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Gearheart,R.A.; Porcella,D.B.; Middlebrooks,E.J.

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AGRICULTURAL CONTRIBUTION TO WATER QUALITY DETERIORATION

BY
Robert A. Gearheart, Assoc. Prof. Civil Engr. Dept., USU
Donald B. Porcella, Assoc. Prof. Civil Engr. Dept., USU
E. J. Middlebrooks, Professor, Civil Engr. Dept., USU

An initial understanding of the beneficial uses of water by agriculture is necessary prior to developing an understanding of the change in the quality of water due to agricultural activity. Water is used directly in such agricultural activities as a water supply in rural areas. Indirectly, water is used as a process water in the preparation of certain food products, such as vegetables, meats, and dairy products, and as a process water in the forest products industry. Of the uses mentioned above, irrigation uses account for 99% of the water use by agriculturists in the State of Utah. The irrigation demand for water amounts to approximately 176 BGD. Of this 176 BGD, about 73 BGD is returned to the water course as return flow. The use of water for irrigation purposes amounts to about 38% of the total water use in the United States annually. Figure 1 depicts the overall water demand in the United States for the various cultural activities.

Another significant element of the effect of agricultural activity on water quality is the amount of total land area upon which this activity occurs. As can be seen in Figure 2, that area which is comprised of crop and livestock production amounts to 58% of the total of 2.3 billion acres of land in the United States. This points to one of the significant aspects of water quality deterioration due to agricultural activity. Urban land amounts to 3% of the total and tends to concentrate tremendous amounts of pollutants in small areas. This is referred to as "point" load of pollutants on a watershed. Agricultural activity [tends ?] to produce a dispersed load of pollutants on a watershed. Obviously there are examples of reverse effect of the above mentioned relationship, but generally the above holds true. Generally speaking, point loads of pollution tend to

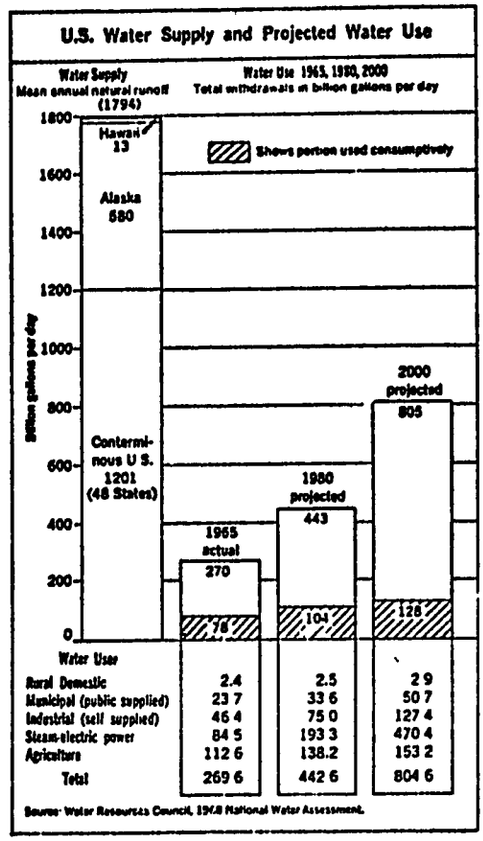

Figure 1. U. S. Water Supply and Projected Water Use

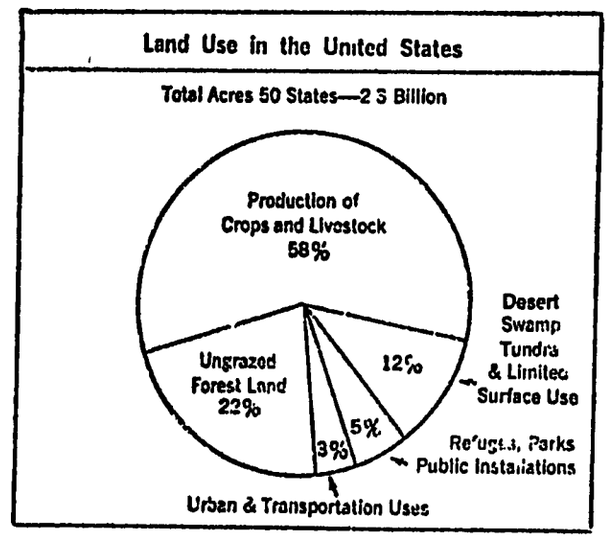

Figure 2. Land Use in the United States

dilute with time, distance, and flow as opposed to dispersed loads which tend to concentrate with time, distance, and flow.

The importance of the point load versus the dispersed load concept lies in the assimilative capacity of stream to allow the waste to be degraded. As can be seen in Table 1, waste can be classified into three groups based upon their level of degradability. Most organic wastes, expecially those produced by agricultural activity, can serve as food for aquatic microorganisms in streams, lakes, and reservoirs.

The aquatic environment normally has a full complement of gases as is found in our atmosphere. This means that oxygen is present in aquatic systems. The amount of oxygen present is dependent upon the temperature of water, the dissolved solids present, and the altitude. Referring back to the organic materials which are serving as food for the aquatic microorganisms, the demand for oxygen by these microorganisms as they consume the organic material is superimposed. This concept is referred to in the language of the water quality specialist as BOD (Biochemical Oxygen Demand). If the BOD of waste stream exceeds the amount of dissolved oxygen present in the stream a condition of no-oxygen exists in the stream or the stream is septic. Since a waste that exerts a BOD is degradable, its concentration decreases with time as a water course proceeds through its course. This is significant difference from the non-degradable waste which would tend to concentrate due to evaporation if no dilution is afforded. Quite often these types of waste are referred to as persistent pollutants denoting the fact that they change only in respect to their form or location in a water course. Those wastes referred to as degradable release approximately 60% of their weight to the atmosphere as carbon dioxide. The remainder of the degradable waste has been changed to cellular material of the microorganisms.

Table 1. Classification of wastes
(Substances that degrade water quality).

Degradable	Non-degradable	Other
Heat	Inorganic suspended solids	Radioactive materials
Organic materials Animal wastes Fruit processing wastes Vegetable processing wastes Paper and pulp mill wastes	Mineral and other inorganic substances Salts Metal compounds Acids Alkalies Plant nutrients	Viruses Detergents
Bacteria	Synthetic organic Chemicals Pesticides	

Sediment

Sediment is composed primarily of clay, silt, sand, rock, crop residues, and other material that can be transported by flowing water. Water picks up this material and deposits it in ponds, lakes, reservoirs, and streams. As the Mississippi River flows to the Gulf of Mexico, for example, it picks up sediment from strip mining in West Virginia, cornfields in Iowa, wheat fields in Montana, rangelands in Colorado, and the Badlands of South Dakota. Its annual flow of 450 million acre-feet of water carries nearly 500 million tons of sediment to the Gulf annually. This much silt is equal to the topsoil from nearly 500,000 acres.

There are nearly 800 million acres of land in the Mississippi drainage basin of which 292 million acres are in cropland. It is apparent that erosion from cropland, and the banks of streams, contributes a large part of the sediment carried by the Mississippi River. Also, erosion from highways and construction sites is increasing rapidly.

The fate of any settlebale particle is to be deposited on some stream, lake, reservoir, or ocean bottom. This eventually fills in the final sediment depository, increasing the velocity because of the decrease in volume. Sediment changes aquatic environments in many ways, thereby forcing a change in the aquatic organisms found. Sediment causes distinct changes in the nature of the bottoms of streams and lakes. Suspended sediment reduces the depth of light penetration in aquatic system affecting photosynthetic organisms such as algae. Suspended material also captures more of the radiant energy than does water without suspended material, thereby increasing the temperature. Those higher aquatic forms such as fish, who rely on sight feeding, are impaired by reduction in light penetration.

Sediment can serve as a transport vehicle for oxygen consuming organic waste, for insecticides and herbicides, nutrients, and salts of certain types. Besides clogging streams and lakes, sediment increases the cost of water clarification in municipal filtration plants.

Disease Transmission

Water's role as a vehicle in the transmission of animal diseases has been poorly documented; however, there is concern. Strong evidence has been presented to show that the transmission of animal diseases by water can occur, but in most cases, epidemiological studies of animal disease outbreaks have not been made.

It is doubtful that any significant concern should be directed toward irrigation return flows, but it is possible that bypass waters could carry animal diseases if the stock has access to the irrigation canals.

In the United States, the major zoonoitc disease is salmonellosis. Approximately 20,000 human cases are reported each year, but estimates are that between 1 to 2 million cases occur. Salmonella survive in water and environment for extended periods of time. The bacteria could survive several weeks to 3 months in drinking water and natural surface water. In 1966, large water-borne outbreaks of human cases occurred at Riverside California, from a Salmonella-contaminated water supply. Although the source of contamination was not identified, it was speculated the water may have been contaminated by seepage from a cattle feedlot. Other bacterial diseases known to be water borne and transmitted by animals to man are: Leptospirosis, Anthrax, Tularemia, Brucellosis, Erysipelas, Tuberculosis, Tetanus, and Calibacillosis. Q-fever is the only rickettsial disease known to affect both man and animal without an arthropod host.

The organism has been isolated from standing water in infected sheep ranches over a 6-week period during the lambing season.

There are over 500 known animal viruses, counterparts of the major viruses known to infect man, that are found in domestic animals. Generally speaking, viruses do not survive for long periods of time outside the animal host. Viruses possess about the same degree of resistance to drying, heat and chemical agents as many of the vegetative forms of bacteria. Those viral disease known to be transmitted from animals to man are: Newcastle disease, Hog Cholera, Foot and Mouth Disease.

There are several parasitic diseases due to protozal, round worms, and flatworms. Listed are several diseases known to infect both man and animals: Balantidiasis, Toxoplasmosis, Ascariasis and Taeniasis.

Insecticides

The major concern of conservationists regarding chlorinated hydrocarbon pesticides is the problem of persistence. The severe ecological effects resulting from pesticide levels which are hardly measurable in the aquatic environment, suggest that there is no safe level of application of these persistent chemcials which is consistent with economic agricultural use. These long-lasting compounds spread worldwide and concentrate in dangerous amounts through the food chain. Some alternatives to the use of persistent pesticides in agriculture are the substitution of organic phosphates and carbonates and the employment of biological controls.

The release of persistent pesticides to the environment can be slowed by more effective treatment of waste discharges from the manufacturing plants, and by minimizing the application of all insecticides. Accidental discharges to water supplies and streams has resulted in numberous problems that could have been prevented by better handling techniques.

Herbicides

The effectiveness of herbicides and the economics involved in agricultural production have caused extensive use of weed control in and adjacent to aquatic areas, especially on irrigation systems. As data are accumulated that describes the residues and toxicity, it is likely that an increase in the use of herbicides will occur. Little is known about the distribution of herbicides by irrigation systems because of the very low concentrations and the lack of adequate anlytical techniques.

The concentrations of herbicides found in irrigation water are generally considered to be unlikely to cause injury to crops. However, little is known about the accumulation of these compounds, and it is possible that this will change. Copper accumulation, from the application of copper sulfate to control algal blooms, has been known to cause toxic effects.

Temperature Increases

The most serious effects from temperature increases are reduction in the dissolved oxygen supply and increased toxicity of polluting substances. Little is known about the quantitative increases in toxicity with increases in temperature, but temperature increases of a few degrees have been known to double the toxicity of certain industrial wastes.

Production of fruits and vegetables is the most intensive high value crop production program. The demand for fruits and vegetables free of insect damage has certainly been met with an intensive use of pesticides.

Home gardens, lawns, and flowers are not usually considered an agricultural problem and yet in the area of pesticide pollution they should be included. The home use of pesticide has a greater probability of misuse due to possible over application, intensity of use, and proximity to other people and should be considered.

Table 2. Average animal waste charcteristics.

Specie	lb./Animal/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	0.0003	11	9.2	11
Swine	0.30	0.90	0.05	0.57	0.60	0.66
Dairy Cattle	1.0	10	0.40	0.13	0.055	0.08
Beef Cattle	1.0	10	0.30	0.17	0.055	0.11

(a) based on average charcteristics in municipal sewage: 0.17 lb. BOD/capita/day, 0.55 lb. total solid/capita/day, and 0.033 lb. total nitrogen/capita/day.

(b) number animals equivalent to one person

(c) total Kjeldahl nitrogen

Table 3. Population equivalents of animal wastes (BOD_5 Basis)

Species	Human Excrement Baseline	Domestic Sewage Baseline
Man	1.0	0.55
Cattle	6.4	3.5
Hen	0.32	0.17
Sheep	0.57	0.31
Swine	1.6	0.9

Chemical pesticides are a threat to the environment. Yet the benefits derived from their use--increased food produciton and prevention of disease--represent an equally strong argument for their continued use. The solution, if there is one, rests in better understanding of pesticide-pollution problems and full evaluation of pesticide alternatives.

Animal Wastes

The animal waste problem can be coupled to several factors that have developed in the last 10 to 15 years. The use of confinement type of facilities, such as feed lots and dairy cattle enclosures, has concentrated the production of animal waste essentially producing a "point" pollutional load. The increase in population and the increase in consumption of meat products has forced increased production. Livestock on American farms produce about 2 billion tons of manure each year. Manure from different classes of animals will have different charcteristics as seen in Tables 2 and 3. Manure from grass fed animals, growing stock and milk stock is less rich than that from animals being fattened or from work animals liberally fed on concentrates.

Highly efficient consumption of feed by animals in confinement produces a waste which contains more material capable of causing nuisance and pollutional problems.

The principal responsibility of the environmental specialist is to insure that the quality of water source is adequately protected such that none of the planned uses are eliminated by wanton action by any of the users. This not only means protecting the water source from agricultural pollution, but also insuring that agricultural uses are protected; also, the realization that complete purity and total protection are impractical, and that certain tradeoffs must be made if production (agricultural and industrial) is to be maintained at an adequate pace to meet our growing needs and wants. To

fulfill the above responsibilities, it is necessary that (a) an overall water quality plan be formulated, (b) a program of protection be implemented, and (c) a monitoring program be planned to insure compliance with standards.

Perhaps the three most significant effects on water quality produced by irrigation practices are the increase in total solids concentration, the addition of nutrients and temperature increases. The solids buildup is obviously of great concern to the agriculturalist and can directly affect production; however, water quality in the traditional sense is affected more seriously by nutrient addition and temperature increases.

Resolution of Water Quality Management Problems Originating Within Agriculture

The first step is being taken toward resolving water quality problems resulting from agriculture by recognizing the importance of water quality problems. The next step is to gather information and facts establishing agriculture's contribution to water quality problems, and then formulate and implement plans for action. Information combined with action, but without emotional reaction, will provide the proper solution to water quality problems contributed by irrigation practices.

Nitrate accumulations beneath feedlots and in soils are a potential for contaminating surface and groundwater. Water containing more than 10 ppm NO_3 - N is considered unsafe for drinking by the U.S. Public Health Servic.

A usually acute and highly fatal disease of animals results from drinking water containing high concentrations of toxic strains of blue-green algae. Extensive loss of life and severe sickness of livestock, pet, wild animals and humans have been associated with algal blooms in the northern half of the U. S. (also in Texas), the southern provinces of Canada, Russia, Argentina, Australia, South Africa and other countries

Poisoning does not occur unless a dense bloom of toxic material occurs. The factors leading to the formation of such blooms include warm sunny weather, ample nutrients (especially nitrates), and a gentle prevailing wind which drifts and collects the algae against the windward shore. Such conditions commonly occur during the summer months in drainage ponds and lakes used for watering livestock.

Early studies indicated the primary toxic principle to be an alkaloid which affects the central nervous system and liver. A secondary toxic principle was described to be algal phycobilin pigments which accumulate in the skin of animals with a resultant increase in photo sensitivity.

More recent research discounts the alkaloidal nature of the toxic principle and incriminates a seven-amino acid cyclic polypeptide which produces rapid toxic symptomatology. In general, the crude toxic principle has the following characteristics: It can exist outside the cells in the water around the algae; it passes through cellophane and animal membrances by dialysis; it is non-volatile; it is relatively heat stable; it is soluble in water, alcohol (95% or less) and acetone, it is resistant to extreme pH changes. Several toxic fractions have been obtained by chromatographic procedures and one of these may be identified by a characteristic adsorption curve having an almost complete absorption from 210-290 millimicrons. This fraction produces paralytic symptons in mice and is lethal to 20 gram mice at a dosage of 0.7 mg.

Clinical Findings

Toxic symptoms appear rapidly, usually within 15 to 45 minutes, after ingestion of poisonous material. Poisoning proceeds rapidly and is severe; death is common, occurring in less than 24 hours, often within one or two hours. The most commonly reported sequence of events are rapid prostration, convulsions and death; although convulsive signs are

not always marked. Abdominal pain, muscular tremors, cyanosis and excessive aslivation are commonly reported. A moderate number of cases have shown severe gastrointestinal manifestations including diarrhea, bloody feces, and icterus. Photosensitization frequently occurs in animals who survive for sveral days.

Control

Removal of all animals from the affected water supply is an essential first step to all other measures. Algae growth may be suppressed with copper sulfate or other algacide treatment, but does not remove the toxin already present in the water. If no other water supply is available, animals should be allowed to drink from the clearest part of the water source opposite the windward shore (wind currents tend to blow and accumulate algal growth on the windward shore).

It is essential that animals dying from algae poisoning not be used for food as the toxic principle is quite stable and consistantly produces toxic symptoms in the consumer. This is especially true with respect to the liver of diseased animals.

The Problem of Eutrophication

As water bodies age they tend to accumulate nutrients and organic material. This is the natural process which leads to a eutrophic or highly enriched stage. The eutrophication process defined as the enrichment due to nutrient accumulation causes waters to become more fertile and acquire a greater capability to grow algae and other forms of unwanted living matter. The detrimental effects of increasing biological activity have been reported extensively (1) (2) (3) (4) (5) and include increase in turbidity, formation of algal scums which wash up on the shore or sink to the bottom and create obnoxious odors through decomposition,

unfavorable tastes in water supplies, clogging of water intakes, removal of oxygen from bottom water of lakes, and the general impairing of recreational uses.

One of the principal factors affecting the role of eutrophication is the extent to which nutrients needed by algae enter the water under either natural conditions or man-created conditions. Cultural developments on the watershed, such as urban establishments and agricultural endeavors, greatly accelerate nutrient input as can be seen in Table 4. Several excellent reviews on the general concepts of eutrophication originating through natural and artificial means have been written (6) (3) (7) (5). The fertilizing elements quoted most often as contributing to lake eutrophication are nitrogen and phosphorus. Ferguson (8), however, discusses the nonmyopic approach to eutrophicationcontrol and states that perhaps too much emphasis is placed on these two nutrients with lettle attention being given to other substances. Provasoli (9) outlines other possible factors such as vitamins and micro-nutrients - manganese, boron, cobalt, iron and vanadium - which play a role in developing aquatic growths. However, present knowledge indicates that these elements are difficult to monitor and their role is not well understood.

Under methods of limiting nutrient concentrations, Oglesby and Edmondson (10) have mentioned three possible control measures of which the first is the removal of nitrogen and phosphorus at their source. Also, MacKenthun and Ingram (3) indicate that in order for control measures to become successful it is necessary to determine that portion of the nutritive input attributable to man-induced pollution which may be corrected as opposed to that input which is natural in origin and, therefore, usually not correctable. As a result of these research needs, investigations have been undertaken to set the problem of eutrophication

Table 4. Estimates of sources of plant nutrients entering Wisconsin surface water.*

Source	N	P
Municipal Treatment Facilities	245	55.7
Private Sewage Systems	5.9	2.2
Industrial wastes	1.8	0.8
Rural Sources		
Manured lands	9.9	21.5
Other cropland	0.7	3.1
Forest land	0.5	0.3
Pasture, woodlot and other lands	0.7	2.9
Groundwater	42.0	2.3
Urban runoff	5.5	10.0
Rainfall on water areas	8.5	1.2

*Corey, R. B., Hasler, A. E., Lee, G. F., Schraufnage, F. H., and Wirth, T. L. 1967. Excessive Water Fertilization Report to the Water Subcommittee.

in proper perspective. However, a majority of these studies (10) (11) (12) (13) have either pertained to estimates of total nationwide contributions from various sources or have dealt with determinations of nutrient contributions, but not loadings. Consequently, as Ferguson (2) quoted, "relatively few studies have been conducted in the U.S. to determine how much growth material is contributed by individual sources." Studies which have been concerned with evaluating nutrient contributors associated with isolated ecosystems include those reported by Orr (14), MacKenthum et al., (4), and Miller and Tash (15). These investigations, however, do not attempt to predict future nutrient levels using model formulations.

Major sources of phytoplankton nutrients include wastewater effluents, agricultural runoff, forest runoff, urban drainage, and rainfall. Considering nitrogen and phosphorus, most work has focused on inputs of phosphorus for reasons listed by Batisch (1). Most important of these is that phosphorus is more amenable to control since there are various largely uncontrollable sources of nitrogen input such as nitrogen fixation from the atmosphere and, secondly, rainfall.

Domestic sewage is perhaps the most common source of nutrients. The greatest contributors of phosphorus in domestic waste are human wastes and built detergents (16). The present phosphorus content of domestic waste varies from about 2-4 lb/capita/year (13). The primary sources of nitrogen are feces, urine and waste food. A report made by Task Group 261 OP (13) indicate average values of nitrogen being 8 - 12 lb/capita/year. Fruh (6) reported a value of 9.7 lb/capita/year.

Agricultural runoff may be the major contributor of nutrients to the tributary streams (17) (18). Sylvestor (11) reported that surface irrigation return flows from farming areas in Yakima Valley, Washington, contained 1.19 to 1.90 mg/l NO_3-N, 0.165 to 0.360 mg/l total -P, and 0.127 to 0.210 mg/l soluble -P. The total phosphorus in the drainage

water varied from 0.9 to 3.9 pounds/acre/year. Farmlands in the Kaskaskia River Basin (19) contributed an average of 225 pounds of total phosphorus (P) peryear per sq. mi. of drainage area. Weibel et al. (20) reported a range of 0.08 - 1.1 mg/l total hydrolyzable -P from agricultural drainage of wheat fields.

Summary

The agriculturist is in an advantageous position compared to the urbanite and industrialite to control pollution due to their innate involvement with the environment. Many of the management techniques necessary to enhance water quality have been practiced to various degrees by the agriculturists for many years. Below is a brief list of the more salient management techniques necessary to reduce water quality deterioration due to agricultural activities.

Sediment:	Crop Selection Soil Preparation Techniques Conservation of runoff
Organic Waste:	Containment Control of runoff Sediment control Return to soil
Nutrients:	Rate of application Time of application Chemical form of fertilizer Sediment control Irrigation techniques Return to soil
Pesticides:	Rate of application Time of application Sediment control Low residual herbicides and pesticides

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