile, wallpaper manufacture
Sugars	Dairies, foods, sugar refining, preserves, wood process
Sulfides	Textiles, tanneries, gas manufacture, rayon manufacture
Sulfites	Wood process, viscose manufacture, bleaching
Tannic acid	Tanning, sawmills
Tartaric acid	Dyeing; wine, leather, and chemical manufacture
Zinc	Galvanizing, plating, viscose manufacture, rubber process

SOURCE: Klein [8]. Reproduced by permission of the publisher.

Table 5-7 *BOD of wastes from selected industries*

Source of waste	5-day, 20°C BOD of waste, mg/liter
Beet sugar refining	450–2,000
Brewery	500–1,200
Beer slop	11,500
Cannery	300–4,000
Grain distilling	15,000–20,000
Molasses distilling	20,000–30,000
Laundry	300–1,000
Milk processing	300–2,000
Meat packing	600–2,000
Pulp and paper	
Sulfite	20
Sulfite-cooker	16,000–25,000
Tannery	500–5,000
Textiles	
Cotton processing	50–1,750
Wool scouring	200–10,000

Source: McGauhey, P. H.; "Engineering Management of Water Quality," McGraw-Hill Book Company (1968).

Table 5-4 *Water requirements per unit of product, selected U.S. industries*

Industry and product	Unit of product, tons (except as noted)	Water required per unit, U.S. gallons
Chemical industries		
Acetic acid	Ton of HAc	120,000–290,000
Alcohol	Gallon	52–138
Ammonia	Ton of NH_3	37,500
Ammonium sulfate	. . .	240,000
Calcium carbide	. . .	36,500
Calcium metaphosphate	Ton of $Ca(Po_3)_2$	2,800
Carbon dioxide	. . .	24,500
Caustic soda	Ton of NaOH (11%)	22,000–26,500
Cellulose nitrate	. . .	12,000
Charcoal and wood chemicals	Ton of $CaAc_2$	79,000
Corn refining	Ton of starch	333
Gasoline	Gallon	7–34
Gunpowder	. . .	200,000
Hydrochloric acid	Ton of 20 Bé° HCl	3,500
Hydrogen	Ton of H_2	800,000
Lactose	. . .	235,000
Oxygen	100 ft^3	65
Soap	. . .	300–600
Soda ash	. . .	18,000–22,000
Sulfuric acid	Ton of 100% H_2SO_4	800–6,000
Sulfur	. . .	3,000
Food and beverage industries		
Beet sugar	. . .	20,000–25,000
Bread	. . .	600–1,200
Beans, green	. . .	20,000
Peaches and pears	. . .	5,300
Other fruits and vegetables	. . .	2,000–10,000
Gelatin	. . .	15,000–24,000
Meat packing	Ton live weight	5,000
Milk products	. . .	4,000–5,000
Oils, edible	Gallon	88
Sugar	. . .	1,200–2,600
Beer	Gallon	15
Whisky	Gallon	80

Table 5-4 *Water requirements per unit of product, selected U.S. industries (Continued)*

Industry and product	Unit of product, tons (except as noted)	Water required per unit, U.S. gallons
Pulp and paper		
Kraft pulp	Ton dry pulp	110,000
Sulfate pulp	. . .	82,000
Sulfite pulp	. . .	82,000–230,000
Soda pulp	. . .	101,000
Paper	. . .	47,000
Paperboard	. . .	17,500–103,000
Strawboard	. . .	31,500
Textile industries		
Cotton	. . .	20,000–76,000
Cotton bleaching	. . .	72,000–96,000
Cotton dyeing	. . .	9,500–19,000
Linen	. . .	200,000
Rayon	Ton of yarn	105,000–240,000
Wool scouring	. . .	40,000–240,000
Metal and metal products		
Rolled steel	. . .	96,000
Finished steel	. . .	79,000
Fabricated steel	. . .	52,000
Steel sheets	. . .	16,000
(Average all products)	. . .	20,000–35,000
Aluminum	. . .	360,000
Miscellaneous		
Electric power	kwhr	85–185
Coal washing	. . .	1,800–4,300
Leather tanning	Ton, raw hide	19,500
Synthetic rubber	. . .	24,000–300,000

Source: McGauhey, P. H.; "Engineering Management of Water Quality," McGraw-Hill Book Company (1968).

EFFLUENT VOLUMES FROM THE MANUFACTURE OF PULP AND PAPER PRODUCTS

Process	Gal per ton
Pulp manufacture	
Kraft and soda pulps	15,000-35,000
Sulfite pulp	40,000-60,000
Semichemical pulp	30,000-40,000
Groundwood pulp	4,000-10,000
Deinked pulp	20,000-35,000
Pulp bleaching	
Kraft and soda pulp	15,000-60,000
Sulfite pulp	30,000-50,000
Neutral sulfite pulp	40,000-60,000
Paper manufacture	
White papers	20,000-40,000
Tissues	8,000-35,000
Kraft papers	2,000-10,000
Paperboard	2,000-15,000
Specialty papers	20,000-100,000

EFFLUENT LOADS FROM PULP AND PAPER MANUFACTURE

Effluent	lb per ton of product	
	Suspended Solids	5-day BOD
Kraft and soda pulp	20-30	25-50
Groundwood pulp	40-80	15-25
Sulfite pulp (no liquor recovery)	20-40	400-600
Neutral sulfite semichemical pulp	100-180	250-450
Textile fiber pulps	300-500	200-300
Straw pulp	400-500	400-500
Bleaching	6-35	12-200
Deinked pulp	500-800	100-130
Fine papers		
Tissue	50-100	15-30
Bond, mimeo, and printing	50-100	20-40
Glassine	10-15	15-25
Coarse papers		
Boxboard	50-70	20-40
Corrugating board	50-70	25-60
Kraft wrapping	15-25	5-15
Newsprint	20-60	10-20
Specialty papers		
Fiber	200-300	140-170
Asbestos	300-400	20-40
Roofing felt	50-100	40-60
Insulating board	50-100	150-250

Source: Gurnham, C. Fred; "Industrial Wastewater Control;" Academic Press, (1965).

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SELECTED BIBLIOGRAPHY RELATING TO BRINE WASTES AND THEIR TREATMENT

Anon. 1969. Water Desalting Techniques--A Summary. Water and Waste Engng/ Industrial 6: F-1 - F-6.

Barnes, G.E., and L.W. Weinberger. 1958. Internal Housekeeping Cuts Wastes Treatment at Pickle Packing Plants. Wastes Engng, Jan., 1958.

Bomben, J.L., E.L.Durkee, and E. Lowe. 1973. Countercurrent Desalting of Pickle Brine Stock. Preprint from USDA-ARS, Western Regional Research Laboratory, Berkele Calif. To be publ. in J. Food Science.

Burr, D., and P.J. Byrne. 1971. City and Industry Cooperate to Solve Brine Waste Problem. Publ. Works 102: 46-48.

Day, M.E. 1970. Brine Disposal Pond Manual. Bureau of Reclamation Report: Office of Saline Water Research and Development Progress Report No. 588.

Downing, D.L. 1971. Environmental Problems in the Food Processing Industry. In Agricultural Wastes: Principles and Guidelines for Practical Solutions, Cornell Univ. Conf. on Agricultural Waste Management, Feb. 10-12, 1971.

Envirogenics Company. 1970. New Technology for Treatment of Wastewater by Reverse Osmosis. Water Pollution Control Research Series 1702DU-09/70, Water Quality Office, EPA, Washington, D.C.

Field, R., E.J. Struzeski, Jr., H.E. Masters, A.N. Tafuri. 1973. Water Pollution and Associated Effects from Street Salting. EPA-R2-73-257, May, 1973.

Fox, R.D., R.T. Keller, and C.J. Pinamont. 1973. Recondition and Reuse of Organically Contaminated Waste Sodium Chloride Brines. EPA-R2-73-200, May, 1973.

Fryberger, J.S. 1972. Rehabilitation of a Brine-Polluted Aquifer. EPA-R2-72-014, Dec., 1972.

Gaffney, J.G., R. Kunin, and D.G. Downing. 1970. Ion Exchange for Industrial Water, pp. 258-293. In E.F. Gloyna and W.W. Eckenfelder, Jr., Water Quality Improvement by Physical and Chemical Processes, Univ. of Texas Press, Austin.

Giannini, A.P., E.P. Ramirez, and E.C. Beck. 1973. Clarifying Processed Food Waste Waters by Electrocoagulation. Presented at 33rd annual IFT Convention, June, 1973, Miami, Fla.

Henne, R.E., and J.R. Geisman. 1973. Recycling Spent Cucumber Pickling Brines. Presented at 1973 Food Processing Waste Management Conference, Syracuse, N.Y., March 26-28.

Hornsby, A.G. 1973. Prediction Modeling for Salinity Control in Irrigation Return Flows. EPA-R2-73-168, March, 1973.

Johnson, W.E. 1969. Freeze-desalting Process for Water Supply and Industrial Waste Treatment. Water and Wastes Engng/Industrial 6: F-20 - F-22.

Little, L.W. 1964. Waste Handling Problems of the Pickle and Olive Industries, pp. 24-33, in Seminar Proceedings, ESE Publ. No. 85, UNC-Chapel Hill.

Lowe, E., and E.L. Durkee. 1971. Salt Reclamation from Food Processing Brines, pp. 77-83. In Proceedings of the Second National Symposium on Food Processing Wastes. Water Pollution Control Research Series 12060--03/71.

Mercer, W.A. 1970. Reconditioning and Reuse of Olive Processing Brine, pp. 281-293, Proc., First Natl Symp. on Food Processing Wastes, Water Pollution Control Research Series 12060--04/70.

Mercer, W.A., J.W. Ralls, and H.J. Maagdenberg. 1971. Reconditioning Food Processing Brines with Activated Carbon. Chem. Engng. Progress, Symposium Series 67: 435-438.

National Canners Association. 1971. Reconditioning of Food Processing Brines. Water Pollution Control Research Series 12060EHU03/71. Water Quality Office, EPA.

National Canners Association. 1971. Reduction of Salt Content of Food Processing Liquid Waste Effluent. Water Pollution Control Research Series 12060DXL 01/71. Water Quality Office, EPA.

Nemerow, N.L. 1963. Theories and Practices of Industrial Waste Treatment. Addison-Wesley Publishing Company, Inc., Reading, Mass.

Ralls, J.W., W.A. Mercer, and N.L. Yacoub. 1971. Reduction of Salt Content of Food Processing Liquid Waste Effluent. In Proceedings of the Second National Symposium on Food Processing Wastes. Water Pollution Control Research Series 12060--03/71.

Riedinger, A., I. Nusbaum, and J. Cruver. 1972. RO Applications in Water Reuse and Recovery. Ind. Water Engng 9: 30-34.

Rinne, W.W. 1970. Brine Disposal. Presented at the Sumposium on Reverse Osmosis, Nov. 4-5, 1970, Roswell, N.M.

Schmidt, C.J., E.T. Conrad, and T.D. Wright. 1971. Characterization of Waste Effluent from Processing of 18 Fruit and Begetable Commodities. Preprint of information for report for EPA Contract # 68-01-0021.

Skogerboe, G.V. 1971. Research Needs for Irrigation Return Flow Quality Control. Water Pollution Control Research Series 13030--11/71, EPA.

Skogerboe, G.V., and Walker, W.R. 1972. Evaluation of Canal Lining for Salinity Control in Grand Valley. EPA-R2-72-047, Oct., 1972.

Young, K.G. 1971. Desalting Technology in Pollution Control Problems. J. Am. Water Wks Assoc.63: 21-24.

From ESE PUBLICATION No. 85, Proceedings of Seminar Series on Food Technology, 1964. RECENT DEVELOPMENTS IN PROCESSES, PRODUCTS, AND PROBLEMS OF THE FOOD INDUSTRY.

WASTE HANDLING PROBLEMS OF THE PICKLE AND OLIVE INDUSTRI

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Linda West Little

Introduction

The pickling of cucumbers and the pickling of olives have in common the production of wastes with a high chloride content, arising from the salt brining process during which the vegetables undergo fermentation. The wastes from the pickled cucumber industry have, in addition to a high chloride concentration, a high biochemical oxygen demand, a low pH, and a high solids content. It is an all too common practice in both the pickled cucumber and the pickled olive industries to dischar wastes without treatment, a practice which has in the former instance resulted in stream pollution and in the latter instance, in ground water contamination.

Processing of Pickled Cucumbers

The practice of pickling cucumbers was brought to America by the early Dutch settlers of the New York region (7). Now, over 100,000 acre of cucumbers are harvested annually for processing. In 1961 17,450,000 bushels were produced, with a farm value of $23,405,000 (1).

The United States Standards for Cucumber Pickles, as set forth in the Almanac of the Canning, Freezing, Preserving Industries, state that

> Cucumber pickles means the pickled product prepared from clean, sound, fresh, immature cucumbers which have been cured by natural fermentation in a solution of common salt with or without the addition of dill herbs and processed or preserved in a liquid packing medium which may be seasoned with suitable nutritive sweetening ingredients, salt, a vinegar or vinegars, spices or flavoring or both, and onions or garlic or both, and with or without other seasoning or flavoring ingredients to give the product a flavor and characteristics of the respective type, with or without the addition of any other ingredient or ingredients which may be permissible under the provisions of the Federal Food, Drug, and Cosmetic Act (2).

The Standards also set forth the proportion of vegetables, such as cauliflower and onions, which may be added to various cucumber products. Styles of pickles are listed as whole, cross-cut, lengthwise slice, cut, and finely cut (2). Types are listed as natural dill, processed dill, sour, sweet, sour mixed, sweet mixed, sour chow-chow, sweet chow-chow, sour relish, and sweet relish (2). The style and type of pickle being processed have an important bearing on the characteristics of the wastes arising; in general, the sweeter or the more finely cut is the product, the greater the pollutional strength of the wastes arising.

Pickle-packing is usually a year-round operation (2, 17), and plants tend to operate on a ten-hour day, five-day week basis (17). Processing of salt stock is done throughout the year, and fresh-pack processing is done during the cucumber harvest season, May through July. Plants commonly produce to order, and therefore the type of product being processed varies from day to day (17). The leading pickle-processing states are California, Michigan, Minnesota, North Carolina, Oregon, Washington, and Wisconsin (2).

A flow-sheet of the steps in converting cucumbers into pickles is shown in Figure 1, page 26. Harvested cucumbers are placed into vats with 15-20 per cent salt brine. Lids are used to keep the cucumbers from floating. After about a week fermentation begins. This fermentation is carried out largely by lactobacilli and closely related bacilli (26), which act on the sugars leached from the cucumber by the brine. After approximately three months in the brine, the pickles are graded and returned to the vats for storage. When the stored salt-stock is needed for processing, the pickles are washed and then "freshened" in an alum and turmeric solution which promotes coloring, swelling, and firming (18). During the freshening air is pumped into the solution to keep the pickles in motion (18). Subsequent processing depends on the style and variety of pickle product desired.

Figure 2, page 26, shows the steps in the preparation of sweet pickle products. Whole pickles go directly into vats for impregnation with vinegar and sugar syrups, whereas pickles destined to become chips, relish, and so on are first sliced to desired degree, usually (18) in a rotating cutter which simultaneously cuts the pickles and sprays the pieces with a jet of water. After the "sweetening" tank, the pickles are packed into jars, covered with the vinegar and syrup, capped, and pasteurized.

Figure 3, page 26, shows the steps in preparation of sour pickle products. The process is similar to that for the sweet pickles, except for the fact that the pickles are impregnated with a vinegar and herb mixture which contains only a small amount of sugar.

The processing of dill pickles is very similar to that for sour pickles. Dill herb is added to the brine tanks during fermentation (producing natural dill pickles) or dill-flavored vinegar is used to impregnate regularly brined pickles (producing process dill pickles).

In each of the above figures, sources of wastes are indicated. In addition to these wastes, significant amounts of wastes are contributed by seasonal conditioning of the vats (18) and by cleanup operations. The major waste sources may be summarized as follows:

1. Lime water from "sweetening" the tanks about once a year.
2. Spent brine from fermentation.
3. Turmeric and alum water
4. Washings, seeds, plant fluids (sap), pickles, and parts of pickles.
5. Processing wastes--overflow, spill, transfer losses, cooling water.
6. Daily cleanup operations.

Figure 1. STEPS IN THE CONVERSION OF CUCUMBERS INTO PICKLES

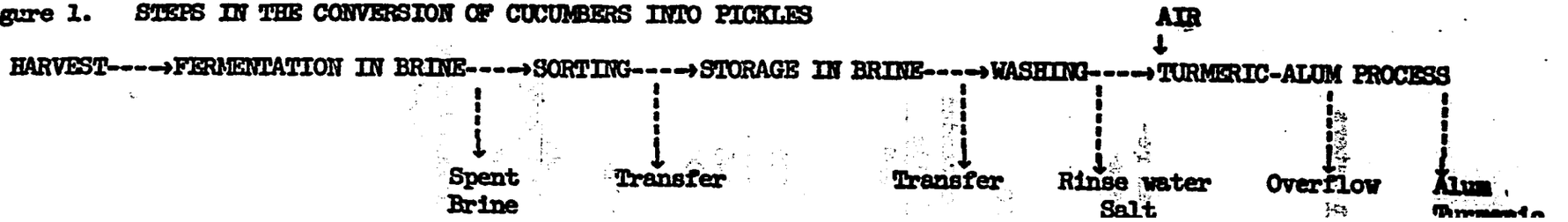


Figure 2. STEPS IN PROCESSING OF SWEET PICKLES

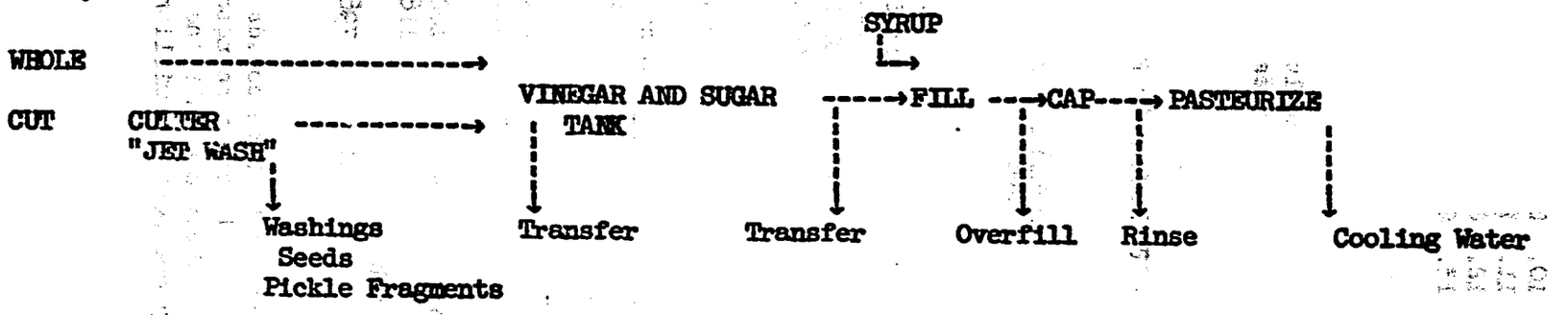
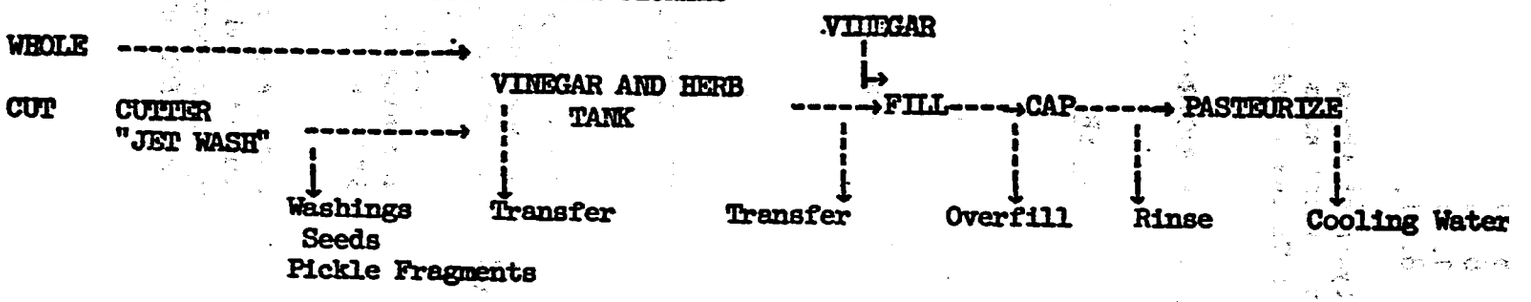


Figure 3. STEPS IN PROCESSING OF SOUR PICKLES



Components of the waste flow may include

1. Alum
2. Turmeric
3. Sodium chloride
4. Acetic acid
5. Lactic acid
6. Lactose
7. Surcrose
8. Spices
9. Dill
10. Saps
11. Pickles, seeds, slices, et cetera
12. Sand and dirt
13. Sanitary wastes

Analyses of the pollutional aspects of pickle wastes have been reported by several authors, and the results of these analyses are summarized in Tables I and II, below.

TABLE I. CHARACTERISTICS OF WASTE FLOW FROM PICKLE PROCESSING

Source	pH	BOD 5 day, 20°C. ppm	Chloride ppm	Total Solids ppm	Suspended Solids ppm
Barnes (5)	3.6-4.4	800-5400	2500-14000	------	------
Haseltine (14)	4.0	2000	6500	13,600	200
Kimball (16)	4.0-6.0	----	----	------	------
Nemerow (18)	3.9-8.8	1070	3000	8000-24000	148
Ryan (23)	4	3000	----	4000	200

TABLE II. CHARACTERISTICS OF WASTE FLOWS FROM SEVERAL PROCESSES

Source	Description of Flow	pH	Susp. Solids ppm	BOD 5 day, 20°C. ppm
Barnes (5)	Sweet liquor	2.9-3.1	----	200000-400000
"	Cleanup wash	3.9-7.0	----	0-800
Nemerow (18)	Alum-turmeric waste,			
	whole pickles	4.1	1024	420
	pickle chips	3.2	1185	1890
	Drainings from relish process	3.2	7980	2500

In brief, the wastes are characterized by high solids content, low pH, high chloride content, and high BOD. It might be noted at this point that the cooling water contributes about one-half the volume of the total waste flow but has a BOD of only one part per million (17).

What is the most widely accepted method of treating pickle wastes? In many cases the raw wastes are discharged directly to a receiving stream without even the most elementary "treatment" afforded by screening and equalization. For example, none of the eastern North Carolina pickle-processing plants provide any treatment at the present time (8, 9,17,19), although efforts are currently being directed toward the correction of this situation. Nemerow (18) relates in great detail another instance in which raw pickle wastes were discharged, at times causing such oxygen depletion in the receiving stream that fish kills were the result.

Biological treatment appears to be satisfactory in some instances. Barnes and Weinberger (5) report the use of trickling filters, activated sludge, and oxidation ponds in the treatment of pickle wastes, but unfortunately no details are given. Haseltine (14) describes pilot studies on the use of trickling filters and concludes that

1. At least 85% reduction of raw waste BOD can be achieved with proper pH control and proper loading.
2. Chloride concentrations up to 5000-6000 parts per million have little effect on treatment efficiency.

Haseltine also reports 65-70% reduction of BOD with chemical precipitation.

Discharge of wastes to a municipal system may offer a satisfactory solution, provided the pickle industry avoids overloading the municipal system and avoids sending slugs of brine to the system. Kimball (16) reports the effect on the municipal system in Crosswell, Michigan, when, due to increased demand for sweet pickles and relish, the BOD load from the local pickle plant increased to three times above the load expected. Odor and corrosion resulted, as well as a drop in efficiency of the Imhoff tank-trickling filter system from 85% to 56%. In Garland, Texas (24), experience with the effects of pickle wastes on the municipal trickling filter system prompted the suggestion that brine tanks be dumped at night, allowing some of the chlorides to bypass the filter. In Faison, North Carolina (8), the Imhoff tank once used for treating municipal wastes was abandoned when wastes from the local pickle plant rusted out the system.

Even without treatment, proper in-plant control can greatly reduce the pollutional load of the pickle-processing wastes. In one instance, a plant was able to achieve a 64% reduction in BOD simply by improving processing routines (5). The following suggestions for in-plant control were compiled from Barnes and Weinberger (5) and Nemerow (18):

1. Screening of tank drains, floor drains, and screens beneath the cutter-washer.
2. Placing of screenings and dropped pickles in garbage barrels.
3. Care to avoid overfill and spill.

4. Complete emptying of finishing tanks, conserving liquor.
5. "Double-netting" transfer if transfer is done manually; one net of pickles is allowed to drain liquids back into the tank while a net already drained is carried to the next process, reducing dripping on the floor.
6. Leak-proof packing tables with devices for collecting drippings.
7. Use of extracted, rather than starch-base, turmeric.
8. Reuse of syrups and liquors and reconditioning of brine.

Control of waste flow components until favorable stream conditions prevail can greatly reduce stream damage. Barnes (5) reports an 80% reduction in total flow BOD achieved by segregating high-strength liquors, these liquors being stored until stream flow was high. Nemerow (13) recommends withholding brine with slow discharge during rainfall or high stream flow and with dilution with lime water and other low-chloride wastes.

The eastern North Carolina pickle industries have banded together to form a cooperative to study means of reducing stream damage due to the wastes from their plants (17). The plants have decided to modernize their equipment to minimize product and liquor losses, and they have conducted pilot studies of several methods of biological treatment.

Processing of Pickled Olives

Nearly all of the olives produced and processed in the United States are produced and processed in California. In 1961, olive production in the United States was 43,000 tons, of which 26,000 tons were canned and 8,800 tons minced and brined (1). The farm value of these olives was $6,966,000 (1). The San Joaquin Valley of California contains about 40% of the state's (and the nation's) olive acreage, and processor-canners in this Valley can about 60% of the total amount of olives canned (15). Two principal types of olives are produced, ripe olives and common green or Spanish olives (15). It is from the processing of ripe olives that the large volumes of high salt wastes arise (15), although green olive processing also produces brine wastes (26).

Steps in the processing of ripe olives may be outlined as follows:

1. Harvesting and delivering to processor.
2. Grading to size.
3. Storage in 5-10% salt brine to soften the outer tissue (26).
4. Treatment with 0.7 to 2.0% lye solution to remove the natural bitterness due to a glucoside, oleuropein (26). Several lye treatments, each followed by washings.
5. Aeration of lye solutions or exposure to the air of the atmosphere to give the black or dark brown color desired. (Green ripe olives do not get this treatment.) (15)
6. Washing with water and/or dilute acid to remove alkali.
7. Fermentation in 2 to 5% brine, from 2-6 weeks (26), This is a lactic acid fermentation similar to that of pickled cucumbers.

8. May or may not have pasteurization at this point (15).
9. Grading and sorting.
10. Packing in cans, filling with hot brine, sealing.
11. Sterilizing.

Olives may be subsequently unpacked, pitted and stuffed with brined pimento, and repacked into jars with salt and lactic acid brine (7).

The major sources of wastes are the strong brine discharged from the storage vats and the lye coming from the processing, this lye coming from the washings since the 0.7-2.0 per cent lye solution is reused (15).

The olive canning season in California runs from October 15-February 15 (2); however, some processors operate all or most of the year (15).

The olive wastes have been a problem in California for many years, Gillespie (12) reporting in 1929 that olive pickling works were among those industries causing stream damage. It is now the practice in California to discharge olive waste directly to land surface via ponds or indirectly to land surface through municipal sewerage systems (15). Municipal plants receiving olive wastes use their effluents at one time or another for irrigation (15). Contamination of ground water with chlorides is in many cases suspected and in some cases proved. In one instance, chloride concentrations in water from wells near the municipal sewage treatment plant have increased by about 150 parts per million in the last ten years (15). It might be noted that the sewage treatment plants do not reduce the mineral concentration of the olive waste and that all the salt discharged by the olive plant gets onto the land sooner or later (15).

The Department of Water Resources recommends placing of restrictions on the "quality of waste waters being discharged to land surface, by means of ponds or irrigation use, to the following maximum limits: chloride concentration of 175 ppm, total dissolved solids concentration of 1,000 ppm, and percent sodium of 70 percent." (15) What can the processors do without resorting to costly methods of chloride removal? Colonel Gorlinski, the executive officer of the Central Valley Region Water Pollution Control Board, California, states that "Probably the greatest unsolved problem...involves in-plant process alterations which are needed to reduce waste effluent volumes and strengths to allow easier handling" and that "Proper control systems within the plant could drastically alter the waste disposal problem, making it much more amenable to control procedures." (13) Gorlinski also reports that the Western Research Lab of the National Canners Association is working on the problem of in-plant changes for olive packing plants.

Conclusions

The pickled cucumber and the pickled olive industries offer two excellent examples of the need for industries to examine and analyze in-plant procedures and to determine means of in-plant control of waste

flows. Such in-plant control can reduce water pollution, reduce the costs of waste treatment, and perhaps even eliminate the need for all treatment beyond screening and equalization. In most cases, the industries themselves benefit by reduction of product losses and by reduction of costs for processing ingredients, such as sugar, salt, and vinegar. In these and similar cases perhaps the best selling point in the "sale" of in-plant control is that the industry itself will benefit financially by such pleasant means as good housekeeping and modernization of equipment.

References

1. Agricultural Statistics, 1962, pp. 306, 272. Washington, D. C.: U.S. Government Printing Office, 1963.

2. Almanac of the Canning, Freezing, Preserving Industries, 48th ed. Westminster, Maryland: Edward E. Judge, 1963.

3. Baffa, John J., "Design of Neutralization Basins for Acid Wastes," Industrial Wastes 5:107-111, (1960).

4. Banadyga, Albert A., Cucumbers for Pickles: A 1948 Survey of Literature Dealing with Their Production. Oak Park, Illinois: National Pickle Packers Association, 1949.

5. Barnes, George E. and Leon W. Weinberger, "Internal Housekeeping Cuts Wastes Treatment at Pickle Packing Plants," Wastes Engineering 29:18-21 (1958).

6. Besselievre, Edmund B. Industrial Waste Treatment, 1st edition, p. 104. New York: McGraw-Hill Book Company, Inc., 1952.

7. Binsted, Raymond, James D. Devey and John C. Dakin, Pickle and Sauce Making, 2nd ed. London: Food Trade Press Ltd., 1962.

8. Cape Fear River Basin, Pollution Survey Report No. 6, N. C. State Board of Health, Division of Water Pollution Control, Raleigh, N. C. 1957.

9. Comprehensive Pollution Abatement Plan for the Neuse River Basin, p. 31. Raleigh, N. C.: State Stream Sanitation Commission, N. C. Department of Water Resources, 1960.

10. Etchells, John L., Evan D. Jones and Thomas A. Poell, "Advances in Cucumber Pickling," in Crops in Peace and War, The Yearbook of Agriculture, 1950-51. Washington, D. C.: U. S. Govt. Printing Office, 1952, pp. 228-236.

11. Foytik, Jerry, "Trends and Outlook, California Olive Industry," California Agr. Expt. Station Extension Service, Circular 492, December, 1960.

12. Gillespie, C. G., "The Sewage Situation in California," Sewage Works Journal 1: 460-475 (1929).

13. Gorlinski, Joseph S., Executive Officer, Central Valley Regional Water Pollution Control Board (No. 5), California. Private Communication.

14. Hazeltine, T. R., "Biological Filtration of Kraut and Pickle Wastes," Water and Sewage Works 99(4):161-165 (1952).

15. "Investigation of Olive Processing Waste Discharges in the San Joaquin Valley," Department of Water Resources, The Resources Agency of California, Unpublished Report, 1962.

16. Kimball, Floyd L., "Treatment Problems Caused by Cucumber Canning Wastes," Journal of the Water Pollution Control Federation 32: 429 (1960).

17. Macon, John, Industrial Extension Service, North Carolina State of the University of North Carolina at Raleigh. Private interview.

18. Nemerow, Nelson L. Theories and Practices of Industrial Waste Treatment. Reading, Massachusetts: Addison-Wesley Publishing Co., Inc., 1963.

19. Neuse River Basin, Pollution Survey Report No. 7, N. C. State Board of Health, Division of Water Pollution Control, Raleigh, N. C., 1958.

20. "Packing Olives the Modern Way," Canner-Packer 130 (11):38-39 (1961).

21. Parry, John W. Spices: Their Morphology, Histology, and Chemistry. New York: Chemical Publishing Company, Inc., 1962.

22. Prescott, Samuel C. and Cecil G. Dunn, Industrial Microbiology, 2nd ed. New York: McGraw-Hill Book Company, Inc., 1949.

23. Ryan, William A., "Effect of Cannery Wastes on Operation of Sewage Treatment Plants," Sewage Works Journal 12 (1):99 (1940).

24. "Sewage Treatment Meets 'Amazing Growth' Problem," Public Works, New York 84 (11):59-60 (1953).

25. "Skillful Pickle Packing in 1500 Ton Plant," Canner-Packer 130 (9): 22-23 (1961).

26. Weiser, Harry H., Practical Food Microbiology and Technology, Westport, Connecticut: The AVI Publishing Company, Ind., 1962.

CHAPTER 35

PRINCIPLES FOR CONTROLLING THE OCCUPATIONAL ENVIRONMENT

Jack E. Peterson, Ph.D.

INTRODUCTION

Hazards and potential hazards in the occupational environment can be purely mechanical in nature, or they can take the form of materials which are capable of causing fire or explosion, or of producing injury by inhalation, skin or eye contact, or by ingestion. Physical forms of energy such as noise, non-ionizing and ionizing radiation, and heat are also potential hazards. Most basic to the control of any hazard is the concept that it can be controlled. Once the hazard is defined properly and the need for and the degree of necessary control is determined, then the only requirements are imagination, trained personnel and money to put the control methods to work.

The basic principles for controlling the occupational environment consist of substitution, isolation and ventilation. Not all basic control principles are applicable to every form of hazard, but all occupational hazards can be controlled by the use of at least one of these principles. Ingenuity, experience and a complete understanding of the circumstances surrounding the control problem are required in choosing methods which will not only provide adequate control, but which will consider installation, operating and maintenance costs and personal factors such as employee acceptance, comfort and convenience. Furthermore, hazards, costs and benefits can change with time so that hazard control systems need continuous review and updating. The aim, then, must be not only to devise efficient hazard control methods, but to evaluate the effectiveness of those methods at regular intervals.

SUBSTITUTION

Usually, when one thinks of controlling a hazard he thinks automatically of adding something to do the controlling. For example, an engineer is more likely to think of controlling a vapor hazard by ventilation than by substituting a less hazardous material for the one which is causing the problem. Yet, substitution of less hazardous materials or process equipment, or even of a less hazardous process, may be the least expensive as well as the most positive method of controlling an occupational hazard.

Unfortunately, substitution is not a technique easily taught. No one can sit down with a slide rule, pencil and paper and decide how to best use substitution to eliminate an occupational hazard. Instead, the principle of substitution is demonstrated best with examples so that by analogy the student may apply what he has learned to his particular problem.

Process

One of the main hazards to our atmospheric environment results from the use of gasoline-powered internal combustion engines in nearly all of our automobiles.[1] Control of this source of air pollution is being attempted in many ways, from the passage of laws to the modification of gasoline to the substitution of a less hazardous process. Substitute processes range from diesel engines to electric motors, and even include the greatly increased use of mass transit systems. That there is no agreement on the best "less hazardous process" (or in fact, that process substitution is necessary) indicates that more study is needed and problem solutions may be political as well as scientific.

Choosing a substitute process is not always difficult. For instance, dipping an object into a container of paint almost always creates much less of an inhalation problem than does the process of spraying that object. Cutting is usually less noisy than breaking or snapping; mechanical stirring causes less material to become airborne than does sparging; generating electric power from nuclear energy causes less air pollution than does the use of fossil fuel, but hydroelectric power is less polluting than either; and distillation usually causes fewer problems than does crystallization.

After considering many examples of process substitution, one principle appears to stand out: the more closely a process approaches being continuous (as opposed to intermittent), the less hazardous that process is likely to be. This principle is a fairly general one and applies to energy hazards such as noise, as well as to the more familiar material hazards. This principle is not always useful, but its application should be considered whenever hazard control by process substitution is attempted.

Equipment

Where the process itself does not need to be changed to reduce hazards, the needed control often can be achieved by substituting either equipment or materials handled, or both. Substituting equipment is nearly always less expensive than substituting processes and often can be done "on the job." On the other hand, finding a substitute material may be easy or may require extensive research and/or process changes. For these reasons, equipment is substituted more often than either processes or materials.

Equipment substitution is often the "obvious" solution to an apparent hazard. An example might be the substitution of safety cans for bottles to store or contain flammable solvents, or the substitution of safety glass for regular window glass in the sash of a "fume" hood. Examples such as these can be multiplied indefinitely because they are obvious on inspection.

One of the main requirements for efficient equipment substitution is the awareness of alternates. Persons concerned with hazard reduction must familiarize themselves with all kinds of "safety" equipment as well as with the processes and process equipment in their jurisdiction. For example, sideshield safety glasses are unlikely to be substituted for regular spectacles unless someone knows the need for, as well as the existence of, the side-shield glasses. Unless someone knows that neoprene gloves are being ruined by contact with chlorinated hydrocarbons, and also knows that polyvinyl alcohol gloves are available and impervious to this kind of attack, a substitution is unlikely.

Realistic suggestions for process equipment substitution are often based on a background in both engineering and industrial hygiene, but even without an extensive background, a fresh look at an old process or problem can pay large dividends. The man who gets out and around within a plant, a company, a city or a nation is likely to observe new solutions to problems and thus is likely to be able to apply them elsewhere. Good equipment substitution is based on common sense, ingenuity, keeping up with the state of the art, and the experience of working with people, processes, and the equipment used by both.

Material

After equipment substitution, material substitution is the technique most often used to reduce or to eliminate hazards in the occupational environment. Examples abound. The substitution (forced by a tax law in 1912) of red for white phosphorus in matches drastically reduced both an industrial and a "general" hazard. Substitution of perchloroethylene for petroleum naphtha in the dry cleaning industry essentially eliminated a serious fire hazard. Using tritium-activated phosphors instead of radium-based paint for watch and instrument dials has reduced the hazards associated with the manufacture of the dials, and in addition has reduced by a small amount the background radiation experienced by the general public. Removing beryllium phosphors from fluorescent lamps not only eliminated a hazard to the general public, but also eliminated a more serious hazard to the men manufacturing such lamps.

Many years ago the principal cold cleaning solvent was petroleum naphtha. Because of its fire hazard, a substitute material was sought. Carbon tetrachloride appeared to be ideal because of its low flammability, good solvent power, and low price. Experience and a great deal of research, however, showed that a serious fire hazard had been traded for a perhaps even more serious vapor inhalation hazard. Today, carbon tetrachloride is being supplanted by several other chlorinated hydrocarbons, notably 1, 1, 1-trichloroethane, trichloroethylene, perchloroethylene and methylene chloride. Each of these substitutes is far less toxic and far less hazardous to handle than is carbon tetrachloride, although each has its own hazards. In addition, the fluorinated hydrocarbons are being used more and more despite their expense, mainly because their inhalation and fire hazards are so low.

The principle of material substitution carries with it the same type of reward and the same potential hazards as other kinds of substitution. Substitution of a different material can reduce or eliminate hazard, but one hazard can be substituted for another inadvertently. A careful watch must be kept for unforeseen hazards that may crop up when any kind of substitution is used. An excellent source of information about the toxic properties and hazards of materials and their substitutes is the Hygienic Guide series published by the American Industrial Hygiene Association.

ISOLATION

Isolation is the term applied when a barrier is interposed between a hazard and those who might be affected by that hazard. The barrier may be physical, or distance or time may provide the isolation considered necessary.

Stored Material

Stored material rarely poses an overt hazard, and therefore, whether it is raw material or finished product, those concerned are likely to take it for granted and to assume that it poses no threat. This assumption can be dangerous.

When flammable liquids are stored in large tanks above ground, common practice is to group the tanks on a "tank farm" but to isolate each tank from the others by means of a dike made of earth or concrete. If a major spill does occur, the (possibly flaming) liquid is restrained by the dike from coming close enough to other storage tanks to affect them. For more positive protection, tanks are buried to interpose an even more formidable barrier between their contents and the general environment. A further example is to restrict the volume of material stored in a single container. This exemplifies the use of isolation to reduce a hazard by imposing many small barriers rather than one large one between the contents and the environment.

Where the principal hazard of a liquid arises from inhalation rather than from fire, the imposition of a physical barrier becomes much more difficult than simply building a dike. When the quantities are relatively small (up to a few tens of gallons, perhaps) the best storage technique uses both isolation and ventilation. An example of this practice is the more and more common use of ventilated storage cabinets in laboratories.[2] Such cabinets are usually made of fire resistant material and air is drawn through them constantly by means of a fan which discharges out-of-doors. This type of arrangement interposes both a physical and a ventilation barrier between the contents of storage vessels and the laboratory environment and in ad-

dition, may free much valuable hood space for other than storage use.

Solids usually are stored either in original containers (bags, cans, or drums), bins, or simply in piles which may even be out-of-doors. Except in unusual cases, solids rarely pose problems in storage which compare in magnitude with those of liquids and gases. Outside storage piles can be unsightly and can be the source of air pollution problems; in such cases a physical barrier is the usual answer. The barrier may be as simple as a tarpaulin or as complex as a storage building with several kinds of materials handling equipment.

Equipment

Most equipment used in processing operations is designed to be safe if it is used properly. On the other hand, there are times and cases where this is far from true. Equipment that is operated under very high pressure, for instance, may well pose a severe hazard even when operated correctly. In such cases, the proper action to take is to isolate the equipment from the occupational environment. Usually physical barriers are used and the barriers may be very formidable ones, indeed. Extensive use may be made of armor plate as well as reinforced concrete, mild steel, and even wood. Viewing the work area may be done by remote controlled television cameras, simple mirrors or periscopes.

Equipment isolation may be the easiest method of preventing hazardous physical contact, for instance with hot surfaces. Insulating a hot water line may not be economical from a strictly monetary standpoint, but may be necessary simply because that line is not sufficiently isolated from people by distance.

Inhalation hazards can often be reduced markedly by equipment isolation. One example is that of isolating pumps. Nearly all pumps used in industry can leak and will do so, at least occasionally. Proper planning should take this fact into consideration, perhaps by arranging vessels and piping so that pumps handling hazardous materials can all be located in one area. That area, then, can be isolated physically from the remainder of the process equipment. If, then, the pump room (and/or each pump) is ventilated properly, minor leaks will be of no consequence, and major ones will be repairable without a serious inhalation hazard to the mechanic.

Process

Process isolation is usually thought to be the most expensive of the isolation methods of hazard control, and thus is probably the least used. Nevertheless, with today's space-shot-perfected techniques, some extremely complex processes and equipment have been shown susceptible to remote control, and in principle there is probably no process which cannot be operated remotely if the expense of remote operation is justified.

Process isolation techniques were given great impetus when men sought ways in which to handle radioisotopes safely. They found that the hazard from external radiation sources could be attenuated with shielding and distance, but both of these techniques required the development of very sophisticated methods of remote operation. Master-slave manipulators were designed to allow direct "handling" of equipment from very remote locations and this, in turn, accelerated the development of different viewing methods, complex electronic systems, and the theory and philosophy of remote operation.

The modern petroleum processing plant is an example of the use of remote processing. Many of the newer plants are based almost completely on centralized control with automatic sampling and analysis, remote readout of various sensors, on-line computer processing of the data, and perhaps actual computer control of process equipment. These techniques were not developed with hazard control uppermost in mind; instead, economy of operation was the spur, but safety was a by-product.

Computer-controlled processing also appears to be gaining acceptance in the chemical industry. For the most part, this change has been in response to economic pressures because, despite their high initial costs, computer-controlled continuous processing plants can be operated with much less expense than that associated with manual operation, and at the same time produce a superior product. Such plants enjoy the advantages of remote operation and also those of continuous processing with attendant relatively low volumes of materials actually being handled. This combination can result in a very low hazard potential.

Process isolation, however, by its very nature can pose some rather extreme hazards. That is, when human intervention is required, the potential hazard may rise abruptly from near zero to near certainty. In such cases, full use must be made of techniques of isolating the man from his environment.

Workmen

Isolating workmen from their occupational environment has been used since antiquity, and will continue to be necessary in the foreseeable future. The first blacksmith to don an apron of hide was using this principle just as certainly as is the present day radioisotope handler with his plastic airsupplied sealed suit and its connecting "tunnel."[4] Pliny, the Elder, wrote about the use of pig's bladders by miners to reduce the amount of dust inhaled[1] and today advertising men extol the virtues of masks made of polyurethane foam to accomplish the same thing.

Using personal protective equipment of any sort exemplifies the principle of isolating man from his occupational environment. Protective equipment for workers should usually be designed for emergency or temporary use, but this does not always hold true. Experts in the safety field stress the continual use of some sort of eye protection if only because loss of vision is such an extreme penalty to pay for a moment's inattention. Hard hats and safety shoes with steel toecaps are other examples of protective equipment designed to be cheap insurance against severe loss. Some kinds of personal protective equipment are so ubiquitous as to be almost a badge of the trade. The butcher's

apron, the chef's tall hat, the welder's helmet, the first baseman's glove, the logger's boots and the fullback's shoulder pads are all devices designed to help isolate man from his occupational environment.

Today it is possible to isolate anyone from practically any environment for nearly any length of time. We can send men through the vacuum of space to the moon, for instance, or send them to the depths of the sea, completely protected from rather extreme environments. Nevertheless, even though essentially complete protection is possible, it is rarely used.

Completely isolating a man from his occupational environment is difficult and expensive; therefore, when worker isolation is necessary, it is usually partial rather than complete. Even partial isolation can result in discomfort (consider wearing a gas mask all day, for instance), and in such cases other techniques of controlling the environment should be considered seriously. Face shields, ear plugs, rubber gloves and the like should always be available if their use is warranted, but the aim of the engineers and planners should be to make their continual use unnecessary. Furthermore, all emergency protective equipment should be inspected periodically and tested if necessary to assure that it will perform its intended function in use.

Testing of protective equipment and planning for proper use (see Chapter 36) are both very complex fields. By its nature, most equipment of this type is designed for use at times when all of the hazards are not delineated readily — where, in fact, the real hazards may never be known. For instance, canister-type gas masks have been regarded as suitable for respiratory protection in emergencies provided that the air still contains enough oxygen to sustain life. Chemical reactors, tanks, sewers and buildings on fire don't always provide enough oxygen to sustain life, and therefore, injuries do occur from asphyxiation. Furthermore, the canister on the mask may not be designed to protect against the air contaminant(s) actually present and again people are injured despite their gas masks. While the traditional gas mask still has uses, in many cases it should be replaced by one of the supplied-air type which can be worn in an oxygen-deficient atmosphere which contains unknown concentrations of unknown gases, vapors and particulates. This type of mask will do a good job in such atmospheres provided that it fits,[5] that the reservoir contains sufficient air for the necessary time, and that the regulator is functioning properly.

Gas masks are not the only pieces of protective equipment that actually may not protect in the emergency where they are used, but they exemplify the idea that obtaining equipment for protection is no guarantee that the equipment will be effective. Judicious testing of equipment designed to isolate man from his occupational environment is a necessity.

VENTILATION

Ventilation (see Chapters 39 and 42) can be used to insure thermal comfort as well as to keep dangerous vapors from the breathing zone of a worker. It can be misused in an attempt to blow away radiant heat or used properly to control the dust hazard from a grinder. Ventilation equipment is found everywhere, much of it designed, engineered, and used improperly, even though a similar expenditure of time, effort and money could well have resulted in adequate or better-than-adequate control of the occupational environment.[6]

From the point of view of the engineer, ventilation systems can be either local or general in nature, and they can attempt control mainly by exhausting or supplying air properly. These designations cannot, of course, be absolute because, for instance, local supply for one area is general supply for any other part of that room or building. Nevertheless, the intention of the planner will control this discussion.

Local Exhaust and Supply

Localized ventilation systems nearly always attempt to control a hazard by directing air movement. The velocity of the moving air may also be a consideration, but except in high velocity-low volume systems, it is used only to assure that the direction of movement is the correct one.

There are two main principles governing the correct use of local exhaust ventilation to control airborne hazards. The first is to enclose the process or equipment physically as much as possible. The second is to withdraw air from the physical enclosure (hood) at a rate sufficient to assure that the direction of air movement at all openings is always into the enclosure. All other considerations are secondary. If these principles are followed, no airborne material will escape from the enclosure so long as the enclosure is intact and the ventilation system is operating properly.

There are times where no enclosure is possible and where control of airborne hazards must be accomplished simply by the direction and velocity of air movement. These cases are not exceptions to the basic principle because, at the point where control must be assured, if the direction of air movement is always into the hood there will be control of materials suspended in that air. Similarly, if an air-tight enclosure were to be used, then no air need be moved to assure control of a vapor or an aerosol, but the principles have not been violated.

Three of the problems associated with local exhaust systems stand out. First, and most obvious, is that of poor design. All too many ventilation systems appear to have been laid out by someone who has no knowledge of how to handle air properly. These systems abound in abrupt expansions and contractions, in right-angle entries, in the overuse of blast gates to attenuate problems, and so on. Since the advent of the ACGIH Ventilation Manual,[7] poor exhaust or supply system design has had no excuse because good technique is so easily available.

The second problem is that of inadequate exhaust. It is exemplified by the exhaust system which has been added to from time to time, until nothing associated with the system works at all

well. The solution is simply to make sure that all systems, old as well as new, are well engineered.

The third problem of local exhaust systems is that of inadequate supply. People who are willing to install extra hoods at the drop of a hat (probably adding them to an already overloaded exhaust system) almost uniformly seem to feel that adequate supply air is a luxury or frill which they can do without. This tendency is accentuated by the widespread knowledge of a "rule of the thumb" which states that so long as the number of air changes per hour in the building is less "X" there is no need for a separate supply system. (The value of "X" varies from thumb to thumb, but is likely to be from 2 to 4.) This rule assumes that the building isn't "tight" and that infiltration of air will equal or exceed that exhausted.

Almost all buildings "leak" a little, and some leak a lot of air. Nevertheless, another principle of controlling the occupational environment by local exhaust is "always supply at least as much air as will be exhausted." A mechanical air supply system can and will do many things that infiltration cannot. A mechanical system can supply air that is filtered (and thus clean), tempered (warmed or cooled as necessary) and in the proper location to eliminate drafts and to avoid excessive disturbance of air at the faces of local exhaust hoods. None of these benefits can be gained by counting on infiltration for supply.

Local supply in itself is used occasionally to effect control or to assist in control of local exhaust. A combination of supply and exhaust, for instance, is sometimes used as a "push-pull" system to control vapors from large open tanks,[8] the supply air being used to "push" vapors into the exhaust system. If properly engineered, such systems can work well and can effect control by the movement of much less air than would be necessary if only exhaust were used.

The main use of local supply systems is not, however, to control hazardous vapors but, instead, to reduce heat stress problems. For this application, air is usually supplied on an individual basis and each man is allowed to control the direction and/or the velocity of air impinging on his work station. The air used is not cooled, but is supplied at high velocities (up to 500 fpm); it cools by sweat evaporation and by convection, if its temperature is below the man's skin temperature (as is usually the case).

General Exhaust and Supply

General exhaust and supply systems attempt to control the occupational environment by dilution. This principle can be used for many types of problems, ranging from hazardous vapors to locker room odors to problems of dust, humidity and temperature. A principle of general ventilation is that it be used to control problems that inherently are widespread. That is, it makes sense to use general exhaust and supply ventilation to control the temperature and humidity of all the air in an office building, but it does not make sense to try to control the fume generated by one welder with an exhaust fan located in the opposite wall. General ventilation is almost always unsuccessful when used to control "point" sources of airborne contaminants, and in addition, is very wasteful of air when used for such purposes.

Even local systems must have air to exhaust, and usually that air is supplied by a general system — one that is not associated with any particular hood or exhaust port. Some dilution of air contaminants will take place because of the general supply system, but its main purpose is simply to provide air to be thrown away by the exhaust system.

Air moving equipment can be expensive, and air filtering and tempering equipment can be even more so. Therefore, some engineers attempt to save money by recirculating some exhaust air back into the supply system. While this practice is standard in office buildings, it is rarely applicable in factories and shops because the air handled by the exhaust system cannot usually be cleaned adequately. Once-through systems, therefore, are standard except where the contaminant in the exhausted air is an easily handled particulate with a low inhalation toxicity. Sawdust, for example, is usually low in toxicity (although some woods are sensitizers), and the particles may be large enough to be removed easily from an air stream. In such a case, recirculation of some part of the exhaust air could be considered.

Inadvertent recirculation of exhausted air is a growing occupational health problem. When exhaust stacks and supply inlets are not separated adequately, part of the exhaust air will be captured by the inlet and recirculated to the building. This problem is prevalent in buildings designed by architects who are more concerned with the appearance of a roofline than they are with the health of those who will work in the building.[9] The problem also occurs between buildings, especially when roof elevation differences are not great, and elsewhere when little or no attention has been paid to the possibility of recirculation.

Recent work has shown that the best way to prevent recirculation is to discharge exhaust air in such a manner that all of it will escape from the "cavity" which forms as a result of wind moving over and around buildings.[10, 11] The intake can then be located at any convenient place, usually close to the roof, with assurance that recirculation will be negligible. Unfortunately, the prediction of cavity height above a roof is not yet an exact science, but enough is known so that intelligent decisions can be made. The recirculation problem must be considered whenever highly toxic, highly hazardous, or highly odorous materials are discharged by an exhaust system, whether or not a mechanical supply system is present.

EDUCATION

The first and most basic principle of almost any discipline is that knowledge is needed in order to apply that discipline to practical problems. Some knowledge comes with experience, but experience can be a poor teacher. More or less formal education can supplement experience and can direct it into the most productive channels. Nearly all people with line responsibility in indus-

try, and many with staff responsibility, can become involved with controlling the occupational environment. All of these people can profit from education in this area.

Management

Few managers become involved directly in the practical aspects of hazard control, yet very little hazard control is done without management backing. Managers exist mainly to motivate people (or to allow people to motivate themselves), but even expert motivators cannot channel activity into areas of which they are ignorant. Education of management should deal much more with the "why" of hazard control than with the how, when, where or whom.

There has been very little effort to formalize the education of managers in most industries; usually they are taught about hazards in meetings, conferences and personal chats by men who work for them. Informal education is better than no education at all, but the present best hope is the recent proliferation of short courses prepared and presented for representatives of high echelon management. A short course is the easy way to obtain quite a lot of valuable information with a small expenditure of time. This approach has been used successfully in the field of hazard control and much more use of it should be made in the future.

Short courses for managers should identify hazards in broad areas; details should be reserved for examples. The courses should concentrate particularly on the costs and benefits of controlling the environment, but should not completely neglect humanitarian aspects. Legal requirements which must be met should also be a part of the course content, but where a "carrot" exists, its use will almost always produce better results than will a club. Particularly for managers, the carrots (rewards) should be searched out, found and emphasized.

Engineers

At least a portion of the work of every industrial hygienist can be traced to equipment and/or process design failure. In many "failure" cases the person who designed the equipment or process simply was not aware of the potential consequences of the failure, or that such a failure was possible. Examples range from the purchase of equipment noisy enough to be hazardous, to the use of carbon tetrachloride or benzene as solvents, to the specification of gasoline-powered lift trucks for an enclosed warehouse, to the omission of a necessary fire door. In general, these failures arise from ignorance rather than from malice or from a "devil-may-care" attitude. Furthermore, the decision which resulted in a failure probably was made by someone quite far removed from the consequences of the decision — a planner, perhaps, or an engineering designer.

Educating engineers in regard to environmental hazards has, in the past, taken place mainly on the job by association with more experienced people. In recent years a few short courses have been given to supplement on-the-job training, but all too often any remedy applied is both too little and too late.

The logical place for engineers to be exposed to the knowledge that the environment abounds with hazards is when they are students at the undergraduate level. What is necessary then is not a program designed to turn these people into industrial hygienists or safety engineers, but instead, a course or courses which tend to open their eyes to the consequences of decisions they may make in their professional capacity. Undergraduate engineers (and most graduate engineers, for that matter) simply are not aware that it is perfectly possible to write noise specifications for much equipment; that carbon tetrachloride and benzene have excellent, much less hazardous, substitutes; that LPG fueled lift trucks generate much less carbon monoxide than do gasoline-powered lift trucks, that electric lift trucks are available and entirely suitable for most lift truck tasks; or when and where to install fire doors. The hazard gamut is so large that the typical short course can only scratch the surface, and a semester-long exposure stands a much better chance of getting the idea across.

Several colleges and universities already offer one or more courses surveying the fields of industrial hygiene for undergraduates especially in engineering curricula. With such courses as the foundation, short courses later in professional life should be able to keep engineers reasonably well up to date on environmental hazard control provided, of course, that they regularly read the literature related to the field.

Supervisors

In most circumstances, the further a supervisor is from actual control of a process, the more he deals with men and the less he deals with things. Supervisors usually work only through other people and consequently, they become aware of most environmental hazards from other people, or through their actions. In the case of an obvious hazard within his jurisdiction, a supervisor either can deal with the hazard with his own resources or he can solicit aid from others. Generally, which action to take is rather obvious, but some of the hazards posed by the occupational environment are subtle rather than obvious, and most supervisors are not equipped to deal with the subtle variety at all.

Education of supervisors usually should be process and process equipment oriented. The aim of the education should be to teach them about the subtle hazards that may be found in the environment of their employees and when and under what circumstances to request aid in solving the problems those hazards pose. Supervisors who are knowledgeable and well informed about hazardous processes, operations and materials are often able to control hazards early enough so that outside aid is not necessary except for periodic checks or reviews.

Workmen

Traditionally, little effort has been made to teach workmen about either the equipment or the materials that they handle. In the past few decades, safety engineers have shown over and over again that there are direct benefits to be gained

from teaching workmen about the physical hazards in their environment and how to avoid those hazards. More recently, industrial hygiene engineers have begun, usually in periodic safety meetings, to teach workmen about the hazards of materials and energies and, perhaps not surprisingly, have found similar benefits.

Hazards associated with the occupational environment impinge first on the men who work directly with materials, process equipment and processes. As these men are the first affected, they may well be the first to recognize adverse effects, and if so, if they are knowledgeable about the effects of the materials and energies they work with, they may be able to pinpoint problems before those problems become severe.

The main arguments against educating workers about the real and potential hazards of the materials and energies to which they are exposed have been that such knowledge would create apprehension, cause malingering, and give the unions another club to hold over the head of management. Where worker education has been used, however, groundless fears have evaporated, attendance has improved, and unions have been more cooperative, especially in matters concerning the health and safety of workmen.

An aware workman can often anticipate and circumvent hazards before they become serious to him, his fellow workers, or to the physical facilities. Furthermore, once the source of a hazard has been found, workmen, rather than supervisors or engineers, quite often have the best ideas of how to eliminate the problem with the least effort and expense. And finally, aware workmen often can be used to assist in industrial hygiene surveys,[12] thereby freeing the industrial hygiene engineer for perhaps more productive tasks.

References

1. STERN, A. C.: *Air Pollution: Volume III*. Academic Press, Inc., New York, 1968.
2. PETERSON, J. E. and J. A. PEAY: Laboratory Fume Hoods and their Exhaust Systems, *Air Cond. Heat. Vent.* 5:63 (1963).
3. CROLEY, J. J. Jr.: Specialized Protective Clothing Developed at the Savannah River Plant. *Am. Ind. Hyg. Assoc. J.* 28:51 (1967).
4. PATTY, F. A.: *Industrial Hygiene & Toxicology, Volume I: General Principles*, p. 2, Interscience Publishers, Inc., New York, 1958.
5. BURGESS, W. A. and B. HELD: Field Fitting Tests for Respirators, *Natl. Safety News* 100:41 (1969).
6. KANE, J. M.: Are There Still Local Exhaust Ventilation Problems? *Am. Ind. Hyg. Assoc. J.* 28:166 (1967).
7. *Industrial Ventilation: A Manual of Recommended Practice*. American Conference of Governmental Industrial Hygienists (12th edition), P.O. Box 453, Lansing, Michigan, (1972).
8. HAMA, G. M.: Supply and Exhaust Ventilation for the Control of Metal Pickling Operations, *Am. Ind. Hyg. Assoc. J.* 18:214 (1957).
9. CLARKE, J. H.: The Design and Location of Building Inlets and Outlets to Minimize Wind Effect and Building Re-entry of Exhaust Fumes, *Am. Ind. Hyg. Assoc. J.* 26:242 (1965).
10. HALITSKY, J.: Estimation of Stack Height Required to Limit Contamination of Building Air Intakes, *Am. Ind. Hyg. Assoc. J.* 26:106 (1965).
11. RUMMERFIELD, P. S., J. CHOLAK and J. KEREIAKES: Estimation of Local Diffusion of Pollutants from a Chimney: A Prototype Study Employing an Activated Tracer, *Am. Ind. Hyg. Assoc. J.* 28:366 (1967).
12. PENDERGRASS, J. A.: Planning Industrial Hygiene Studies to Utilize Plant Personnel, *Am. Ind. Hyg. Assoc. J.* 25:416 (1964).

Preferred Reading

1. PATTY, F. A.: *Industrial Hygiene & Toxicology: Volumes I and II*. Interscience Publishers, Inc., New York, 1958.
2. HEMEON, W. C. L.: *Plant and Process Ventilation, 2nd Ed.*, Industrial Press, Inc., New York, 1963.
3. *Industrial Ventilation: A Manual of Recommended Practice*, American Conference of Governmental Industrial Hygienists (12th Edition), 1972.
4. CRALLEY, L. V., L. J. CRALLEY and G. D. CLAYTON: *Industrial Hygiene Highlights*, Industrial Hygiene Foundation of America, Inc., 1968.
5. McCORD, C.: *A Blind Hog's Acorns*. Cloud, Inc., New York, 1945.
6. HAMILTON, A. and H. HARDY: *Exploring the Dangerous Trades*. Little, Brown & Company, Inc., Boston, 1943.
7. JOHNSTONE, R. T. and S. E. MILLER: *Occupational Diseases and Industrial Medicine*. W. B. Saunders Company, Inc., Philadelphia, 1960.

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OF THE COUNCIL OF MINISTERS OF THE USSR

SANITARY NORMS AND STANDARDS FOR PLANNING INDUSTRIAL UNDERTAKINGS
SN 245-71

Date of coming into force: 1 April 1972

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Note: This translation comprises only Sections 1, 2, 6 and 8 of the above Sanitary Norms and Standards, which may be of value to professional workers concerned with norms and standards in basic sanitation. The original section numbers have been retained. Section 12, entitled "Maximum permissible concentrations of harmful substances in the water of watercourses used for hygienic and domestic purposes", lists maximum permissible concentrations for 294 substances. This list has been discussed in a paper by D. Stöfen (1973) The maximum permissible concentrations in the USSR for harmful substances in drinking water, Toxicology, 1, 187-195. The latter paper also compares these values, where possible, with those published by WHO in European standards for drinking-water, 2nd ed., 1970 and International standards for drinking-water, 3rd ed., 1971.

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que leurs auteurs.

1. GENERAL INSTRUCTIONS

1.1 These Sanitary Norms and Standards shall apply to the preparation of plans for constructing or reconstructing undertakings, buildings or installations for industry, transport, communications and agriculture, including power stations and pilot factories and plant.

1.2 These Norms and Standards shall not apply to the preparation of plans for underground installations and mines, or for temporary industrial buildings and installations erected for the duration of the building work and with a service life of under five years.

1.3 Planning shall also comply with the sanitary requirements for the particular type of industrial production concerned, including the industrial processes of transport, communication, agriculture, etc., undertakings, as set forth in the relevant regulatory texts and agreed or approved in accordance with established procedure.

1.4 The plans for undertakings or individual production units shall make provision for industrial processes and equipment such as shall ensure that:

(a) there is very little or no escape into the air of the premises, into the atmosphere or into waste waters of harmful or malodorous substances; and likewise very little or no escape of heat or moisture into the working premises;

(b) there is very little or no generation of noise, vibration, ultrasound, electromagnetic waves at radio frequencies, static electricity or ionizing radiation.

1.5 When planning the technological aspects of undertakings, provision shall be made for:

the replacement, in the production process, of harmful substances by harmless or less harmful ones; and the replacement, in the processing of dust-generating materials, of dry techniques by wet ones;

the replacement of processes and industrial operations generating noise, vibration and other harmful factors by processes or operations not producing such factors or doing so at a lower intensity;

the replacement of flame methods of heating by electrical ones, and the replacement of solid or liquid fuels by gas;

the hermetic closure or maximum sealing of joints and connexions in industrial equipment and piping to prevent the escape of harmful substances during the production process;

insulation of heated surfaces on equipment, air ducts and piping;

complex mechanization, including automation, remote control and automatic signalling, during individual processes and operations liable to emit harmful factors;

continuous production processes;

covers for mechanical transport, and the use of hydraulic and pneumatic modes of transport for dust-generating materials;

recovery of harmful substances and their removal from industrial wastes, to ensure compliance with the provisions of paragraphs 2.4, 2.15 and 5.6 of these Norms and Standards.

preferential use of equipment having a good health rating;

automatic shutdown devices for industrial equipment and sanitary engineering appliances, and the use of equipment with built-in local exhaust pumps and lighting;

noise-deadening and vibration-absorbing devices;

rational layout of work areas and their protection from exposure to electromagnetic waves at radio frequencies and ionizing radiation;

use of processes producing the minimum amount of waste water.

Notes: 1. The use of industrial processes and equipment liable to emit or generate harmful factors in considerable quantity thus requiring additional measures (such as special protective devices, waste disposal plant, more intensive treatment of industrial and ventilation wastes and enlargement of the health protection zone) to reduce such factors to the levels provided in the Norms and Standards, shall have to be justified on both technical and economic grounds.

2. A calculation of the atmospheric and water pollution likely from the harmful substances contained in industrial wastes and acoustic calculations shall be included in the technical part of the plans for an undertaking.

To that end, the plans shall make provision for a combination of measures to ensure that the design conditions regarding the emission of harmful substances are met in actual operation. The necessary conditions for the use of appliances to measure and continuously record the quantities of harmful substances entering air and water and appliances to regulate the amounts emitted by intensifying treatment, modifying the rate of production, or other measures, shall be laid down in special instructions issued by the Gosstroj of the USSR in agreement with the Ministry of Health of the USSR.

1.6 Any modification of industrial processes or equipment, any increase in productive capacity, any intensification of manufacturing processes or any other changes to the undertaking shall comply with the requirements of the present Norms and Standards.

2. REQUIREMENTS FOR SELECTING BUILDING SITES AND PREPARING MASTER PLANS

2.1 Building sites for undertakings shall be selected, and their buildings and installations located, in accordance with the requirements of those chapters of the Building Standards and Regulations relating to the preparation of master plans for industrial undertakings and with the requirements of the present Norms and Standards.

2.2 Undertakings, or their individual buildings and installations, using industrial processes liable to emit harmful or malodorous substances into the environment or generate high levels of noise, vibration, ultrasound, electromagnetic waves at radio frequencies, static electricity or ionizing radiation shall be separated from residential areas by a health protection zone.

2.3 The width of the health protection zone up to the edge of the residential area shall be measured:

(a) for undertakings using industrial processes liable to pollute the atmosphere with harmful or malodorous substances, direct from the sources of concentrated wastes (chimneys, shafts) or dilute wastes (vents in buildings, etc.) polluting the atmosphere, and also from places where raw materials are unloaded and from open stores;

(b) for undertakings using industrial processes liable to emit noise, vibration, electromagnetic waves at radio frequencies and other harmful factors into the environment, from the buildings, installations or sites where the industrial equipment (assembly, machinery) producing those harmful factors is installed;

(c) for heat-and-power stations and for boilers used for industrial or heating purposes, from the smoke stacks.

2.4 Undertakings, or their individual buildings and installations, using industrial processes liable to emit harmful or malodorous substances into the atmosphere, or liable to generate external noise at levels exceeding those laid down in the Norms and Standards for residential areas, shall not be located upwind (with regard to the direction of the prevailing wind) of a residential area.

Undertakings using industrial processes not releasing harmful substances into the atmosphere, using processes not generating external noise or other harmful factors at levels exceeding those laid down in the Norms and Standards for residential areas and not requiring an access railway line shall be permitted within residential areas.

Industrial building sites shall be selected with reference to the atmospheric and climatic features and topography of the locality, the direct solar irradiation and natural ventilation and also with reference to the conditions governing dispersal of industrial wastes in the atmosphere and those governing the formation of fog.

2.5 Undertakings, or their individual buildings and installations, using industrial processes liable to produce harmful industrial factors shall be assigned the following health protection zones depending on their production capacity; the conditions under which the industrial process is carried out; the nature and quantity of the harmful or malodorous substances released into the environment; the noise, vibration, electromagnetic waves at radio frequencies, ultrasound or other harmful factors produced; and with reference to the measures provided for reducing the harmful effects of such factors on the environment and for ensuring compliance with the requirements of Sections 9-14 of the present Norms and Standards relating to the sanitary classification of undertakings, production units and premises:

Class I	1000 m
Class II	500 m
Class III	300 m
Class IV	100 m
Class V	50 m

The sanitary classification and size of health protection zones for undertakings, production units and premises using industrial processes liable to give rise to the above-mentioned harmful industrial factors in the environment shall be established in accordance with Section 8 of the present Norms and Standards.

Note: When an undertaking located within a population centre is being rebuilt, the width of the health protection zone shall be established by joint decision of the Ministry of Health and the Gosstroj of the Union Republic.

2.6 The health protection zone for undertakings and working premises may be enlarged if necessary for technical, economic or health reasons, but by no more than a factor of three, by joint decision of the Central Board of Sanitation and Epidemiology of the Ministry of Health of the USSR and the Gosstroj of the USSR:

(a) depending on the degree of effectiveness of the measures that are provided or are practicable for treating wastes released into the atmosphere;

(b) in the absence of any means for treating wastes;

(c) where it is necessary to site a residential area downwind (with regard to the prevailing wind direction) from an undertaking, in a zone liable to atmospheric pollution;

(d) in accordance with the wind distribution pattern or other unfavourable local conditions (such as frequent windless spells or fogs);

(e) where it is impossible to reduce the noise, vibration, electromagnetic waves at radio frequencies or other harmful factors entering the atmosphere below the limits established by the Norms and Standards;

(f) when new production units that have not yet been adequately tested for any harmfu effects they may have on health are being built.

2.7 The width of the health protection zones for individual groups or complexes of large Class I or II undertakings in the chemical, petrochemical, metallurgical, engineering or other branches of industry, including heat-and-power stations, that emit wastes liable to cause large concentrations of various harmful substances in the atmosphere, that generate noise, vibration, electromagnetic waves at radio frequencies or other harmful factors or that have a particularly adverse effect on health and on living conditions affecting health, shall be established in each particular case by joint decision of the Central Board of Sanitation and Epidemiology of the Ministry of Health of the USSR and the Gosstroj of the USSR.

2.8 The width of the health protection zone for undertakings, buildings and installations in which radioactive substances are handled shall be established in accordance with the sanitary regulations relating to the handling of radioactive substances and sources of ionizing radiation, approved in accordance with established procedure.

2.9 The width of the health protection zone may be reduced in cases where:

(a) it is established, as a result of calculation of the dispersion in the atmosphere of the harmful substances remaining after treatment of wastes, improvement of industrial production processes, or other measures, that the content of harmful substances in the air of population centres will not exceed the levels given in Section 9 of the present Norms and Standards;

(b) it is established, as a result of analysis of noise levels, that the levels of noise within residential areas will not exceed those laid down in Section 13 of the present Norms and Standards;

(c) the levels of vibration, ultrasound, electromagnetic waves at radio frequencies, static electricity and ionizing radiation in residential areas will not exceed those set down in the Norms and Standards.

Notes: 1. Both calculation of the atmospheric dispersion of harmful substances contained in industrial wastes and determination of noise levels shall be performed in accordanc with the regulatory texts that have been approved or agreed, in accordance with established procedure.

2. Determination of the width of the health protection zone on the basis of the calculated atmospheric dispersion of harmful substances shall be carried out with reference to the total pollution of the outside air, by existing (background) pollutan as well as by industrial and ventilation wastes.

3. The existing (background) pollution of the air in an area proposed for building or rebuilding an undertaking shall be determined by the local sanitary, epidemiologica and hydrometeorological authorities and submitted to the planning organization for use in determining the health protection zone for the undertaking.

2.10 No part of a health protection zone shall be considered as spare land for the undertaki and used for the extension of its industrial activities.

2.11 The suitability of land set aside as a health protection zone for agricultural use (for growing crops or as hay meadows or pasturage) shall be determined with reference to the nature and quantity of the harmful substances contained in the industrial wastes falling on the healt protection zone, and shall be subject to the agreement of the local authorities of the Ministr of Agriculture of the USSR and, where necessary, of the sanitary and epidemiological authorities.

2.12 The land of the health protection zone shall be laid out and planted with greenery in accordance with a plan for the provision of amenities prepared at the same time as the plans for building or rebuilding the undertaking. The plan for the provision of amenities and the selection of vegetation for planting shall comply with the requirements of those chapters of the Building Standards and Regulations relating to the preparation of master plans for industrial undertakings.

When planning the amenities of the health protection zone, provision shall be made for retention of the existing vegetation. On the side bordering a built-up are provision shall be made for a strip not less than 50 m wide or, where the zone width is under 100 m, not less than 20 m wide, to be planted with trees and bushes.

2.13 The following shall be permitted in the health protection zone:

(a) undertakings, or their individual buildings and installations, that lie in a lower class with regard to the generation of harmful factors than the production unit for which the health protection zone was established, provided that the harmful factors are of the same nature in both cases;

(b) fire stations, bath houses, laundries, garages, storehouses (other than public or specialized food stores), administrative buildings, design offices, educational facilitie shops, public catering undertakings, polyclinics and research laboratories that service the undertaking in question or neighbouring undertakings;

(c) premises for staff on standby duty and watchmen on duty roster, parking space for public and private transport, local and through roads, power transmission lines, power stations, oil and gas pipelines, artesian wells supplying water for industrial purposes, water-cooling installations, installations preparing water for industrial purposes, water and sewage pumping stations, closed cycle water supply installations, underground reservoirs, and nursery gardens preparing plants for planting on the premises of the undertaking and in the health protection zone.

Notes: 1. The siting of the premises referred to in paragraph 2.13 shall comply with the requirements laid down for such premises in the regulatory texts.

2. Undertakings, industrial buildings and installations shall not be sited in the health protection zone in cases where harmful industrial factors emitted by any such undertaking may adversely affect the health of workers, or damage materials, equipment or finished products, at another undertaking, or where there is a resultant increase in the concentration of harmful factors in a residential area above the permissible levels laid down in the present Norms and Standards.

3. The siting of sports facilities, parks, children's establishments, schools, curative, preventive and health establishments serving the general public shall not be permitted in a health protection zone.

2.14 The siting in the open air of industrial plant, appliances, assemblies or equipment emitting harmful industrial factors shall comply with the requirements of the Norms and Standards for industrial planning that have been agreed in accordance with established procedure.

2.15 Individual buildings and installations shall be so sited within the precincts of the undertaking concerned as to ensure that at the designed or other air intakes for ventilation or air-conditioning systems the content of harmful substances in the outside air does not exceed 30% of the maximum permissible concentrations for work areas in industrial premises.

To that end, the need to comply with the provisions of paragraphs 1.4, 1.5 and 5.6 of the present Norms and Standards shall be taken into account.

2.16 The width of the gaps left for health purposes between buildings and installations lit by light entering through window openings shall not be less than the height to the top of the eaves of the tallest of the buildings or installations opposite.

Notes: 1. If one of the buildings or installations opposite has no openings for the admission of light on the side facing the other where overshadowing is likely to occur, then the distance between such buildings or installations shall be determined solely by the height of the building or installation without such openings.

2. Tall installations without openings for the admission of light (chimneys, towers, platforms, columns, etc.) may be sited at a distance not less than their width from the walls of buildings with such openings. Where the wall of the building likely to be overshadowed by a tall installation has no openings for the admission of light, the distance between the building and the installation shall be exempt from the provisions of the present Norms and Standards.

3. For buildings with longitudinal clerestories less than 3 m from the front wall of the building, the height of the building shall be taken as the height to the top of the clerestory eaves.

4. The gaps referred to in paragraph 2.16 of the present Norms and Standards may be reduced in cases where, with reference to overshadowing of the windows of the buildings opposite, calculation shows that each of the buildings opposite will receive the amount of natural lighting specified by the Norms and Standards.

2.17 Where technological considerations make it necessary to store dust-generating materials in the open or in open sheds, then the distance between such stores and the nearest openable lights shall be not less than 50 m for industrial and auxiliary buildings and premises and not less than 25 m for other buildings and premises.

2.18 On sites set aside for the building or rebuilding of enterprises, an area for games or athletics shall be set aside for the use of the workers of the undertaking.

As a rule, the land allocated for this purpose shall be that with the lowest level of air pollution, least exposure to other harmful factors and at a distance from major transport routes.

6. REQUIREMENTS FOR WATER SUPPLIES AND SEWERAGE

6.1 Water supplies and sewerage for buildings and installations belonging to undertakings shall be planned in accordance with the requirements of those chapters of the Building Standards and Regulations relating to the planning of water supplies and sewerage and with the requirements of the present Norms and Standards.

6.2 Provision shall be made for both internal and external systems of water supply and sewerage for industrial and auxiliary buildings, and for industrial sites, for the purpose of delivering water for industrial, domestic and drinking purposes and of removing wastewater.

Note: The provision of domestic and drinking water supplies and sewerage for industrial and auxiliary buildings shall not be compulsory in cases where a centralized water supply and sewerage system is not available to the undertaking and the number of workers per shift does not exceed 25.

6.3 The choice of the source of water supply and the quality standards applicable to water used for domestic and drinking purposes and showers shall be governed by the corresponding All-Union State Standards (GOSTs).

6.4 The source selected to provide water for domestic and drinking purposes shall be submitted for approval to the local Soviet of Workers' Deputies and the local sanitary and epidemiological authorities when the building site is selected.

The maximum permissible concentrations of harmful substances in the water of reservoirs supplying water for sanitary and domestic purposes shall not exceed the values laid down in Section 12 of the present Norms and Standards.

6.5 The connexion of a system supplying water for domestic and drinking purposes to a system supplying non-potable water shall be prohibited.

Note: Exceptionally, in individual cases, and subject to approval in accordance with established procedure, provision may be made for using a supply of water provided for domestic and drinking purposes as a source of water for a system supplying non-potable water. The connexion between the systems shall be made in such a way that an air gap is left between them.

6.6 Where domestic and drinking water supply systems are fed from urban water mains, they shall have no direct connexion with other domestic and drinking water supply systems fed from local sources of water.

6.7 Ground water and infrabed water that satisfy the sanitary and hygienic requirements for domestic and drinking water shall be primarily used to supply water for domestic and drinking purposes.

6.8 Plans for the supply of water for domestic and drinking purposes shall make provision for health protection zones around the water sources and water supply installations in accordance with the existing provisions and requirements laid down in those chapters of Building Standards and Regulations relating to the planning of water supplies.

6.9 The norms governing the amount of water to be delivered for domestic and drinking purposes in industrial and auxiliary buildings belonging to undertakings, and the water consumption variation factors, shall comply with those chapters of the Building Standards and Regulations relating to the planning of internal water supply systems for buildings.

Notes: 1. The water consumption norm shall be reduced to 15 litres per worker per shift for any undertaking without a sewerage system.

2. The quality of the water to be used for showers, wash-hand basins and foot baths of all kinds and that to be used for ventilation intake systems, spray, air-cooling systems and dust-settling systems shall comply with the requirements of the State Standards relating to drinking water.

3. Where the supply of water of drinking quality is insufficient, lavatory and urinal cisterns may be supplied from the industrial water supply system; and geothermal water, where available, may be used to supply hot water for showers and wash basins. The suitability of the water in question shall be assessed by the sanitary and epidemiological authorities.

6.10 Provision shall be made for the discharge and treatment of waste water in accordance with the existing regulatory texts establishing the conditions of such discharge and the degree of purity of the waste water.

6.11 The discharge of sewage and industrial waste water into absorbing wells shall be prohibited.

Waste water from closed cycle water supplies shall be discharged only into the industrial drainage systems of industrial undertakings.

Unpolluted industrial waste water may be discharged into storm drainage systems.

Waste water from showers or wash basins shall be discharged into the sewerage system or the industrial drainage system of the undertaking.

6.12 In the case of the removal and discharge of industrial effluents that give off gases, measures shall be taken to prevent the entry of such gases into the premises.

6.13 The bulking of effluents, where this would cause chemical reaction leading to the emission of harmful gases (such as hydrogen sulfide, hydrogen cyanide or hydrogen arsenide), shall be prohibited.

6.14 Waste water containing harmful substances may be discharged into an urban sewerage system provided that after such waste water has mixed with the main mass of waste water the concentrations of harmful substances in the latter do not exceed those laid down in the Norms and Standards or adversely affect the rate of biological treatment of effluent.

6.15 Waste water treatment plants may be installed in industrial buildings provided that neither the composition of the waste water nor any mixing or treatment it may receive will cause the formation or emission of harmful or malodorous fumes or gases (such as mercaptans, hydrogen sulfide, hydrogen cyanide, or hydrogen arsenide) or provided that all waste water treatment processes are carried out under hermetically sealed conditions.

6.16 The location of external water supply and sewerage systems and installations shall comply with the provisions of the relevant chapters of the Building Standards and Regulations.

The widths of the health protection zones for sewerage installations shall be determined in accordance with Section 8 of the present Norms and Standards.

6.17 The provision of a supply of drinking water for workers shall be planned with reference to the requirements of those chapters of the Building Standards and Regulations relating to the planning of auxiliary buildings and premises belonging to industrial undertakings.

8. SANITARY CLASSIFICATION AND SIZE OF HEALTH PROTECTION ZONES FOR INDUSTRIAL UNDERTAKINGS AND PRODUCTION UNITS, HEAT-AND-POWER STATIONS, AND STORAGE FACILITIES AND INSTALLATIONS

8.1 Undertakings, buildings and installations using industrial processes liable to emit harmful industrial factors into the environment shall be provided with a health protection zone in accordance with Section 2 of the present Norms and Standards and in accordance with their sanitary classification.

Note: When new technological processes are introduced the width of the corresponding health protection zone must be determined in each particular case and approved by the Central Board of Sanitation and Epidemiology of the Ministry of Health of the USSR and by the Gosstroj of the USSR.

INDUSTRIAL UNDERTAKINGS

8.2 Industrial undertakings shall, in accordance with their capacity and type of production, have the following health protection zones.

The chemical industry

Class I: Health protection zone 1000 m wide

1. Production of nitrogen compounds (ammonia, nitric acid, and fertilizers).
2. Production of intermediate products of the aniline dye industry in the benzene and ether series (aniline derivatives, nitrobenzene, alkyl amines, phenol, etc.) where total output is over 1000 tons per year.
3. Production of intermediate products in the naphthalene and anthracene series (1-naphthalenol, anthraquinone, phthalic anhydride, etc.) in amounts exceeding 2000 tons per year.
4. Production of iron (III) bromide.
5. Production of paper pulp and hemi-cellulose by the sulfite, bisulfite, and monosulfite processes involving the combustion of sulfur or sulfur-containing materials; also production of paper pulp by the sulfate process.
6. Production of illuminating gas, water gas, or producer gas in amounts exceeding 50 000 m^3 per hour.
7. Plants for the underground gasification of coal.
8. Production of caustic soda and chlorine by electrolysis.
9. Production of rare metals by the chlorination process (titanomagnetite, etc.).
10. Production of artificial viscose fibre and cellophane.
11. Production of concentrated mineral fertilizers.
12. Production of organic solvents and oils (benzene, toluene, xylene, naphthalenol, phenol, creosol, anthracene, phenanthrene, acridine, carbazole).
13. Production of arsenic and its inorganic compounds.
14. Production of petroleum gas in amounts exceeding 5000 m^3 per hour.
15. Oil refineries.[1]

[1] Where oil with a sulfur content (by weight) of less than 0.5% is being refined, the health-protection zone is 500 m wide.

16. Production of picric acid.
17. Production of hydrofluoric acid, calcium fluoride, hydrogen fluoride, and other fluorides
18. Coal processing plants.
19. Plants for the chemical processing of peat.
20. Plants processing fuel shales.
21. Production of mercury.
22. Production of carbon black.
23. Production of sulfuric acid, fuming sulfuric acid, and sulfur dioxide.
24. Production of carbon disulfide.
25. Production of hydrochloric acid.
26. Production of superphosphate.
27. Production of phosphorus (yellow or red) and organophosphorus compounds (parathion, malathion, etc.).
28. Production of chlorinated and hydrochlorinated hydrocarbons.
29. Production of calcium carbide, acetylene from calcium carbide, and acetylene derivates.
30. Production of dimethyl terephthalate.
31. Production of caprolactam.
32. Production of cellulose nitrate fibre.
33. Synthesis of ethanol by the sulfuric acid process or by direct hydration, in plants with departments for concentrating sulfuric acid or carrying out desulfurization.
34. Production of artificial rubber.
35. Production of blowing agents for the rubber industry.
36. Production of amines (methylamine, dimethylamine, diethylamine, triethylamine, etc.).
37. Production of cyanides (calcium, sodium, copper, etc.), dicyanamide, calcium cyanamide).
38. Production of aminoheptanoic aminoundecanoic, aminononanoic, thiopentanoic, and isophthalic acids.
39. Production of sodium nitrite, hydrazine sulfate, hydrazine hydrate, ammonium sulfate, thionyl chloride, and ammonium carbonate.
40. Production of acetylene from hydrocarbon gas
41. Production of dimethyl formamide.
42. Production of ethyl fluid.
43. Production of catalysts.
44. Production of products and intermediate products used in the synthesis of polymers.
45. Production of organosulfur dyes (sulfur black, etc.).
46. Production of hydrocyanic acid and its derivatives (acrylates, diisocyanates, etc.).
47. Production of beryllium.
48. Production of synthetic pharmaceuticals.
49. Synthesis of fatty acids and production of higher fatty alcohols by direct oxidation.
50. Mercaptan production and central plants for odorizing gas with mercaptans including facilities for odorant storage.
51. Potassium works.

Class II: Health protection zone 500 m wide

1. Production of urea and thiourea.
2. Natural-gas processing plants.
3. Production of niobium.
4. Production of tantalum.
5. Production of producer gas from coal and peat at a rate of 25 000-50 000 m^3 per hour.
6. Production and processing of natural tars and their residues (pitch, etc.).
7. Production of soda ash by the Solvay process in amounts exceeding 400 000 tons per year.
8. Synthesis of ethanol by the sulfuric acid process or by the direct hydration process in plants lacking a department for concentrating sulfuric acid or, in the case of the second process, a desulfurization installation.
9. Production of ammonium, potassium, sodium, and calcium nitrates.
10. Production of organic chemical reagents.
11. Production of plastics from cellulose esters.
12. Production of corundum.
13. Production of barium chloride with the use of hydrogen sulfide.
14. Industrial hydrogenation of fats (non-electrical process using hydrogen).
15. Production of synthetic fibres (e.g., acetate, polycaprolactam, polyesters, polyvinyl chloride, and polyamides).
16. Production of ultramarine.
17. Production of chromium trioxide and chromates.
18. Production of artificial leather with the use of volatile organic solvents.
19. Production of esters.
20. Production of the products of organic synthesis (ethanol, ethyl ether, etc.) and petroleum gases at a rate of over 5000 m^3 per hour.
21. Production of intermediate products of the aniline dye industry in the benzene and ether series (aniline derivatives, nitrobenzene, alkyl amines, phenol, etc.) where total output is under 1000 tons per year.
22. Production of intermediate products in the naphthalene and anthracene series (1-naphthalenol, anthraquinone, phthalic anhydride, etc.) for a total output of up to 2000 tons per year.
23. Production of vat dyes from all types of azotols and azoamines.
24. Experimental plants in the aniline dye industry with a total capacity of 2000 tons per year and an output of under 1000 tons per year.
25. Plants for the production of asbestos goods.
26. Production of acetic acid.
27. Production of polyethylene and polypropylene from petroleum by-product gas.
28. Production of food and fodder yeasts and furfural by hydrolysis of wood pulp and agricultural wastes.
29. Production from petroleum by-product gases of ethylene and propylene copolymers and higher polyolefin polymers.

30. Production of tar, liquid and volatile distillates of wood pulp. methanol. acetic acid. turpentine, acetone, and creosote.

31. Production of nicotine.

32. Production of phenolic, polyester, epoxy, and other synthetic resins in amounts exceeding 300 tons per year.

33. Production of synthetic camphor by the isomerization process.

34. Production of melamine and cyanuric acid.

35. Production of polycarbonates.

Class III: Health protection zone 300 m wide

1. Production of bitumen and other products from the distillation residues of coal-tar, crude oil, pine tar (asphalt, polyasphalt, etc.).

2. Production of soda ash by the Solvay process in amounts under 400 000 tons per year.

3. Production of caustic soda by the Löwig and soda-lime processes.

4. Production of mineral salts, with the exception of the salts of arsenic, phosphorus, chromium, lead, and mercury.

5. Production of petroleum gas at a rate of 1000-5000 m^3 per hour and of producer gas at a rate of 5000-25 000 m^3 per hour.

6. Production of plastics.

7. Production of phenolic moulding materials and of moulded or rolled goods from paper and textiles impregnated with phenolic resins, in amounts exceeding 100 tons per year.

8. Production of artificial mineral dyes.

9. Rubber-reclaiming plants.

10. Production of tyres, industrial rubber goods, ebonite and bonded footwear, and the rubber stock used in their manufacture.

11. Chemical processing of rare metal ores for the extraction of salts of antimony, bismuth, lithium, etc.

12. Production of fertilizer mixtures.

13. Production of carbon goods for the electrical industry.

14. Vulcanization of rubber goods using carbon disulfide.

15. Production of acetaldehyde by the vapour-phase process without the use of metallic mercury.

16. Production and bulk storage of ammonia water.

17. Production of polystyrene and copolymers of styrene.

18. Production of organosilicon varnishes, liquids, and resins.

19. Plant for distributing gas to the mains network, including installations for odorizing the gas with mercaptans.

20. Production of sebacic acid.

21. Production of vinyl acetate, polyvinyl acetate, polyvinyl alcohol, polyvinyl emulsions, and acetals.

22. Production of polyfluorethylene resins.

23. Production of plasticizers.

24. Production of food and fodder yeasts by the hydrolysis of wood pulp and agricultural wastes (sunflower husks, maize stalks, straw, etc.).

25. Production of iso-octyl alcohol, butyric anhydride, butyric acid, foam plastic, vinyltoluene, polyvinyltoluene, polyurethane for casting, polyformaldehyde, reclaimed organic acids (acetic, butyric, etc.), formaldehyde, urotropin, penta-erythritol, methylpyrrolidone, polyvinylpyrrolidone, and of derivatives of petroleum gas, where production is less than 5000 m^3 per hour.

26. Production of lacquer, spirit varnishes, printer's varnish, varnishes for the rubber industry, insulating varnishes, etc.

27. Production of drying oils.

28. Production of phenolic, polyester, polyamide, epoxy, and other synthetic resins in amounts of up to 300 tons per year.

29. Production of metal carbonyls.

30. Production of methionine.

31. Production of antibiotics by biological methods.

Class IV: Health protection zone 100 m wide

1. Production of paper from prepared cellulose and rags.

2. Production of casein plastic and other protein plastics (amino plastics, etc.).

3. Production of glycerol.

4. Production of enamels from condensation resins.

5. Soap production.

6. Processing of animal organs.

7. Production of producer gas from coal and peat in amounts of up to 5000 m^3 per hour.

8. Chemical processing of rare metal ores to extract the salts of molybdenum, tungsten and cobalt.

9. Production of phenolic moulding materials and of moulded or rolled goods from paper or textiles impregnated with phenolic resins, where production does not exceed 100 tons per year.

10. Industrial hydrogenation of fats (using hydrogen produced electrolytically).

11. Salt making (evaporation and rolling).

12. Production of potassium salts for phamaceutical purposes.

13. Production of rubberized footwear without the use of organic solvents and of rubber stock without the use of carbon black.

14. Production of liquid fertilizers.

15. Production of vanillin and saccharin.

16. Production of petroleum gas at a rate of up to 1000 m^3 per hour.

17. Production of moulding materials (phenol-formaldehyde, urea-formaldehyde, melamine-formaldehyde, organosilicon, etc.).

18. Production of artificial leather from polyvinyl and other resins without the use of organic solvents.

19. Production of polyvinyl plasticizers, vinyl plastics, plastic separators for polyurethane foam, aerated plastics, glass-fibre-reinforced plastics and expanded polystyrene.

20. Production of alkaloids and galenicals.

21. Production of natural mineral dyes (chalk, ochre, Prussian red, etc.).

22. Production of perfumes.

23. Production of tanning extracts.

24. Production of goods from synthetic resins, polymers, and plastics by various methods (moulding, extrusion, injection moulding, vacuum-forming, etc.).

25. Production of synthetic detergent powders.

Class V: Health protection zone 50 m wide

1. Production of inorganic reagents in plants without a chlorine shop.

2. Vulcanization of rubber without the use of carbon disulfide.

3. Production of carbon dioxide and "dry ice".

4. Production of artificial pearls.

5. Production of goods from plastics and synthetic resins (mechanical operations only).

6. Production of photochemicals (photographic plates, cine-film, and photographic paper).

7. Production of fertilizers using carbon dioxide.

8. Depots for cleaning, washing, and steaming-out tanks used for the transport of crude oil and petroleum products.

9. Production of various types of paper and cardboard from imported semi-processed materials; production of wood pulp and hemi-cellulose with the use of soda or monosulfite in plants where prepared monosulfite is used, spent lyes and other compounds are not burnt, and liquid sulfur dioxide is not used.

10. Production of printing inks.

11. Compounding of pharmaceutical preparations.

12. Production of condensed and liquified products from the separation of air.

The metallurgical, machine-tool, and metal-working industries

Class I: Health protection zone 1000 m wide

1. Plant for secondary processing of non-ferrous metals (copper, lead, zinc) at a rate of over 3000 tons per year.

2. Coking.

3. Iron-smelting where the total volume of the blast furnaces is over 1500 m^3.

4. Plants carrying out all processes of iron and steel production, with an output of over a million tons of iron and steel per year.

5. Steel-smelting by the open hearth and converter techniques in works equipped to process wastes (milling of Thomas slag, etc.), where output of the basic product exceeds one million tons per year.

6. Smelting of non-ferrous metals (including lead, tin, copper, and nickel) direct from ores and concentrates.

7. Production of aluminium by electrolysis of fused aluminium salts (alumina).

8. Smelting of special types of pig iron; production of ferroalloys.
9. Plants for the sintering of ferrous and non-ferrous metal ores and pyrites cinders.
10. Production of alumina.
11. Production of cast-iron sections in amounts exceeding 100 000 tons per year.

Class II: Health protection zone 500 m wide

1. Magnesium production by any technique except the chloride process.
2. Production of non-ferrous metals in amounts exceeding 2000 tons per year.
3. Plants for secondary processing of non-ferrous metals (copper, lead, zinc, etc.) in amounts from 2000 to 3000 tons per year.
4. Iron-smelting, where the total volume of the blast furnaces is between 500 and 1500 m^3.
5. Plants carrying out all processes of iron and steel production, with an output of up to one million tons per year of iron and steel.
6. Steel-smelting by the open hearth, converter, and electrosmelting techniques in works equipped to process wastes (milling of Thomas slag, etc.), where output of the basic product is less than one million tons per year.
7. Production of lead accumulators.
8. Milling of Thomas slag.
9. Production of antimony by pyrometallurgical methods.
10. Production of cast-iron sections in amounts from 20 000 to 100 000 tons per year.
11. Production of zinc, copper, nickel, and cobalt by electrolysis of their aqueous solutions.

Class III: Health protection zone 300 m wide

1. Concentration of metals without hot processing.
2. Production of lead-covered or rubber-insulated cable.
3. Production of cast-iron sections in amounts from 10 000 to 20 000 tons per year.
4. Plants for secondary processing of non-ferrous metals (copper, lead, zinc, etc.) in amounts up to 1000 tons per year.
5. Production of non-ferrous metals in amounts from 100 to 2000 tons per year.
6. Production of mercury and apparatus containing mercury (mercury rectifiers, thermometers, valves, etc.).
7. Iron-smelting, where the total volume of the blast furnaces is less than 500 m^3.
8. Casting of non-ferrous metal sections under pressure with an output of 10 000 tons of castings per year (9500 tons of aluminium pressure castings and 500 tons of zinc castings).
9. Production of metal electrodes with the use of manganese.

Class IV: Health protection zone 100 m wide

1. Manufacture of electrical engineering machines and apparatus (dynamos, condensers, transformers, projectors, etc.), where foundries and similar installations are small.
2. Production of bare cable.
3. Manufacture of boilers.
4. Production of metallic electrodes.

5. Metal-working factories for cast-iron, steel (in amounts up to 10 000 tons per year), and non-ferrous (in amounts up to 100 tons per year) castings.

6. Production of antimony by electrolysis.

7. Type foundries where lead may be emitted into the air.

Class V: Health protection zone 50 m wide

1. Metal-working industries using heat treatment, but with no foundries.

2. Production of alkali accumulators.

3. Type foundries.

4. Production of instruments for the electrical engineering industry (lamps, headlights, etc.) in factories without foundries and not using mercury.

5. Production of hard alloys and refractory metals in plants containing no departments for chemical ore processing.

6. Printing works.

Mining of ore minerals and non-metallic minerals

Class I: Health protection zone 1000 m wide

1. Plant for the extraction of crude oil, where 0.5-1 ton of hydrogen sulfide is discharged per day and the oil has a high proportion of volatile hydrocarbons.

2. Mining of lead ores, mercury, arsenic, and manganese.

3. Plants for the extraction of natural gas.

Class II: Health protection zone 500 m wide

1. Plants for the extraction of phosphorite, apatite, or pyrites without chemical processing.

2. Plants for the extraction of fuel shales.

3. Mining of hard coal, brown coal, and other coals.

4. Open-cast mining of iron and complex metallic ores (with the exception of lead ores, mercury, arsenic, and manganese), and the quarrying of rock of grades VIII-XI.

Class III: Health protection zone 300 m wide

1. Plants for the extraction of crude oil, where the amount of hydrogen sulfide discharged is less than 0.5 tons per day and the volatile hydrocarbon content of the oil is low.

2. Quarrying of rock of grades VI-VII: dolomites, magnesites, asbestos, tars and asphalts.

3. Open-cast mining of metalloid compounds.

4. Production of briquettes from powdered peat and coal.

5. Hydraulic mines and wet-dressing plant.

Class IV: Health protection zone 100 m wide

1. Mining of rock salt.

2. Peat-cutting.

3. Mining of metal and metalloid ores in pits, except for lead ores, mercury, arsenic, and manganese.

The building industry

Class I: Health protection zone 1000 m wide

1. Production of Portland, Portland-slag, and other cements in amounts exceeding 150 000 tons per year.
2. Kilning of magnesite, dolomite, and fire-clay in shaft or rotary kilns.

Class II: Health protection zone 500 m wide

1. Production of gypsum (alabaster).
2. Production of asbestos.
3. Production of lime in factories with shaft or rotary kilns.
4. Production of Portland, Portland-slag, and other cements in amounts up to 150 000 tons per year.
5. Production of asphalt concrete in mobile plants.

Class III: Health protection zone 300 m wide

1. Production of artificial fillers (clay and other fillers).
2. Production of glass wool and slag wool.
3. Production of local cements (calcined-clay cement, Roman cement, slag-gypsum cement etc.) in amounts up to 5000 tons per year.
4. Production of tar paper and rubberoid roof-sheeting material.
5. Production of asphalt concrete in permanent plants.

Class IV: Health protection zone 100 m wide

1. Production of artificial stone and concrete articles.
2. Hoists for lifting cement and other dust-producing building materials.
3. Production of building materials from heat-and-power station wastes.
4. Production of articles from asbestos cement.
5. Production of polymerized building materials.
6. Production of porcelain ware and earthenware.
7. Production of red brick and silica brick.
8. Production of ceramic and refractory ware.
9. Production of stoneware.
10. Glass manufacture.

Class V: Health protection zone 50 m wide

1. Quarrying of rock without blasting and plants for working natural stone.
2. Production of plaster goods.
3. Production of reedbourd, strawboard, etc.
4. Pottery production.

The wood industry

Class I: Health protection zone 1000 m wide

1. Chemical processing of wood and the production of charcoal.

Class II: Health protection zone 500 m wide

1. Production of charcoal by the retort process.

Class III: Health protection zone 300 m wide

1. Plants for impregnating wood in order to preserve i
2. Production of articles from wood fibre using artificial resins as binders (chipboard, fibreboard).

Class IV: Health protection zone 100 m wide

1. Production of wood fibre.
2. Saw mills and factories producing plywood and wood parts for buildings of standard design.
3. Shipyards for the construction of wooden craft.
4. Production of wallpaper.
5. Production of vitamin-enriched pine-needle flour, chlorophyll-carotene pastes and pine extracts.

Class V: Health protection zone 50 m wide

1. Wood-working, manufacture of furniture, parquet, and boxes.
2. Plants for the protective treatment of wood by impregnation with aqueous solutions (other than arsenic salts).
3. Production of articles from wood fibre (chipboard, fibreboard, cement-fibrolite board, etc.).
4. Production of barrels using prepared staves.
5. Production of bast matting.
6. Boatyards for the construction of launches and small craft.

The textile industry and light industry

Class I: Health protection zone 1000 m wide

1. Plants for the primary processing of cotton which have departments for treating seed with organomercury compounds.

Class II: Health protection zone 500 m wide

1. Plants for the chemical treatment and processing of textiles with carbon disulfide.
2. Production of artificial leather, sheeting, oilcloth, and plastic for shoe soles where volatile organic solvents are used at the rate of up to 2 ton

Class III: Health protection zone 300 m wide

1. Plants for continuous impregnation of textiles and paper with oil-varnish, oil asphaltum, bakelites, and other varnishes, where the rate of production of impregnated material exceeds 300 tons per year.
2. Plants for the primary processing of vegetable fibres (flax, hemp, cotton, etc.).
3. Plants for the treatment and processing of textiles without the use of carbon disulfide (leatherette, leather substitute, etc.).
4. Bleaching, dyeing, and finishing plants.
5. Production of polyvinylchloride sheeting reinforced on one side, blended polymer sheeting rubber for shoe soles, and reclaimed rubber, where solvents are used at the rate of one ton per day.

Class IV: Health protection zone 100 m wide

1. Plants for the continuous impregnation of textiles and paper with oil-varnish, oil-asphaltum, bakelite, and other varnishes, where the rate of production of impregnated material is less than 300 tons per year.
2. Manufacture of cottonin.
3. Silk filatures.
4. Manufacture of mixture fabrics.
5. Manufacture of hemp cordage, rope, and twine.
6. Manufacture of yarn and textiles from wool, cotton, and linen in mills with dyeing and bleaching departments.
7. Production of fancy leather board with polymer finishes, where organic solvents are used at a rate of up to 0.5 tons per day, and rubber for shoe soles without the use of volatil organic solvents.

Class V: Health protection zone 50 m wide

1. Manufacture of cotton, linen, and woollen yarns and textiles in mills without dyeing and bleaching departments.
2. Manufacture of knitwear and lace.
3. Silk weaving.
4. Clothing factories.
5. Manufacture of carpets and artificial astrakhan.
6. Production of insole board from leather and leather-cellulose fibre without the use of solvents.
7. Footwear manufacture.

Processing of animal products

Class I: Health protection zone 1000 m wide

1. Factories manufacturing glue from hide remnants, bone refuse, and other animal wastes and residues.
2. Production of industrial gelatin from bone refuse, scrapings, hide remnants, and other animal wastes and residues in plants where such material is stored under cover or in the open air.
3. Salvaging plants for processing animal or fish wastes and residues into fats, animal feed, fertilizers, etc.

Class II: Health protection zone 500 m wide

1. Plants for roasting and grinding bones.

2. Fat rendering plants producing industrial fats and greases in amounts exceeding 30 tons per year.

Class III: Health protection zone 300 m wide

1. Plants for preparing belts for dyeing (sheepskin, tanned sheepskin, furs) and the production of suede, morocco leather, kid, etc., with facilities for processing wastes.

2. Plants for processing raw cattle hides; raw-hide dressing and tanning with facilities for processing wastes.

3. Production of industrial fats and greases in amounts up to 30 tons per year.

4. Wool-washing plants.

5. Storehouses for wet-salted and unprocessed hides (storage capacity for over 200 hides).

Class IV: Health protection zone 100 m wide

1. Production of skeletons and visual teaching aids from animal carcasses.

3. Feed concentrate plants using animal and food wastes.

3. Felt manufacture.

4. Production of high grade gelatin from fresh bones kept for as short a time as possible under refrigeration in special stores.

5. Plants for processing hair, bristle, down, feathers, horns, and hooves.

6. Production of gut and catgut.

Class V: Health protection zone 50 m wide

1. Manufacture of patent leather.

2. Manufacture of leather goods.

3. Manufacture of brushes from bristle and hair.

4. Depots for the temporary storage of wet-salted hides (up to 200), where no processing is carried out.

5. Felting shops.

Food processing and the production of flavourings

Class II: Health protection zone 500 m wide

1. Stockyards to hold over 1000 head of livestock after shipment.

2. Abattoirs for cattle and sheep, meat-packing plants, and meat-packing houses, with stockyards for holding animals before slaughter that, at maximum capacity, represent three days' supply of meat.

3. Plants for melting down blubber from marine animals.

4. Plants for washing intestines.

5. Disinfection and cleansing stations for washing down trucks in which livestock have been shipped.

Class III: Health protection zone 300 m wide

1. Beet-sugar refineries.
2. Factories producing feed antibiotics.
3. Fisheries.
4. Stockyards holding up to 1000 head of livestock after shipment.
5. Plants for the production of enzymes by the surface culture technique.
6. Slaughterhouses for small animals and poultry.

Class IV: Health protection zone 100 m wide

1. Flour mills, hulling mills, grain shellers, and feed concentrate mills.
2. Grain elevators.
3. Coffee-roasting plants.
4. Cheese-making factories.
5. Production of oleomargarine and margarine.
6. Meat-curing plants.
7. Production of alcohol for the food industry.
8. Fish canneries and fish filleting plants with departments for processing wastes; fish-packing plants.
9. Plants for the production of enzymes by submerged fermentation.
10. Beet-sugar refineries without facilities for storing beet pulp.
11. Cornflour and corn syrup factories.
12. Production of albumin.
13. Vegetable processing (drying, salting, or pickling) plants.
14. Production of dextrin, glucose, and molasses.
15. Starch production.

Class V: Health protection zone 50 m wide

1. Confectionery factories.
2. Production of table vinegar.
3. Tobacco-curing plants and cigarette factories.
4. Tea-blending plants.
5. Distilleries.
6. Oil mills (vegetable oils).
7. Canneries.
8. Vegetable storehouses.
9. Sugar refineries.
10. Brandy distilleries.
11. Breweries (without malthouses).
12. Pasta factories.

13. Milk and dairy product factories.

14. Sausage factories with an output of over 3 tons per shift.

15. Factory-type bakeries.

16. Factories preparing foodstuffs.

17. Refrigerating plants with a capacity of over 600 tons.

18. Plants for the initial stages of wine-making.

19. Wine-making establishments.

20. Production of grape juice.

21. Production of fruit and vegetable juices and non-alcoholic beverages.

22. Plants for the production of commercial malt and yeast.

23. Fish-curing plants.

Heat-and-power stations and boiler installations

8.3 Health protection zones for heat-and-power stations and boiler installations shall be determined in accordance with the dispersion in the air of the harmful substances contained in the wastes discharged, as calculated on the basis of the official publications on standards.

Sanitary engineering installations and municipal undertakings

8.4 The width of health protection zones for sanitary engineering installations and municipal undertakings shall be established on the basis of the sanitary classification and production capacity of such installations and undertakings.

Class I: Health protection zone 1000 m wide

1. Controlled unimproved tips for liquid and solid domestic wastes of organic origin.

2. Fields where septic-tank contents are ploughed in or spread.

Class II: Health protection zone 500 m wide

1. Burial-places for cattle.

2. Salvaging plants for the disposal of animal carcasses and condemned meat.

3. Principal centres for salvage and incineration of refuse.

4. Improved tips for solid wastes.

5. Centralized composting areas for solid wastes and refuse from population centres.

Class III: Health protection zone 300 m wide

1. Cemeteries.

2. District centres for salvage and incineration of refuse.

3. Principal collection centres for utilizable wastes.

4. Cattle burial-places with carcass destruction chambers.

5. Outfall works.

6. Greenhouses and hothouses making use of refuse.

7. Composting of refuse containing neither manure nor fecal matter.

Class IV: Health protection zone 100 m wide

1. District collection centres for utilizable wastes.
2. Depots for vehicles used for refuse collection in towns.
3. Places for the temporary storage of scrap material without processing.
4. Servicing stations for heavy goods vehicles and for buses belonging to the urban transport system.

Class V: Health protection zone 50 m wide

1. Servicing stations for motor vehicles (cars, except for privately owned cars, and buses outside the urban transport network).

8.5 Health protection zones for sewage treatment installations

Types of installations	Width of zone (in metres) for installations with treatment capacity of (m^3/day)			
	< 200	200-5000	5000-50 000	50 000-280 000
Installations for mechanical and biological treatment of sewage with sludge beds for digested sludge, and installations with sludge beds alone	150	200	400	500
Installations for mechanical and biological treatment of sewage and thermomechanical processing of sludge in closed premises	100	150	300	400
Filter beds	200	300	500	1000
Sewage farms	150	200	400	1000
Waste stabilization ponds	200	200	-	-

Notes: Health protection zones for sewage treatment installations with a capacity exceeding 280 000 m^3/day and for installations not using approved sewage-treatment and sludge-processing techniques shall be established by joint decision of the Central Sanitary and Epidemiological Board of the Ministry of Health of the USSR and the State Committee for Construction of the USSR.

Filter beds with an area of up to 0.5 ha and installations for mechanical and biological treatment of sewage with a capacity of up to 50 m^3/day shall have a health protection zone 100 m wide.

Municipal sewage farms with an area of up to 1 ha shall have a health protection zone 50 m wide.

Underground filter beds with a capacity of 15 m^3/day shall have a health protection zone 15 m wide.

Where dwelling houses are located downwind of the treatment installations, the health protection zones may be enlarged, but to no more than twice the width indicated in the table. They may be reduced in the case of a favourable wind distribution.

8.6 The width of the health protection zones for sewage pumping stations shall be:

(a) 20 m for a treatment capacity of 50 000 m^3/day;

(b) 30 m for a treatment capacity exceeding 50 000 m^3/day.

Pumping stations with a capacity of up to 200 m^3/day are permitted a health protection zone 15 m wide.

The widths for health protection zones indicated in the table also apply to food production plants.

HEALTH PROTECTION ZONES FOR AGRICULTURAL UNDERTAKINGS AND AGRICULTURAL PREMISES

Types of undertaking or premises	Width of health protection zone (metres)
Farms:	
stud farms and rabbit farms	100
cattle farms (all types), sheep farms, and fur farms	300
poultry farms	300
pig farms	500
Poultry factories	1000
Veterinary surgeries	200
Hothouses and greenhouses:	
heated biologically (using manure)	100
heated biologically (using refuse)	300
using electrical, steam, or water heating systems	no standard
Premises for preparing feed:	
without the use of food wastes	no standard
with the use of food wastes	100
Undertakings and premises for the initial treatment and processing of milk, fruit, or vegetables	no standard
Garages and yards for the repair, servicing, and parking of cars and agricultural machinery, with a capacity of over 200 machine units	100
Storehouses for fruit, vegetables, potatoes, grain, other agricultural produce, and other stores	50
Buildings for housing animals and poultry kept for private use in residential areas	50
Storehouses:	
for mineral fertilizers	200
for mineral fertilizers and up to 20 tons of pesticides	200
for pesticides:	
up to 20 tons	200
20-50 "	300
50-100 "	400
100-200 "	500
300-500 "	700
over 500 "	1000

Note: Specialized complexes used for raising pigs on an industrial scale shall be assigned health protection zones according to their individual requirements.

Warehouses

8.7 Health protection zones for warehouses shall be established in accordance with the existing design standards for the various types of warehouses as approved or accepted by the State Committee for Construction of the USSR.