WRRC Bulletin 13

Water Pollution by Nutrients-Sources, Effects and Control

Papers Presented at 1969 Annual Meeting of Minnesota Chapter Soil Conservation Society of America

The Conference to which this Bulletin relates and publication of this Bulletin were supported in part by funds provided by the United States Department of the Interior, Office of Water Resources Research, as authorized under the Water Resources Research Act of 1964, Public Law 88-379.

JUNE 1969
MINNEAPOLIS, MINNESOTA

WATER RESOURCES RESEARCH CENTER
UNIVERSITY OF MINNESOTA
GRADUATE SCHOOL

CONTENTS

FOREWORD

The Water Resources Research Center of the University of Minnesota has established for the purposes of encouraging, supporting and coordinating research and education in all aspects of water resources. Among the more urgent water resources problems requiring additional research are those dealing with water quality, including the problem of nutrient pollution in Minnesota's numerous lakes and streams. In view of the great public concern and the urgent need for information on this topic, this Bulletin is being published by the Water Resources Research Center as a public service. It is thus being made available to a wide variety of people concerned with the research, technical, educational and operational aspects of water resources.

The Bulletin includes the papers presented at a conference on "Nutrient Pollution - Sources, Effects and Control" at the Twins Motor Inn on January 8, 1969. The conference was planned as the Annual Meeting of the Minnesota Chapter, Soil Conservation Society of America. However, because of the broad interest in this topic, non-members interested in the subject were invited and many attended.

The Program Committee for the conference included the following persons:

Curtis L. Larson, (Ch.) Professor of Agricultural Engineering, University of Minnesota, St. Paul
Roger R. Bay, Project Leader, U.S. Forest Experiment Station, Grand Rapids
John W. Bedish, Biologist, Soil Conservation Service, St. Paul

Uel O. Blank, Extension Resource Economist, University of Minnesota, St. Paul
Lawrence E. Foote, Director, Environmental Services, Minnesota Highway Department, St. Paul
Lowell D. Hanson, Extension Soils Specialist, University of Minnesota, St. Paul
George V. Holmberg, State Resource Conservationist, Soil Conservation Service, St. Paul
William P. Oemichen, Project Leader, W. Central R. C. & D. Project, Soil Conservation Service, Benson.

The chairman of the Minnesota Chapter, SCSA, was Harold C. Pederson, Program Leader, Agricultural Extension Service, University of Minnesota and the Secretary-Treasurer was John W. Bedish.

INTRODUCTION

by

Curtis L. Larson

Nutrient pollution is the presence of excessive quantities of plant nutrients in lakes, streams and reservoirs. Although the nutrients themselves are normally not toxic or harmful, they cause excessive growth of algae and weeds in water bodies and other side effects. These effects interfere with various water uses, especially recreational use of water areas.

Algae and weed growth has apparently been increasing gradually for many years in Minnesota lakes and streams. Recently, it has reached nuisance levels in a number of cases. As a result, the general public has become aware of the problem and has begun to express its concern and desire for corrective measures. Research efforts have been initiated or accelerated. Very little of this research, however, has been underway long enough to produce major results.

The overall objective of this conference was to provide an understanding of the problem of nutrient pollution in terms that laymen as well as scientists can grasp. What are the critical nutrients? What are the effects of nutrient pollution? In what ways is nutrient pollution detrimental? What are the principal sources of nutrients in water supplies, and the relative importance of each? Are these sources likely to increase, decrease, or remain the same? Can nutrients be removed from or controlled in a lake or stream, or must they be controlled at the sources? If the latter, is this technically feasible with our present knowledge? When it is feasible, who will pay the cost? Will new laws or institutional arrangements be necessary to solve the problem of nutrient pollution?

It is evident that some of these answers are not yet available especially those concerning solutions to the problem. Nevertheless, the first step to solving a problem is understanding of the problem itself. Hopefully, the conference and these proceedings will provide a general understanding of this problem to those who attended and to the readers of this report. It is further hoped that this knowledge will enable them to import a modest degree of understanding and perspective to the general public, and that this will lead to adequate support for research, education and action programs which will eventually control nutrient pollution.

The Program Committee was very pleased to note that, in the 170 or more people who attended the conference (and many from outside the Twin Cities who had to cancel plans because of a snowstorm), an unusually wide range of interests was evident. The Soil Conservation Society is itself an interdisciplinary

group, including soil scientists, plant scientists, foresters, agricultural engineers, agricultural economists, biologists and others. Though agriculturally oriented for the most part, the Society membership has become increasingly concerned with problems of the general environment. Thus, it was indeed gratifying to have as guests at the conference a substantial number of civil engineers, geologists, limnologists, ecologists, environmental health specialists, recreation specialists and others. The various people present represented a wide variety of federal, state, local and private groups concerned with the research, educational and action aspects of the common problem of nutrient pollution. It proved to be a unique opportunity for communicating and increasing understanding between agencies and disciplines. Hopefully, this bulletin will, in a small way, provide a similar benefit and, in addition, provide a basic though elementary knowledge of the nutrient pollution problem.

NUTRIENTS AND OTHER FORMS OF POLLUTION

by

Gene H. Hollenstein

Pollution and eutrophication are common words in our vocabulary today. Despite this, there is much confusion concerning the meaning of these two terms.

Pollution is defined as the introduction of energy in any form into a resource which could interfere with, adversely effect, or destroy the resource for a particular use. The forms of energy may range from organic materials and heat to inorganic substances and radioactivity.

Eutrophication in the most simple definition is the process of enrichment of waters of lakes and streams with nutrients. The term eutrophication is derived from the Greek words "eutrophia" and "eutrophos" which literally means "well nourished or nourishing". Websters dictionary defines eutrophic as "relating to or being in a well-nourished condition".

Pollution and eutrophication are not synonymous. A body of water may become eutrophic as a result of certain types of nutrient pollution; but all pollution is not eutrophication. For example, the discharge of arsenic, DDT or copper compounds into a receiving body of water may cause pollution. These toxic substances do not lead to an enriched well-nourished eutrophic condition but rather, depending on the concentration may actually have drastic negative effects on aquatic life.

The waters in Minnesota's lakes and streams are constantly undergoing changes. Some of these waters undergo drastic changes while in others the changes are slight and hardly noticeable. The causes of changing conditions in lakes and streams may be natural or may be the result of man's activities.

Natural changes occur as a result of precipitation and the natural surface and underground drainage from forest and plain areas which contribute nutrients that support and enhance the growth of marine animals and plants. These natural changes occurred before the advent of man and still occur today.

Man's activities have had a great effect in altering the natural environment because of urbanization, discharge of sewage, industrial waste and waste treatment plant effluents, and certain agricultural practices which have increased the amounts of nutrients and of toxic substances which may be detrimental to waters of the State.

The major problem today concerning eutrophication is that man's activities have increased to such a degree that the normal aging processes have been greatly accelerated and the increased growth of plant life and changes in chemistry have rapidly caused the life span of some lakes and streams to shorten.

New industrial processes have produced new industrial waste disposal problems and consequently new toxic substances which require special treatment. Agricultural advances have resulted in the widespread use of chemicals to control weeds and insects and the extensive use of chemical fertilizer in order to increase crop productivity. The expanding population has resulted in increasing encroachment of urban and suburban communities on lands which were once in a natural state or were utilized for limited agricultural purposes. This change in the face of the land has produced costly problems in handling, processing and disposing of storm wastes and sewage effluent from the expanding population.

The process of excessive nutrient exrichment, sedimentation and other forms of pollution which occur as a result of man's activities often changes the quality of our lake and stream waters materially and at a relatively rapid rate. Obviously, there is no single cause of or single solution to the problems of eutrophication and pollution which face our state and our nation today. We cannot blame industry alone for all of our pollution and nutrient enrichment problems just as we cannot blame urbanization or agriculture alone. It is the responsibility of every citizen to be aware of these problems and to make a concerted effort to prevent their causes and to assist in solving them.

Let's briefly look at the matter of eutrophication and the nutrient enrichment of our waters.

Since the definition of eutrophication is based on an increase in nutrients, it is obvious that one of the major determinations of the degree of eutrophication concerns the measurements of concentrations of nutrients in the water involved. Many specific nutrients have been studied including carbon, nitrogen, phosphorus, potassium, silica, trace metals and vitamins. Nutrients which have been studied most extensively are nitrogen and phosphorus mainly because, as you know, after carbon they are needed in the greatest quantities for the production of green plants.

In order to evaluate the nutrient effects and their significance, it is necessary to obtain surface and groundwater flow information and quality analyses, primarily of nitrogen and phosphorus in water entering, leaving and retained in the lake as stream being studied.

In these kinds of studies extensive sampling may be required to distinguish between natural runoff, agricultural runoff, sewage and waste effluents, urban runoff, groundwater flow patterns and contributions from precipitation. It is necessary to actually prepare a budget and in addition to the budget items rated above, there are other factors which must be evaluated such as nutrient content of fish removed from the lake, emerging insects and nutrients leached from eroded, suspended and deposited material.

In some areas major nutrient contributions are from natural and agricultural runoff whereas in other areas sewage and urban drainage provide most of the nitrogen and phosphorus.

A. W. Taylor, an authority on phosphorus, eutrophication and pollution, has observed that the most notable characteristic of phosphorus in the soil is its immobility due to the strong absorption of the element by finely divided soil particles. This is important since it indicates that "except in areas of intensive agriculture where large amounts of irrigation water are applied to highly fertilized soils, there is not significant transport of phosphorus through percolating ground waters. The element moves through erosion on surface soil on which it is absorbed".

Significant amounts of nutrients may under certain circumstances enter streams and lakes from animal manure, particularily where the manure is spread on farm land near a body of water. For example, a detailed study of nutrients in the Lake Mendota, Madison, Wisconsin drainage basin indicated that of the total rural runoff contributed, about 45,000 pounds of soluble nitrogen and about 15,000 pounds of soluble phosphorus were derived from manure.

As noted previously, there are other instances where nutrients have been largely derived from domestic waste disposal. In Lake Waubesa, Madison, Wisconsin, a study in 1942-44 showed that at least 75 percent of the inorganic nitrogen and 88 percent of the inorganic phosphorus was from sewage effluent.

There are certain indices used to determine the measure of eutrophication in addition to the chemical quality and hydrologic data previously noted. Some of the other indices include:

1. Secchi disc measurements which indicate the changes in transparency of water in a lake. Because there is an increase in the number of plankton as a result of increased nutrients, there is a subsequent decrease in the clarity of the water and Secchi disk readings taken through the summer months for several years may be good indices of eutrophic activity.

2. Other indices of eutrophication which have been used are the intensity and frequency of algal blooms and the changes in species composition; the chlorophyll content; the primary productivity, which is the rate at which energy is stored in the form of organic substances; analyses of sediment cores; changes in fish population and changes in total dissolved solids which reflect nutrient changes by increases in major ion content.

Eutrophication is not always an entirely detrimental process. Additional nutrients usually result in increased growth of microscopic marine organisms and a consequent increase in fish production. There must, in fact, be some eutrophic activity to support and maintain aquatic life in a lake or stream. The major problem is, therefore, the development of methods of preventing and controlling the amount and rate of eutrophic activity.

The aesthetic values of a lake may be lowered appreciably because of increased algal and weed growth which creates a nuisance to those who wish to use the water for recreational purposes. There may be other effects such as undesirable tastes and odors if the lake is used for water supply.

What can be done to prevent and control excessive nutrients from entering lakes and streams and accelerating eutrophic activity?

In situations where there is a discharge of sewage effluent into a certain lake or stream, it may be possible to divert the effluent and in some cases this may be a suitable means of reducing nutrient levels in these waters.

Harvesting of weeds, algae and rough fish are also means of reducing some of the nutrient content in water but the total amount of nutrients removed is small in comparison to the amounts of nutrients actually present in the waters and in bottom sediments. The removal of rough fish, such as carp, may be quite beneficial in shallow bodies of water since these fish, being avid bottom feeders, tend to stir up the nutrients from the sediments and increase eutrophic activity.

Low flow augmentation, if feasible, could provide more water to dilute the receiving waters and increase the rate of flushing action to keep the nutrients from settling out.

There are a great variety of physical, chemical, and biological processes for nutrient removal from waste water which are presently being evaluated through laboratory and pilot plant studies.

An effective method to reduce nutrient transport from agricultural and urban runoff is through zoning of residential, industrial, recreational and agricultural lands. The promotion of good farming practices to reduce erosion and sedimentation provides benefits not only for the farmers but for the other people who utilize the water resources of a drainage basin.

There is no question that eutrophication and pollution are problems today and that there is an increasing rate of eutrophication and a speeding up of aging of lakes and streams in Minnesota, particularily in the areas of naturally shallow and fertile lakes of much of the state. It must be kept in mind that we cannot expect the lakes in Minnesota to be crystal clear and free from water plants. The algae that cause lakes to be green in summer are among the oldest plants in the world and the water weeds that create a nuisance for boating and swimming have provided food and shelter for fish and wildlife for a long time.

We must realize that our major task should be to control and slow the rate of eutrophic activity in our waters in order to allow them a natural span of life.

The speakers who follow will discuss in more detail specific aspects related to water pollution - sources, effects and control. I would like to leave you with several thoughts regarding water and its value to you and the State of Minnesota.

There is no life without water--it is a resource indispensable to man and essential for all the processes of life.

Fresh water resources of Minnesota are abundant but they are not inexhaustible. It is vital that these resources be wisely conserved, controlled, utilized and whenever possible, increased for future generations.

The quality of our water resources must be kept at levels suitable for the uses to be made of them and must meet appropriate public health standards.

To pollute our water resources is to bring harm to man and other living creatures which are dependent on these water resources.

It is the duty and responsibility of all of us to recognize the great value of our state's water resources. Each of us must be aware of this responsibility and make every effort to use this resource carefully and economically and must above all prevent the unwise pollution and impairment of our water resources.

DIAGNOSING POLLUTION IN LAKE MINNETONKA

by

Robert O. Megard

Watershed management plans for controlling the growth of algae in lakes must be properly designed in order to be effective and economical. There is no single prescription for rehabilitating all lakes. A pollution abatement program adequate for one lake might be quite inadequate for a neighboring lake where the watershed is used differently. It is the purpose of this report to show that the abundance and daily growth rates of algae may be measured to provide both a yardstick for comparing lakes and a baseline for assessing the effectiveness of nutrient abatement programs. Also the nutrient budgets of lakes are shown to be different from their water budgets. Factors affecting the fate of nutrients in lakes are described, and the rate at which phosphorus is deposited in the sediments is estimated. The quantity of phosphorus in a lake may actually decrease even though enough is added each year for the quantity to double: thus the design of a nutrient abatement program depends upon the total quantities of nutrients present in a lake as well as the rate of delivery from the watershed and the rate of loss at the outlet.

It is often stated that our lakes are dying, but I prefer not to use that metaphore, mostly out of the fear that it will induce attitudes of futility and resignation among the citizenry. After all, if someone is dying, what can be done but call a mortician? I prefer to say that lakes, like people, may become sick. An important difference between lakes and people, however, is that people may be suddenly killed by disease whereas lakes always die slowly. They may become permanent invalids, chronic lesions on the landscape filled with evil-smelling water, but they will not die during our lifetime so that they may be conveniently forgotten after a respectable period of mourning. Our lakes were formed after the glaciers melted 10,000 years ago. Although many lakes are now dead -- their basins filled with sediment -- the lakes that remain will not die until their basins are also filled with sediment, a process that will require tens of thousands of years even if severe pollution continues. Hydrographic maps of Lake Minnetonka, for instance, show that sedimentation has been insignificant since 1905. Sediment borings in the Upper Lake, where the water is more than 80 feet deep, indicate that only about 25 feet of sediment have been deposited since the basin was formed. We obviously are going to have to live with our lakes. Their condition is our responsibility; we must maintain and rehabilitate them or they will become persistent liabilities rather than healthy partners in our environment.

It is often contended that many lakes are naturally fertile, that they were green and scummy before European man arrived, and that it is futile or unnatural to attempt to improve them. Advocates of this point of view overlook the fact that we have improved other aspects of our environment in many unnatural ways. It is unnatural, for instance, to raise corn on prairie grasslands and it is unnatural to build cities beside lakes, but the benefits of raising corn and building cities justifies the cost.

Many lakes are deteriorating rapidly, either because of our ignorance or because we emphasize immediate economic benefits of industry and overlook the remote cost -- the cost of a deteriorating environment. It is now evident, however, that the ecologic consequences of technology are important enough to offset many of the benefits. From the immediate economic benefits of industry we shall have to subtract the less direct costs of decreasing the recreational potential and aesthetic value of our environment. It is often stressed that agriculture is a billion-dollar industry in Minnesota; but tourism, which depends to an important degree upon clean lakes and streams, will also become a billion-dollar industry soon. The argument that "pollution control is too expensive" has lost its validity. We can no longer exempt particular industries from pollution abatement on the grounds that the cost will damage the economy. Someone, somewhere, is paying. Our waste, or someone elses, comes to haunt us.

The cheapest sanitation practice, for instance, is to collect municipal and industrial waste in sewers, to treat the wastewater so that it is not a health hazard, to discharge it into a convenient lake or stream, and to rely on natural geochemical processes to complete the treatment. As populations increase, however, the capacity of waters to "absorb" waste is exceeded, and nutrients released by decomposing sewage stimulate the growth of microscopic algae. With this scheme mother nature bears much of the cost of waste treatment. Now, we must assume an ever larger share of the cost.

Buffalo polluted their environment until a century ago, but the buffalo didn't know any better. Furthermore the buffalo moved to greener pastures when the environment became inhospitable; we don't have any greener pastures. We discover that there is always someone else upstream. Just as we have the technological capacity to exterminate buffalo herds, to clear the forests, and to plow the prairie, we have the ability to make the scummiest lake tolerable if we alter our economic priorities. Obviously it is unnecessary and undesirable to reclaim all lakes. It should be equally obvious, however, that lake deterioration is not the inevitable "price for progress". It is the price of narrow economic thinking.

What is to be done? First we must recognize the necessity to waste less and to spend more on waste disposal and watershed management. Second, waste disposal and watershed management plans must be designed with as careful attention to costs, effectiveness, and benefits as are other engineering projects. Sewage treatment facilities are now designed with the narrow objective of minimizing health hazards; the scope of treatment must be expanded

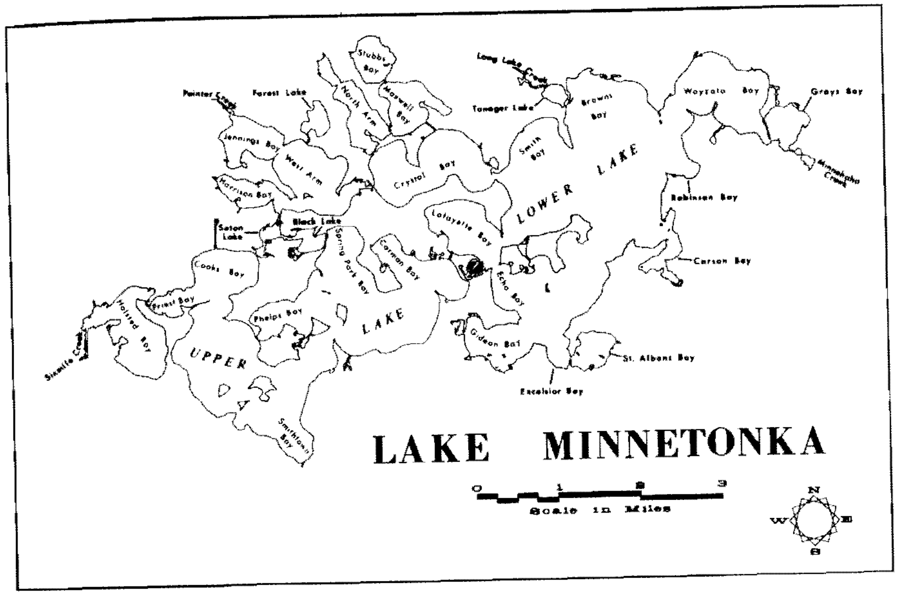


Fig. 1. Map of Lake Minnetonka

to include the broader objectives of maintaining the recreational and aesthetic qualities of the receiving waters.

Lake Minnetonka is a large lake that is almost surrounded by suburbs of Minneapolis. It is one of the largest lakes in Minnesota, with a total area of 14, 500 acres. The lake is really a group of basins, many of which should be regarded as distinct lakes (Fig. 1). A group of seven northern and western bays, in which mean depths are between 10 and 17 feet, are connected by navigation channels to the Upper Lake, Crystal Bay, and the Lower Lake. The latter three basins are relatively deep, with mean depths of 23, 30, and 30 feet respectively and they contain about 90% of the water in the lake. Although the basins are interconnected, the quantities of water and nutrients that move between them are probably small relative to the basin volumes. This is a crucial factor for designing a nutrient abatement program.

Six of the 15 municipalities in the watershed have sewage treatment plants that discharge into the lake or its tributaries. Twenty percent of the water entering the lake from tributaries between June, 1966, and July, 1967, was sewage effluent. Eighty percent of the phosphorus and 30% of the nitrogen that entered the lake from tributaries during that period came from sewage plants (Schoell and Madson, Inc., 1967).

Chlorophyll analyses were performed to measure the abundance of algae in 11 different parts of the lake during spring and summer 1968. At the same time photosynthesis experiments were performed to measure the daily growth rates of the algae in their natural environment. The abundance and growth rates were then compared with phosphorus concentrations in the same water samples. Chlorophyll concentrations ranged from 20 to 120 μg/L (1 μg = .001mg) during June, July, and August. The dominant algae was usually Aphanizomenon flos-aquae in most basins. Algae were more abundant in the shallow northern and western bays than elsewhere. These basins evidently act as nutrient traps for the Upper Lake, where algae were least abundant.

One μg chlorophyll corresponded to between 28,000 and 347,000 algae. Water containing more than 10 μg/L chlorophyll is obviously green to casual observers. Average daily algal growth (net photosynthesis) in the Lower Lake amounts to about 26 lb. dry organic matter per acre. This is the highest average measured in any Minnesota lake, somewhat higher than in Shagawa Lake (16 lb./acre) near Ely or Sallie Lake (17 lb/acre) near Detroit Lakes and almost four times the average for Lake Itasca (7 lb./acre).

Concentrations of total phosphorus ranged from 25 to 170 μg/L (.025 - .170 ppm) and there was a direct relationship between phosphorus concentration and algal growth during July and August. Each μg (microgram) phosphorus corresponded to the production of about 80 μg new organic matter each day at optimal illumination where phosphorus concentrations exceeded 40 μg/L (.040 ppm). Phosphorus was evidently the critical nutrient that controlled algal growth in July and August, but the algae in May and June were not able to utilize the phosphorus that was present. Some other nutrient, possibly nitrogen, was critical at that time.

The surface water in which there was enough light for photosynthesis contained about 2.8 lbs. phosphorus per acre. Thus the algae produced about 9 lbs. new organic matter each day for each pound of phosporus in the surface waters. Each pound of phosphorus was therefore probably responsible for the production of more than 500 lbs. of dry algae during the two months that it was the critical nutrient.

Because there are strong indications that phosphorus abatement would reduce algal growth most effectively, it is pertinent to compare estimates of the phosphorus influx from the watershed with the quantity of phosphorus in the lake at different times of the year (Table 1). The quantity in the Lower Lake at various times in 1968 and 1969 was computed by multiplying the average phosphorus concentration by the volumes of water in 10-ft depth intervals. The monthly influx from tributaries was assumed to be the same in 1968-69 as during the previous year, when it was estimated by Schoell and Madson, Inc. (1967). This assumption seems reasonable because most of the phosphorus comes into the Lower Lake from sewage plants, which have relatively stable

flow. The estimate ignores phosphorus loss at the outlet, which was about 12% of the annual influx, but it also ignores influx from sources other than tributaries, which were probably much larger than the loss through the outlet. The estimates of the phosphorus influx are therefore conservative.

Table 1. The phosphorus content of Lower Minnetonka and the estimated phosphorus influx from tributaries between June, 1968 and May, 1969.

	Calculated phosphorus content (tons)	Estimated phosphorus influx (tons)
June		0.9
July	14.8	0.7
August	17.1	1.1
September		1.6
October		1.0
November		2.4
December		1.9
January, 1969		1.4
February	13.5	0.1
March	9.5	1.4
April	19.6	1.7
May	9.2	2.9
Total influx, June - May		17.1

The phosphorous content of Lower Lake Minnetonka is highest in April. It decreases rapidly in May, increases during the summer, and decreases during the autumn and winter to a low in March. The content increased more than 10 tons between March and April, 1969, but the influx from tributaries was probably less than 2 tons, which implies that 8 tons may have entered as direct land runoff. The phosphorus lost in May--5 tons in 1968 and 10 tons in 1969 -- must have been deposited in the sediments. Data that are not shown indicate that almost 2.5 tons may have been liberated from the sediments into deep water between May and August, which is similar to the quantity that entered from tributaries. It must be emphasized that this phosphorus accumulated beneath the thermocline, where there was no oxygen and where it was not available to algae. Furthermore, it did not remain in the lake, as indicated by the phosphorus decrease from 17 tons in August to 9.5 tons in March.

These data indicate a cycle in which phosphorus is rapidly deposited in the sediments during the spring, with some of it liberated again during the summer and slowly redeposited during the autumn and winter. Since the lake lost 8 tons between April, 1968 and March, 1969, while more than 17 tons entered from tributaries, the total annual phosphorus deposition in Lower Lake Minnetonka must exceed 25 tons, or 8 lbs per acre. The lake sediments are obviously an important nutrient trap. It is pertinent to note that the phosphorus content of the lake in April represents about 1 year's influx from the tributaries, which implies a phosphorus turnover period of about 1 year, whereas the replacement period for the water in the lake is about 15 years (Schoell and Madson, Inc., 1967). The water budget and the nutrient budgets are different entities, and the conclusion that the lake will recover from pollution very slowly because 15 years would be required to "flush out" the nutrients is based on faulty assumptions (E. A. Hickock Associates, 1969). The data presented here imply that the lake would respond very quickly to an effective nutrient abatement program. It will not be necessary to replace the present lake water with water of substantially better quality, only to reduce the rate of nutrient influx. The present annual influx from the tributaries (17 tons) would double the average phosphorus concentration in the Lower Lake each year in the absence of the biogeochemical processes that remove phosphorus from the water. The Lower Lake should therefore improve substantially if the annual influx were reduced to perhaps 8 tons. Eight tons (about 8,000 kilograms) dissolved in Lower Lake Minnetonka, which contains about 216,000,000 cubic meters (175,000 acre-feet) of water, yields a concentration of 0.037 ppm (37 μg/L). This is very similar to the average concentration in the Lower Lake in late winter and in the surface waters of the Upper Lake during mid-summer.

It must be emphasized that this discussion of the phosphorus budget refers only to the Lower Lake, which receives most of the sewage effluent. Halting or reducing the influx of sewage to the Lower Lake will probably have little impact on the other basins, because there is little nutrient movement between the various basins. The dominant nutrient sources for many of the other basins must be from farmland, lawns, and domestic septic systems. The magnitude of these sources must be evaluated for each basin in order to devise a comprehensive nutrient abatement program for the entire lake.

References

1. E. A. Hickock Associates, 1969. Overall plan for water management. Minnehaha Creek Watershed District, Wayzata, Minnesota. 81 p.

2. Schoell and Madson, Inc. 1967. Report on bacteriological and chemical sampling of Lake Minnetonka, 1966-67. League of Lake Minnetonka Municipalities, Excelsior, Minnesota. 52 p.

EFFECT OF EUTROPHICATION ON FISH AND RELATED ORGANISMS

by

Lloyd L. Smith

In discussions of pollution and eutrophication, it must be recognized that they are harmful only when some particular water use is adversely affected. When waters primarily used for production of fish receive nutrients or polluting materials, they will suffer only if production in pounds of desirable fish produced per acre per year are reduced. Since the fishery biologist and manager has one objective, to produce the maximum poundage of fish of desirable species in any lake, the following discussion on eutrophication must be evaluated in this framework. If a lake is made unsuitable aesthetically because excessive algae growth results from eutrophication, the fishery manager is not directly concerned unless fish production is also reduced. In order to put the problem of the fish management in the proper prospective, a simple formulation of the production problem should be set forth. In any year an existing fish population is increased in size by growth of alll the individuals in that population and by addition of new fish to it. The population is reduced during the same period by natural mortality, which removes fish from it, and by fish harvest which takes fish for human use. The objective of fishery management techniques is to increase growth, increase recruits to the population, and reduce natural mortality. Attainment of these objectives will permit the maximum harvest to be made each year without reducing the parent stock. It follows from this simple objective that any pollutant, such as nutrient materials, which increases growth or addition of new fish is desirable and that any added material which reduces growth or recruitment or increases natural mortality, is undesirable.

Eutrophication, which is the addition of nutrient materials, will increase fish production up to a level at which some adverse effect of nutrient addition sets in. In other words, the more fertilizer you put into a lake, the more fish can be produced because fish production is directly dependent upon the extent of the nutrient resource. There are many cases in which the addition of nutrients increases fish production but which also causes aesthetic deterioration. When the effect of eutrophication on use is evaluated, the advantages to fish production must be balanced by the disadvantages to aesthetics. There was an interesting case many years ago where a very infertile mountain lake was polluted by dumping a number of animal carcasses into it which had died in a snow storm. The addition of this organic material or eutrophication, created a fishing lake where there previously had been no fishing and did not decrease its aesthetic or recreational value.

Eutrophication can adversely affect fish populations. This action is primarily related to reduction of oxygen levels in lakes and streams. The effect is noted much more commonly in streams than in lakes, primarily because the relative addition of nutrients to streams is usually much greater during any annual cycle than it is to lakes, and further, because lakes are in a constant progression of eutrophication from natural causes. When there is eutrophication extending over a period of years, we may see limnological changes which reduce oxygen levels in cold water portions of the lake and a shift from more desirable cold water species to less desirable warm water species; in some cases a shift to rough fish of little value. Parts of a lake may be removed from active fish production because eutrophication results in oxygen depletion in certain areas, particularly the hypolimnion. It should also be recognized that when oxygen levels are lowered, other problems related to heat and toxic pollutants are aggravated. From these considerations it is apparent that eutrophication, which results in lowered oxygen, frequently decreases directly or indirectly the quality of the fish habitat.

Since lowered oxygen is the principle disadvantage of eutrophication to fish, illustrations drawn from work of fishery biologists may help to understand these problems. It has been shown that some reduced oxygen levels which have been considered quite suitable in evaluating sanitary engineering problems, are, in fact, quite unsatisfactory for the reproduction and growth of fish populations. It is especially true when other pollutants are present in the habitat. If oxygen levels running between 0 and 10 ppm are considered, it is evident that when these levels fall below 5 ppm, growth rate, swimming ability, size of young fish at hatch, and survival of newly hatched fry are drastically reduced. At 2 ppm, these vital functions are essentially reduced to zero and mortality can be anticipated from prolonged exposure at summer temperatures. Under some conditions, particularly at lower temperature, fish may survive long periods of oxygen levels of 2 ppm or less, but they cannot satisfactorily complete their life cycles and produce a harvestable crop.

It has been shown that below 5 ppm of oxygen fish swim more slowly, are less efficient in foraging, and have a lower efficiency of food conversion. It is apparent, therefore, that when eutrophication results in oxygen reductions below the points indicated above, it will reduce the harvestable crop and possibly even the existance of fish in particular habitats.

Sometimes the addition of nutrients reacts in a very unexpected fashion. An outstanding example of this action was demonstrated several years ago in the investigation of paper-mill pollutants in a Minnesota river. Wood sugars and other carbohydrates released as wastes from paper making were not present in sufficient quantities in the river water to reduce oxygen levels and were in no sense toxic to the aquatic organisms. They did, however, provide an excellent food source for a filamentous bacterium called *Sphaerotilus*.

This organism, which thrives on the nutrients from paper-mill wastes in flowing water, is similar in appearance to a very small filamentous algae. On first appearance this organism which coats rocks and sticks in the river and which provides forage for some fish and for aquatic organisms does not have any deleterious effect on fish. However, when the hatching of walleye pike eggs and the resulting reproduction was examined, it was noted that the nutrient materials resulted in an elimination of satisfactory hatching. This effect was brought about by an interesting chain of circumstances. The nutrients produced a heavy growth of *Sphaerotilus* which covered walleye eggs that had been deposited on the river bottom. As the growths developed, an intricate network of fibers covered the egg shells but did not appear to harm the developing embryos. When the fish were ready to hatch and started to break out of the egg, they were completely inhibited by this net of natural material from making their escape and consequently perished. The result was a complete failure of walleye-pike egg hatch and consequent failure of reproduction. Since the network also excluded oxygen from the developing egg, it is apparent that the fry at the time of emergence were less able to break out of the shell and had they done so, would have been less able to survive the rigors of early larval life.

Another point on the adverse effects of eutrophication relates to increased plant growth which in turn produces increased beds of detritus. In the process of decay these beds form, among other decomposition materials, quantities of hydrogen sulfide. Examinations made of the effect of hydrogen sulfide evolved from detritus and sludge beds on fish and fish eggs, indicated that the quantities released could be highly lethal to fish and fish eggs and, to a somewhat lesser degree, to fish food organisms. The reason this deleterious effect of decomposition has been rarely noted is that H_2S oxydizes very rapidly in water and consequently its presence has not been recognized. In our observations, H_2S evolved from the bottom was found in the zone from 0 to 10 millimeters above the mud-water interface. In this zone highly toxic levels of H_2S were noted even though in upper levels none was present. When we consider that the early life stages of fish occur on the bottom or in the few millimeters above the bottom, it is apparent that H_2S in these zones derived from bottom decomposition can be extremely important. In cases of extreme eutrophication, which results in much detritus, such conditions have been observed even in unpolluted natural waters. It is therefore apparent that eutrophication, while it is useful in increasing fish production may also result in increasing natural mortality or shifting of species complexes to less desirable types.

The vital point to be made with reference to eutrophication is that in many areas it is now progressing at a much more rapid rate than would occur in a state of nature and that events which might take many hundreds of years under ordinary conditions, are being compressed into one or two human life times. This alteration is especially noticeable where the physical nature of the lake changes oxygen and temperature relationships as a result of added nutrients. There is a notable example in European lakes where eutrophication as a result of artificial nutrient addition has shifted a lake from highly desirable cold water fish to warm water fish populations because oxygen was reduced in the cold water areas.

It has been repeatedly demonstrated that some of our less desirable fishes are much more able to withstand reduced oxygen levels than a more desirable species. It should be noted, however, that when we change species composition from the desirable cold water species to the less desirable species we usually get a higher annual production in terms of pounds of fish per acre. In evaluating the long term effect of eutrophication, therefore, the possibility of increased protein production should not be overlooked.

In summary, it should be noted first that eutrophication usually increases fish production in terms of total annual harvest. Second, eutrophication, depending upon its extent, will frequently cause decrease in oxygen levels which may be undesirable for fish and may cause adverse aesthetic effects. Third, eutrophication may indirectly upset the ecological structure of a fish habitat in an unexpected manner which results in lowered fish production. And finally, eutrophication in the long run usually changes the species complex in many lakes.

HEALTH ASPECTS
SURFACE AND GROUND WATERS

by

Henry Bauer

In the consideration of the health aspects of surface and ground waters within the allotted time I will only be able to give a brief introduction to the subject. There immediately comes to mind materials which might contaminate the water and endanger the health of man. These might be human and animal feces and urine infected with pathogenic bacteria, parasites or viruses, industrial and household wastes containing harmful chemicals. The contaminated surface or ground waters might be contaminated to the extent that man's health is affected by drinking or being in contact with such water.

To relate human disease or other undesirable effects to waste products containing pathogenic organisms, chemicals or both is not a simple procedure. The chain of events from waste material to human affliction must be validated. Validation is dependent upon (1) the demonstration of a harmful or potentially harmful agent; (2) demonstration that such agent is in or associated with the waste; (3) occurrence of disease or other effects in the community which may be either caused by or associated with the agent; (4) demonstration of the links in the chain of events leading to the occurrence of disease or other effects; and (5) demonstration of the absence or reduction of disease or other effects by interrupting or eliminating certain or all links in the chain of events that could be responsible for the unfavorable effects.

A simplified diagram of the general mode of disease transmission is shown:

<u>Source or Reservoir</u> →	<u>Means of Transmission</u> →	Vehicle	<u>Susceptible Host</u>
1. Infected Human Animal	1. Direct Contact	1. Water	1. Human
2. Solid, Liquid or Gaseous Waste	2. Indirect Contact	2. Food	2. Animal
3. Degradation - Products of Solid and Liquid Wastes	3. Droplet	3. Plasma	
	4. Airborne	4. Vector	

As illustrated by the diagram, water is a vehicle for the dissemination of disease.

I. Pathogenic Organisms

Surface waters contaminated with human and animal feces or urine provide a potential source of pathogenic bacteria, parasites and viruses. Examples of some of the disease-producing agents which might directly or indirectly infect man by way of contaminated surface waters are:

1. BACTERIA

   a. Salmonella - There are about 1,000 serotypes that infect a variety of animals including dogs, cats, birds and reptiles. About 100 are pathogenic for man. Salmonella typhi has been documented in waterborne outbreaks. Although other Salmonella have been isolated from surface water, the pathway from this source to human infection is not clear.

   b. Cholera vibrio - (Not found Today in United States)

   c. Shigella - Fecal source is primarily man. The mode of transmission varies. Good personal hygiene, sanitation and a safe water supply is necessary to reduce infection.

   d. Leptospira - Spirochetal disease of animals. Leptospira pomona is frequently the organism found in infected animals. Sources of human infections have been traced to "swimming holes", rice fields and sewers, in addition to persons who are in close contact with infected animals.

2. PARASITES (Protozoa, Cysts, Eggs)

   a. Entamoeba histolytica - (Amebic dysentery) There is documented evidence that this disease can be transmitted through human fecal contaminated water.

   b. Diphyllobothrium latum - fish tapeworm. Part of the life cycle of this tapeworm is in fish. Sanitary disposal of human feces containing the viable eggs of this tapeworm will protect man and fish.

3. VIRUSES

   a. Poliomyelitis, Coxsackie and ECHO Viruses - These viruses are fecal-borne and have been found in surface waters. The role of surface waters contaminated with these viruses as a source of infection in man is not clear.

   b. Infectious Hepatitis - There is documented evidence that this disease can be transmitted through fecal contaminated water.

II Chemicals and Other Nutrients

Surface waters contaminated with chemical wastes are believed by some to create a hazard to public health. Currently there is considerable discussion on the accumulation of DDT in fish and hazard of these fish when eaten by man. There is need for more information about waste toxins which might enter edible aquatic life and on the effect on man through the consumption of the toxin-containing fish, oysters, etc.

Methemoglobinemia is due to nitrates in the water. Nitrates and nitrites in water have been incriminated and there is evidence that their presence is from pollution due to biological wastes.

Surface waters heavily contaminated with fertilizers, barnyard runoff, and sewage provide a fertile substrate in which algae can proliferate. Some species of algae produce powerful toxins. There is documented evidence of animals dying after drinking water containing these toxins.

In contrast to surface waters, ground waters are generally pure because they have had most of their contaminants filtered off on their downward passage through soil. Some of the purest waters are obtained from deep wells. Shallow wells can yield safe water if located at a proper distance from barnyard or septic tank drainage field. In addition, shallow wells should be constructed to prevent surface drainage, be capped and provided with a pump. Time does not permit to discuss the problems of ground waters but leakage from chemical storage tanks, cesspools, and waste disposal wells are sources of contamination of ground waters.

The question has been asked. "Do excessive nutrients in water sometimes have harmful effects on humans through (a) body contact, or (b) drinking the water?"

If the question implies biological waste as a nutrient free of all pathogenic organisms and it alone is directly related to possible harmful effects, the answer would, with few exceptions, be speculative. There is evidence that methemoglobinemia in infants is associated with the drinking of water high in nitrates. There is chemical evidence that nitrates and nitrites are degradation products of biological wastes. There is a need for information concerning biological and chemical pollutants (nutrients) and their degradation products on the health of man, either by direct contact or through drinking water.

On the other hand, if the question is stated to mean biological nutrients such as feces, and includes the pathogenic organisms, then the answer can with certain limitations be in the affirmative for direct contact or through drinking water. For example, if there is adequate nutrient and the temperature and pH are favorable, many of the disease-producing bacteria can multiply, thus increasing the chance of infection. Infection with leptospira would be favored under such conditions and leptospira can penetrate abraded skin.

ANIMAL WASTE DISPOSAL PROBLEMS AND TRENDS IN MINNESOTA

by

E. R. Allred

In recent years we have all seen greatly increased efficiencies in agricultural production. Perhaps we have also noted that in many instances agricultural production (especially animal production) and the quality of our environment are obviously and inescapably tied together. Adjustment or change in one requires adjustments or changes in the other.

Under natural conditions the energy-food production cycle is well understood: with energy from the sun, plants synthesize organic matter from water, mineral nutrients and carbon dioxide. Directly or indirectly all other living creatures feed upon these plants. For completely balanced conditions, all such food and by-products of consumption are returned to the soil where they are thus again made available to the plants as raw material.

Obviously, to suppose that such a cycle can be kept in complete balance is being grossly idealistic. As soon as man appeared on earth he tended to unbalance the cycle. With his ability to transport and store food stuffs, man has seen fit to move into the cities instead of living on the land where the food is produced. Under such a system food production occurs at one place, consumption and excretion at another. With steady flows of food being produced over widely scattered areas and thence transported into our metropolitan centers, where all except that which is breathed away becomes concentrated waste, sanitary engineers and others working with municipalities have long recognized the seriousness of the problem.

Each year larger percentages of farm animals are being raised on fewer farms. Livestock and poultry, once raised in scattered herds and flocks throughout the countryside, are now largely confined in densely - populated feed lots and broiler farms. Similarly, feed is collected over widely scattered areas and shipped to such areas of livestock concentrations, where it is consumed and excreted. Because of the enormous amount of manure produced, pollution problems often result. Waste from food processing plants may also contribute to the problem. Until methods are found whereby such mineral nutrients can be returned economically to the soil from whence they came, the energy - materials cycle will remain unbalanced. Here again, the concept of a totally unimpaired, or a totally polluted, environment is not meaningful. It is obvious that a practical compromise must be obtained.

In recent years one of the factors having a most noticeable affect on animal production has been the mechanization and scientific feeding of livestock. Confinement feeding of animals has increased significantly in those

areas of the nation having an abundant supply of feed grains. For this reason, Minnesota and other cornbelt States find themselves in the center of the cattle and hog feeding industry. It follows then, that we also have most of the problems associated with disposal of waste from such an industry.

The trend toward confinement feeding of livestock, and to the resultant increase in number of animals per production unit, it is firmly established in the United States. The 3.4 billion dollar poultry industry is a good example. It has been estimated that at the present time from 50 to 80% of the laying hens and nearly all of the broilers are currently being raised in confinement. Most large poultry operations are highly mechanized, with some operations geared to handle over 1 million birds.

In a similar manner the number of cattle on feed for slaughter has increased some 66% in the past eight years, and 100% in the past 15 years. The number and size of commercial feedlot operations throughout the nation has also increased. Mechanization, improved production methods, better nutrition and disease control have enabled the livestock producers to handle more animals without increased help. Figure 1 shows these trends. Certain types of livestock operations have attained optimum size consistent with

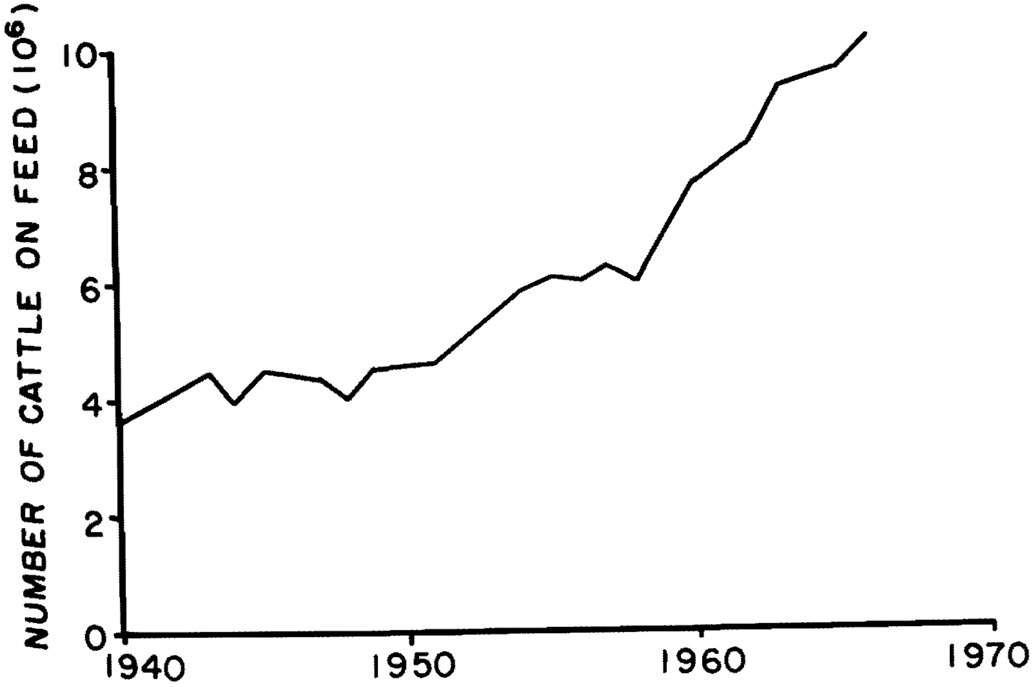


Figure 1. Recent trends in cattle feeding in the United States

present technology. Others have not. The downward trend in the number of livestock operations is expected to continue due to the enlargement of existing units and to their affect on the operation of farms less able to adjust to an economic size.

One obvious reason behind such increases in number of animals for slaughter is because of increases in per capita consumption. People in the United States are showing a growing taste for beef and broilers, and a slightly decreased taste for pork. Figure 2 shows the per capita consumption of all meats increased by about 15% between 1950 and 1960, while that of beef increased some 34%.

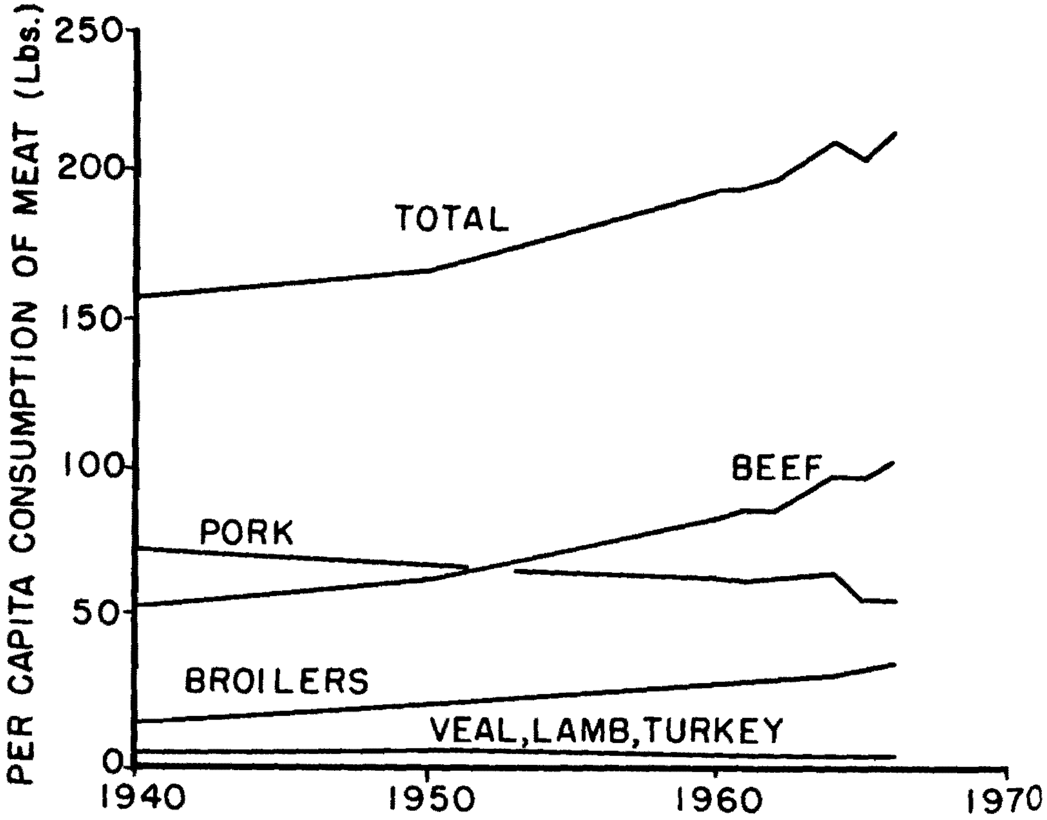


Figure 2. Meat consumption trends in the United States

Most of us are aware of the livestock trends occurring in Minnesota today. A review of the census data over the past 20 years, also shows a decrease in the number of farms in Minnesota with livestock. As expected, this decrease has accompanied with a marked increase in the number of livestock per farm. As indicated in Table 1, by 1980, the average dairy herd size in Minnesota is expected to increase about two-fold; hogs to increase over 2 1/2 times; the size of chicken flocks to increase about 4 times; and so on with beef, turkeys and other types of livestock. Although these increases in herd size are quite considerable, just looking at herd averages can be misleading since it is with the above average size of herd that problems occur. Data available on the size of chicken flocks well illustrate how misleading average figures can become. According to our extension poultry specialists, the average size chicken flock in Minnesota is about 400 birds. In general, poultry enterprises this size would not create problems in waste disposal. A closer look at the poultry data, however, shows numerous commercial installations in Minnesota in the range of 15,000 to 20,000 birds each, and one with about one quarter million birds. Obviously, waste disposal problems occur with the larger operators rather than with the average or a small operation. Similar caution must be applied when analyzing average herd data size for other types of livestock.

Table 1

Projected Changes in Average Herd (or Flock) Size on Minnesota Livestock Farms

	Average Size		Ratio of Increase
	Present	1980 (Projection)	
Hogs	100	1,000	10
Fed Cattle	40	425	10
Dairy Cows	20	50	2.5
Beef Cows	25	200	8
Turkeys	16,500	50,000	3
Laying Hens	400	30,000	75
Sheep	50	500	10

The data shown in the extreme right hand column of Table 2 gives an indication of the number of farm operations we can expect by the year 1980. These values were obtained by dividing the number of present producers shown in the table by the number of producers projected to 1980. In the case of hogs for example we presently have 50,000 producers. Since there is a projected estimate of 6,000 producers by 1980, this means that by 1980 only one out of the present eight producers will still be in business. Extending this type of analysis to some of the other types of livestock listed in the table, in-

Table 2

Trends of Number and Size of Livestock Farms in Minnesota

Type of Livestock	Present		Possible by 1980		Producer Ratio
	No. of Producers	Size	No. of Producers	Size	
Hogs	50,000	100	6,000	1,000	8:1
Fed Cattle	20,000	40	3,000	425	7:1
Dairy Cows	60,000	20	16,000	50	4:1
Beef Cows	20,000	25	4,000	200	5:1
Turkeys	1,000	16,500	400	50,000	2:1
Laying Hens	28,000	400	200	20,000	14:1
Sheep	10,000	50	400	500	25:1

dicates that only one out of every four present dairy operations will be in business by 1980, and that only one out of every five farmers will be raising beef cows by the same year. The projections shown in table 1 were compiled by our own agricultural extension economists. If the projections on the number and size of livestock farms in Minnesota hold true, as indicated in table 1 and 2, the energy materials production balance in nature is certainly going to be even further unbalanced in the future.

Problems associated with animal waste disposal have existed for a number of years. Many past attempts to solve waste disposal problems in the animal industry have failed for one of three reasons; (1) Because we have used approaches which were developed for wastes of other characteristics; (2) Because we have emphasized cheapness rather than adequacy of method; and (3) Because we have considered the problem as being separate from other parts of our society.

Livestock producers are of course interested in waste treatment and disposal methods that have low labor requirements, reduced nuisance conditions, and improve sanitation at minimum cost. At present, producers are handicapped by the lack of available technical information. They are also handicapped by the common premise that treatment and disposal of animal waste should involve no extra cost and, therefore, should not increase the cost of the product.

The tonnage of manure to be hauled from a livestock farm is staggering. It is estimated that the average size dairy cow excretes over 2 tons of dry fecal matter per year. Since manure is usually transported to the field in a wet or moist state, the total tonnage to be hauled will exceed 8 tons per cow

per year. The energy required to move this amount of material becomes a major item of cost for the farmer. One possible way of reducing the tonnage of this waste would be to digest the manure in some form of treatment plant, similar to that presently being done by municipalities. Here again, the cost of doing so becomes prohibitive. On the basis of BOD (biochemical oxygen demand), we get an idea of how animal wastes compare with that of human wastes as treated by municipalities. Table 3 shows that hogs have a population equivalent of two. This means that one hog has the same loading requirements, insofar as the BOD is concerned, as two humans. Similarly, one beef animal is the equivalent of ten persons. These data further indicate that

Table 3

Population Equivalents for Typical Animal Wastes

	Population Equivalent
Hogs	2
Beef	10
Dairy Cows	15
Chickens	1/10

with a population equivalent of 1/10, a 250,000-bird poultry enterprise in Minnesota has a BOD waste equivalent equal to that of a city of 25,000 persons. Similarly, a 200-cow dairy herd is equivalent to a city of 3,000 people. Few, if any, farmers are likely to be in a position to pay for such a treatment facility. Until some inexpensive source of energy can be found which can be employed to haul animal manures to the fields, to assist in the decomposition processes, or to obtain tonnage reduction by dehydration and incineration, the disposal of animal manures will continue to be a difficult economic problem for both the farmer and the consumer of farm products.

Our severe Minnesota winter weather often presents additional problems in animal waste disposal. Studies in both Minnesota and Wisconsin, although not yet conducted as extensive as needed, show in some instances where a large part of the stream or lake pollution which occurs during spring thaw is thought to have originated from fields where farmers have spread manures on frozen ground during the previous winter months. This situation suggests that a farmer should field-spread the manure before freeze-up in the fall, or at some time following the spring thaw. To do this it would be necessary for him to provide suitable storage for the manure for as long as six months. Again, production costs are greatly increased if the job is to be done correctly.

In summary, it becomes evident that future population increases in the nation, together with the increase in the per capita consumption of meat, will result in a greater number of animals being raised. A program of waste management, with the economic implications understood by both the consumer and by society, is necessary. The public must be made to realize that the cost of animal waste disposal is a part of the price to be paid for a high standard of living. Better solutions will emerge when waste management systems are developed that will give society its desired level of sanitation, and at the same time convince society of the necessity of paying for it. No immediate simple solution is yet in sight.

MANAGING LIVESTOCK WASTES TO CONTROL POLLUTION

by

J. A. Moore

Each of the speakers which have preceded me and those which will follow will discuss the sources, affects and control of pollution and its affect on environment. In these discussions each of the speakers will undoubtedly use the word pollution and they will reference it from their particular position as it affects our water quality. Dr. Megard has discussed with us the effects of nutrients on the plant and animal growth patterns in our lakes. Professor Smith has explained the effects of nutrients on our fish and related organisms as seen through the eyes of a Professor of Entomology, Fisheries and Wild-life. The impact of this pollution on our health has been discussed by Dr. Henry Bauers. This afternoon you will hear discussions about other waste sources and the need for water quality standards in Minnesota. I suggest to you that each of the speakers will discuss water quality and pollution from a different point of view. We must all recognize that everyone does not have the same definition and opinion about pollution, its causes and affects and the steps necessary to regulate and control this pollution. In the remainder of this paper, I will discuss livestock waste as the pollutant source and the various avenues we have for managing this waste to maintain or upgrade our present water quality.

Professor Allred has already discussed the growing problem of managing livestock wastes. In summary, he has indicated that these wastes do present a problem because of the changing in the livestock industry. Today we can see a strong trend toward increased concentrations of livestock units. As larger operations decrease labor costs, capitol costs, and provide other economic advantages, they usually enlarge the waste management problem.

This changing face of the industry of agriculture is also paralleled by a changing attitude in our general society. City dwellers with more time and money are spending a greater percentage of their leisure time in rural areas. These suburbanites travel to the country or forest to enjoy outdoor activities. They refuse to travel these distances and be offended by nuisances which are generated in livestock operations. A practice which was acceptable on the farm yesterday can be called a problem area today and indicates mismanagement when it creates odors and unsightliness which offend our city cousins.

These two trends which complex the agricultural waste management picture are relatively new to the livestock industry. In the last ten years we have seen researchers from our universities, government agencies, and individuals representing private industry begin to work toward solutions which will solve this waste management problem. Today we know the quality and quantities of the waste material generated by our livestock industry. Efforts are being made today to manage these animal wastes in a manner which will provide maximum utilization or efficient and nuisance free disposal.

Any attempt to manage a waste must start with a description of this material. Table 1 shows the volumes and total solids of the waste generated by different species of livestock. Any waste management system must be designed to handle not only these large volumes of material but also take into account the different characteristics of these wastes. The human demands that his food be highly processed and must contain only those portions which are necessary and tasty. Animals do not have the opportunity to be quite as selective and consequently consume large quantities of roughage in the form of hulls, stems and stalks. Therefore it follows that the waste generated by these animals will contain larger quantities of these inert and biologically stable materials.

Table 1

The defecation data for various types of animals.

Animal	Wet Manure lbs/day	Total Solids %	Total Solids lbs/day
Chicken	0.117	45.0	0.053
Swine	8.4	13.1	1.10
Dairy	71.0	16.0	11.40
Beef	41.0	24.0	9.85
Human	--	--	0.38

Most of the treatment systems which were designed to handle human wastes have been applied to the treatment of livestock waste. For the reasons mentioned above many of these systems cannot provide adequate treatment to animal wastes. Those systems which are capable of providing satisfactory treatment are seriously limited by cost. Home owners pay approximately 0.9 cents per pound for municipal refuge collection, treatment, and disposal, but at similar rates a dairyman would have to pay $200 per cow per year. To overcome these economical and technical problems, modifications of conventional treatment systems have been de-

vised to provide satisfactory treatment of livestock wastes at an acceptable cost.

In the past we have seen treatment systems designed to remove organic loading and reduce the BOD of human waste. BOD stands for the biochemical oxygen demand and is used as an indicator of pollutional strength. The desire to remove the organic loading from waste products has now been expanded to include the desire to remove nutrients, namely nitrates and phosphates from any waste product. Table 2 shows the amount of N, P, and K that are produced by the three common livestock groups. Unfortunately the systems which I will discuss have not been designed to remove these nutrient elements from animal manures. In fact there are no systems designed specifically to remove the nutrients from livestock waste and this kind of system must be developed in the future.

Table 2

The pounds of N, P, and K which are produced in the waste of agricultural animals.

Animal	N	P_2O_5	K_2O
	(pounds per animal per day)		
Hen (5 lbs)	0.0056	0.0036	0.0018
Swine (100 lb)	0.051	0.032	0.062
Cattle (1000 lb)	0.360	0.115	0.274

Manure cannot usually be allowed to accumulate in the confinement area until use because of the sanitation hazards of fly breeding, odors, dust, animal health and potential water pollution. Therefore, four steps in the management of manures need to be considered: (1) collection, (2) processing, (3) storage, (4) utilization or disposal. These are the same basic operations that sanitary engineers consider in the handling and treatment of municipal and industrial waste.

Collection and transportation of solid manure is a materials handling problem. It can be mechanized as other bulk commodity handling has been. The farmer may collect and transport the manure with liquid carriage, as in washing out the milking barn, or he may handle it as a solid. The choice depends upon and affects, how or if the manure will be processed, stored, utilized, or disposed of, The extravagant use of water, so typical in conveying human waste is not practical in handling animal waste, because it would take 8 gallons of water per chicken or 1200 gallons per cow to dilute the daily extrement of one animal to the concentration of sewage. Although liquid collection and transportation of manure may be simple. The chore of treating and disposing of this increased volume may be more difficult.

Processing of livestock manures is the most challenging aspect of agricultural sanitary engineering. Processing may sometimes be a secondary effect of storage, as in the case of natural drying and composting. Although manure processing may be similar to sewage treatment in physical, chemical, and biological phenomia, there is a fundamental difference in purpose. Sewage treatment was designed to upgrade the quality of water which is polluted with organic matter. Manure processing is based on the need to stabilize waste organic matter which is contaminated with water. If the manure were dried, many of the sanitation problems would be eliminated. Dry manure is stable, relatively odorless and breeds very few flies. In certain parts of the country such as the southwest, solar energy may be utilized to promote natural drying. Other areas have used the drying process but have found it necessary to assist mother nature by providing a supplimentary fuel source. Composting is another process which is utilized in managing a small amount of our agricultural manures. A complete processing and disposal system can be obtained by using incineration. This method is used by few processors since it is rather expensive.

Processing methods for liquid-carried manure include sedimentation, aerobic and anaerobic digestion. Liquid carried animal manures can be treated by sedimentation to reduce the amount of settleable solids. This type of treatment is used to prevent the formation of sludge banks, to reduce the BOD in diluting waters, and to prepare the waste for subsequent treatment. Sedimentation basins may be operated on the batch or continuous flow bases. In the batch system sedimentation takes place during the period that the basin stands full. Using the continuous flow basins the liquid is allowed to flow slowly through the basin with sedimentation taking place as the liquid passes through this tank. While this method can be classified a treatment system, this process does nothing more than separate the waste. Some provisions must be made for additional treatment or disposal of the solids which do settle out. The most common disposal of the settled solids are application of this material back onto the land.

Any biological treatment system does nothing more than provide a conducive environment for the specific bacteria. The anaerobic systems operates without the presence of dissolved or molecular oxygen while the aerobic systems need oxygen. In general we may state that both anaerobic and aerobic organisms respond favorably to an increase in temperature and their metabolic rates double for about every 10°C increase in temperature.

The success of any one system depends upon many things, such as loading rate, alcolinity, pH, temperature, and detention time which all play a role in the satisfactory operation of a treatment system.

In general, the purpose of anaerobic lagoons is the removal, destruction, and stabilization of organic matter. These deep manure stabilization ponds are strickly anaerobic since their biochemical oxygen demand (BOD) loading is about 20 times that of the aerobic sewage lagoon. Loading values should be based on pounds per volume per time as is done with other digestion systems. Loadings of 1 to 15 lbs of total solids per day per thousand cubic feet have been reported for lagoons treating a variety of wastes. However this system has been reported to successfully handle loading rates of over 300 lbs of total solids per day per thousand cubic feet. Depending upon the type of waste, a floating scum will usually occur on the liquid surface.

Data from both laboratory and field studies over a long period of time have indicated that animal manures can be treated aerobically. The traditional oxidation pond depends upon the oxygen introduced by algae and the oxygen transferred to the pond by natural reaeration and wind turbulence to maintain aerobic conditions. The following loadings have been suggested for each acre of aerobic lagoon treating animal waste: 50 dairy or beef animals, 150 hogs, or 3000 laying hens. These loading figures vary over quite a wide range depending upon such factors as temperature, frequency and duration of sunlight, and wind patterns.

Aerobic systems using mechanical aerating systems have been employed to reduce the quantity of land needed for aerobic treatment. These units maintain sufficient dissolved oxygen in the liquid to allow the bacteria to complete their degradation process. The oxidation ditch is one system which uses a mechanical rotor, or beater, to mix and reaerate the liquid in the channel. Research has indicated that the oxidation ditch can digest animal manures and suggests the minimum ditch volume needed for each animal is 10 cubic feet per hog, 80 cubic feet per head of dairy or beef cattle and 1 1/2 cubic feet per chicken. Such factors as retention time, diet of the animals, and acceptable degree of treatment must be defined before such a system is used.

As a unit operation, storage cannot be omitted or ignored because it occurs even when manure accumulates in the corral or chicken house. The emphasis in manure management is that storage, when and where it occurs, must be complete and sanitary. It does no good to process manure after it has breed flies or is allowed to leach part or all of the nutrients into the soil. Impervious bottom tanks or storage areas should be considered when manure is held over winter or for any extended period of time.

There are only three possible areas where we can dispose of manures: the air, the water, and the soil. The major disposal for most manure is its return to the soil. Since animal manures cannot compete with commercial fertilizers, its use or disposal as far as the livestock farmer is concerned will have to be subsidized. This means that the livestock farmer will have to pay more and more for the cost of collection, processing, storing, hauling and spreading the manure onto the field.

Processing by drying reduces the volume and weight and concentrates the fertilizer nutrients. Dry manure may thus command some reasonable price during the foreseeable future. But even so, it is unlikely that this price will completely cover the cost of sanitary manure management. One reason why manure stabilization ponds are so popular is that the livestock farmer does not have to be concerned with disposal of the manure. The lagoon acts as its own disposal sink and is expected to need minimal sludge removal and disposal.

Simply because animal manures do not economically compete with commerical fertilizers does not mean that they do not have a place on the land. Animals will continue to generate large volumes of these materials and we must continue to dispose of or utilize them. Applying animal manures to agricultural crop lands does increase the tilth of the soil and provide subsequent plants with nutrients which are beneficial. The cost of this disposal or utilization system must be considered a part of the overall management of any livestock operation.

Managing livestock waste to control pollution must be a part of every livestock operation. An awareness of the problems and solutions is being developed by the general public and the livestock industry. Researchers are presently working on disposal and utilization systems which will allow us to maintain our present water quality at an acceptable cost. You and I must be tolerant during this transition period while both the farmer and his city cousin are made to realize the complex nature of this pollution problem and its solutions.

RUNOFF AND SEDIMENT AS NUTRIENT SOURCES

by

R. F. Holt

Whenever a water source (i.e. precipitation, snowmelt, etc.) is supplied to a sloping soil surface at a rate that exceeds the infiltration rate into the soil, runoff occurs. This runoff will contain small amounts of dissolved chemicals and may contain small or large sediment loads. The qualitative and quantitative nature of the dissolved chemicals will depend on the soil, vegetation, organic residue and management practice which prevails on the area from which runoff occurs. The sediment load will depend largely on the soil, topography and vegetation. The sediment is primarily top soil that is carried off the land surface, and it will contain varying amounts of the chemicals which are essential for plant growth (nutrients). Nitrogen and phosphorus are the two chemical elements thought to be most critical in the growth of algae and aquatic weeds in surface water impoundments. The amount of nitrogen and phosphorus supplied to surface waters as a result of runoff and sediment loads will be discussed.

Sediment

Soil losses from sloping land in western Minnesota (Barnes Soil) have been determined under natural rainfall conditions (1). Table 1 indicates the magnitude of nutrient losses (based on a two-year average) associated

Table 1. Average soil loss (2 years) and associated nutrient losses from a Barnes Loam.

Cropping Treatment	Crop	Average annual soil loss Tons/acre	N Lbs./acre	P Lbs./acre
Fallow	None	7.0	56.7	0.30
Continuous corn	Corn	1.8	11.5	0.10
C-O-H	Corn	0.4	3.8	0.09
C-O-H	Oats	0.5	4.6	0.03
C-O-H	Hay	0.0	0.0	0.00

with sediment. The two-year soil loss average is about one-third that obtained for a seven-year average. Consequently, nutrient losses based on the seven-year soil loss average would be estimated to be three times as great. Appreciable amounts of nitrogen and smaller amounts of phosphorus are removed with sediments. The extent to which the sediment contributes to the nutrient content of surface waters is not known. Some indication of the phosphorus equilibrium between lake bottom sediment and water containing varying amounts of dissolved phosphate has been obtained (3) (Table 2).

Table 2. Equilibrium phosphorus values for lake bottom sediments

	Concentration of added solution, PPM P			
	8.2		42.0	
	Concentration of solution in equilibrium with sediment, PPM			
	Ortho	Total	Ortho	Total
Norway Lake	0.01	0.10	0.02	0.11
Big Stone--HB	0.03	0.07	0.05	0.07
Big Stone--O	0.01	0.02	0.03	0.05

These studies indicate that the sediment has a high capacity to remove phosphate from solution. Based on this information and a knowledge of the soils in the area, we could expect that sediment would not be a major contributor to the soluble phosphorus contents of impounded waters and could reduce the dissolved phosphorus levels in some instances. Sediment could be a high capacity, low level source, however, because of the rather rapid equilibrium between water and sediment.

The relation between lake bottom sediments and dissolved nitrogen is complicated and closely associated with the microbiological activity at the lake bottom. Little information is available concerning the equilibrium between lake sediments and soluble nitrogen.

Runoff Water

Water that runs off the land contains small amounts of dissolved nutrients. The quantity of nutrients carried off in the runoff water from experimental plots conventionally planted to continuous corn and a corn-oats-alfalfa rotation has been determined (1). Table 3 gives the annual average dissolved nitrogen, phosphorus and potassium in runoff water expressed as

Table 3. Annual average dissolved N, P and K losses per acre in runoff waters for various cropping treatments.

Cropping treatment	N Lbs.	P Lbs.	K Lbs.
Corn-Continuous	0.70	0.06	0.28
Corn-Rotation	1.08	0.06	0.45
Oats-Rotation	0.67	0.01	0.12
Hay-Rotation	3.10	0.21	2.97

pounds per acre. The nutrients in solution in the runoff are low amounting to about 1.8 lbs. N, 0.08 lbs. P and 0.9 lbs. K per acre per year for land that is in 50 percent corn, 25 percent oats and 25 percent alfalfa. The importance of these small quantities becomes more clear when one considers the case of Big Stone Lake which forms a part of the boundary between Minnesota and South Dakota. A survey of phosphorus sources to Big Stone Lake (2) has estimated that 57,000 pounds of the total 90,000 pounds phosphorus entering the lake each year comes from agricultural land runoff. Calculating the phosphorus contributed by runoff from the 735,000 acre watershed based on 0.08 lbs. P/A gives 58,800 pounds of phosphorus. This amount added to the volume of water in Big Stone Lake would give a concentration of 0.15 parts per million phosphorus; well above the threshold value for profuse algae growth. Similar calculations on the soluble nitrogen would give 1,323,000 pounds of nitrogen and a concentration of about 3 parts per million nitrogen.

It would appear therefore, that there are conditions associated with some lakes which can make agricultural land runoff the major contributor of nutrients. Eutrophication is a natural phenomenon in the life cycle of many lakes. The important consideration becomes the extent to which agriculture contributes to the acceleration of the eutrophication of impounded waters. In this respect, it is interesting to note that the largest soluble phosphorus quantities were observed to come in snowmelt runoff from hay (alfalfa) plots. Unpublished results of laboratory studies has shown that fresh alfalfa plants which are frozen and then leached with water release relatively large amounts of water soluble phosphorus. While this information needs further verification, it does lead one to speculate as to the contribution that spring snowmelt might have made to the phosphorus levels of lakes at the time that western Minnesota was covered with tall grass prairies.

Acceleration of the eutrophication process must be eliminated or minimized whether the source be agricultural, industrial, or municipal. It should be kept in mind however, that the increase in nutrient levels of lakes is a natural process and in most instances probably cannot be reversed.

References

1. Timmons, D. R., Burwell, R. E. and Holt, R. F. Loss of crop nutrients through runoff. Minnesota Science, Vol. 24, No. 4. 1968.

2. Big Stone Lake Study. A joint report by Minnesota and South Dakota. Governor Harold Levander and Governor Nils Boc. Nov. 1, 1967.

3. Latteral, J., Timmons, D. and Holt, R. Unpublished Manuscript. 1968.

CONTROLLING NUTRIENTS AND ORGANIC TOXICANTS IN RUNOFF

by

William P. Martin

It is a fact that the role of agriculture in environmental improvement must by necessity be a major one. The Secretary of Agriculture listed for priority treatment in Memorandum. 1631, dated March 19, 1968, the "reduction of the damages and losses to soil, water, and air by agricultural chemicals; crop, livestock and forestry wastes; sediment; sewage and others." Agriculture must continue to be concerned with the production of more and better food and fiber for our rapidly expanding population, but agricultural pollution is fast becoming an explosive issue.

Nothing points up the problem of maintaining environmental quality better than the problem of the disposal of organic wastes which in a water supply become high BOD toxicants, for it is our expectation that the only logical way these can be effectively handled is through the soil system which includes the water phase. However, we must take stock of our land resources and assay to what extent this so-called self rejuvenating environment is in fact threatened by pollution or contributes to it through erosion and water polluting sedimentation. Fortunately the "soil conservation movement" of the past 35 years has created a public consciousness of the significance of soil erosion to our national well being. The present concern with environmental quality can effectuate a healthy rejuvenation of the movement, and help garner the funds needed to get the research facts on which to base management decisions. Soil is an essential link in the food chain from plants and animals to man, and we must be concerned with its use as a waste disposal system and about the rapidly increasing acreages of land being taken out of production to accommodate the billions of tons of waste that are coming from our burgeoning society.

What I'm suggesting, in effect, is that the best way to control nutrients and organic toxicants in runoff is to effect adequate and effective disposal on the land together with conservation measures that will minimize runoff and sedimentation.

Soil Surveys and Interpretative Evaluations Necessary

Soil is not a simple entity to be considered as such in the context of a waste disposal medium. There are many different kinds of soils and it is important that one take stock of Minnesota's soil resource base. The task of evaluating use potentials is formidable, and the technology of their use for the dissipation of organic wastes is undergoing rapid and fundamental changes.

There are 57 soil associations in Minnesota which represent major soil differences and some 600 soil types distributed within the different associations. (See Ref. 1)

The Minnesota Soil Survey, a cooperative effort of the Soil Conservation Service and the University, is mostly active in some 87 organized Soil and Water Conservation Districts and, though published soil survey reports are generally lacking, progress is being made. It is exceedingly important that soil surveys be accelerated inasmuch as land-use decisions are greatly dependent on this basic resource information including the potential use of different soils for waste disposal purposes. Special projects provide interpretive information for planning and zoning, as examples, and interpretive information is being assembled which can aid in location and construction of feedlots and identify the areas best suited for the disposal of solid and liquid wastes so as to minimize leaching and erosion and contamination of underground supplies.

It is a fact that feedlots, barnyards and disposal areas have generally been located without regard to the soil inventory and associated topographic characteristics. Surface runoff to streams with subsequent damage from high BOD wastes is common, infiltration of nitrates from manures to well waters from poorly located animal holding areas is well known (3, 4) and field disposal of large concentrations of manures on shallow sandy soils overlying high water tables, for example, can lead to contamination of underground supplies.

In this connection, Dr. Webber and associates (2) at the University of Guelph, Ontario, Canada collected manure samples, both solid and liquid, from 6 dairy farms, 12 hog farms, 6 beef farms and 10 poultry farms during 1966 for nutrient analysis and, though there was large variation between farms, depending on method of treatment, volumes of water added by runoff from lots and buildings, leakage and related, postulated required acreages in continuous corn required to efficiently use the nitrogen in the manure without adversely affecting crop yield or quality of ground water nitrogen levels. A minimum of a half-acre was suggested as being needed to accommodate the manures from 1000 broilers, 100 laying hens, 10 hogs (30-200 lbs), 2 feeder cattle (400-1100 lbs.) or 1 dairy cow (1200 lbs.); nitrogen excreted varied from 115-155 pounds and 300-400 pounds of nitrogen

---

1. H. F. Arneman: Soils of Minnesota. Ext. Bull. 278, University of Minnesota. Agr. Ext. Service, St. Paul, 1963.

2. L. R. Webber: The nature of the problem: soil pollution. Ontario Pollution Control Conference, Dec. 4-6, 1967. Toronto, Ontario, Canada).

over the growing season was recommended as a maximum application rate. For cereal grains, much lower applications were found to be necessary to avoid injury.

Dr. Smith, of Missouri (3), recommended that to be on the safe side, not more than 100 pounds of nitrogen be used on sandy soils where there are high water tables and also admonished that nitrogen not be used in excess of plant needs as a combination of that applied in an organic nitrogen waste and in fertilizer.

So far as the organic constituents are concerned, it is axiomatic that the microbial population of most soils by rapid multiplication in the presence of organic food sources (energy supply) is capable of decomposing almost any amount applied. At Guelph, on medium textured and well drained soils, 250-300 pounds of BOD per acre per day were easily biodegraded during the growing season. It was noted that, in terms of nitrogen, this was well within the 300 pounds per acre on corn or hay-pasture mixtures recommended during the growing season to be used by the crop and not contaminate water supplies (5).

Soil Properties Influence Nature and Magnitude of Pollution

As mentioned earlier, soil can affect the decomposition of large quantities of organic debris without injury to the environment and should therefore be utilized in the moderation of harmful pollution of our water supplies. Understanding of the physical and chemical environment and of the microbiological processes occurring in soils is important to such uses. The solid inorganic particles make up about half the volume of most soils and can be classified as to texture. Sandy soils are not plastic or cohesive and they drain quickly. Silt particles are more cohesive in the formation of soil aggregates, but act more like sands than like clays. It is the clay fraction that controls most of the important physico-chemical properties of soils along with humic materials which make up from one to six percent of most Minnesota surface soils. The size, shape and arrangement of soil aggregates largely

---

3. G. E. Smith: Nitrate problems in water as related to soils, plants and water. Water Forum. Special Rpt. No. 55, U. of Missouri, Columbia, Mo., 1968.

4. B. A. Stewart, et al. : Distribution of nitrates and other water pollutants under fields and corrals in the middle south Platte Valley of Colorado. (USDA-ARS Pub. 41-134, Beltsville, Md. 1967).

determines the porosity of soils and organic colloids are the principal cementing agents. They are intermediate products in the decay of plant residues or are produced by soil microorganisms during the decomposition of organic substances. An ideal structural condition within the soil profile is one in which stable aggregates provide fairly large pores extending from the soil surface to the water table or drainage tiles. This will insure rapid infiltration of rain or irrigation waters including those enriched with organic waste product for land disposal purposes satisfactory percolation through the profile and drainage of excess waters from the subsoil layers. Aeration is assured and the heterotrophic bacteria, actinomycetes and fungi which occur largely in the surface horizon can function in an aerobic environment for the rapid degradation of organic waste products. Soil microorganisms are also largely responsible for the nitrogen cycle.

Keeping high BOD materials out of lakes and streams and effecting degradation within the soil mass necessitates an understanding of the soil chemistry of nitrogen and phosphorus. These nutrients in surface runoff or underground supplies may be harmful to humans and livestock or supportive of the growth of algae which hastens the eutrophication of our lakes and reservoirs as noted earlier in discussions.

Chemistry of Nitrogen

Over 90% of the total nitrogen in soils is found in the humic fraction and that in manures is also mostly organic. Microbial decomposition of the organic nitrogen compounds releases nitrogen as ammonia, a process called ammonification and it occurs under aerobic as well as anaerobic conditions. Ammonium cations are held tightly by the soil and organic colloids and thus being immobilized do not move in the soil solution nor does ammonia-nitrogen appear in runoff waters.

Soils in good structure which are well aerated favor the activity of nitrifying bacteria which quickly oxidize released ammonia first to the nitrite anion and then to nitrates. Different organisms are involved in the

---

5. L. R. Webber and D. E. Elrick: Research needs for controlling soil pollution. Agr. Sci. Rev., 4:10-20, Coop. State Res. Service, USDA, 1966.

6. G. E. Smith: Water pollution as related to agriculture. Joint Seminar, University of Missouri and Water Pollution Board, State of Missouri, Columbia, Mo., April 9, 1968, pp. 13-27.

two steps of the nitrification process. Nitrates are completely soluble in the soil solution and will move through the soil profile with the percolating waters if not first used by plants. If nitrates move into poorly aerated areas within the profile, denitrifying bacteria will affect reduction to elemental nitrogen or the gaseous oxides and nitrogen will be lost to the atmosphere. Thirty percent or more of the nitrogen contained in manure is usually lost by leaching, volatilization or denitrification before field spreading and additional losses can occur prior to incorporation. In fact, the holding lagoon or rotation spreading of sewage or barnyard debris in settling or groundwater recharge basins can be manipulated so as to effect both aerobic and anaerobic conditions to eliminate nitrate by denitrification and keep it out of groundwater supplies. It is perhaps significant to note that Dr. Wadleigh has pointed out (7) that we have lost from our agricultural soils in the United States during the past hundred years 1 3/4 trillion tons of organic nitrogen and that cultivated crops on some 294 million acres remove in excess of 9 million tons of nitrogen annually. We are still rapidly depleting our soils' nitrogen supplies. Lysimeter studies have consistently shown that nitrogen in the leacheate is very small where growing plants are present to intercept and rapidly absorb nitrates in the root zone and in Colorado it has been shown that alfalfa grown in the spreading area or irrigated with renovated sewage effluent high in nitrate will remove nitrates to a depth of 20-25 feet and will even remove nitrates from the water table if it is within that depth range.

---

7. C. H. Wadleigh: Wastes in relation to agriculture and forestry. (USDA Msc. Publ. 1065, Washington, D. C. 1968, and: Farm Wastes Symposium on Animal Waste Disposal in Agriculture, Institute of Agriculture, University of Minnesota and Minnesota Pollution Control Agency, cooperating. St. Paul, Minnesota, Nov. 21, 1968.)

8. B. A. Stewart, et al.: Agriculture's effect on nitrate pollution of groundwater. J. Soil & Water Conserv. 23: 13-15, Jan.-Feb., 1968) and

9. F. E. Allison: Evaluation of incoming and outgoing processes that affect nitrogen. (Soil Nitrogen. Amer. Soc. Agron. Monograph #10:578-606, 1965).

Chemistry of Phosphorus

Phosphorus also exists in part in the organic form in surface soils, though more than half is combined inorganically with iron and aluminum in acid soils and calcium in alkaline soils and these phosphates are essentially insoluble. Phosphorus applied to soils or released from organic combination by soil microorganisms is quickly "fixed" in these slowly available forms. Leaching does not occur and phosphorus in the soil solution is usually less than 0.1 ppm and drainage losses less than 1.0 pound per acre per year. Even where erosion occurs and soil becomes sediment in a water supply and total phosphorus may be as high as 1,000 pounds/1,000 tons of sediment, only about 10% becomes available for the growth of water plants, the rest remaining in an unavailable form. Sediment, in fact, because of high phosphorus-fixing abilities, can and does decrease and deactivate soluble phosphorus which may have gotten into our lakes and streams from other sources such as from detergents.

Erosion and Sedimentation

As noted earlier, nutrient losses and contamination of water supplies may be substantial as a result of erosion and also from manures that are applied on frozen soils adjacent to water ways. Erosion is the dominant problem on 39% of the cropland in Minnesota and a secondary problem on two or three million additional acres. Over half the sediment getting into our lakes and streams originates on agricultural land. Research has shown that land cover and treatment is the chief deterrent to sediment delivery and much empirical data have been accumulated on susceptibility of soils to erosion and a mathematical model prepared, called the "universal erosion equation", which aids in the prediction of soil losses, the target level being to keep annual soil losses below 3-4 tons/acre. Conservation practices such as contouring, strip-cropping, mulching and minimum tillage can reduce erosion by 25 to 75 percent and soil and water conservation programs on the farm are more important than they have ever been before.

---

10. R. B. Corey, et al.: Excessive water fertilization. Report to the Water Subcommittee of State Agencies, State of Wisconsin, Madison, Jan. 31, 1967.

11. Soil and Water Conservation Needs - - A National Inventory. Misc. Publ. 917, USDA, Washington, D.C., 1965.

Specific Examples of Successful Land Disposal Systems

Research on ways to reduce the nutrient content of solid and liquid wastes is increasing. Use can be made of denitrification processes under anaerobic conditions in the presence of organic energy sources. In lagoon and basin spreading systems, lime or fly-ash (which releases lime) and aluminum sulfate have been used experimentally to precipitate phosphates and by creating alkaline conditions volatilize some ammonia. Dryup periods for recharge basins can be manipulated so as to favor nitrification in the surface aerated soils and denitrification in the lower water-logged and poorly aerated layers.

The "Flushing Meadows Project" in Arizona consists of several recharge basins some consisting of bare soil, others covered with sand and gravel, and some with grass sod (12). Secondary sewage effluent from Phoenix, Arizona was used for inundation on a varied wet and drying cycle. Approximately 2 feet of water per day could be infiltrated through the grassed plots and less through the gravel plots. Samples from a 30-foot observation well showed that all of the BOD material had been removed and phosphorus dropped from 20 to 5 ppm. Nitrogen was converted to nitrate and the amounts found varied with the dryup schedule, as anticipated, being lowest (1 to 10 ppm) for the wet schedules of 5 days wet and 2 days dry.

A waste water reclamation project at Penn. State University (13) has been in operation since 1962 and makes use of the "living filter" concept in which agronomic plants for the utilization of nutrients during the renovation process complement the microbiological and physico-chemical systems in the soil. Waste water is applied by sprinkler irrigation in a rotation schedule to plot areas of 4.4 acres at the rate of 0.25 inches/hr and 2 inches per week. Crops are grown in strips across each plot and rotated between corn, alfalfa, and oats for two years. The entire area is surrounded by forest plantings as a "guard" strip. The fertilizer equivalent of the waste water applied was equal to 2000 pounds of a 5-10-15 fertilizer in 1965 as an example. Soil water samples were collected by suction lysimeters to a depth of four feet. After three years of operation and an application of 170 inches of waste water, renovation was still good. Detergent molecules (alkyl benzene sulfonates) were reduced 90% and phosphorus 99% to 0.05 to 0.10 ppm. Nitrate nitrogen was reduced up to 82 percent or to 1.6 ppm. Crop yields were increased sub-

---

12. Herman Bouwer: Returning wastes to the land, a new role for agriculture. (J. Soil and Water Conserv., 23:164-168, 1968)

13. Louis T. Kardoes: Waste water renovation by the land - A Living Filter. (In Agriculture and the Quality of Our Environment, N.C. Brady, editor, Amer. Assoc. Adv. Sci., Publ. 85:241-251, 1967, Washington, D. C.)

stantially and corn silage removed the equivalent of 104% of the applied nitrogen. The weak link in the system, however, is the eventual breakthrough of substantial amounts of nitrate-nitrogen from additive effects.

In Oregon, two Hansell brothers are flushing the wastes from some 15,000 hogs into two lagoons using 400 to 1200 gallons per minute for pen cleaning (14). They then pump from the lagoons to irrigate some 500 acres using self-propelled electric sprinklers on wheels with screens at the intake to remove large solids. Their system puts about 5 pounds of actual nitrogen per acre on each field per irrigation and they irrigate only the root zone of the hay, grain and pasture fields used. Odors are minimal and little additional fertilizer is needed.

Canning companies, cheese factories, pulp and papermill companies, sugar and vegetable processing companies and many others (15) are beginning to use spray irrigation and natural soil filters for the disposal of waste waters and Professor Rouse Farnham of the Soil Science Department staff is intensively studying the use of peat soils in the bog or as an addititve to mineral soils for improvement in renovating capacity.

Removal of Nutrients

Brief mention should be made of nutrient removal possibilities. Reference should be made to a report noted earlier titled: "Excessive water fertilization" (10, pp. 36-49). Rough fish and aquatic plant (including algae) harvest and removal has been suggested for nutrient reduction. However, the possibilities here are minimal and costs excessive. At a harvest rate of 100 pounds of fish per acre annually, nitrogen would be reduced by 2.5 pounds per acre and phosphorus 0.2 pounds. In Lake Mendota, six species of rooted aquatics contained a dry weight average of 3% nitrogen and 0.47% phosphorus, and with machines that can cut up to four tons of drained plants per hour or close to 1,000 tons per year, only about 2 1/2 percent of the phosphorus

14. Clarence Underwood: Irrigating with animal waste. (Soil Conserv., 34:81-82, 1968)

15. W. E. Bullard, Jr.: Natural filters for agricultural wastes. (Soil Conserv., 34: 75-77, 1968) and Crops & Soils 21:25, 1968, Amer. Soc. Agron., Madison, Wisconsin)

and 1 1/2 percent of the nitrogen input per year is being removed. The cost of removal of aquatics per ton is $41.00. It is much more important and feasible that the nutrients entering the waters be controlled preferably by suitable land disposal methods.

Conclusion

The natural biosphere based on use of land and water resources has been significantly altered by man to assure his food and fiber supply and to favor living and recreation interests. But he has had to use management practices which accelerate the production of wastes or input amendments which increase the pollution hazard and particularly as regards organic wastes, nitrogen and phosphorus. Land disposal methods for dissipation of wastes and water renovation must be researched to accomodate the natural ecology of the area and to support the s lf-rejuvenating interactions of the physical and biological components of the soil-water system. Much more research and study are needed.

TREATMENT OF MUNICIPAL WASTES

by

Walter K. Johnson

Previous discussions centering on disposal problems from feed lots and poultry installations posed problems similar to those in municipalities. The need for municipal waste disposal is also a consequence of concentration, the concentration of people in a given area. As our urban areas continue to grow, the effect of wastes on receiving waters is accelerated.

Regardless of how wastes are treated, there always are at least some solids leaving the treatment plant with the effluent waters, and the capacity of a lake or river to assimilate these solids without suffering some apparent pollutional effects is limited. As the population increases, the municipal flows increase, and because of the limited assimilative capacity of receiving waters, permissible concentrations of solids in treated effluents become necessarily less. In other words, municipalities are faced with the need for ever increasing the degree of wastewater treatment as the population continues to concentrate within the urban area. In 1964 approximately 64 percent of the sewered population in the United States was served only by primary treatment facilities. Although this has improved considerably since, a continual upgrading of treatment facilities will be necessary. We have the technology to improve treatment. What we need to do the job is people and funds.

Municipal wastes come from four sources, as shown in Figure 1: domestic; commerical; industrial; and infiltration. Domestic wastes are those produced from individual homes and are reasonably consistent in characteristics. Commercial and industrial wastes will vary in volume and composition depending on the local situation. Total municipal flows divided by the population usually show average values of 120 gallons per person per day of which approximately 60 gallons per day is the domestic flow. The solids contained in the wastewater are described in terms of biochemical oxygen demand (BOD), suspended solids (SS), and individual elements such as nitrogen and phosphorus as shown in Figure 1. BOD is an indirect measure of the organic or decomposable solids and an average concentration is 250 mg/l (milligrams per liter). The SS concentration is usually about 300 mg/l and the total nitrogen and phosphorus concentrations are approximately 25 and 10 mg/l respectively.

One of the problems in dealing with municipal wastewaters is that we must process very dilute solutions, and the rates of flow and solids concentrations vary continuously throughout the day as shown in Figure 1. In fact, industries discard dilute solutions of solids as wastewater because it is uneconomical or too difficult for them to recover these materials. Yet in many cases the wastewater treatment facility is and will be required to remove such materials from the flow to prevent water pollution.

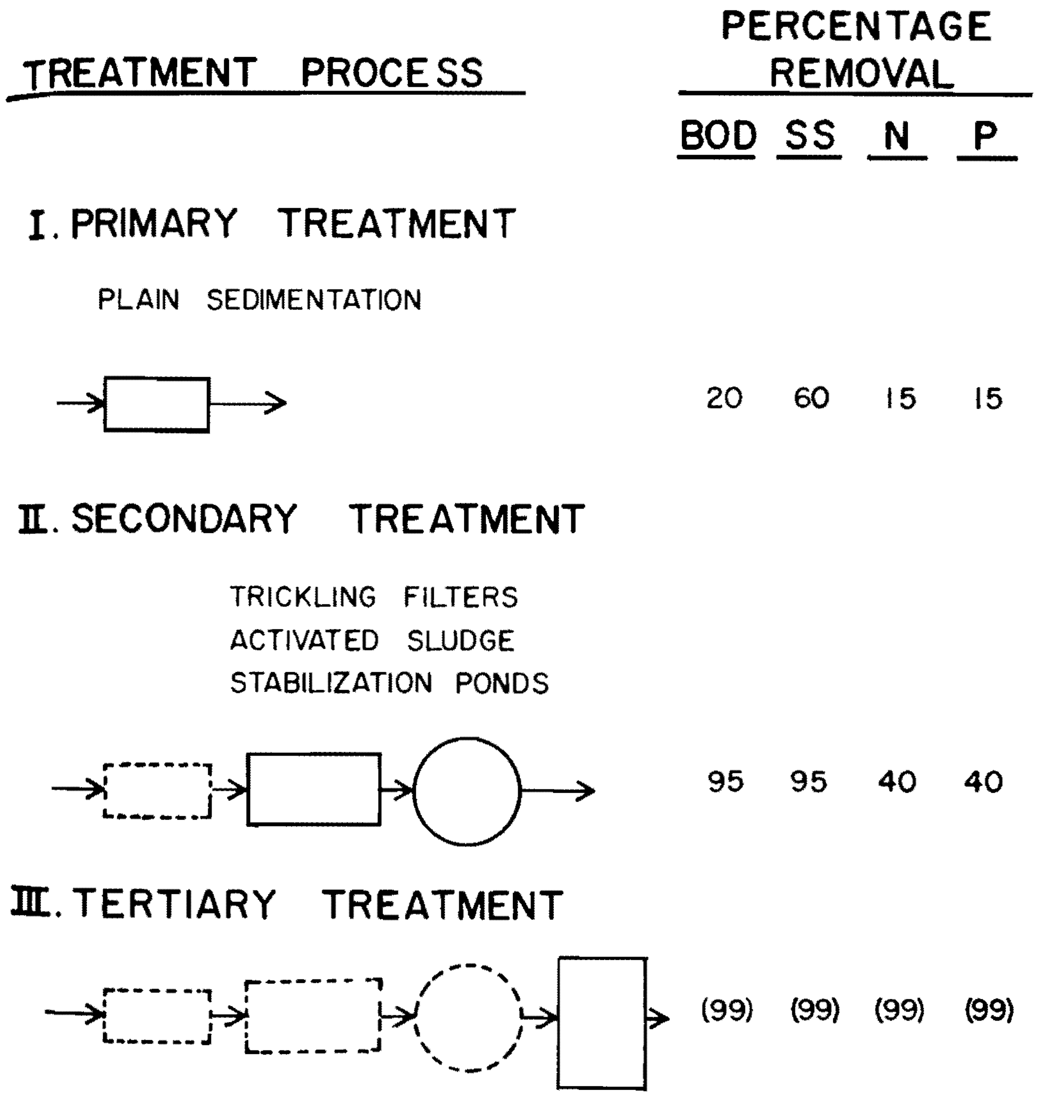


Figure 2. Typical Treatment Efficiencies with Various Degrees of Waste Water Treatment

Typical treatment of municipal wastes first starts with primary treatment as shown in Figure 2. Primary treatment usually involves a plain sedimentation process with removal efficiencies as shown. Secondary treatment is the second step up the treatment ladder and results in increased removals of most all types of solids except many dissolved salts. The type of treatment is usually a biological process involving trickling filters, activated sludge, or stabilization ponds. Removals with such units will vary but all may be operated under certain conditions to obtain the removals shown in Figure 2. Soon all treatment plants will include a secondary treatment process.

The third step in treatment is to employ tertiary processes for increasing further the degree of removal of solids. Tertiary treatment is usually always preceded by a primary and secondary process and may be used to remove a portion or all of the solids remaining after secondary treatment. Our technology today will permit us to have a closed water system for our municipalities; that is, we can process our wastewater and reuse it directly as a water supply. However, the cost of such a system would be relatively high.

Processes available for tertiary treatment are listed in Table 1 and refer specifically to methods for removing nitrogen and phosphorus. For general overall removal of solids, filtration through sand or similar media is often used as in water treatment. Adsorption is accomplished using activated carbon, and reverse osmosis is a process involving the separation of solids by forcing the water through selective membranes.

Table 1. Processes Available for Tertiary Treatment of Municipal Wastes

NITROGEN REMOVAL	PHOSPHORUS REMOVAL	GENERAL REMOVAL
Ammonia Stripping	Chemical Precipitation	Filtration
Denitrification	Biological Removal	Adsorption
Ion Exchange	Ion Exchange	Reverse Osmosis

Phosphorus removal may be accomplished by chemical precipitation with lime or alum. Biological treatment with activated sludge plants has been shown to give high phosphorus removals when operated in a certain manner. Orthophosphate may be removed by ion exchange in an anion exchange unit.

Nitrogen removal by ammonia stripping involves the conversion of nitrogen to the ammonia form by biological treatment and the subsequent stripping by aeration under high pH conditions. Denitrification is a form of biological treatment whereby the nitrogen is converted to the nitrate form and then biochemically denitrified to nitrogen gas. Ion exchange may be used by passing

I. SOURCES

DOMESTIC	INDUSTRIAL
COMMERCIAL	INFILTRATION

II. TYPICAL CHARACTERISTICS

FLOW: 120 GALLONS / CAPITA / DAY

BOD:	250 mg/l
SUS. SOLIDS:	300 mg/l
NITROGEN - N:	25 mg/l
PHOSPHORUS - P:	10 mg/l

III. DIURNAL VARIATIONS

FLOW AND CONCENTRATION

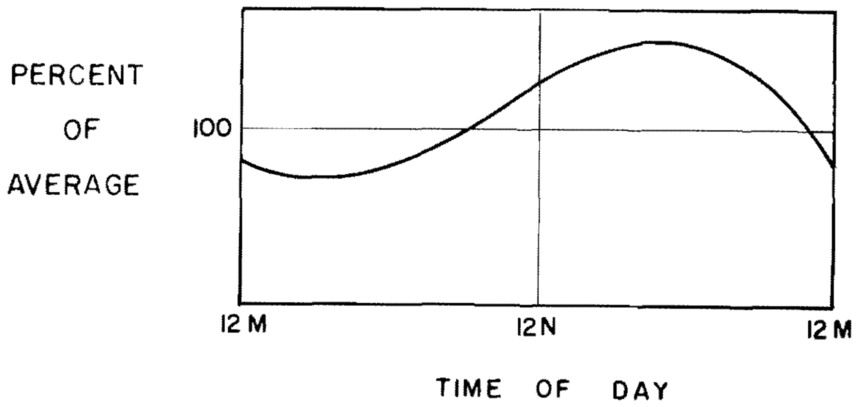


Figure 1. Sources, Characteristics, and Flow Variations of Typical Municipal Wastes

the flow through cation and anion exchangers to remove the ammonia, nitrite, and nitrate forms of nitrogen.

Many combinations of these unit processes are being proposed and in not too many years we will have many tertiary treatment plants in operation.

SEPTIC TANK EFFLUENTS

by

Robert Charles Polta

Septic tank effluents are generally discharged to the soil by way of tile fields or seepage pits. This being the case, any nitrogen and phosphorus compounds in the effluents are potential ground water contaminants and, as such, also potential surface water contaminants - either by direct flow or indirectly by pumping, use and subsequent discharge to a surface water.

The average use of water for domestic purposes in households served by septic tank - soil absorption systems is approximately 50 gal/capita/day. For a typical family of five the waste water flow to the disposal system then amounts to approximately 250 gal/day.

The septic tank generally consists of a concrete tank with a baffled inlet and outlet. The tanks should be of such capacity to provide for a detention time of 2 to 4 days. The minimum capacity recommended by USPHS and the Minnesota Department of Health is 750 gal. As the waste water enters the tank the heavy solids begin to settle to the bottom and the lighter materials, greases and oils, float to the top. Very little of the soluble organic material is stabilized in the septic tank. In fact, the major reaction in the septic tank is that of liquifying some of the solids that enter, thus increasing the concentration of soluble contaminants.

The suspended solids and water soluble material then pass to the soil absorption system, where a combination of physical, chemical and biological reactions stabilize the effluent. An average septic tank effluent contains:

Organic N	10 mg/l
NO_2-N	0
NO_3-N	0
NH_4-N	25
PO_4	20

For the typical family of five this represents approximately 5 pounds of phosphorus and 27 pounds of nitrogen applied to the soil per year.

The hydraulic loading rate and, in turn, the required adsorption area are determined by the rate at which water will percolate down through the soil. The standards recommended by the Minnesota Department of Health require a minimum of 300 ft^2 absorption area in trenches which would require approximately 1200 ft^2 of surface are (100 ft x 12 ft). The loading rates based on 1200 ft^2 are approximately 200 lb P/acre/year and 1000 lb N/acre/year. A more meaningful measure of the rate of application to the soil and ground water below, especially in a highly developed residential area, is based on the total land area - lot size. For a lot size of 75' x 200' the loading rates reduce to 15 pounds phosphorus and 80 pounds nitrogen per acre per year. The considerable magnitude of these rates can be illustrated by comparing them with the application rates on agricultural lands of up to 300 pounds nitrogen and 90 pounds phosphorus per acre per growing season.

Many soils are capable of fixing large quantities of phosphorus thus making it unavailable to plants as a nutrient. The mechanism of phosphorus fixation is quite complicated. The processes include (1) adsorption, (2) replacement reactions which may involve changes in the mineral crystalline structure, and (3) precipitation reactions through which the soluble phosphates react with iron, aluminum, or calcium to form insoluble compounds. The phosphorus fixation capacity of soils have been reported to be as high as 8,000 lb P/acre to a depth of 6 inches. The surface soils generally have the greatest fixing capacity however the capacity of the subsurface soils is also considerable. Thus for agricultural purposes, land having a high phosphorus - fixation capacity presents a great problem. On the other hand these soils are ideal for waste water soil absorption systems because of this capacity to remove soluble phosphates from the percolating water and essentially eliminate them from consideration in terms of water pollution.

The nitrogen compounds present an entirely different problem. As well as contributing to the problem of excessive growths in lakes and streams that may be fed by ground waters, one form - nitrate nitrogen - also has a public health significance as it is the cause of the disease METHEMOGLOBINEMIA in bottle fed infants.

The two main factors affecting the movement of nitrogen compounds in soils are (1) the adsorption - ion exchange phenomenon exhibited by the soils and (2) the action of the nitrifying and denitrifying bacteria.

Most soils in nature possess a net negative change which means that they have the capacity to attract and hold cations (+ ions) out of solution. The magnitude of this capacity depends on many variables including: soil type, pH, cation type and concentration, anions present, ions previously adsorbed, etc. As indicated previously most of the nitrogen in septic tank effluents is in the ammonia form. At normal effluent pH (less than 8.5) most of this is in the form of the ammonium ion, NH_4^+. The combination of the (-) charge on the soil particle and the (+) charge on the ammonium ion lead to an efficient nitrogen fixing mechanism. For the concentration of ammonia nitrogen applied in soil absorption systems the adsorption capacity of a soil may vary from 2 mg N/100 gm (0.002% of soil weight) for

a sandy soil to 10 mg N/100 gm (0.01% of soil weight) for a fine grained soil (30% clay).

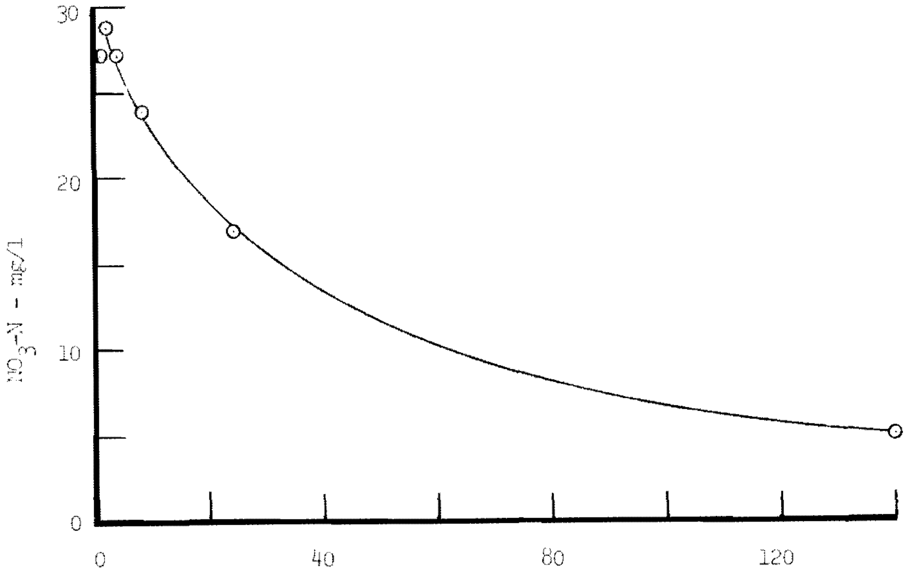
The nitrifying bacteria act in opposition to the adsorption process in terms of nitrogen mobility. The dietary requirements of these organisms are very simple. They consist of mineral salts always present in the soil, ammonia nitrogen, carbon dioxide, and oxygen. The two genera of most importance are NITROSOMONAS and NITROBACTER. Their combined end product is the oxidized form, nitrate nitrogen. The nitrate ion has a (-) charge and therefore is not adsorbed to any appreciable extent by the soil. However it is very soluble in the percolating water and is therefore carried down to the ground water table where it is free to move with the ground water flow.

Under anaerobic conditions some bacteria can utilize nitrates, along with organic carbon compounds as a source of energy. The nitrates replace oxygen in the metabolism of the organism. The end products of the reaction are molecular nitrogen, nitric oxide, and nitrous oxide. Under the optimum conditions considerable quantities of nitrate may be removed from the percolating water through this process.

The Sanitary Engineering Division of the Civil Engineering Department has carried on research relating to the movement of nitrogen compounds in the soil-ground water environment for several years under the sponsorship of the USPHS, National Institutes of Health. The projects included the operation of a simulated soil absorption system along with a series of some 20 ground water observation wells located in a sand soil. This system has been in operation during the warm weather months of the past four years. The system simulates the effluent, in terms of total flow and ammonia nitrogen concentration from a typical family of five, as applied to the soil in a seepage pit.

During the period of operation approximately 32 pounds of nitrogen in the ammonia form has been applied to the soil without affecting a change in the ammonia nitrogen concentration of the ground water. However, the nitrifying bacteria have utilized the adsorbed ammonia as illustrated below. A significant concentration of nitrate nitrogen was detected in the shallow ground water at a distance of 140 feet "downstream" of the seepage pit. At a distance of 70 feet downstream the NO_3-N concentration was approximately 10 mg/l which is the maximum limit recommended by the USPHS in their drinking water standards.

At the present time there does not seem to be any workable method available to limit the nitrification process. By limiting the supply of oxygen in the soil the production of NO_3-N could be stopped and the nitrogen could be stored on the soil in the form of the ammonium ion. However, when the soil absorption systems go anaerobic ferrous sulfide is often pro-



duced and clogs the soil leading to hydraulic failure of the system. If the flooded system is allowed to dry out the ferrous sulfide is oxidized and the system may then be returned to normal service.

Bactericidal agents may be applied to the soil to inhibit the growth of the nitrifying bacteria however they may also inhibit the growth of the other organisms and thus prevent the stabilization of the effluent and lead to hydraulic failure as the solids, carried over from the septic tank, clog the soil.

Individual wells may be protected from contamination by nitrate by placing them far enough "upstream" of the soil absorption system so that they will not be affected by the movement of the percolating waters. In a developed residential area entirely served by individual wells and soil absorption systems this may not be possible. Under such conditions the well should be driven as deep as possible as the soluble contaminants tend to remain at the water table surface. However this is only a temporary solution as the contaminants will diffuse down through the water over a period of time.

In summary we may make the generalization that the phosphorus contained in septic tank effluents applied to the soil does not present a serious

problem to the ground water or surface waters. However, the nitrogen compounds of the effluent applied to a working soil absorption system are rapidly oxidized to nitrate nitrogen which may seriously contaminate the shallow ground water in the immediate vicinity and for considerable distances in the direction of the ground water movement.

WATER POLLUTION IN RECREATIONAL AREAS--SOURCES AND CONTROL

by

Michael A. Barton

Introduction

The problems associated with campgrounds, beaches, resorts, and similar recreational developments may be likened to the problems encountered in the use of septic tanks and domestic sewage. These areas have been discussed by earlier speakers. Therefore, I shall confine my remarks to recreational areas such as the Boundary Waters Canoe Area of the Superior National Forest. I will make only passing reference to other recreational areas and leave the extrapolation of my remarks to the audience.

Further, since the primary pollution problem in these wilderness areas is nutrient enrichment, I will make only occasional reference to other forms of pollution. The morning panel on "Effects of Nutrients and Other Pollutants" makes it possible for me to dwell primarily on sources and control.

The pollution and/or enrichment of waters in strictly recreational areas has generally not proceeded to the same extent that it has in the more populated areas. The reason is obvious. The lack of concentrated populations and industries has spared these areas from the severity and rapidity of the problem as it exists in urban areas. However, the original quality of the receiving waters in recreational areas is generally of much higher caliber. Small amounts of artificial inputs are more noticeable in higher quality waters than they are in waters already receiving such inputs.

At this time, there remains open to us the possibility of preserving the generally excellent quality of the water in recreational areas. Prevention is much more likely to succeed and much less costly than correction. Should it become necessary to use corrective instead of preventive measures in recreational areas, we must bear in mind that corrective measures can only alleviate the grosser aspects of the problem and will, in all probability, never restore to the water its original quality.

If we restrict ourselves to artificial nutrient enrichment the problem becomes highly complex. It is easy to see that as use of an area doubles it becomes necessary to reduce by one-half the allowable nutrient concentrations in the effluent of sanitary systems if the quality of the waters of the area are to be maintained. The use would not have to double very many times before an effluent of essentially distilled water would be required.

Therefore, we must either develop no-effluent systems or determine which watersheds are to be protected and which to be used for nutrient disposal. We should not delude ourselves into thinking that the currently popular irrigation methods of waste disposal will serve to protect the waters in the long run. Protection by this means merely buys time. The amount of time is determined by the proximity of the irrigation system to water and the rate of the various hydrological, biological, geological, and chemical processes occurring on the watershed. Thus, the ultimate solution to artificial nutrient enrichment is the development of no-effluent systems or export of nutrient from the watershed to be protected.

The magnitude of the problem in areas specializing in wilderness experiences may seem like an exercise in minutiae. Not true! The relatively large areas associated with most wilderness areas is misleading. The vast majority of the use of wilderness areas is concentrated in the more accessible regions. For example, 76 percent of the visitors to the BWCA entered the area through only eight of the 66 entry points. Furthermore, we estimate that these visitors imported to the waters of the area in 1967, excluding inputs from solid waste and outboard engines, eight tons of sodium chloride, one ton of phosphate, and 12 tons of nitrogen.

As a final word of introduction, I would like to say that one of the biggest water quality problems in some recreational areas is the inflow of highly enriched waters to the area. For example, a municipality discharges the effluent of a secondary sewage treatment plant into the headwaters of the Boundary Waters Canoe Area. This drainage then flows through a number of lakes in the heart of the BWCA contributing to the fertility of the waters. Thus, a problem that at first appears to be inherent to the recreation area is really externally imposed.

Visitor Inputs

The disposal of sanitary waste from a visitor to a recreational area designed to yield a wilderness experience is a complex problem. There are no roads and no energy sources. Often times, the physiography renders the common pit toilet inadequate for the protection of the health of the public or the preservation of the quality of the environment. Here a no-effluent system such as a combustion toilet or waste export system is needed. We are experimenting with a wilderness type combustion toilet. We hope to evaluate the use of airplanes and helicopters as "flying honeywagons", if you will, to function as a nutrient export system.

In addition, the visitors to the area contribute to the over-all chemical budget in other ways. The use of outboard motors by the recreationist may be quite detrimental to water quality. The New York Conservation Department (1, 2) recently completed a study which demonstrated that four gallons of gasoline out of ten may be discharged into the water from outboard motors. The use of leaded gasolines may result in lead accumulations in the bottom mud which interrupt decomposition cycles and disturb the food chain. The oil, as well as the lead, contained in this gasoline can create problems. One gram of oil requires 3.3 grams of oxygen for complete oxidation. Oil slicks interfere with gas exchange across the air-water interface. The phosphates and other chemicals contained in the oil are often undesirable. At the present, the only control is education in the use of unleaded gasolines and non-detergent oils. Various engine manufacturers are striving to design more efficient engines.

The problem of solid waste disposal cannot be ignored in recreational areas. For example, during the summer of 1969 we expect 120,000 visitors to the Boundary Waters Canoe Area to import 360,000 pounds of bottles, cans, and other non-burnable refuse. Disposal would require an investment of $150,000. Decomposition of these materials provides an abundant supply of trace elements as well as some major ions. Suitable land-fill sites are rare and merely delay the entry of these materials to the waters. Therefore, we export these materials from the area. Education of the visitor in the use of disposable containers and carrying out non-burnables is the best control. 100 percent success cannot be achieved and some means of picking up the remaining trash is necessary, however.

Management Inputs

Recently, Bormann and Likens (3, 4) Yale University and Dartmouth College respectively, in cooperation with U.S. Forest Service at the Northeast Forest Experiment Station's Hubbard Brook Experimental Forest have demonstrated that certain silvicultural practices on lands managed for multiple use (recreation, timber, wildlife and water) can increase the chemical concentrations in waters leaving the area. By clear-cutting and herbiciding an area (a common practice in northern Minnesota) the nitrate concentration of a stream was raised to over 50 mg/l, a 20 fold increase. This concentration is considered beyond the limit for potable water by the U.S. Public Health Service. Increases in other elements were less dramatic but still substantial. Algal blooms were produced in a stream where none were known to occur before. It would certainly be reasonable to expect increased concentrations to result from such practices here in Minnesota, although probably not of the same magnitude. Control may consist of eliminating clear-cutting and herbiciding as a tool of timber management.

Another silvicultural practice utilized on recreational lands has been the use of pesticides. This practice has long been criticized as pollution of the environment. Hard insecticides such as DDT have been shown to persist for years and accumulate in various organisms. Elimination of the use of such hard pesticides is the best control. Other pesticides which rapidly decompose into harmless components and do not accumulate in the tissue of organisms should be used with buffer strips around the waters to be protected. Better still, the development of biological controls, with full investigation into their total ecological impact, could drastically reduce the use of pesticides. An example is the use of the French Wasp to control the Elm Bark Bettle and prevent the spread of the Dutch Elm Disease.

Natural Inputs

The discussion has centered on artificial inputs. The natural enrichment of waters in recreational areas cannot be ignored. In many cases, natural sources contribute the largest quantities of the nutrient elements.

Sedimentation is a natural source that can be controlled. Proper land treatment and shoreline stabilization measures can prevent the direct contribution of sediment to the nutrient budget of waters as well as precluding turbidity and smothering the bottom flora and fauna. Eroding shoreline, such as on Lake Winnibigoshish were the shoreline has receded forty feet a year in some areas, have contributed substantial quantities. Fortunately, most soils that are so susceptible are usually infertile.

Vegetation and soils on the watershed can contribute substantial quantities of nutrients in run-off. The Burntside River, near Ely, demonstrates the contribution of legumes to the nitrogen concentration. Concentrations of elements from four forested watersheds in the Ely area can be seen in the accompanying table.

Table I. Selected ion Concentrations in drainage from forested watersheds in northeastern Minnesota.

Water shed	(Acres) Area	Ca	NH_4	NO_3	Organic N	P
Ionic concentration (mg/l)						
2	5310	54	.04	.50	.18	.032
3	7040	64	.08	.91	.69	.060
4	2370	38	.06	.42	.66	.047
6	32100	17	.03	.34	.38	.023

Precipitation and atmospheric fall-out have been demonstrated by Gorham (5), Dugdale (6), Junge (7), and others to be significant in some areas. The quantity and quality, except for nitrogen, of atmospheric fall-out tend to be associated with proximity to likely sources such as industries, agricultural areas, and large water bodies such as the sea. We have found that in the Ely area nitrogen is the only measurable element received consistently from the atmosphere.

Monitoring Systems

A monitoring system should be established to monitor the effectiveness of the control measures. Such a monitoring system should monitor all inputs to the recreational area, discharge from the area, and probable trouble spots within the area.

The monitoring system should consist of a period in which the water is initially characterized and a base-line is established. Parameters to be evaluated should include not only chemical but biological, bacteriological, physical, and aesthetic properties as well.

Following this period of initial characterization, selected parameters should be monitored to determine any changes that occur. Such parameters might include nitrogen, phosphorous, chlorides, lead, oils, fecal coliform, transparency, productivity, and phytoplankton quality.

Conclusions

In conclusion, recreational sources of pollution are seldom as obvious or as severe as pollution problems in urban areas. This situation is misleading since the quality of the waters being polluted is generally much better than the receiving waters in other areas. Further, it is ironic that man expects a higher quality of water in his recreation areas than he does in his living areas.

References

1. Muratori, Alex, Jr. 1968. How outboards contribute to water pollution. The Conservationist, June-July, 1968. State of New York Conservation Department.

2. Stewart, Ronald and H. H. Howard. 1968. Water pollution by outboard motors. The Conservationist, June-July, 1968. State of New York Conservation Department.

3. Bormann, F. H. and G. E. Likens. 1967. Nutrient cycling. Science 155:424-429.

4. Bormann, F. H. and G. E. Likens, D. W. Fisher, and R. S. Pierce. 1968. Nutrient loss accelerated by clear-cutting of a forest ecosystem. Science 159:882-884.

5. Gorham, Eville, 1961. Factors influencing supply of major ions to Inland waters, with special reference to the atmosphere. Geological Society of America Bulletin. 72:795-840.

6. Dugdale, Richard C. and Vera A. Dugdale. 1961. Sources of phosphorous and nitrogen for lakes on Afognak Island. Limnology and Oceanography 6:13-23.

7. Junge, Christian E. 1958. The distribution of ammonia and nitrate in rain water over the United States. Transactions of American Geophysical Union 39:241-248.

SETTING WATER QUALITY STANDARDS AND REGULATING NUTRIENT SOURCES

by

John P. Badalich

Water quality standards have perhaps been given more press, been the subject of more debate, and precipitated more emotion during the past few years than is due them. Probably this is because of the general lack of understanding by the public as to what standards are, how they are developed, and what they are designed to do. The "great debate," if we can use that phrase to describe the goings-on over the past few years regarding standards, has, aside from the general public, involved the technical people of Pollution Control Agencies, such as ours, in all the states with what might at first glance look like a confrontation with the Department of the Interior's Federal Water Pollution Control Administration, since according to Federal law the individual state standards for interstate waters must be approved by the Secretary of the Interior.

The argument has never been over clean water versus dirty water, or adequate treatment versus inadequate treatment, but rather the disagreements have been, to a very large measure, over how we state the same thing. For example, the insistence on secondary sewage treatment for all sources on interstate waters really means (upon reading the small print) "adequate treatment to protect legitimate stream uses," which all states would agree to without argument, and which we feel should be stated in that manner, and yet it is not acceptable to the Secretary.

One significant difference between the state agencies and the Department of the Interior is that the states are not only in the business of developing standards, but also enforcing them on a daily basis, and we want to be sure that what we adopt as law will withstand the test of litigation. An unreasonable standard is no more defensible under Federal law than it is under State law. Reasonableness, in one word, is what all the discussion over the past few years has been about. There really isn't a nickel's worth of difference between the goals of the FWPCA and the goals of the MPCA as regard to maintaining water quality, and it is very unfortunate that as of this date the Minnesota standards (as well as those of many other states) have not been approved in their entirety so that the regulations can be published and issued.

To better understand water quality standards, we should review some of the considerations used in developing and adopting them.

Basis for Establishment of Water Quality Standards

The basis in law for setting water quality standards at the state level is contained in Minnesota Statute 115.44, entitled Classification of Waters; Standards of Water Quality and Purity, in which the Legislature has gone into great detail as to how standards should be adopted and what factors must be considered in establishing them. This section refers to all waters of the state, and not just interstate waters. We are concerned, therefore, that there not be any great inequities between water quality standards for interstate and intrastate waters.

Minnesota law also makes a distinction between stream standards and effluent standards, permitting the use of the latter where the Agency deems it advisable and practicable. It should be noted that whereas effluent standards are permissive in the law, stream standards are required.

The basis in law for water quality standards at the Federal level is contained in PL 660, Section 10, which states, very briefly, that pollution abatement is a state responsibility and that the states should adopt water quality standards (stream standards) for interstate waters, subject to the approval of the Secretary of the Interior, at which time the state standards for interstate waters will also become the Federal standards. There is no specific provision in Federal law for effluent standards, nor is there any provision for enforcement action, except under special conditions prescribed for displacement of state action.

Methodology of Establishing Water Quality Standards

There are three terms which are often used in a confusing way which require an explanation. Criteria are what we consider the use-quality requirements. For example, a game fishery requires at least 5.0 milligrams per liter (mg/l) of dissolved oxygen in order to survive and propagate without measurable damage.

The classification of the stream states what its uses are, or what we want them to be. As an example, the Mississippi River, in the reach from above Anoka to Minneapolis, is used for domestic water supply, game fish, industrial consumption, irrigation, and waste disposal. Each of these various uses has quality requirements, or criteria, with the most stringent parameters applying in the case of multiple use.

The criteria and the water classification, when combined, then becomes the standard. We have also included as a part of the standard the implementation and enforcement plan, or, in other words, who must provide what treatment works and when they must do it.

In developing the criteria, we relied quite heavily on the current literature and on consultation, correspondence, and public hearings to obtain from those expert in the various use-categories, for their recommendations as to what parameters and what limits for the various parameters should be included. In the case of domestic water supply, for example, we used the recommended U.S. Public Health Service drinking water standards, using both the recommended and the mandatory standards. Similarly, with agricultural uses we relied on published information, and received considerable useful information from the U.S. Department of Agriculture on suggested limits.

Listing of parameters must, of necessity, be only partially complete, and we have attempted to list individually only those parameters which are significant or which one might normally expect in waste effluents. We could not, for example, list individually the thousands of organic compounds, so what was done was to cover this type of thing by general statements regarding their effect on the designated uses or on the aquatic habitat.

We have included, where applicable, physical parameters, such as temperature; chemical parameters, such as phenol, and bacteriological parameters, such as coliform group organisms. In the case of multiple use for a specific stream, the criteria for one use might override that of another, with the most stringent limit applying.

We expect that as technology develops further and more information becomes available on limitng parameters, that the standards will need modification or revision. Even at present there is a great deal of discussion and disagreement by authorities on what the temperature limits should be, which would indicate that more work needs to be done in this area and, in fact, the matter is currently under study at the Corvallis, Oregon, Water Quality Laboratory. In the interim, our standards have been established on a sliding scale, relating them generally to ambient temperatures by month. One would not expect, for instance, that the temperature criteria for northern climates should be the same as for our southern states.

In our standards we have included quality differences within use categories. As an example, the fisheries category includes three sub-classes: cold water fishery (trout waters), normal game fish (which would include the bulk of our fisheries water), and resident fisheries (which is a polite way to say "rough fish"), the latter being generally limited to intermittent streams or special situations. Despite all the discussion you must have heard or inferred to the contrary, these sub-classes permit overall upgrading of the standards because standards, above all, must be reasonable, and if we were limited to only one fishery class it would, therefore, have to be reasonable for the lowest quality water and would downgrade present high quality waters.

Along this same line, the variance provision which is a part of all our standards applies and serves the purpose of maintaining a higher water standard, while permitting variance therefrom in special isolated instances rather than making the exceptional case the control.

Theoretically, variances can be applied for relief in time; relief from specific parameters, or a combination of both, either on a temporary or permanent basis. All will be given special consideration by the Agency, but we certainly envision that they will be the exception rather than the rule because if variances become commonplace, it would probably mean that the standards were not proper and we would assume that the Agency would grant them only upon demonstration of need.

Application of Standards

The distinction was made earlier between stream standards and effluent standards, and perhaps a word of explanation is in order regarding each.

The stream standards as described earlier relate stream uses (i. e., water supply, fishery, recreation, etc.) to necessary water quality for that use, and they provide little direct information as to what a discharger must provide for treatment works. (There are exceptions to this in the case where stream standards are applied as effluent standards, such as is the case with coliform group organisms. In other words, we have allowed no dilution and no mixing zone for coliform or bacteriological contamination.)

Generally, what is necessary is for the discharger, in the absence of effluent standards, to calculate what effluent will be required to meet the stream standard at the base flow used. This is by no means a simple dilution calculation, and may require very costly mathematical models due to the many variable and interrelated chemical and biochemical activity in the stream. This is particularly true in the case of waste strength or BOD.

Effluent standards, on the other hand, require no interpretation by the discharger and, hopefully, afford him an equitable and reasonable limit for effluent strength which will protect the stream standard and apply equally to all dischargers in any particular reach of stream.

While the stream standards (and therefore the effluent standards) are based on a specified stream flow for design purposes, it is not anticipated that the discharger will be allowed to "ride on the river" at higher flows. For example, we have used as a design flow the 7-consecutive-day-flow expected to occur once in ten years, and it is that flow upon which treatment works must be designed. The discharger will be required to operate the facility at design capacity, even though the base flow is exceeded.

Table 1 : Interstate Water Quality Standards, Minnesota Pollution Control Agency Regulation WPC 15.

A. Water Use Classifications

1. Domestic Consumption (to include all interstate waters which are or may be used as a source of supply for drinking, culinary or food processing use or other domestic purposes, and for which quality control is or may be necessary to protect the public health, safety or welfare.)

2. Fisheries and Recreation (to include all interstate waters which are or may be used for fishing, fish culture, bathing or any other recreational purposes, and for which quality control is or may be necessary to protect aquatic or terrestrial life, or the public health, safety or welfare.)

3. Industrial Consumption (to include all interstate waters which are or may be used as a source of supply for industrial process or cooling water, or any other industrial or commerical purposes, and for which quality control is or may be necessary to protect the public health, safety or welfare.)

4. Agriculture and Wildlife (to include all interstate waters which are or may be used for any agriculture purposes, including stock watering and irrigation, or by waterfowl or other wildlife, and for which quality control is or may be necessary to protect terrestrial life or the public health, safety or welfare.)

5. Navigation and Water Disposal (to include all interstate waters which are or may be used for any form of water transportation or navigation, disposal of sewage, industrial waste or other waste effluents, or fire prevention, and for which quality control is or may be necessary to protect the public health, safety or welfare.)

6. Other Uses (to include interstate waters which are or may serve the above listed uses or any other beneficial uses not listed herein, including without limitation any such uses in this or any other state, province, or nation of any interstate waters flowing through or originating in this state, and for which quality control is or may be necessary for the above declared purposes, or to conform with the requirements of the legally constituted state or national agencies having jurisdiction over such interstate waters, or any other considerations the Agency may deem proper.)

B. Secondary Treatment Requirement

It is herein established that the Agency will require secondary treatment or the equivalent as a minimum for all municipal sewage and biodegradable industrial or other wastes to meet the adopted water quality standards unless the discharger can demonstrate to the Agency that a lesser degree of treatment or control will provide for water quality enhancement commensurate with present and proposed future water uses and a variance is granted under the provisions of the variance clause. A comparable high degree of treatment or its equivalent also will be required for all non-biodegradable industrial or other wastes. Secondary treatment facilities are defined as works which will provide effective sedimentation, biochemical oxidation, and disinfection, or the equivalent, including effluents conforming to the following:

Substance or Characteristic	Limiting Concentration or Range
5-Day biochemical oxygen demand	25 milligrams per liter
Total coliform group organisms	1,000 MPN/100 ml
Total suspended solids	30 milligrams per liter
Oil	Trace
Turbidity	25
pH range	6.5 - 8.5

C. For streams with intermittent flow, flow less than effluent flow and where nature mixing is not effective in preventing pollution:

5-Day biochemical oxygen demand	20 mg/l
Total phosphorous	1 mg/l
Total suspended solids	20 mg/l

D. Temperature Requirements

1. Fisheries and Recreation (Classification 2)

Class A - Permit the propagation and maintenance of warm or cold water sport or commerical fish, suitable for aquatic recreation of all kings, including bathing.

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 7 milligrams per liter from October 1st and continuing through May 31st and

	Not less than 5 milligrams per liter at other times
Temperature	No material increase

Class B

Dissolved oxygen	Not less than 6 milligrams per liter from April 1 through May 31, and Not less than 5 milligrams per liter at other times.
Temperature	86^oF in July and August)Or 5^oF above 80^oF in June and September)ambient, which- 67^oF in May and October)ever is greater, 55^oF in April and November)except that in no 43^oF in March and December)case shall it ex- and ceed 90^oF. 37^o in January and February) and 37^oF in January and February)

Class C - Permit propogation and maintenance of fish of species commonly inhabiting these waters under natural conditions, suitable for boating, limited contact with water.

Dissolved oxygen	Not less than 5 milligrams per liter from April 1 through May 31, and Not less than 3 milligrams per liter at other times.
Temperature	90^oF in July and August)Or 5^oF above 87^oF in June and September)ambient, which- 75^oF in May and October)ever is greater, 63^oF in April and November)except that in 51^oF in March and December)no case shall it and exceed 90^oF. 45^o in January and February)

Regulation of Nutrient Sources

In recent years much concern has been expressed toward nuisance growths of algae and aquatic weeds. This problem has been most severe in the case of lakes and reservoirs which afford the quiescent conditions conducive to heavy plant growth when the other conditions, such as the availability of plant nutrients, are favorable.

The levels of plant nutrients necessary for nuisance growths of algae are extremely low. Sawyer and others have estimated that only 0.01 mg/l of phosphorous, and 0.3 mg/l of inorganic nitrogen, are necessary at the be-

ginning of the growing season to produce nuisance blooms of algae in shallow, warm-water lakes and reservoirs. For the purposes of this discussion, we have considered only phosphorus and nitrogen, while recognizing that many other elements are required in trace amounts.

Eutrophication is not wholly a man-caused process, and one need only observe the vast acres of peat bog to assure himself of this. However, eutrophication is clearly a man-accelerated process, and it is this acceleration to which we must direct our efforts if we are to be effective.

Plant nutrients are contained in many waste effluents, with perhaps the largest contributor of phosphorus in sewage and industrial wastes being from the phosphate builders in cleaning compounds.

We are really faced with two distinct types of nutrient sources; one being from point sources, such as sewage treatment and industrial treatment plants, and the other being from areal run-off which would include agricultural, as well as natural sources of nutrients. We do not have any good figures on how much each type contributes, either relatively or absolutely, but some of our monitoring has indicated--for example at Big Stone Lake--that the vast majority of nutrients are contributed by areal run-off and drainage of agricultural lands, including confined-feeding operations. The nutrient value of manure will have to be admitted without contest, and you can be assured that the algae appreciate and use this source with the same vigor as a cash crop. The same argument will have to be admitted by definition for commerical fertilizers.

There is but one "hooker" in this argument, and that is that in order to be utilized at all by aquatic plants, the nutrients must gain access to the water. And that is wherein the control lies for areal sources. Keep the fertilizer on the land by good soil conservation practices and out of the water, and we will have the battle won. We cannot realistically expect an elimination of nutrients, but we can effect a drastic reduction and some effective control by good soil conservation practices.

The point sources of nutrients, such as sewage and waste treatment plant effluents, offer another challenge to the design engineer. In this instance, we have the wastes contained and under our control for the application of various treatment methods.

While certain parameters are well understood and treatment works are capable of reducing these parameters to acceptable effluents, others are not. Phosphorus and nitrogen, for example, are elements that are not easily removed from effluents by conventional treatment works. While it is true that pilot scale and new designs can effectively remove phosphorous and nitrogen, we must face reality and note that many of the plants in operation today are limited in what can be accomplished in nutrient removal, short of abandoning existing facilities and starting all over again.

We have proposed a statewide effluent standard (Regulation WPC 23) which includes, where applicable, a phosphorus limit of 1 mg/l. We recognize that this is probably not adequate to protect certain waters, since algae blooms are known to occur in waters of one-tenth this concentration, we do feel, however, that the 1 mg/l limit is attainable through moderate expansion and additions to existing plants for chemical treatment and removal of phosphorus. When the state of the art has improved, we envision that the phosphorus limit will be reduced and, hopefully, eliminated from controllable discharged. In the case of phosphorus, then, we have set an attainable limit rather than a protective limit, because that seems to be the extent of our technology at present. Even this limit, which we admit to be inadequate, will roughly double the cost of conventional treatment plant operation.

In closing, let me state that the MPCA, in determining the classification and standards of purity and quality for the state's waters, considers the best usage of these waters in the interest of the public, and further that these regulations are reasonable, feasible, practical and attainable under the circumstances.

The Agency also, to the greatest extent possible, implements and enforces these water quality and effluent standards in order to provide the people of the state with a healthy ecology and economy.

It must be noted that regulations, standards and even litigation do nothing directly to clean up our environment. It is only through research, construction and operation of needed facilities that real progress is made, and these efforts are best sustained over the long term by mutual agreement on reasonable requirements and a true spirit of cooperation of the part on all concerned

POLLUTION CONTROL RELATING TO AGRICULTURE

by

Merlon England

The State Soil and Water Conservation Commission has been working with the Pollution Control Agency on regulations relating to agriculture.

Mr. Badalich asked me to send WPC 22 out to all of our 89 Soil Conservation Districts hoping they would make comments and suggestions on how they felt on this matter. We received 75 answers from our districts. All of them made some positive suggestions on how feedlot effluent should be handled. All of them recognized that there was a problem and that there was a need for control measures being applied.

Wherever a feedlot was located adjacent to a lake or stream, the standard recommendation was that measures be taken to control the effluent to keep our streams and lakes clean. If, however, the feedlot was a distance from open water there were many other considerations that were very important such as soils, slopes, various types of control measures available, vegetation and many other things to be considered.

Other comments made by district supervisors regarding general agricultural pollution was that the conservation practices that have been applied over the past thirty years or more are the ones that can still be used for the control of siltation. It is also possible to redesign some structures that will allow for specific measures for pollution abatement. From the answers to the WPC 22 questionnaire it is evident that the Soil and Water Conservation District supervisors are well aware of the pollution problem and are willing and able to fully contribute to their solution.

IS COMMUNITY ACTION NECESSARY?

by

Hibbert M. Hill

I would like to address myself to this question specifically as it bears on lake eutrophication problems. I am a resident and councilman of the village of Chanhassen. We have in that village half a dozen small lakes which are highly eutrophic. I am also concerned with nearby Lake Minnetonka, a large, intensively used eutrophic lake, or perhaps more exactly, a cluster of diverse lakes, all eutrophic in various degrees, joined by channels.

I would like to make two points briefly, derived from observations of the communities around these lakes.

First, community action is necessary because the community, which will pay the costs, has to decide what condition of the lake is satisfactory to that community. The small lake I live on is green with algal scums, yet the people who live on it swim in it, water ski on it, and fish in it. Anyone of these people, if asked, would no doubt agree that he would prefer a less turbid lake, but so far, at least, the community would rather bear the ills they have than to subject themselves to the costs and restrictions necessary to obtain something better. It seems to me that this is a legitimate community choice.

Secondly, it seems to me that the communities or organizations making such choices should be as compact as possible, that is, should be no larger than necessary to encompass an identifiable problem. To illustrate, the first attempt at community action with respect to Lake Minnetonka as a whole was the establishment of a watershed district encompassing the lake and Minnehaha Creek below the lake. Because of the diversity of interests between the lake and the creek, the immediate effect was one of division rather of unity in a common objective. The lake community reacted by establishing, through legislation, a second organization encompassing the lake only, having powers similar to those of the already existing watershed district. The effect has been to diffuse efforts and funds.

On the other hand, the lake community has identified sewage influents to the lake as contributing to eutrophication and has, quite independently of the competing districts, taken action to divert them from the lake. Further, the residents around one of the interconnecting lakes which make up Minnetonka have organized on an entirely voluntary basis to apply copper sulfate treatments to that bay, which they have done effectively for a number of years. In each case there was an identifiable community of interests which led to action.

IMPLEMENTING POLLUTION CONTROL

by

Richard D. Wenberg

I want to take this opportunity to relate one example of a positive solution to feedlot pollution control presently on the ground. We have heard a lot today about the agricultural sources of pollution and some of the possible remedies. We have one example in the Big Stone Lake area of a feedlot that we had the pleasure of working with through the local soil conservation district. This particular lot has in the neighborhood of 1200 beef cattle on full feed today. We did work with the owner to divert about 106 acres of drainage area around the feedlot rather than having it go through the feed yard, cutting the direct runoff area including the feedlot to about 8 acres. The impoundment dam to contain the feedlot runoff took 1100 cubic yards of earth fill and a secondary diversion was installed from the feed yard to the impoundment. No positive plans are prepared at this time as far as taking care of the liquid and solid wastes that will accumulate in this reservoir. We did allow for a reasonable annual accumulation of livestock wastes as far as solids and liquids are concerned as well as the direct runoff based on a 50-year frequency design. We and the landowner (David Lindholm) realize that he will have to clean this reservoir from time to time, probably spreading wastes on farmland annually. This improvement entailed a $3400 expenditure and was done in the name of erosion and sediment control. He did have some financial assistance in this endeavor.

Mr. Lindholm owns two other farms in this vicinity. These units are used mainly for holding and feeding of young beef stock prior to moving them into this main feedlot. On one of these farms we are developing another plan to divert 176 acres of drainage around the yard and the remaining 2 acres will be put into a pit type storage basin. There are probably 3 more similar projects to come up in the Big Stone drainage area that we will be working on later this year.

TREATMENT OF CANNARY WASTES

by

Dale C. Bergstedt

I am a guest here, and not a member of your society, but I appreciate this chance to tell you a little bit about an answer to one of your questions, "What is being done?" During the last year and a half North Star has been working on a project sponsored by the Federal Water Pollution Control Administration and four companies, two of which you probably all know quite well. These are Green Giant and General Mills plus the Ralston Purine Company and Central Soya. Dr. Brooks Church is the principal investigator on this project. He heads our Microbiology group, and was formerly on the faculty of the University of Minnesota.

We are investigating a better means of treatment of food canning plant waste. Now this type of waste, I think, is something that you folks dealing with soil conservation and land planning are aware of, in the sense that many of the canneries are seasonal operations and utilize land for the final disposal of the effluent on an intermittent basis. The problem is that there is a high loading, such a high BOD, and the season is so short that there isn't time for living out a normal biological oxidation process. As a result, we find that these wastes are put into lagoons and left to sit there until next spring when hopefully the rivers are at a high stage and the plant can discharge the waste water, or else some other act of God helps us out and a dike "breaks".

But, getting into the heart of the matter, what I wanted to tell you about is this: At North Star we have been utilizing a particular organism in essentially pure culture, conditions that are not normally found in municipal or industrial waste treatment plants. We are using an imperfect fungus, trichoderma viride. This fungus grows in liquid waste and has capabilities of forming large mycelial masses during growth, something like the mold that you see on bread. We find that this particular organism forms a very filterable mass. In other words the solids that are formed are quite easy to separate, when things are going good, from the liquid. We find also that they have a high protein content. We are now beginning feeding tests to determine the nutritive value of the protein content of this material.

This is an answer to the question, "Well, how do you make any money treating waste water?" From our initial economic projections, if the goals are realized there will be a substantial income, although not necessarily a profit making operation involved here. At least there will be some derived revenue that will help offset the cost of treating these wastes that are of no value whatsoever and definitely a detriment to the community in which this food processing plant, exists.

The particular program that I have been speaking about deals with corn processing wastes which are quite troublesome. This is waste from the packing of canned corn, and we are well on our way towards the bench scale or laboratory continuous culture processing solution to this problem. Soon we hope to be moving into pilot scale continuous operation. We find the advantage of this approach over conventional waste treatment is that the process stabilizes within a few days, as contrasted with perhaps 3 to 4 weeks in a conventional biological system. With a canning season of only 8 weeks duration one can't very well wait 3 or 4 weeks for the waste treatment system to balance out and produce a good quality water. So this is a definite plus for this particular system. Another aspect of our work that I think might interest some of you, is that this method is also applicable to wastes from soy protein production, which is also a very troublesome waste. The soy waste is very high in BOD, up around 7,000 to 8,000 milligrams per liter, and because of the nature of the precipitation process, it also contains sulfur dioxide. Dr. Church has found that he can culture strains of these fungi imperfecti that can utilize this sulfur dioxide in their normal growth processes rather than being killed off by it. We would hope that we might thus be able to take the sulfur dioxide out of the soy processing waste, by utilizing it in the fungi's "diet", and in that way avoid the detrimental affects that it would have if it is dumped into a river.

What I have tried to do in these few moments here is paint a picture for you of what is being done in a form of applied research. We are very interested in the economics of the process and the practicalities. At the same time we are trying to solve this problem in the way that you might approach a research program in a university setting. I think we are on the way toward achieving some notable results. Thank you very much.

LIST OF CONFERENCE SPEAKERS

Evan R. Allred, Professor of Agricultural Engineering, University of Minnesota, St. Paul

John P. Badalich, Executive Director, Minnesota Pollution Control Agency, Minneapolis

Michael A. Barton, Watershed Scientist, Superior National Forest, U. S. Forest Service, Ely

Henry Bauer, Director, Division of Medical Laboratories, Minnesota Department of Health, Minneapolis

Dale C. Bergstedt, Senior Engineer, North Star Research and Development Institute, Minneapolis

Merlon England, Executive Secretary, State Soil and Water Conservation Commission, St. Paul

Hibbert M. Hill, Director, Water Research Foundation, Excelsior

Gene H. Hollenstein, Supervisor, Waters Section, Division of Waters, Soils and Minerals, Minnesota Department of Conservation,

Robert F. Holt, Director, North Central Soil Conservation Research Center, Agricultural Research Service, Morris

Walter K. Johnson, Associate Professor of Civil Engineering, University of Minnesota, Minneapolis

Curtis L. Larson, Professor of Agricultural Engineering, University of Minnesota, St. Paul

William P. Martin, Professor and Head of Soil Science, University of Minnesota, St. Paul

Robert O. Megard, Assistant Professor, Limnological Research Center, University of Minnesota, Minneapolis

James A. Moore, Instructor in Agricultural Engineering, University of Minnesota, St. Paul

Robert C. Polta, Research Fellow in Civil Engineering, University of Minnesota, Minneapolis

Lloyd L. Smith, Professor of Entomology, Fisheries and Wildlife, University of Minnesota St. Paul

Richard D. Wenberg, Assistant State Engineer, Soil Conservation Service, St. Paul