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9. ABSTRACT
Near livestock feedlots, cities, and certain types of industrial plants, considerably larger than average amounts of nitrogen in such forms as nitrogen oxides and ammonia occur in the rain. All too often the natural and artificial atmospheric inputs are overlooked and a portion may end up by being incorrectly assigned to the agricultural sector. Also, changes occur from time to time in lakes and reservoirs causing inversions and stepped-up release of nutrients from the bottom deposits. Where situations have worsened in recent years, due chiefly to cities and industry, agriculture has received too much of the blame. To date there is no conclusive evidence that proper fertilizer use has increased the nitrate level of streams or wells in the U.S. Over the past decade many towns, cities and factories have added waste treatment facilities and others have improved their degree of waste treatment before dumping effluents into streams. This has greatly reduced the organic food for bacteria, and in turn reduced the biological oxygen demand (BOD) on the stream. Research programs, although meager, are seeking new techniques for disposing of organic wastes and more effective means of conserving soil and keeping it from blowing and washing away. When land is properly farmed and managed, little sediment gets into streams and lakes. There is yet a long way to go in most countries until all land is properly maintained and protected against soil erosion. Man has greatly accelerated the process of eutrophication by organic waste products from his sewage, factories, livestock and pets. He is learning how to treat and handle waste from such sources. In due course, but at high cost, man's contribution likely will be controlled. Intensive research and extensive action programs (Cont.)

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will be required, ano although these will appear to be costly, in reality they will return untold future dividends. Scientists lack sufficient information to determine agriculture's exact contribution, and several years of tedious work in numerous watersheds will be required by skilled soil scientists and hydrologists to obtain this information.

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Agricultural Production in Relation to the Environment

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STAFF PAPER 1/

Agricultural Production in Relation to the Environment

1/ From a paper prepared by Willard H. Garman 2/ member of an Expert Panel on Fertilizers and the Human Environment, sponsored by FAO and the Government of Sewden and held 24-28 January 1972, Rome, Italy. Views expressed are those of the author and not necessarily those of agencies of the U.S. Government.

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See Appendix to this paper for answers to frequent questions about agriculture and the environment.

Office of Agriculture
Bureau for Technical Assistance
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

PREFACE

The Office of Agriculture, Technical Assistance Bureau (TA/AGR) is issuing a series of technical papers on subjects of primary importance to the developing countries. As was the case with previous issues in this series, this one treats its subject in a general sense and it does not attempt to come to grips with the particular problems of any specific country.

For extended use in an individual country, this bulletin should be supplemented with more detailed information on the application of principles to local conditions. From time to time as deemed appropriate an up-to-date version of the information provided will ultimately be prepared indicating the application of the basic principles to the particular circumstances prevailing in the individual country.

Additional copies may be obtained from TA/AGR or through the USAID Mission. For more detailed information, requests should be directed to the Office of Agriculture, Technical Assistance Bureau, Agency for International Development, Washington, D. C. 20523.

Omer J. Kelley
Director
Office of Agriculture
Technical Assistance Bureau

SUMMARY

While it is relatively easy to determine the contribution of a city or of a factory to the pollution load of a stream, it is much more difficult to do so for a farming or forested area. Chiefly, this is because of the large number of variables plus some unknown factors.

Rainfall averages about 0.7 of a part per million of nitrogen. Near livestock feedlots, cities, and certain types of industrial plants, considerably larger amounts of nitrogen in such forms as nitrogen oxides and ammonia occur in the rain. Nitrogen oxides going into the atmosphere in the USA from automobile exhausts, homes, factories and power plants and being returned to land and water surfaces with rainfall is about 17 million tons a year. All too often the natural and artificial atmospheric inputs are overlooked and a portion may end up by being assigned to the agricultural sector. Also, changes occur from time to time in lakes and reservoirs causing inversions and stepped-up release of nutrients from the bottom deposits. Where situations have worsened in recent years, due chiefly to cities and industry, agriculture has received too much of the blame.

In Lake Erie, USA, for example, organic matter from sewage, waterfowl, fish and rooted water plants provides food for bacteria to multiply. They give off carbon dioxide, which, along with water and sunlight, are among the essential ingredients for growth of plants. When carbon dioxide is plentiful, massive growth of algae occurs when light, temperature and nutrients are adequate. The process is difficult to control because the bodies of dead algae and other plants furnish food for more bacteria to evolve more carbon dioxide to grow more algae. This is why removal of phosphorus (phosphate), as from detergents, cannot be expected to control excessive

growth of unwanted plants. Control measures must be aimed at eliminating energy by destroying organic matter, but even this will not provide the desired control in all situations, as near to an airport or city where carbon dioxide is plentiful.

Although nitrogen is an essential constituent of every living cell, it happens that there is enough of it available in rainfall to support algae growth, besides the fact that 40-some species of algae can fix their own nitrogen. Thus, no further input is necessary, as from fertilizer, unless one's objective is to grow enough phytoplankton for fish production. Here a program of fertilization is usually essential to get enough plankton to shade out rooted water weeds.

No lake or body of water is permanent. Each has four stages of life: birth, existence, old age, and disappearance. Examples of all stages can be found in the United States, Canada, Alaska, Siberia, Brazil, and Africa, in surroundings practically untouched by man and certainly never touched by agriculture.

Chemical nutrients at or near the earth's surface are subject to movement by water and air. In nature there is a continual downhill movement of these nutrients into streams, lakes, and oceans.

When man entered the geological picture, this movement (or water-enrichment process) became more active because of working the soil to grow food. This caused more soil particles and organic matter to move into water bodies. These substances, for ages of time, have been accumulating under water along the shorelines of the world.

Thus, eutrophication may be looked upon as nature's age-old geological process of supplying waters with chemical nutrients. Without this process, there would be no coal, oil, or muck deposits on our planet. Nor would

there be marine life.

In North America, one has only to fly from Minneapolis to Winnipeg on a clear day to observe all stages of eutrophication over vast areas practically untouched by man, and certainly untouched by agriculture.

When farmland is maintained in a high state of fertility with plants growing as much of the year as possible, very small amounts of nutrients are lost to surface or underground water. To date there is no conclusive evidence that proper fertilizer use has increased the nitrate level of streams or wells in the U.S. Over the past decade many towns, cities and factories have added waste treatment facilities and others have improved their degree of waste treatment before dumping effluents into streams. This has greatly reduced the organic food for bacteria, and in turn reduced the biological oxygen demand (BOD) on the stream. The result is that both the nitrate and oxygen levels should now be higher than when the stream was overburdened with decomposing organic matter. Obviously, when the BOD is great, bacteria will use oxygen and nitrate as they become available, and neither will be present in a medium (unless a toxic substance or other condition prevents growth of bacteria).

Conclusion

Research programs, although meager, are seeking new techniques for disposing of organic wastes and more effective means of conserving soil and keeping it from blowing and washing away. When land is properly farmed and otherwise handled, little sediment gets into streams and lakes. Unfortunately there is yet a long way to go in most countries until all land is properly maintained and protected against soil erosion.

People in all lands need to understand that although man has not been on the scene very long, he has greatly accelerated the process of eutrophication

by organic waste products from his sewage, factories, livestock and pets. He is learning how to treat and handle waste from such sources. In due course, but at high cost, man's contribution likely will be controlled.

People everywhere also need to be aware that both intensive research and extensive action programs are going to be required, and although these will appear to be costly, in reality they will return untold dividends because only fertile soils will support man in the future and because it is twenty-fold cheaper to keep soil in place than it is to dredge it out of reservoirs and lakes.

Scientists everywhere should realize that they lack sufficient information to determine agriculture's exact contribution, and that several years of tedious work in numerous watersheds will be required by skilled soil scientists and hydrologists to obtain this information.

If water or health problems are likely to occur from use of fertilizer, surely they would have been evident before now in Holland, Denmark, and Japan, where fertilizer usage is older and more intense per unit of area, for example, than in the United States and most other countries.

AGRICULTURAL PRODUCTION IN RELATION TO THE ENVIRONMENT

In terms of land area and value of natural resources, agriculture and forestry constitute the largest environmental complex on earth. Although the problems associated with this complex may differ from region to region, one can safely say that at least for the so-called developed nations its major problems are sediment and dust, plus organic wastes from livestock and the food and forestry processing industries. To the extent that developing nations follow the same pattern as developed countries, they too will face similar problems.

Sediment burdens in waters flowing from agricultural lands in the United States are estimated at two billion tons per year, an amount equal to the quantity of livestock wastes produced. Both are immense problems, and would be very costly to handle even if the will and the technology existed. Fortunately the amount of sediment has been reduced during the past generation due to soil conservation programs and efficient crop production methods which have permitted several millions of marginal acres of U.S. crop land to be retired from cultivation. With sustained effort during the 1970's, sediments arising from water and wind erosion, should be brought under reasonable control on both farms and forests. In passing, one might note that sediment from highway and urban and industrial growth is also about two billion tons a year, but as of now hope for rapid improvement in control of these sediments in the United States is not bright.

Livestock numbers in the U.S. are on the increase and because of concentrations of feeding operations for meat and milk, the volume of livestock wastes is growing faster than disposal technology. Many people today say

that disposal of manure is agriculture's greatest problem in developed countries. They believe that the only solution lies in spreading more and more of it on rural lands. It appears quite likely, therefore, that the U.S. soon will see some shifting away from the huge feeding operations where thousands of cattle are finished annually, to smaller ones with lower-density stocking. Such a shift will facilitate control of waste runoff as well as getting the manure spread on the surrounding agricultural land. The cost will appear to be high because of reduced efficiency and because the value of the nutrients will not pay for the labor required. Thus, one can anticipate added food costs or increased taxes, and these must be evaluated in terms of enhanced environment. For less developed countries, the problems may be avoided by keeping livestock dispersed on the land.

City tax burdens are already great in the U.S. and are skyrocketing for handling of human sewage and urban wastes. A number of joint city and federally sponsored experimental projects are currently under way to find out how much organic matter or sludge from sewage treatment plants can be accommodated by spreading on a given area of land, at what cost, with what social objection, if any, and with what toxic effects on plants, if any.

Because most streams in the U.S. already are overburdened with organic matter arising from sewage systems or from industrial wastes, not only is the demand for improved treatment technology imperative, but it appears that we must look to waste disposal on the land to provide relief for streams and lakes in the near-term future. Hopefully, for the long-term, new technology will develop economic techniques for dissipating oxidizable carbon so that streams can handle urban effluents with no adverse effects. Hopefully, too, new techniques will provide means of handling livestock wastes to protect both streams and underground waters.

Unfortunately certain rather recent cropping pattern changes in the U.S. and particularly in the midwestern states, have not led to improvement in stream quality. Today millions of acres of land are devoted to soybeans whereas formerly they were used for barley, oats, wheat and hay, crops which provided considerable soil protection, especially during periods of heavy snow melt and spring rainfall. This is in marked contrast to the lack of protection now provided in the dormant season of 6 to 8 months yearly by dead and shredded residues from the soybean crop. Residues from the vast acreages of corn are handled similarly, and provide little protection against soil movement by erosion. It would surely follow, therefore, that adjacent streams are receiving much greater amounts of water runoff (1)* containing organic matter and plant nutrients, leached out of the crop residues.

FERTILIZER BLAMED

Recently commercial fertilizers have been blamed for deterioration of water quality in U.S. streams, through contribution of nutrients. There is very little conclusive evidence that this is true based on a check or natural background areas for comparison. According to Dr. Frank G. Viets (15) of the U.S. Department of Agriculture, some of the best information to date on the effect of fertilizers was ontained in Canada on a Brookston clay soil. Here the experiments included various crops on fertilized and unfertilized plots. The amount of nitrogen and phosphrous fertilizer applied is referred to as "higher than normally recommended."

The 7-year average composition of the tile drainage water was:

	PPM	
	NO_3-N	P
Fertilized	8.1	0.21
Unfertilized	6.4	0.18

*numbers in parens refer to references, page 16.

Although amounts of nitrogen and phosphorus from both the treated and untreated plots are relatively small, they are very much more than those required for support of plant growth in aqueous systems. The same can be said for the results of all other similar work reported; as for example, the data reported by Viets (15) for different types of land use, on which values averaged from 7.4 to 13.4 ppm of NO_3-N in drainage water reaching the water table at a depth of 20 feet.

Paired watersheds under study by the U.S. Department of Agriculture (19) throw further light on agriculture's small contribution. One watershed in Ohio is farmed and fertilized, and the other is in forest. The amounts of nitrogen and phosphorus being released annually from both watersheds are almost the same, and very small, but enough to support aquatic plants. Similar results have recently been reported from Canada (2), where the amount of nitrogen in Canal Lake coming from rainfall exceeds that coming from surrounding farm lands.

Extremely interesting to reflect on at this point is a publication by Drs. Stout and Burau (17) in which they calculated the nitrate concentration in leachates from U.S. prairie soils from a century of cultivation. If the soils originally contained 0.1 per cent organic nitrogen in the top foot, and if one-fourth was lost during 100 years of cultivation, and one-hundredth was lost as nitrate in 12.6 inches of percolate annually, the water would contain 28.6 ppm of NO_3-N. This leads one to the belief that in the early years of cultivating these soils, when the rate of organic matter destruction was quite high, waters naturally must have been considerably higher in nitrate than is true today.

The above date cited by Viets, and the lines of reasoning by Stout and Burau seem to lend strong support for looking beyond plant nutrients as pollutants,

and instead considering organic matter as the pollutant, rather than its nutrients. Perhaps only when nutrients are present to the degree of causing an undesirable toxic or salt effect should they be looked upon as pollutants. Water can contain all essential nutrients in the best possible balance for plants and yet be a sterile medium. Unless energy is provided for bacteria, little life will ensue. In the laboratory, unless air (containing carbon dioxide) is bubbled through the medium, very limited production of algae occurs until organic matter builds up. Dr. H.S. Swingle of Auburn University found this out more than 20 years ago when he obtained negative results from fertilizing fish ponds. He reasoned that bacteria would be necessary to generate enough carbon dioxide for the photosynthetic plants such as algae, if they were to serve as the base for the food chain for fish production. It was only after he supplied energy sources, as cottonseed meal or soybean meal, that he got good yields of phytoplankton, zooplankton and fish.

More recently, scientists of the Tennessee Valley Authority fertilized paired coves (small inlets or bays) over a two year period to see if nutrients would cause increased algae-growth for fish production. They found that the addition of soluble inorganic nutrients (nitrogen and phosphorus) produced no measurable effects on phytoplankton or on fish. Had they included a readily available source of organic carbon, it is almost certain that profound effects would have occurred.

In nature, where organic matter is nearly always present, it is well established that very small quantities of nitrates and mineral nutrients will sustain luxuriant growth of aquatic plants, and that certain rooted plant species obtain nutrients through their roots (10). Upon plant decay, these nutrients, plus those added by wildlife and transient waterfowl (5) are cycled over and over by bacteria, algae and other plants and animals. One cannot, therefore,

envision a situation in nature where man-induced inputs of these nutrients are necessary for eutrophication; otherwise how can one account for the earth's vast coal, oil, and peat deposits? Likewise one cannot envision any existing situation where removal of a nutrient other than carbon from municipal effluents could have any measurable effect on the receiving stream or natural body of water. To be effective the principle of nutrient removal surely will have to be applied to the body of water itself (7). And, if and when it is, it likely will be based on the removal of one or more of the micronutrients, as by chemical precipitation, plus harvesting of algae or other plants at certain intervals.

Slowing the process of accelerated eutrophication will indeed be difficult because the input of both organic and inorganic carbon must be controlled. The present tremendous volumes of human and livestock wastes dictates that control over the organic carbon input should take first priority, not only for sanitary reasons, but because it offers a means of partial control over accelerated eutrophication. But, until the turn over of carbon dioxide can be returned nearly to nature's equilibrum level,* there is little hope of bringing eutrophication under reasonable control, especially near airports and cities.

BETTER COMMUNICATIONS ESSENTIAL

Around the world people are aware that considerable effort is going forward in the United States to remove phosphorus from sewage, prior to its discharge. Unfortunately both the people and the political decision-makers were led to believe that this would halt eutrophication, whereas it can lead only to wasted effort and money (7). Repetition of this type of error must be avoided by the developing nations, and this will require skillful attention to communications between the scientists and the country leaders.

*that existing prior to the huge inputs from human respiration and power sources.

Actually communications of elementary information on pollution sources should not be too difficult because there are only a few major ones of significance:

1. Sediment, dust, and inorganic industrial wastes,
2. Organic matter:
   a. Domestic animals, human, and wildlife wastes,
   b. Industrial wastes,
   c. Plant and animal remains,
   d. Improperly used chemicals.
3. Energy wastes:
   a. Transportation (emissions from internal combustion engines),
   b. Heating and power plants.

On the other hand, communications of information on how to bring pollution sources under control is quite something else and much more difficult. All too often factual data are lacking or not yet conclusive enough for decision making. This is the area of speculation now occupying efforts of the "prophets of doom", who rarely let the absence of facts keep them from talking and writing.

Two basic conditions now are evident, however, and these should not be difficult to communicate to the lay community and its decision makers.

These are:

1. The human population eventually must be balanced against natural resources, and the ability of a country or region to cope with the wastes of its society.
2. People of every nation must prepare to meet the high cost of disposing of their organic and energy wastes at the same time preserving the productivity of their lands.

3. As each nation develops it should avoid unnecessary concentration of wastes, and insist on proper treatment of wastes at their source.

ESSENTIALS OF NATURE AND AGRICULTURE

Although often overlooked, certain simple situations and facts of nature and agriculture need to be understood by decision and policy-making people, both in the developed and less developed nations, if costly mistakes are to be avoided.

Simplified View of Nutrient Cycles

A simplified view of the earth is that the chemical elements at or near the surface and in the air are in a continuing state of movement, or subject to forces which can cause movement. The outstanding characteristic is that outgo of inorganic elements (including plant nutrients) from land to water greatly exceeds input over most land surfaces of the earth. The same degree of negative balance does not apply, however, to the non-mineral nutrients, carbon, nitrogen, oxygen and hydrogen. With them, there is a turn-over through the atmosphere, land, organic matter, and water; with outgo from land almost being balanced by inputs, except for agricultural areas of the world where crop and livestock removals are causing a deficit and for lake shorelines, swamps and bogs where plant remains are accumulating.

Nitrogen - the Mobile Element

Fortunately, man has learned how to fix nitrogen from the air into forms (fertilizers) that he can handle and use to nourish crops. If this had not been true, he might already be on the verge of extinction. It is fortunate, too, that most crop plants have the ability to synthesize more protein as their supply of soil nitrogen is increased by additional fertilizer or other means.

It has been estimated (3) that 90 million metric tons of nitrogen are fixed biologically on the earth every year, largely through algae in water and bacteria on land, and that an additional 10 million tons are added by rainfall. This 100 million tons is almost four times the 25.6 million metric tons of fertilizer nitrogen consumed in world agriculture in 1970. It is only in the more advanced countries that synthetic sources of nitrogen play a key role in food production. These countries fix three-fourths of the world's nitrogen, but contain only one-fifth of the world's people (13).

In 1968, C.C. Tanner (14) confirmed earlier studies that the Fertilizer Nitrogen Equivalent of Diets (FNED) is generally related to per capita income. Tanner's work has been confirmed by FAO studies. The dietary method has been used to supplement other techniques for projecting future needs for nitrogen.

Based on projected dietary protein and other needs of the world in the year 2030, when population may be 12 billion people (4 times the present level) more than 200 million tons of nitrogen will be required to grow food and fiber to meet man's needs. Most of this nitrogen will have to come from the fertilizer factory.

Because nitrogen looms so great in man's future, and because vast quantities of it are constantly moving about in our environment, a few facts should be kept in mind. Even though the atmosphere contains about 35,000 tons of nitrogen over each acre, this represents only about 2% of the earth's supply of the element, the major portion being in minerals, rocks, and soils.

According to a recent review (6), the United States (exclusive of Hawaii and Alaska) receives 10 million tons of nitrogen from biological fixation. Add to this amount the 5 million reaching United States soils and waters in rainfall,

7 million tons from fertilizers, and some 7 to 8 million tons from combustion of fuels (17) in factories, autos, and homes, 10 million in livestock wastes, and 8 million tons which go down the sewer every year from the food consumed in the U.S., and it is obvious that the amount of nitrogen transient in the environment is indeed very great. Still an additional source of transient nitrogen is the 20 million tons arising from the yearly decay of organic matter in soils of the United States, including forest lands. About half of this is utilized each growing season by plants and soil organisms, and recycled (12). Actually, the total or net loss from soil organic matter is lower today than formerly. The first 25 years of cultivation of land in the Midwest destroyed about 25 per cent of its original nitrogen. During the next two 20-year periods losses amounted to approximately 10% and 7%, respectively (11).

Yet, many of these same soils still contain up to five tons of nitrogen per acre plow-depth. In terms of nitrate, this is equivalent to 45,000 pounds per acre. Such soils obviously could lose 100 pounds of nitrate per acre per year for a half century and still have at least 2.5 tons of nitrogen remaining. The soils' reserve of nitrogen, however, should be no less then than now because profitable cropping practices will be adding large quantities of organic matter. In spite of this, even out best lands likely will not be able to supply enough nitrogen during the growing season for optimum yields unless nitrogen fertilizer is used.

Dr. Stanford of the U.S. Department of Agriculture (12) has emphasized that little movement of nitrate occurs below the root zone of a properly fertilized crop, and then only when rainfall or irrigation water is supplied in excess of that used by the crop and retained in the soil profile. Under most farming conditions in Europe and America, except on sandy lands, there

is little opportunity for nitrogen loss by leaching during the growing season. This will not hold true, however, in the humid tropics and needs to be studied. No doubt new slow-release sources of nitrogen will be economically essential.

Because nitrogen is present everywhere and because it is such a mobile nutrient in water, land, and air, it has received very wide attention in recent years with respect to excessive growth of unwanted aquatic plants, especially algae. However, if one remembers the above figures, and considers that rainfall contains from 0.5 to 1.0 ppm of nitrogen and that 40 some species of algae get their own nitrogen from the air as needed, it does not appear likely that nitrogen from fertilizer is generally increasing aquatic plant growth. It must be remembered, too, that only 0.3 ppm of nitrogen, or half that in ordinary rainfall, will support growth of algae.

Phosphorus: Non-Mobile

Phosphorus, unlike nitrogen, is highly immobile in soil. Nevertheless it is receiving a great deal of attention in connection with pollution. Like nitrogen, however, it is an essential constituent of every plant and animal cell and thus a major component of the human diet as well as that of livestock, pets, and wildlife. Because phosphorus is ever-present in both soil and water, and always will be, there is little cause for concern over it, especially when less than 0.01 mg/l (10 ppb) of it in a lake is enough to support algae blooms. Underwater deposits of organic matter, silt, and clay will provide enough available phosphorus for decades to come, to grow many species of aquatic vegetation. Besides, certain rooted plants obtain their supply of mineral nutrients through their roots (10). Upon death of all plants, nutrients are released and are subject to being cycled over and over again by countless forms of aquatic life.

The eroded soil sediment that reaches lakes and coastal waters contains phosphate ions tightly adsorbed on the surfaces of clay and colloidal particles. The amount of phosphate thus adsorbed may amount to 1.0 ppm. Distinction must be made, however, between adsorbed phosphorus and phosphorous in true solution when one considers growth of algae. To control algae by controlling the amount of phosphorus in true solution means that the quantity of such phosphorus must be maintained below 0.01 mg/l (10 ppb) and this would seem to be impossible in most situations (7, 8, 9).

Thus it is difficult to envision a water environment in nature, let alone actually find one, where growth of algae, for example, is or could be inhibited because of lack of phosphorous.

Regarding nutrient input-output relationships, the study of nutrient budgets for continents, or watersheds such as the Nile or Mississippi, seems rather useless except for knowing the seriousness of the occurring losses. On a smaller scale, however, nutrient budgets may serve a useful purpose for areas such as a dairy farming region (4), a livestock feeding area, or a small watershed.

Carbon has Great Significance

Over thousands of years great earth stores of carbon were fixed by plants and are still held in soil organic matter, peat, muck, coal, and oil deposits. The stores in soils of many areas of the world are being depleted by poor farming practices, and our fuel sources are being dissipated for heat, power, and transportation.

Although biologists and ecologists recognize how important carbon is to life processes on earth, most have yet to recognize that at times it may be the controlling (18) or most limiting factor for plant growth.

Consider first a soil-grown crop, and look at the major nutrients required to grow 150 bushels of corn grain per acre, (including tops, grain, and roots):

N	385	lbs. to the acre
P	66	" " " "
K	255	" " " "
Ca	70	" " " "
S	42	" " " "
Mg	60	" " " "
Oxygen	5	tons " " "
Carbon	8	" " " "
Water	4,000	" " " "

Plus small amounts of micronutrients (as Cu, Zn, B, Mn, Fe, Mo, Co)

The earth's atmosphere over one acre, at sea level, weighs about 47,000 tons. This weight is composed largely of nitrogen and oxygen, but contains also carbon dioxide, hydrogen, water vapor and inert gases in small amounts. The major components of interest are:

Nitrogen	37,500	tons over each acre
Oxygen	9,500	" " " "
Carbon dioxide	21	" " " "

The 21 tons of carbon dioxide contain 5.7 tons of carbon, or only three-fourths of the 8 tons used by the crop.

Then consider pure water which contains and can supply much less carbon dioxide than air. Many scientists now beleive that carbon is the plant nutirent most likely to control rate of growth of aquatic plants. It is only when organic industrial wastes, waterfowl excrements or decaying plants and animals furnish energy for growth of bacteria in water that massive growth of aquatic vegetation is obtained.

Almost always overlooked is the fact that algae require 100 to 200 times more carbon than phosphorous. One ton of algae tissue (dry matter basis), will contain 1000 pounds of carbon and only 5 to 10 pounds of phosphorous. The latter can be supplied by almost any body of water from fresh organic inputs (5) without even considering the vast phosphorus stores which have accumulated over centuries in bottom muds and organic deposits.

But, where does the 1000 pounds of carbon come from? Ordinary water contains only 0.40 to 1.00 ppm of carbon dioxide, or the equivalent of 0.10 to 0.25 ppm of carbon. Pure water in equilibrum with normal air could not possibly grow one ton of dry algae tissue per acre in two months, as often occurs.

This point is so important that it warrants further detail and review. Organic matter, such as sewage, is utilized by bacteria, which evolve the carbon dioxide for growth of algae. Once the process gets going, it is difficult to control, because the algae release oxygen to stimulate bacteria and when both die, their carbon is consumed by more bacteria, which, in turn, evolve more carbon dioxide to grow algae (20). As yet, all of the details of the complex "symbiosis" are not fully understood. Enough is known, however, to realize that removing phosphorus or other nutrients from city effluents (7) will not control growth of algae in natural or man-made bodies of water (unless inputs of carbon also are controlled).

Algae Often Useful

Without algae to fix nitrogen and to convert carbon dioxide into oxygen around the world, animal life never could have developed. Nor would we have our vast deposits of coal, oil, and peat. Even today algae are, perhaps, the most versatile form of life on earth. According to Steward (13), the more extreme the physical conditions are, the more likely one is to find blue-green algae, provided that light, water, and carbon dioxide are available at some period. He cites two examples: In Antarctica, on rock and soil surfaces, the Nostoc species fixes nitrogen alone, or in lichen symbiosis, at low temperatures, and accumulates to depths of 15 cm. as algal peat. In Yellowstone Park, USA, the color of large thermal areas of surface water is due largely to blue-green algae, where nitrogen fixation occurs at temperature up to 55°C.

Historically, blue-green algae have been beneficial in helping produce rice, the staple food for over half of the world's population, because they fix from 30 to 50 kilograms of nitrogen per hectare per year under paddy conditions.

How Pure Need Water Be?

What degree of purity do humans need, and can they afford?

Even remote mountain streams are not pure in the sense of being sterile. Excreta from wildlife and fish, and decaying plant and animal remains keep these streams constantly "polluted" in warm weather. Wild ducks use certain flyways and frequent numerous lakes and reservoirs. A government report (5) for a lake in Illinois indicates an addition of 12.8 pounds of nitrogen and 5.6 pounds of phosphorus per acre per year to water, from the transient duck population.

Runoff from urban streets, sidewalks, rooftops, highways, and playground areas is high in chemical nutrients. Even rainfall itself is not pure when it reaches ground level but contains many types of chemical compounds and substances absorbed from the air.

So, we must ask ourselves, "What is pure water and where do we find it?" We don't. What we have in the future will depend upon the use to which it is to be put and the cost each use will justify.

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APPENDIX

Answers to Commonly Asked Questions about Agriculture and the Environment*

ARE HEALTH PROBLEMS ASSOCIATED WITH NITROGEN FERTILIZERS?

A repeated warning is that of associating blue baby disease (cyanosis or methemoglobinemia) with use of nitrogen fertilizers. Records of the U.S. National Institutes of Health and of various state departments of health, do not reveal a single instance associated with fertilizer use. Nor is there a case on record where a child has become afflicted with the disease from eating processed baby foods.

Ruminant animals reduce nitrate to toxic nitrite and thus are susceptible to excessive intake of the nitrate ion in their diets. Certain crops are high in nitrate and if consumed under certain conditions, (as on a low-energy diet), the animals will develop toxic symptoms and may die. In fact, death of cows was once a common occurrence in Wisconsin due to high-nitrate weeds in pastures, and in the Dakotas from grazing small grains prior to the time fertilizer came into use.

Frost or drouth during the growing season to stop protein synthesis may cause high nitrate in plant tissue, and grazing is to be avoided.

Water-related or health problems involving fertilizers are not likely to occur in the United States because none has yet developed in Holland, Denmark, or Japan, where fertilizer use is much greater per acre, covers a much higher proportion of total land area, and goes back over a much longer period of time.

DOES FARMING CONTRIBUTE TO THE LEVEL OF NITRATE IN STREAMS AND LAKES?

Results of the most conclusive agricultural nitrogen study to date have recently been published by the U.S. Department of Agriculture for the Upper

*Although the answers in this Appendix express the views of the author, they are based largely on the writing of the persons listed on page 16.

Rio Grande River Valley. During the past 30 years, when use of fertilizer increased 35 to 100 fold in the Rincon, Mesilla, and El Paso Valleys, no increase occurred in the nitrate content of the river waters.

Analyses of Midwest streams tend to confirm that their nitrate level has not increased in recent years even though use of nitrogen fertilizers and livestock feeding have more than doubled. Where exceptions may be cited, there appear to be other circumstances such as unusually heavy spring runoff from fields standing over winter in corn and soybean stubble. Soluble nutrients from these decaying plants no doubt contribute nutrients to the runoff water. But, where crops are well fertilized and managed, soil loss is minimal, as is the loss of nitrogen.

DO NITROGEN FERTILIZERS GET INTO WELLS?

Nitrate fertilizers sometimes are listed as contaminants of farm wells. Extensive studies of 6000 wells in Missouri, and studies in certain other states, have uncovered no conclusive evidence associating fertilizer use with high nitrate in wells. The major findings thus far are that wells with high nitrate are usually shallow, poorly constructed, near to a feedlot, farmyard or septic tank, often contaminated with organic matter and bacteria, or located in areas of sandy soil.

DOES NITROGEN CAUSE EXCESSIVE GROWTH OF ALGAE?

Although nitrogen is an essential constituent of every living cell, it happens that there is enough of it available in rainfall to support algae growth, besides the fact that 40-some species of algae can fix their own nitrogen. Thus, no further input is necessary, as from fertilizer, unless one's objective is to grow enough phytoplankton for fish production. Here a program of fertilization is usually essential to get enough plankton to shade out rooted water weeds.

DOES USE OF NITROGEN FERTILIZER UPSET THE NITROGEN CYCLE?

Less than 10 per cent of the seven million tons of nitrogen applied to United States soils is in the nitrate form. Even if all of it were applied in the nitrate form, however, the end result would be no different than if all of it came from organic matter. It happens that plants do not know whether their nitrate, or other nutrients, arise from an organic or an inorganic source. Fortunately, fertile agricultural soils readily convert organic nitrogen into nitrate, whether the source, for example, is urea fertilizer or barnyard manure.

Soils in midwestern U.S., for example, release an average of about 80 pounds of available nitrogen* per acre from organic matter every growing season, while total loss from all U.S. farm soils amounts to more than 20 million tons of nitrogen a year. About 10 million tons of nitrogen enter our environment from nitrogen-fixing bacteria and algae, five million tons from the atmosphere, 10 million tons from livestock wastes, and eight million tons (in sewage) from the food we eat. When added to the nitrogen coming from food and fiber processing industries, the total amount of it moving about in our environment is vast, indeed. In comparison, the seven million tons of fertilizer nitrogen used to nourish growing plants last year in the U.S. is but a very small part.

*This is available for use by growing plants, leaching, or loss to the atmosphere by bacteria action (denitrification).

HAS IMPROPER FERTILIZER USE DAMAGED SOILS?

Long-term experiments in Illinois, Missouri, Pennsylvania and England prove to the contrary.

Plots of soil, depleted of organic matter and tilth because of no fertilizer, or improper fertilization, during a century of experimentation responded immediately to good fertilizer and lime treatment once applied according to crop need. In fact, yields were restored almost to normal the very first year of adequate fertilization.

Neighboring plots, receiving good fertility treatments during this time, showed no decline in yielding ability, regardless of whether the fertilizer nutrients came from manure or inorganic fertilizers. Also, there was never any discernable difference in quality of wheat or corn produced regardless of the source of nutrients, i.e., organic or inorganic, so long as the amounts were the same.

WHAT IS EUTROPHICATION?

Chemical nutrients at or near the earth's surface are subject to movement by water and air. In nature there is a continual downhill movement of these nutrients into streams, lakes, and oceans.

When man entered the geological picture, this movement (or water-enrichment process) became more active because of working the soil to grow food. This caused more soil particles and organic matter to move into water bodies. These substances, for ages of time, have been accumulating under water along the shorelines of the world.

Thus, eutrophication may be looked upon as nature's age-old geological process of supplying waters with chemical nutrients. Without this process, there would be no coal, oil, or muck deposits on our planet. Nor would there be marine life.

WOULD EUTROPHICATION BE SPEEDED UP IF USE OF FERTILIZERS WAS CURTAILED?

Yes, because agricultural land soon would be unable to support protective vegetation and would be subject to nature's wind and rain storms. Besides millions of additional acres would have to be cultivated.

WHY ARE ALGAE SOMETIMES CALLED THE KEY TO LIFE?

Because certain algae can utilize atmospheric nitrogen, they are regarded as the early "base of life" for the storing of vast amounts of carbonaceous matter or energy on earth.

Algae also are important because of the link they provide in the food chain for animal life in aquatic environments.

Surely, if it were not for algae and other green plants, man would perish because the process of photosynthesis maintains carbon dioxide as a level he can tolerate in the air he breathes.

ARE LAKES PERMANENT OR DO THEY DISAPPEAR?

No lake or body of water is permanent. Each has four stages of life: birth, existence, old age, and disappearance. Examples of all stages can be found in the United States, Canada, Alaska, Siberia, Brazil, and Africa, in surroundings practically untouched by man and certainly never touched by agriculture.

Although the aging process has been accelerated by virtue of man's activities, one must not overlook the contribution of sewage and other organic waste products. More than 1000 communities in U.S.A. still discharge all of their wastes into water without treatment of any kind. An equal number of cities employ primary treatment which removes from 30 to 40 per cent of pollutants.

Many authorities agree that organic matter in sewage and livestock manures, when added to soil sediments, constitute our greatest water pollutants. Until and unless these are controlled, tax dollars spent for water quality improvement cannot result in the quality of water desired.

HOW DOES ORGANIC MATTER CONTRIBUTE TO ALGAE GROWTH?

In Lake Erie, for example, organic matter from sewage, waterfowl, fish and rooted water plants provides food for bacteria to multiply. They give off carbon dioxide, which, along with water and sunlight, are among the essential ingredients for growth of plants. When carbon dioxide is plentiful, massive growth of algae occurs when light, temperature and nutrients are adequate. The process is difficult to control because the bodies of dead algae and other plants furnish food for more bacteria to evolve more carbon dioxide to grow more algae. This is why removal of phosphorus (phosphate), as from detergents, cannot be expected to control excessive growth of unwanted plants. Control measures must be aimed at eliminating energy by destroying organic matter, but even this will not provide the desired control in all situations, as near to an airport or city where carbon dioxide is plentiful.

IS PHOSPHATE (PHOSPHORUS) THE CAUSE OF EXCESSIVE ALGAE GROWTH?

Phosphorus, an essential constituent of every living cell, is utilized by plants and animals mainly in its phosphate (oxidized) form.

In believing that phosphorus is the key to growth of algae, and the cause of the death of lakes, people overlook the fact that algae require 100 to 200 times more carbon than phosphorus, depending on the particular algae species. One ton of algal tissue, dry weight basis, which can develop in six weeks of good growing conditions, in an acre of lake area, will contain approximately 1000 pounds of carbon but only five or six pounds of phosphorus. The latter can be supplied by the water because of the recycling of organic phosphorus from decaying rooted plants, animal remains, waterfowl excrement, and often from sewage and industrial wastes. Even without these sources, the vast stores of phosphorus laid down in the bottom muds and organic deposits over ages of time are sufficient to satisfy demands for it.

But, where does the carbon come from? Ordinary water contains only small amounts of bicarbonate ions and of dissolved carbon dioxide. Normal water, in equilibrum with normal air, could not furnish enough carbon to grow one ton of dry algae tissue in six weeks. Either bacteria, nourished by sewage or other organic matter, must be present to generate needed carbon dioxide, or it must come from atmospheric inputs. The latter can be considerable near jet flyways and industrial centers.

WHAT IS BALANCE OF NATURE?

When speaking of "balance of nature", a frame of reference and a time in history are needed. Dinosaurs did not survive. Certainly, the early American Indians, who lived as close to nature as humans have at any time in history, had but a very short natural life span. Was nature in balance during those times?

Until man found out how to grow plentiful and nutritious food and to combat diseases and insects with modern-day chemicals, his own life span was very short.

Dr. Cecil H. Wadleigh, former science advisor for Natural Resources, U.S. Department of Agriculture, has said: "Make no mistake! Nature alone could not sustain the world's population for one day -- not in food, not in clothing. Truth is that nature never maintained a balance in favor or man, or other animals, and never will".

In the days of the buffalo, vast regions of our river and streams were muddy wallows and polluted beyond description. Range lands often were deviod of vegetation because of overgrazing. Today, most of these same lands and waters are in much better condition.

IS WATER PURE?

Mr. D.A. Williams, former administrator, United States Soil Conservation Service, and one of America's most ardent conservationists, made this statement in 1969.

"Water vapor is pure, but when it condenses and falls into the earth's atmosphere, it becomes a solvent for many substances. Pure water is seldom found anywhere in nature. Falling rain dissolves gases, including oxygen, nitrogen, and carbon dioxide, and carries them into the soil.

"Water dissolves chemical nutirents in the soil and carries them into plants. This is not pure water, but a solution containing hundreds of different chemical compounds and substances."

"Today, man has the knowledge to enrich this soil solution through proper use of commercial fertilizers so as to produce his food and fiber in higher quality and in greater quantity than at any time in the world's history. Today, man also has the knowledge of soil conservation techniques to maintain agricultural lands in a high state of productivity with practically no loss of sediment and its nutrients to streams and lakes. Unfortunately, we have some way yet to go before all of our land is protected. But, we do know that vigorous plant growth and good ground cover, often made possible with adequate fertilization, provide a most effective deterrant to soil erosion and its pollution of lakes and streams."

WHAT FERTILIZER FACTS SHOULD EVERYBODY KNOW?

Chemical fertilizers are purified or upgraded products of nature, being recycled back through nature by man for crop and livestock production.

There is no discernible difference in nutritional quality of crops grown with fertilizers, manure, or human wastes. Once in the soil, organisms free organic nutrients by releasing them into inorganic forms for plants to use.

Without commercial fertilizers, upgrading of diets for the growing populations in the developing nations would in no way be possible, and the standard of living in the more advanced would decline at a rapid rate.