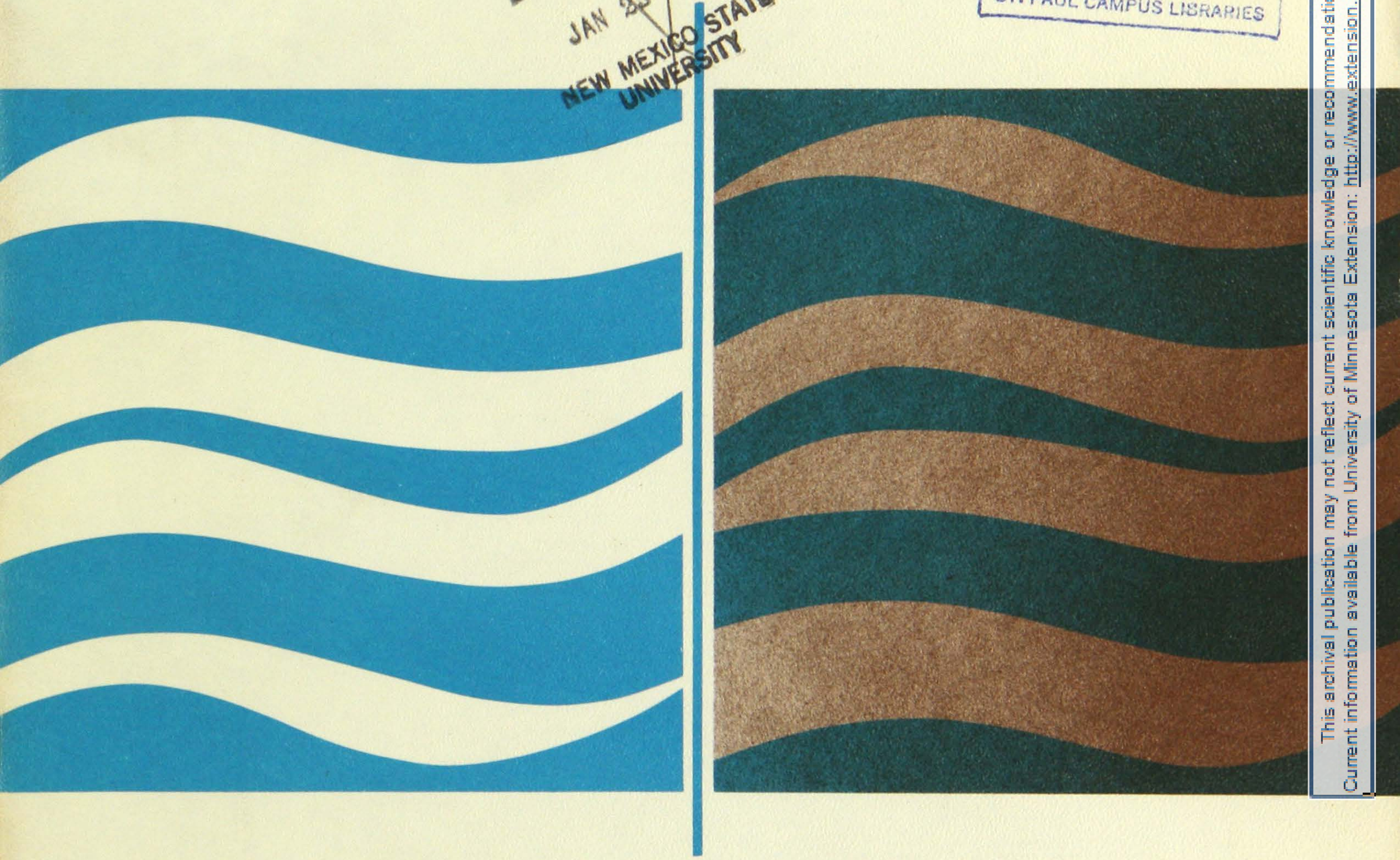
UNDERSTANDING THE WATER QUALITY CONTROVERSY IN MINNESOTA

JOHN J. WAELTI



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"All the rivers run into the sea;
yet the sea is not full;
unto the place from whence the rivers come,
thither they return again."

Ecclesiastes 1:7

FOREWORD

Trying to siphon through the controversial, complex issues on which public decisions are (or perhaps are not) being made often leaves the individual citizen feeling frustrated and ineffective. The breakdown in communications between citizen and government, which may result from a feeling of being unable to significantly influence the decisions which so profoundly affect life, is not by intention or design of sinister forces, but is often the unfortunate consequence of the complex and technical nature of the questions involved.

Obtaining a working knowledge of a technical subject, such as water pollution, is difficult and certainly time consuming for the average citizen. Although in a democracy, public employees are elected and appointed to make certain decisions and perform functions which cannot be efficiently performed on an individual basis, overall goals and policy directions must reflect the will of the electorate. This publication is designed to assist Minnesotans in attaining an elementary understanding of some of the more important aspects of water pollution and to facilitate meaningful, rational debate and better communications between citizen and government — communication which is necessary if public policy is to accurately reflect citizen objectives.

No comprehensive policy suggestions for alleviating pollution problems are made in this publication. Instead, emphasis is on explaining the problems and organizing issues in such a manner that, from debate, sound public policy proposals can arise. Although effort was made to be objective and impartial, the reader will detect throughout the author's belief that more should be done about water pollution and more resources should be allocated to the problem's solution than presently is the case.

Every effort was made to state the subject matter as simply as possible while retaining a high degree of technical accuracy.

In recent years, there has been increasing public concern over the pollution of Minnesota's lakes and streams. The quality of water is an important facet of the quality of our total environment. Clean water, clean air, freedom from excessive noise, and adequate open space and recreational opportunities are among the conditions necessary for a healthful, pleasant environment.

A growing population with greater affluence, more leisure time, and greater mobility has imposed competing demands on the natural resources of Minnesota. Industrial development and urban growth have accelerated the deterioration of quality in Minnesota's lakes, streams, and ground water supplies. As a consequence of expanding demand, fresh water must be used and reused many times before it returns to oceans or to the hydrologic cycle. Each use generally results in deterioration of water quality.

The use of rivers and streams as sewers for dilution and transport of waste materials competes with their use as a source of municipal and industrial water supply, as a habitat for fish and wildlife, as a base for recreational activity which is extremely important to the economy of Minnesota, and as an aesthetic factor contributing to the general quality of our environment. The construction of homes and cottages adjacent to lakeshores accelerates the pollution of lakes. Urban growth patterns which discourage central sewage disposal systems often cause ground and surface water pollution.

Competition for limited resources gives rise to controversy — and even in Minnesota, which is generally viewed as a "water rich" state, water is sometimes a very limited resource depending on alternative uses.

Rosebush Creek near Grand Marais, Minn.

"Much water goeth by the mill that the miller knoweth not of" — John Heywood

Some Basics of Water Pollution

What Is Water Pollution?

It might at first appear that there is no question about the definition of the term "water pollution." However, there are a number of different kinds of pollutants which affect water in various ways.

The terms "contamination" and "pollution" are sometimes used interchangeably. Generally, "contamination" refers to an impairment of the quality of water by wastes, to the extent that a health hazard is created through poisoning or spread of disease. In contrast, "pollution" does not necessarily refer to a public health hazard, but means waters are adversely affected for domestic, industrial, agricultural, or recreational uses. Discussion throughout this publication will focus on the more general term of pollution, rather than contamination.

The term "pollution" often means different things to different people. A given body of water may or may not be "polluted" depending on actual or potential uses. Water which is of adequate quality for one purpose, irrigation, for example, may not be satisfactory for supporting game fish. Therefore, the various types of pollutants and their effects on water must be examined in light of intended or potential uses.

Classification of Pollutants

Although the most obvious signs of pollution include grease, oil slicks, floating solids, and offensive odors, there are many other forms of pollutants occurring in both solid and liquid form. *Pollutants in solid form* may consist of materials such as sand, gravel, soil, ashes, cinders, sludge or other solid sewage matter, any vegetable or other garbage, offal or parts of the carcass of any animal, rubber, wood, gelatin, and paper or paper pulp.

Pollution in liquid form occurs through discharge of municipal, industrial, and agricultural wastes into streams. Pollutants in liquid form may contain minerals in solution, dissolved material or suspended matter, and dissolved noxious gases. Material carried in stormwater runoff is another potential source of pollution.

Chemical pollution may occur in either organic or inorganic form. Organic chemical pollution results from discharge of municipal, industrial, and agricultural wastes including resins, coal, oil, tars, dyes, synthetic detergents, and toxic organic chemicals, such as DDT. A significant effect of organic matter of any kind is to reduce the dissolved oxygen content of the receiving water. However, some organic chemicals also have a toxic effect on fish and other aquatic life, and on bacteria which are useful in the decomposition of organic matter. Some synthetic detergents cause foam on water and may be toxic to aquatic life. Oils may form a film on the water surface, decreasing the oxygen-absorbing capacity of water. Oil in lakes and streams causes tainting of fish flesh, incapacitates water fowl, and seriously damages other aquatic life.

Inorganic chemical pollution may result from discharge of acids and alkalies, toxic inorganic compounds such as hydrogen sulfide and chlorine, and soluble salts such as nitrates, chlorides, sulphates, bicarbonates, phosphates, and metallic salts. Acids cause corrosion of metal and concrete structures, destroy useful bacteria, and are lethal to fish and other forms of aquatic life. Acids may react with sludge and river mud to form foul smelling hydrogen sulfide. Concentrations of ammonia, chlorine, cyanide, and salts of many metals such as copper, chromium, zinc, and nickel are toxic to fish and to bacteria which are useful in the decomposition of organic matter. Copper and zinc are especially toxic to fish. Some soluble salts, such as bicarbonates, sulphates, and chlorides of calcium and magnesium cause "hardness" in water leading to incrustation of pumps, pipelines, and other metal and concrete structures. Nitrates and phosphates enrich the water and foster algal growth. Radioactive materials are still another form of chemical pollutant.

Physical forms of pollution affect the color, turbidity, and temperature of water. Examples of *physical pollutants* are solids and suspended matter, foam, froth, and scums. Suspended solids, including silt from land erosion, create turbidity which can damage fish and render water less desirable for municipal, industrial, and recreational uses. The larger suspended solids settle out, forming a sludge blanket along the stream bottom which may damage spawning beds and smother organisms useful as fish food. Sludge deposition may increase the need for dredging channels and reduces dissolved oxygen. An increase in water temperature, known as *thermal pollution,* reduces dissolved oxygen holding capacity of water and fosters algal growth. Power generating plants are the primary sources of discharges of heated water.

Biological pollutants include pathogenic (disease-producing) bacteria and protozoa, certain forms of fungi, algae, viruses, and parasitic worms. Some forms of bacteria provide a useful and necessary function in the breakdown of organic matter. However, the primary concern is with species causing water-borne diseases such as typhoid, dysentery, and cholera. Excessive growth of algae, another form of biological pollution, causes odors and nuisance conditions when plants die and decompose.

Common Chemical, Physical, and Biological Pollutants*

Chemical	Physical	Biological
Organic (carbon) compounds	Floating solids	Pathogenic bacteria and protozoa
Inorganic (mineral) compounds	Suspended matter	Viruses
Radioactive materials	Settleable matter	Parasitic worms
	Foam and froth	Algae
	Heat	Aquatic weeds

* Although many of these items occur in water as part of a natural cycle, excessive intrusion renders water less desirable for various uses.

Degradable and Nondegradable Pollutants

Although pollutants can be classified according to chemical, physical, and biological criteria, a very useful distinction is degradable and nondegradable pollutants. Some pollutants are broken down or decomposed by natural physical, biological, or chemical processes in water. These are referred to as degradable pollutants. Sometimes the term "biodegradable" (decomposition by biological processes) is used. Nondegradable pollutants are those not altered by the processes which occur in natural waters.

Nondegradable pollutants include inorganic chemicals such as chlorides, nitrates,[1] phosphates, sulphates, and various metallic salts. Another form of nondegradable pollutant is suspended matter such as silt. While most suspended materials eventually settle out, contributing to sludge problems referred to previously, colloidal material may remain, causing water turbidity or cloudiness.

Chemical compounds which are resistant to biological breakdown are sometimes called *hard chemicals.* Some detergents, resistant to biological breakdown, are known as *hard detergents.* They form froths when they mix with receiving waters. In recent years, the detergent industry has made commendable progress in manufacturing and marketing detergents which are degradable and do not cause frothing. (Nearly all detergents now on the market are soft detergents.)

Some pollutants are somewhat degradable, but because the process occurs so slowly, are for practical purposes classified as nondegradable. For example, the decay of some radioactive waste products is extremely slow. Some organic compounds, *hard* detergents and chlorinated hydrocarbons such as DDT, chlordane, and endrin, are extremely persistent in their resistance to decay.

In contrast to nondegradable pollutants, degradable pollutants are broken down by bacteria into nondegradable, relatively stable materials such as bicarbonates, nitrates, sulphates, and phosphates.

Degradable pollutants	Nondegradable or extremely decay resistant pollutants
Most organic matter	Certain forms of chemical elements: Nitrates*, Phosphates, Sulfates, Metallic salts
Oil and grease	Chlorinated hydrocarbons
Soft detergents	Colloidal matter
Organic nitrogen, nitrites, and ammonia	Hard detergents
Phenols	
Cyanides	

* Under some conditions, may be converted by bacteria to nitrites or to free nitrogen.

Natural and Manmade Pollution

Normally, it is desirable for water to be high in dissolved oxygen, low in temperature, low in minerals, salts, and chemicals which might affect taste, color, or odor; and free of excessive algae, weeds, or other plant life. The various pollutants which adversely affect these measures of quality result from natural forces and from activities of man.

Examples of natural sources of pollution include soil erosion and siltation, floods, and deposition of organic matter such as leaves, weeds, brush, and dead animals in waterways. Natural sources of pollution do not normally constitute a problem and are a part of a natural cycle in which waters are purified by natural biological processes. Activities of man upset the balance of this natural cycle by speeding up the natural forces of soil erosion and siltation. Foreign elements such as grease, oil, and synthetic chemical compounds are introduced and the load of organic matter from municipal, industrial, and agricultural sources is greatly increased. Man's activities often increase the rate of enrichment of lakes and streams and the rate of pollution of ground and surface water to the extent that natural processes are no longer able to absorb the pollutants introduced into the system.

[1] Strictly speaking, nitrates can under some conditions be chemically reduced by bacteria to nitrites and free nitrogen. However, the major portion of elemental nitrogen entering a water body as nitrites, ammonia, or nitrogenous organic matter normally is oxidized to nitrates and is potentially damaging to water quality.

"When we try to pick out anything by itself, we find it hitched to everything else in the universe." — John Muir

Important Problem Areas

Organic Matter, BOD, and Oxygen Sag

Of the various measures of water quality, one of the most important is dissolved oxygen, which is necessary for the existence of fish and other desirable aquatic life as well as for *self-purification* of streams.

Self-purification is the somewhat deceptive term used to denote the remarkable capacity of a freeflowing stream to reduce organic pollution through natural physical and biochemical processes. Micro-organisms, mainly bacteria which require dissolved oxygen in the water, utilize organic matter as food. The complex organic compounds are broken down to more simple end products. The process of breakdown of organic matter by oxgen-using bacteria is said to proceed *aerobically,* meaning *with oxygen.* The oxygen utilized by bacteria is replaced by *reaeration,* the absorption of air into the water, as the stream flows along, enabling continuation of the process of aerobic decomposition.

As long as available dissolved oxygen in the water is not used up, aerobic breakdown of organic matter proceeds. However, if the load of organic matter is heavy, oxygen will be used up at a faster rate than it can be replenished. If these conditions continue long enough, the level of dissolved oxygen drops to zero. When dissolved oxygen is depleted, aerobic decomposition no longer can occur and decomposition then must proceed *anaerobically,* meaning *without oxygen.* Disagreeable conditions accompanying anaerobic decomposition are masses of floating sludge, production of offensive gases such as hydrogen sulfide, and death of fish and other desirable aquatic life.

The term *biochemical oxygen demand,* called *BOD,* refers to the amount of dissolved oxygen required by bacteria when breaking down decomposable organic matter under aerobic conditions.[2] BOD thus indicates sewage load; a larger discharge of sewage will require a larger amount of oxygen for decomposition.

The level of dissolved oxygen in a stream depends on the rate of reaeration, and the rate of utilization by microorganisms.[3] Since the removal of oxygen from water resulting from aerobic decomposition of organic wastes takes time, the low level of dissolved oxygen occurs some distance downstream from the point of waste discharge.

The so-called *oxygen sag curve* is illustrated in figure 1. The rate of oxygen use initially exceeds the rate of reaeration, causing a decline in the level of dissolved oxygen. After partial decomposition of the oxygen-depleting wastes, the rate of oxygen gain through reaeration exceeds the rate of ultilization, enabling an increase in dissolved oxygen. If the sewage load is particularly heavy relative to the oxygen-holding capacity of the stream, the level of dissolved oxygen may drop to zero, causing *anaerobic conditions* as in figure 2.

The combined rate of oxygen utilization and reaeration depends on many factors, including the strength and volume of the discharge of organic matter, the nature of the organic matter (compounds such as cellulose are not as readily decomposed as most other organic compounds), the physical characteristics of the stream, water temperature, and kind and number of micro-organisms present in the waste discharge.

In general, factors which tend to slow down the rate of oxygen utilization tend to flatten and lengthen the oxygen sag curve. The *rate* of oxygen depletion under aerobic decomposition is higher in warm than in cold water. Similarly the oxygen-holding capacity of warm is lower than cold water which, when combined with the faster rate of oxygen utilization in warm water, and low summer flows, causes greater danger of low oxygen levels in summer than in winter. In figure 3, curve A represents an oxygen sag curve in summer relative to that resulting

[2] The standard BOD test is based on the *amount* of oxygen used in aerobic decomposition over a 5-day period. Thus, BOD is technically a *rate* of oxygen utilization. With the time being understood as 5 days, the *rate* becomes an *amount.*

[3] Some oxygen also results from photosynthesis by algae in the water.

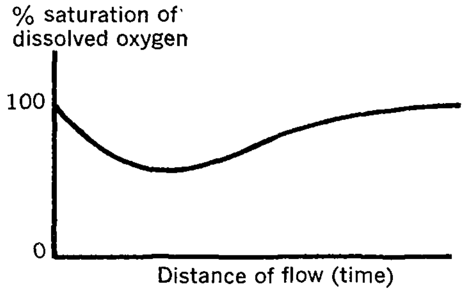


Figure 1. Typical oxygen sag curve.

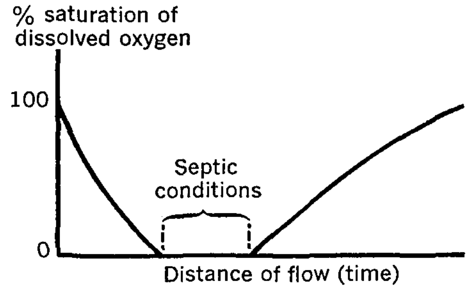


Figure 2. Septic conditions in an oxygen sag curve.

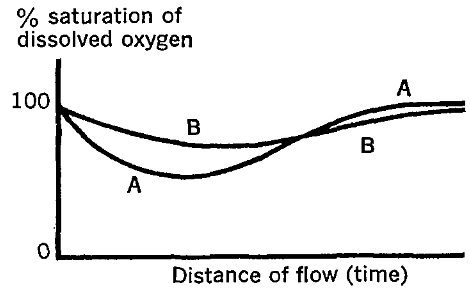


Figure 3. Oxygen sag curves under differing stream conditions.

from an equivalent waste discharge in winter, represented by curve B. Note the more rapid recovery of curve A following a sharper initial decline in dissolved oxygen.

A very turbulent, rapidly moving stream has greater oxygen-absorbing capacity than a slowly moving stream, other factors such as volume of water and temperature being equal. A given volume of water with a large surface area will be reaerated faster than the same volume of water with less surface exposure, all other factors being equal, and thus have greater self-purification capacity.

The typical oxygen sag curve with one sewage outfall is changed by the addition of other outfalls and factors such as locks, dams, and falls. The diagram of the level of dissolved oxygen at various points in a stream is known as the *oxygen profile*. Figure 4 shows the oxygen profile for a portion of the Mississippi River in 1964-65. Note the oxygen sag occurring immediately after sewage outfalls, and the sudden increase in dissolved oxygen resulting from reaeration below locks and dams.

The oxygen-holding capacity of clean water varies from 7.6 mg. per liter at 86° F. to 14.6 mg. per liter at 32° F. Game fish require at least 5 mg. per liter and rough fish from 3-4 mg. per liter for propagation.

A major purpose of sewage treatment facilities is to accelerate decomposition of organic matter so that a substantial portion of the decomposition process has already been achieved before discharge into a stream. The greater the portion of decomposition that is completed in a waste treatment plant, the smaller the amount of dissolved oxygen required to complete the process when the effluent is discharged into a stream.

There are three stages of sewage treatment.

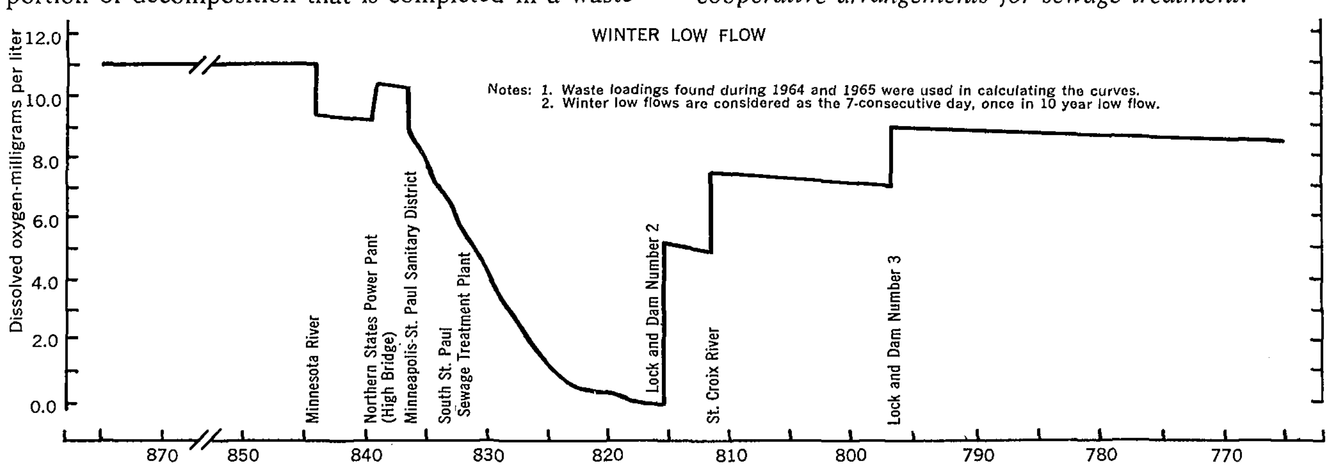
Primary treatment refers to the settling out of the larger suspended solids by screening and sedimentation before either discharging it or subjecting it to further treatment. Primary treatment normally accounts for about 40 percent BOD removal.

Secondary treatment refers to additional treatment by biological processes to break down organic matter remaining in the sewage. Secondary treatment can remove an additional 45-55 percent of the BOD for a total of 85-95 percent BOD removal. The greater the BOD removal, the higher is the cost. Costs mount rapidly when 90 percent BOD removal is approached.

Effluent from primary and secondary sewage treatment is usually chlorinated before discharge to kill *pathogenic* or disease-producing bacteria which might be present.

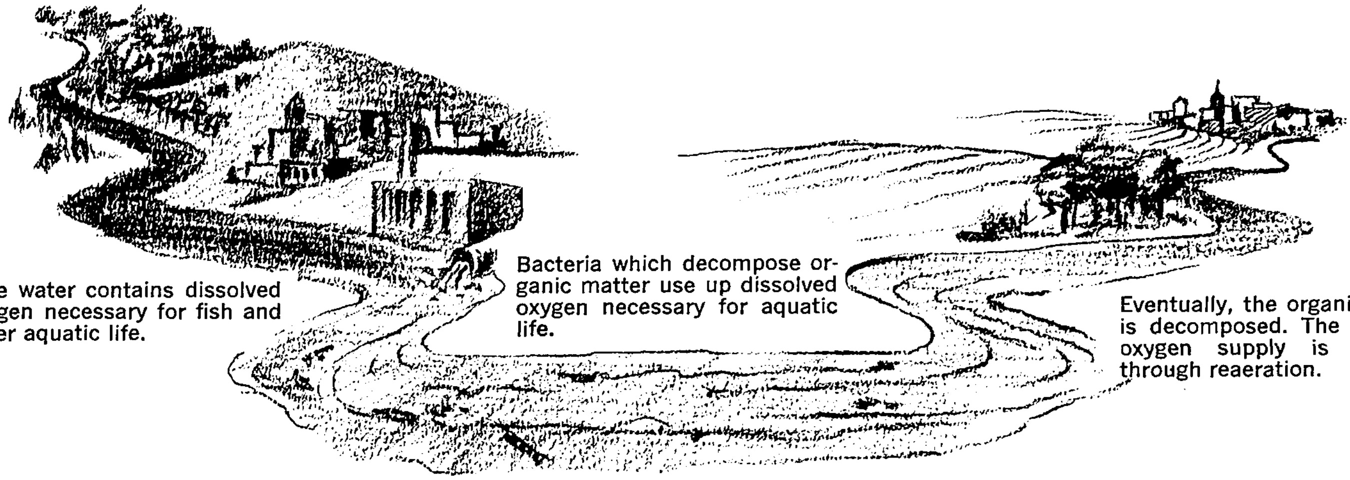
Tertiary treatment refers to treatment of sewage beyond the secondary stage to accomplish a very high degree of BOD and/or nutrient reduction.

Much of the controversy regarding water quality concerns the degree to which sewage should be treated before discharge into streams and who should pay the treatment cost. In the Twin Cities, there is additional controversy among various governmental units regarding financing and cooperative arrangements for sewage treatment.



(Courtesy Federal Water Pollution Control Administration)

Figure 4. Oxygen profile of the Mississippi River, Twin Cities area.



WATER QUALITY PROBLEMS IN DENSELY POPULATED AREAS

Existing Facilities in Minnesota Municipalities

Sewage disposal problems are an important part of the larger problem of water quality control. Inadequate sewage disposal facilities sometimes cause pollution of ground water as well as surface water and pose especially difficult problems in urban and other densely populated areas.

The normal means of collection and treatment of sewage in urban areas is through a system of mains which convey sewage to a central treatment plant. At the plant, sewage is given secondary and/or primary treatment and usually discharged into a stream.

As shown in table 1, over 75 percent of Minnesota's population is served by municipal sewer systems. However, nearly 15,000 people are served by a sewer system which does not have treatment facilities, and over a quarter million people are served by a primary treatment system only.

Twenty percent of Minnesota's residents live outside municipalities, and in most rural areas central sewage collection and disposal facilities are not necessary or feasible. However, congested areas, such as lake fronts which do not have central sewage systems, either have experienced serious pollution problems or have this potential as will be discussed in the section on Eutrophication and Pollution of Lakes.

Table 1. Waste treatment facilities in Minnesota

Treatment	No. of municipalities	Population	Percent of population
No sewer system	340	151,399	4.4
Sewer system, but no treatment facilities	26	14,694	0.4
Sewer system and primary treatment only	55	237,084	6.9
Sewer system and secondary* treatment (378 plants)	431	2,339,300	68.5
Population outside municipalities	...	671,387	19.8
TOTAL	852	3,413,864	100.0

* These figures include 43 municipalities with sewer systems tributary to the Minneapolis-St. Paul Sanitary District Sewage treatment plant. Source: Minnesota Pollution Control Agency. 1968.

Problems With Onsite Disposal Systems

Considerable controversy may center on the matter of providing sewage disposal facilities for newly developing areas. Before World War II, when urban growth was relatively slow and orderly, most new construction simply relied on an extension of existing urban services, including water and sewer lines. Most new areas closely resembled the existing city and the small amount of development that occurred in unserviced areas was usually in the form of widely scattered, individually built homes.

After World War II, however, there was an extremely large unfilled demand for new housing for which cities were generally not able to provide the necessary public services. Because of lower cost land, the availability of Federal Housing Administration (FHA) and Veterans Administration (VA) mortgage guarantees for new housing, absence of building regulations, and increased mobility provided by automobiles, much of the new housing was constructed beyond the areas served by central water and sewer systems.[4]

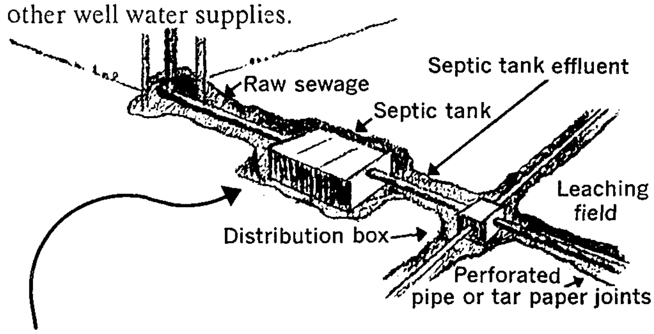
In the absence of sewer and water mains, it became necessary to find alternative ways to provide sewage disposal facilities and water supplies to new developments. At first, individual wells and septic tanks were used. While such facilities are suitable for farms and individual scattered homes, they are not satisfactory for densely populated areas.

In the septic tank method of onsite sewage disposal, the larger solids are separated from the liquids. The effluent which contains organic matter, partially decomposed under *anaerobic conditions* in the tank, is discharged into the subsoil through either a seepage pit or a system of perforated pipes called a leaching field. Although the sewage undergoes some biological decomposition in passing through the tank, a high degree of bacterial removal is not accomplished and pathogenic bacteria may still be present. Organic matter and nutrients also remain in the effluent. The primary purpose of the tank is to condition the sewage by removing solids so that it can pass through the disposal

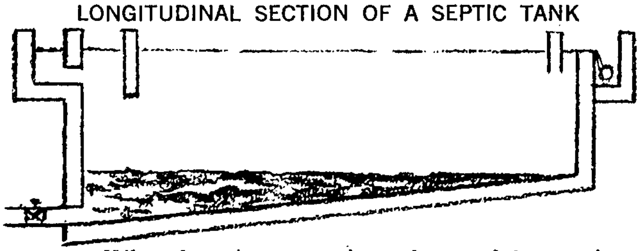
[4] Eligibility for FHA and VA *new* construction home loans in developing or developed areas now generally requires that the house be connected to public sewage and water systems. For *existing* construction, water supply tests are required if the house is not connected to central water and sewage facilities.

field where biological decomposition is completed under *aerobic conditions.*

Since the actual purification of the sewage occurs in the soil, the effectiveness of the system depends on local soil characteristics. Where there are adverse conditions, including clay soils not conducive to seepage, high ground water, or bed rock close to the surface, the septic tank system of disposal is not satisfactory. Even in soils conducive to seepage, it is not satisfactory in areas of high population density because eventually, the ground water is displaced by effluent which may get back into individual or other well water supplies.



LONGITUDINAL SECTION OF A SEPTIC TANK



When locating a septic tank, careful attention must be given to the soil's capacity to absorb the effluent. Because of the possibility of ground and surface water contamination and the limited capacity of any soil to absorb sewage, septic tank systems are only suitable for isolated farmsteads and single family dwellings at low density. In areas with the most favorable soil and ground water conditions, a density of one or two homes per acre could be adequately sewered by septic tanks for years.

A report by the Twin Cities Metropolitan Planning Commission[5] observed:

1. Septic tanks do not provide a satisfactory solution to the sewage disposal needs in any area where the housing density exceeds two homes per acre.

2. In areas with lower densities, soil tests and other investigations are required to determine whether a septic tank should be used on a specific site.

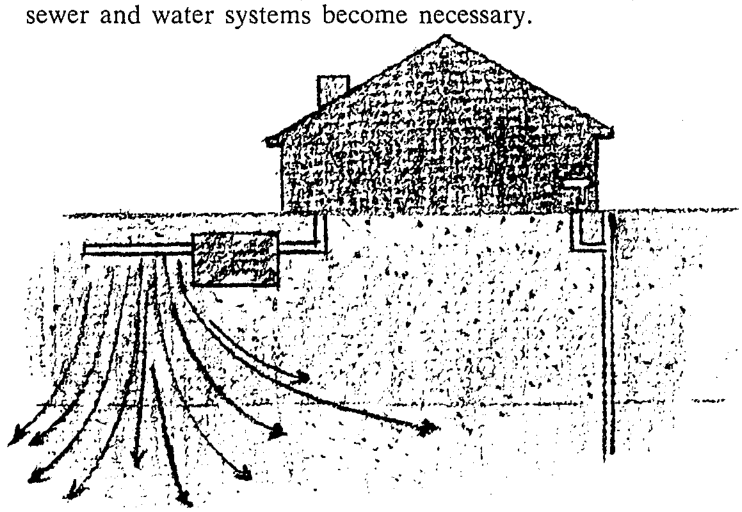
There are still some people in the Twin Cities metropolitan area who obtain their water from household wells and dispose of their sewage through septic tanks, both located on the same lot.

There are several good reasons for the construction of sewer and water systems instead of septic tanks and wells. If a community originally served by septic tanks constructs sewers but continues to rely on household wells, there still remains a danger of pollution from the residual pollutants in the soil. Also, in some areas, the natural ground water is insufficient to meet the water requirements without the addition of sewage effluent. Then it may become necessary to deepen wells after sewers are built.

In some areas having a high water table, the ground cannot absorb the effluent load safely, especially after water is no longer removed by household wells. This situation can result in sewage being forced to the surface and draining into natural water courses, or into wells in the area. There is the potential danger that septic tank effluent may pollute water in the deep rock strata that supplies central drinking water systems.

In an effort to delay the need for sewer systems, local ordinance has sometimes limited the number of homes constructed in a given area, assuming that septic tank systems will be satisfactory if density is kept low enough. This policy has sometimes had the adverse effect of delaying central sewer systems because of the increased per unit cost of sewer extensions with lower density housing.

To insure the protection of ground water supplies, it appears that all urban areas must be sewered, even though financial costs may be high. Stringent building and subdivision regulations would help to prevent wasteful practices such as an instance of a home owner having to abandon ineffective onsite septic tank-well facilities when public sewer and water systems become necessary.



Septic tank effluent sometimes pollutes drinking water.

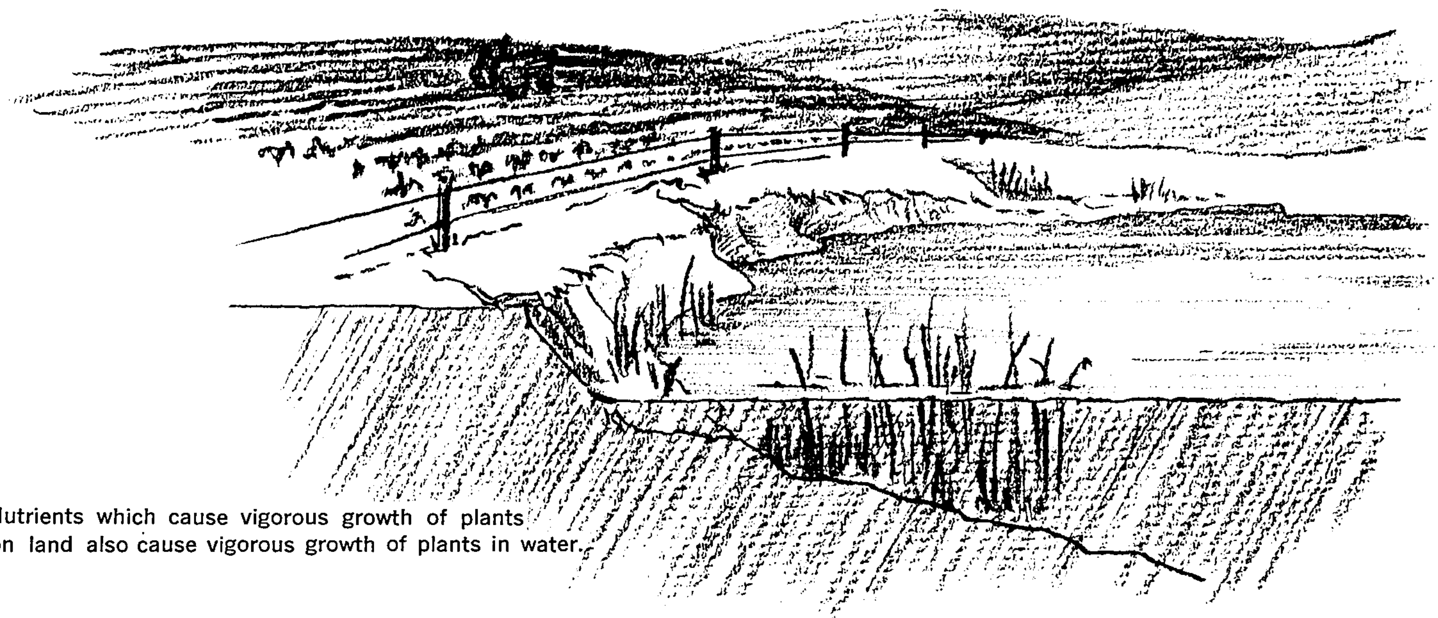
Eutrophication and Pollution of Lakes*

Lakes are generally more sensitive to pollution than flowing streams and present problems not encountered in streams. The relatively still waters of lakes provide a habitat for microscopic, free-floating algae which cannot thrive in rapidly flowing waters.

Because algae are the ultimate source of food for fish and other aquatic organisms, it is essential that some algae be present. However, a problem arises when large influxes

[5] Twin Cities Metropolitan Planning Commission, "Metropolitan Sewage Study," Metropolitan Planning Rpt. No. 7, Aug. 1960.

* The author is grateful to Robert O. Megard, Limnological Research Center, University of Minnesota, who provided valuable technical assistance for this section.



Nutrients which cause vigorous growth of plants on land also cause vigorous growth of plants in water.

of nutrients, such as nitrogen and phosphorus, stimulate algal growth. *Nutrients which enable vigorous growth of plants on land also enable vigorous growth of plants in water.*

With rapid enrichment of lakes by nutrients, the types of algae that are favored are those that form large, visible colonies that float on the surface and accumulate on beaches. Large quantities of organic matter are produced and, when decaying, cause noxious odors and deplete the water's oxygen supply. These enriched lakes are less desirable for recreational activities and harbor a greater proportion of rough fish than game fish.

Enriched lakes of this type are called *eutrophic,* which literally means "well nourished." The *process* of enrichment is called *eutrophication.*

Lakes undergo eutrophication naturally as they age and the basin becomes filled with sediment. This type of eutrophication occurs slowly and imperceptibly over a span of thousands of years. In contrast to eutrophication under natural processes, the activities of man can increase the rate of enrichment to the extent that visible and disturbing change may occur in less than a decade.

Runoff from land on which commercial fertilizers or animal manures have been spread contains nutrients in solution and, sometimes, organic matter in which these nutrients remain upon decomposition. (Runoff from unfertilized land, as well, contains some amount of nitrogen and phosphorus.) Effluent from septic tanks and wastes from municipalities and industries that drain into lakes are other sources of nutrients directly attributable to man's activities.

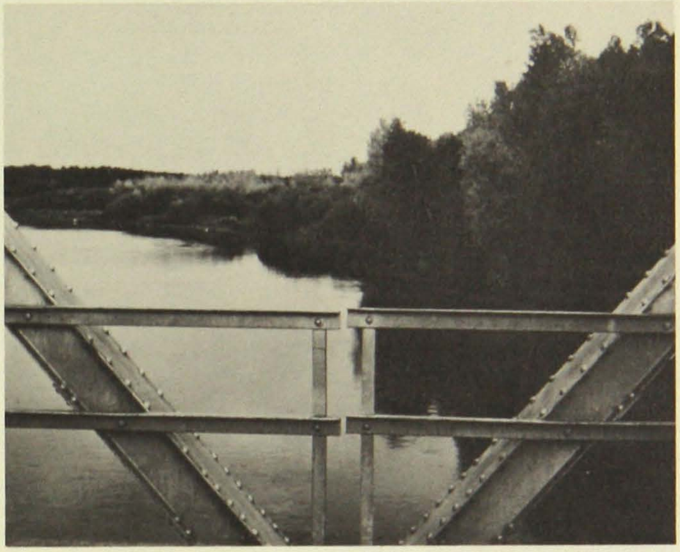
Algal growth is inhibited by low temperature and lack of sunlight. For these reasons, deep lakes containing large volumes of water in cooler climates, age less rapidly than smaller, shallow lakes in warmer climates. The shallowest of the Great Lakes, Lake Erie, has been most affected by eutrophication, and Lake Superior, the largest and deepest, least affected. Many smaller lakes in Minnesota, particularly those in the southwest are in an advanced state of eutrophication. Larger lakes adjacent to Twin Cities urban development, such as Lake Minnetonka, have also been affected. Most alarming, however, is increasing weed and algal growth even in some lakes in sparsely populated resort areas of the state.

Soft water lakes are generally more susceptible to eutrophication than hard water lakes. This is particularly relevant as some of the lakes and streams in Minnesota's most scenic recreational lands, such as the Boundary Waters Canoe Area, contain soft water. Recognizing the tendency toward pollution, the U.S. Forest Service is conducting a special program of instruction for campers on disposal of wastes to minimize damage to lakes and the environment.[6]

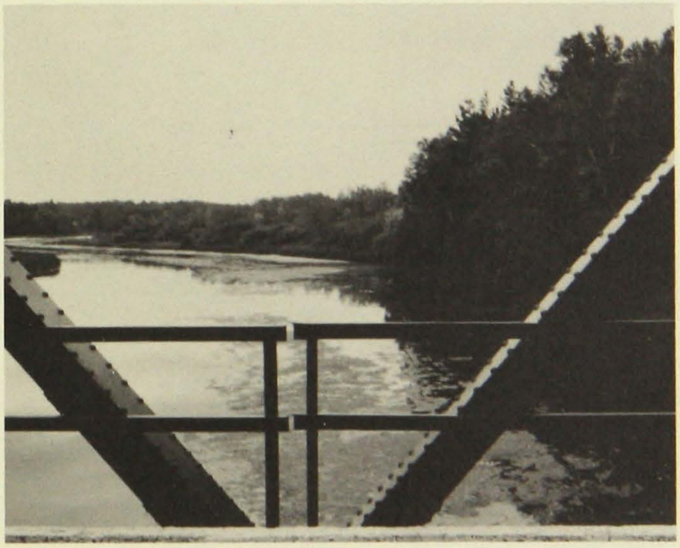
To prevent nutrients from entering lakes, it will be necessary in many areas to remove dissolved minerals from sewage effluent. This process, under present technology, is costly compared with conventional treatment. However, to ensure preservation of Minnesota's lakes, more resources must be devoted to this purpose. (One estimate is 4 to 5 cents per 1,000 gallons treated for removal of phosphates. A limitation is that such treatment is not feasible with the septic tank method of disposal and requires the existence of a system of mains and a central treatment plant.)

[6] The necessity of proper waste disposal by campers and other visitors to the Boundary Waters Canoe Area (BWCA) is dramatized by the fact that the waste load over a year is equivalent to a day's production of raw sewage in Milwaukee, Wisconsin. The reader who is interested in reading more about water quality in the BWCA is referred to Michael A. Barton, "Waters of the Canoe Country," *Naturalist,* Vol. 20, No. 1, 1969.

Sewer line and pollution near Mississippi River headwaters.



View of the Mississippi River 14 years apart (1954, above; 1968, below). Note the increased algal growth by 1968.



Sewage or sewage effluent is sometimes transported completely outside the drainage area of a lake to slow down the process of eutrophication. For example, Lake Tahoe, in California's Sierra Nevada Mountains, has experienced some algal blooms as a result of enrichment caused by sewage and septic tank effluent and runoff from fertilized lawns and golf courses. The proposed solution is to collect sewage from lakefront homes and commercial enterprises through a system of mains, give the sewage tertiary treatment, and transport it out of the basin.[7]

A critical matter relating to lake pollution is that Minnesota has no statewide regulations concerning placement of septic tanks on lake lots. However, a bill passed by the legislature provides for the mandatory adoption of zoning standards for lakeshore development by all of the counties by 1972 (see footnote 27).

[7] California Assembly Committee on Water, "New Horizons in California Water Development: A Report of the Assembly Interim Committee on Water," Vol. 26, No. 16, Sacramento, 1966.

Agricultural Pollution Problems*

In the past, serious pollution problems were associated primarily with densely populated areas. Recently, however, there has been increasing concern over the pollution caused by various agricultural wastes. The contribution of commercial and natural fertilizers and soil erosion to sedimentation and eutrophication of lakes has already been mentioned. However, there are additional problem areas.

The rapidly increasing agricultural production which enables the abundant, varied, low cost food supply enjoyed by the people of the United States results in part from increased use of pesticides.[8]

Many pesticides are synthetic organic chemical compounds which are included in a broad class, chlorinated hydrocarbons. Many chlorinated hydrocarbons, including DDT, endrin, and dieldrin, break down very slowly.

Most fish species are highly susceptible to chlorinated hydrocarbon pesticides. The order of toxicity to most fish among chlorinated hydrocarbons is as follows: endrin, toxaphene, dieldrin, aldrin, DDT, heptachlor, chlordane, methoxychlor, and lindane. (Greater concern over DDT is probably attributable to its common use.) In addition, fish may concentrate these compounds from organisms in the natural food chain in water because this class of pesticides has a high affinity for lipids or fats. Because of the persistence of compounds such as chlorinated hydrocarbons in the environment, and the unknown potential harmful effects, research is urgently needed to find effective pesticides which break down more rapidly.[9] In 1967, pesticides were identified as the source of at least 32 fish kills, including one in Minnesota.[10]

Another increasingly serious problem area is pollution from animal manures from feedlots. As long as animals graze freely over extensive areas, there is no significant problem involved. However, confinement of animals creates a concentration of wastes in small areas. When these wastes are washed into waterways by heavy rains, a sudden demand for dissolved oxygen is created.

Feedlot pollution was listed as the cause of three major fish kills in 1967,[11] although none was reported in Minnesota from this source. In addition to lowering dissolved

* The author is grateful to Laurence K. Cutkomp, Department of Entomology, Fisheries, and Wildlife, University of Minnesota, who provided valuable technical advice on the effect of pesticides for this section.

[8] The term pesticides is inclusive of a broad class of agents including insecticides, herbicides, fungicides, algicides, nematocides, and rodenticides.

[9] A source of technical information on the subject of pesticide levels relative to man and his environment is the *Pesticide Monitoring Journal,* a quarterly published by the U.S. Public Health Service.

[10] Federal Water Pollution Control Administration, "Pollution Caused Fish Kills," 1967, Eighth Annual Report, p. 9. The incident in Minnesota resulted following the use of an algicide (an agent designed to kill algae) in a lake. There is some question as to whether the fish died as a result of the chemical or as a result of oxygen depletion when the algae decomposed.

[11] Federal Water Pollution Control Agency, op. cit., p. 3. According to the report, two of the fish kills from cattle feedlots occurred in Kansas and one in Texas.

oxygen, the nutrients contained in feedlot wastes contribute to eutrophication. Research is needed to find economical methods of minimizing the pollution from wastes of farm animals.[12]

Industrial Pollution

There are an estimated 930 Minnesota industries which discharge wastes. These represent industries such as paper production, iron ore processing, oil refining, vegetable processing, sugar production, rendering, meat and poultry processing, milk processing, and power production. The nature of industrial wastes varies greatly within an industry and from industry to industry.

Industrial pollution was the leading source of fish kills nationally in 1967. Of four reported incidents in Minnesota, three were caused by industrial pollution.[13]

In the Twin Cities area, including the Mississippi River from Anoka to Lake Pepin, and the Minnesota River from Mankato to its meeting with the Mississippi, there are over 300 industries with waste discharges, most of which are connected to municipal facilities. Information concerning production, employment, method of waste treatment, and estimated waste load of 33 industries which discharge wastes directly into water courses may be obtained in a recent report of the Federal Water Pollution Control Administration.[14]

Industrial wastes may be detrimental to waters in sparsely populated areas, such as northern portions of the state where high water quality is crucial to the vitality of the tourist industry. Paper mill wastes can be especially damaging. However, an example of how industrial responsibility is being assumed is a northern Minnesota paper company which is building special treatment plant facilities designed to eliminate objectionable material from its waste discharges to the Mississippi River.[15]

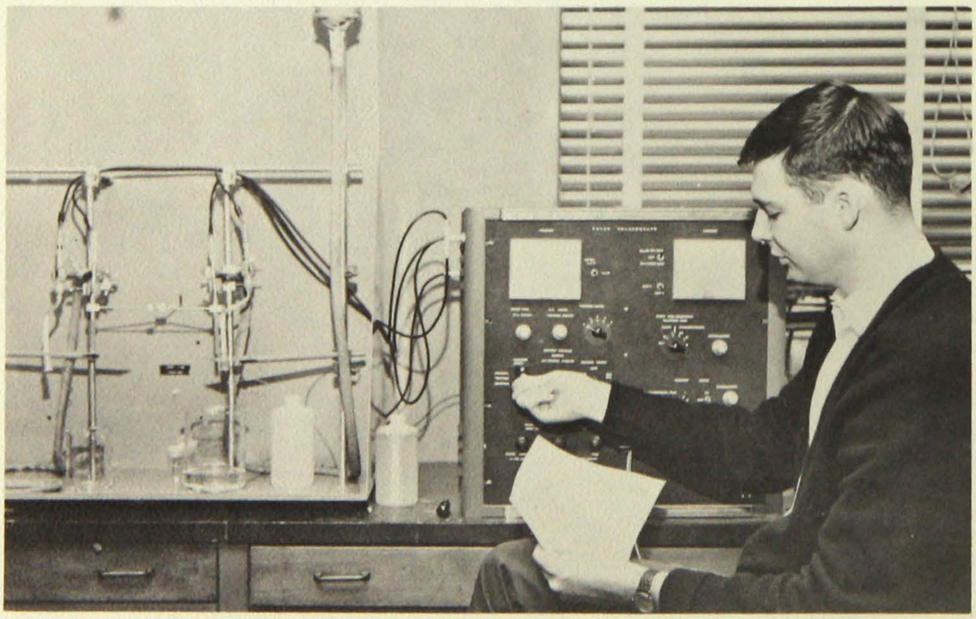
Included in the controversial areas of industrial pollution are the extent to which industries should be required to treat wastes and the kind of incentives or persuasion that is best used to attain objectives. Where industries are discharging wastes to municipal treatment facilities, controversy may be over the proportion of costs the industry should pay.

[12] A nine member Agricultural Advisory Commission has been created to advise the Minnesota Pollution Control Agency on coping with animal waste problems. Some work on this problem is also being conducted in the Department of Agricultural Engineering, University of Minnesota. The University's Institute of Agriculture is devoting increasing resources to solving problems of environmental quality.

[13] U.S. Federal Water Pollution Control Administration, op. cit. p. 3.

[14] U.S. Federal Water Pollution Control Administration, "A Report on Pollution of the Upper Mississippi River and Major Tributaries," July 1966.

[15] Progress toward this goal, involving the construction of an industrial waste treatment system, has been enabled by the Company, the Village of Grand Rapids, the Minnesota Pollution Control Agency, and the Economic Development Administration of the U.S. Department of Commerce.



Minnesota Pollution Control Agency research scientist David Gray adjusts the pulse polarograph which he built. The new instrument detects toxins and pollutants in water, air, blood, and urine in a fraction of the time of gas chromatography.

"There are few, if any, useful ideas in economics that cannot be expressed in clear English." — John Kenneth Galbraith

Economic Aspects of Water Pollution

Loss of Economic Product

The losses resulting from water pollution represent economic losses to society. High water temperature, unfavorable pH or acid balance, and low dissolved oxygen either directly cause fish kill or increase the sensitivity of fish to toxic substances in the water. Other forms of pollution, such as floating solids and debris, foam from detergents, organic dyes, grease and oil slicks, and odors are offensive and make water undesirable for recreation. Intensive algal growth makes water less desirable for swimming, fishing, and other types of recreation.

The value of these lost activities to society is substantial. Although activities such as recreation are not measured by market prices, they are as important in the spectrum of human wants and needs as if they were measured by market prices, and must be considered in public decisions. There have been no estimates made of the loss of economic product attributable to water pollution in Minnesota, but the losses are surely substantial.

In addition to the loss of economic product to society in general, a deterioration in water quality could adversely affect the state economy, especially those northern and central counties heavily dependent on tourism. Minnesota tourism receipts approximate \$500-\$600 million per year. Statewide, receipts support more than 600 hotels, 900 motels, and 3,000 resorts. A substantial portion of these receipts depends on the high quality, appealing environment which attracts vacationers to Minnesota.

Misallocation of Resources

Less obvious than the direct loss of economic product to society or loss of income to a region is the effect of water pollution on the allocation of resources. A major strength of the American economic system is the efficiency with which resources are allocated through the price and market mechanism. The efficient functioning of a price and market system is based on the assumption that all costs and benefits of decisions are realized by the decision maker. However, where outcomes of decisions are realized by someone other than the decision maker, an inefficient allocation of resources occurs.

As an example, consider a factory or municipality discharging wastes into a stream. In the absence of regulations or a sense of social responsibility, the industry's decision concerning the treatment of wastes is based on its profit and loss, and a municipality's decision is based on available public revenue. Under these conditions, it is in the decision maker's *shortrun* interest to spend as little on waste treatment as possible.

This decision, *based on shortrun interests,* causes a deterioration in water quality and has two sets of economic consequences. First, a cost is imposed on downstream users, forcing them to bear additional costs to treat the water or to forego its use altogether.[16] There is a direct loss to society as the stream will be less desirable for fishing and other forms of recreation. Costs which are incurred by a single decision unit and shifted to society as a whole are referred to by economists as *social costs.*

The second set of consequences is relevant to pricing and output of goods, when this production results in water pollution. With an industrial polluter, the total costs of production are not absorbed by the producer. That is, the costs of water pollution are shifted to society as a whole, enabling that particular product to be produced "artificially cheap" compared with production costs occurring if the waste discharger were forced to absorb all costs of pro-

[16] Recent research has shown that although low quality water is more costly to use for municipal purposes, on strictly monetary grounds, it is "cheaper" to utilize the self-purification potential of the stream and treat water at the intake point rather than give sewage a high degree of treatment. The practical implication of this conclusion is that sewage treatment and high water quality standards must be justified largely on recreational and esthetic grounds. See for example Richard D. Frankel, "Water Quality Management Engineering — Economic Factors in Municipal Waste Disposal." *Water Resources Research,* Vol. 1, No. 2. American Geophysical Union, 1965.

duction including costs of treating the wastes. *The net result is that more resources are devoted to the production of such products and less to water quality control. If in polluting a stream the polluter was harming itself, rather than recreational areas, more resources might be allocated to water quality control.*

An analogy can be drawn for a municipality. The costs of releasing untreated wastes are imposed on downstream users. The costs of sewage disposal to the municipality are "artificially cheap" and result in too few resources devoted to water pollution control.

Consider the problem in another way. A price and market system is a sound basis for many pricing and production decisions required in an advanced industrial economy. However, it must be recognized that not all costs and benefits are registered through the price system. This may result in underproduction of some goods, such as water pollution control facilities, relative to amounts desired by society. Where the price and market system does not result in the level of production of such goods in the amounts desired by society, or where services can be more economically provided by the public sector, there is reason for public direction and responsibility.

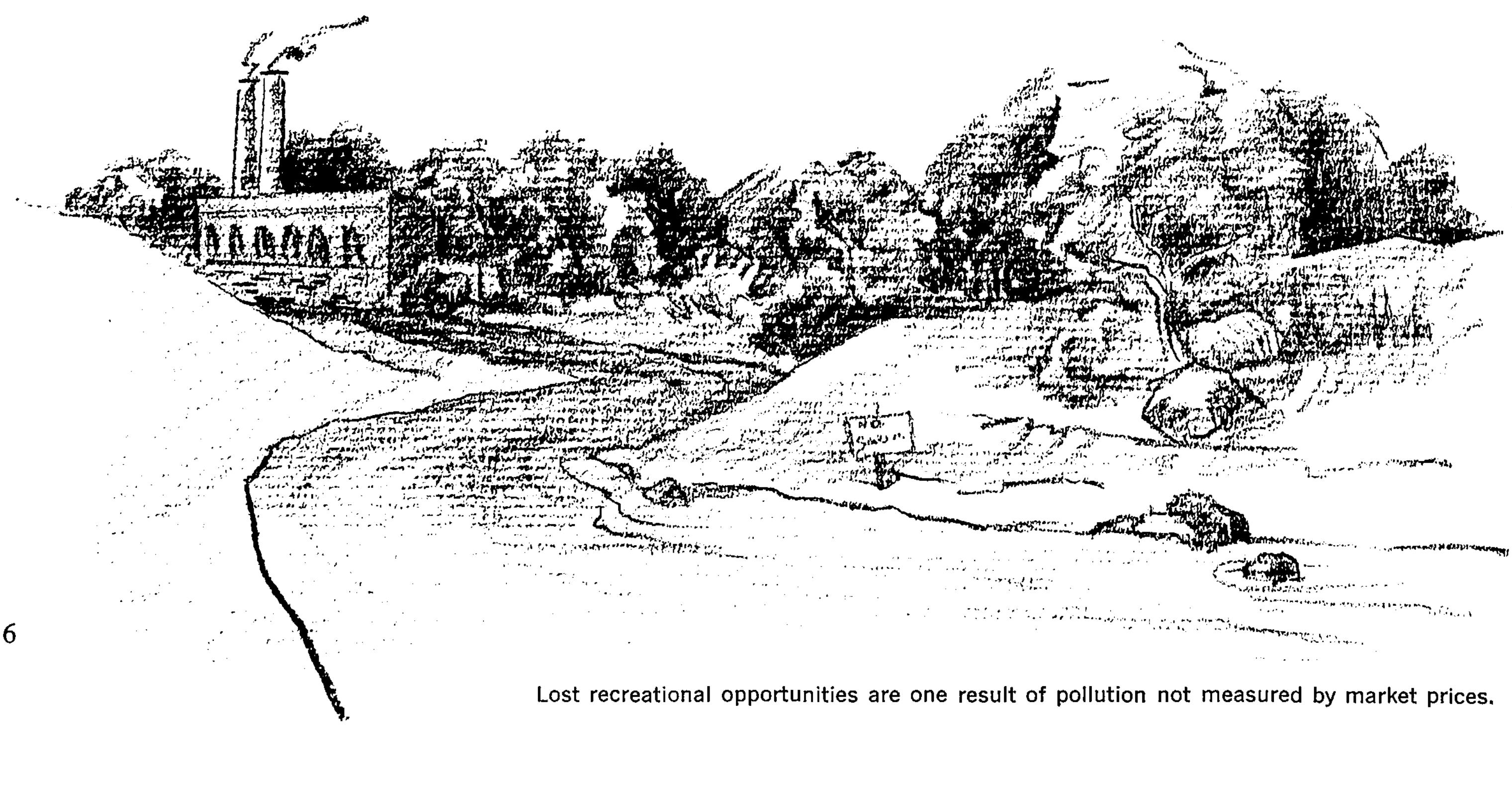
Considering water quality control, this may take the form of changes in laws that require waste dischargers to absorb costs of waste treatment, or the levy of taxes which enable a public agency to directly perform waste treatment and pollution control functions, or a combination of these measures.

Social and Aesthetic Considerations

In addition to the direct loss of economic product and the misallocation of resources resulting from water pollution, there are values which are not strictly economic. Even if a person never fishes or swims in a lake, he may derive a certain amount of satisfaction just from knowing that the lake is there for him to enjoy should he decide to take advantage of it.

The availability of water suitable for recreation may be especially important in congested, low income urban areas where recreational sites are in short supply. Much of the development of outdoor recreation has occurred some distance from the largest population centers. However, these areas are primarily available to people with sufficient income and mobility to travel considerable distances. If society is going to provide needed recreational and scenic resources for people in low income urban areas, the potential opportunities associated with riverfront areas in central cities must be realized.

Although the tools of economics cannot measure the social values of a clean, attractive lake or stream, these values must be considered in the political processes by which laws and regulations regarding pollution control are passed and enforced. *While it is not clear whether society is willing to pay for these values, it would appear that an affluent society is increasingly able to do so.*



Lost recreational opportunities are one result of pollution not measured by market prices.

"Government is a contrivance of human wisdom to provide for human wants." — Edmund Burke

Governmental Responsibility in Water Quality Control

PHILOSOPHY AND OBJECTIVES OF GOVERNMENTAL RESPONSIBILITY

Bases of Public Responsibility

It is generally agreed that there is some basis for governmental responsibility in the field of water quality control, but controversy arises over the degree of responsibility, the level at which it should be assumed, and how it should be exercised. The activities of government in the area of water quality control generally center around the provision of public goods and the establishment of rules and regulations to maintain water quality. Both of these bases of responsibility can be illustrated by the patterns of municipal sewage treatment that have existed in the past.

The history of sewage disposal in the Twin Cities is typical of other areas in Minnesota and across the nation. In the early days of settlement, disposal of wastes was left to the individual. After the Civil War, public collection systems were begun, but no treatment facilities were included. Raw sewage was discharged directly into the Mississippi River. Few people had enough leisure time to be concerned about recreation, and as long as population remained low, a degree of river pollution was tolerated.

However, as population, industrial development, and the level of pollution increased after 1900, the bad smelling river became intolerable. Citizens avoided the riverfront and both property values and tax revenue fell along the river. In the 1930's the Minneapolis-St. Paul Sanitary District was established and the construction of a treatment plant begun.[17]

In a densely populated area, individuals are not able to handle sewage efficiently. The *first basis for governmental action* is to provide public goods such as municipal sewage and waste treatment systems. However, the municipality has only limited constituency (and funds) and is not likely to consider the interests of downstream users. The *second basis for governmental action* then, is to establish rules and regulations at a level where a larger number of constituents (and funds) are represented. Rules and regulations established at the regional, state, or federal level are likely to be responsive to a larger number of interests than would occur at the municipal level.

These two bases of governmental responsibility are now discussed in greater detail.

The Provision of Public Goods

Although in a private enterprise system, most goods and services are provided through a price and market system, some goods, referred to as *public goods,* are provided by local, state, or federal government, and financed by taxes and other sources of public revenue. Examples of public goods include national defense, administration of justice, highways, public educational facilities, public parks and recreational facilities, and waste treatment facilities.

Public goods have several distinguishing characteristics. First, they are indivisible in the sense that they are available only in such large units that they cannot normally be purchased in whole units by individuals. Second, the benefits of public goods are incident upon the community as a whole and are not limited to those who contribute to the purchase of the goods. Third, the individual consump-

[17] The objective of this section is to illustrate the rationale for public action. For a more complete report of the Twin Cities sewage problem, see: Twin Cities Metropolitan Planning Commission, "Metropolitan Sewage Study," Metropolitan Planning Rpt. No. 7, Aug. 1960, and Barry Peterson, "The Sanitary Sewage Problem." The Joint Land Use-Transportation Planning Program, Physical Development Section, Metropolitan Council, Pap. No. 4, Dec. 30, 1966.

tion of such goods does not preclude consumption of these goods by others.[18]

The provision of waste treatment facilities is generally the responsibility of municipal or regional government. Although the wisdom of the collective provision of waste disposal facilities is apparent, considerable controversy may occur between municipalities in coordination and methods of financing and cost sharing.

In addition to the provision of waste treatment facilities, other public goods pertaining to water quality include research and development on waste treatment and monitoring techniques. Individuals generally do not have the resources to carry out these activities. Although private enterprise may play a significant role in development of equipment for waste treatment and water quality monitoring, the public sector provides the major market.

Up-to-date equipment aids in monitoring water quality at the Minneapolis Office of the Federal Water Pollution Control Administration.

The Fallacy of Limited Decisions

The second area in which government activity may be involved is establishing and enforcing rules and regulations regarding water quality control. As pointed out earlier, the provision of waste treatment facilities is normally at the municipal level. However, municipalities, in the absence of regulations imposed from a level of government having a broader constituency, have little or no incentive to consider the interests of downstream users. The proposition that downstream users should be protected, certainly a reasonable one, opens the way for governmental authority at the state or regional level.

Public authority at local, state, and federal levels is sometimes vigorously opposed. A possible explanation is *the fallacy of limited decisions.* This fallacy assumes that there is a limited number of decisions to be made by society. Therefore if an increased number of decisions are made by the public sector, fewer will *necessarily* be left to the private sector.

The proposition that a greater number of decisions made by the public sector implies less to be made by the private sector is not necessarily true. *Soundly conceived and competently executed public policy may substantially increase the options open to individuals and to private enterprise.* As an example, public policy may establish standards designed to maintain water quality and thus restrict the options available to waste dischargers. However, this may open up a vast array of options to individuals, such as fishing, boating, and other recreational opportunities previously not available. This may have secondary effects such as increased sales of equipment, receipts to the regional economy through tourism, and increasing property values. Thus, governmental establishment and enforcement of water quality standards cannot necessarily be opposed on the grounds of restricting individual freedom.[19]

Limitations of Governmental Responsibility

Although it is clear that government has a legitimate and important role in water quality control, it cannot be assumed that the problem will necessarily be solved by the public sector. An important limiting factor is that influence on legislative bodies responsible for passing laws does not *necessarily* occur in proportion to *numbers* of constituents. Small, well organized interest groups are frequently able to exert more legislative influence than larger, unorganized groups which have less access to the legislature.

Another fact which must realistically be considered is that the enactment of legislation does not necessarily mean that a problem is solved. For example, water quality standards, whether for stream standards or effluent standards, require monitoring and, possibly, legal action to ensure enforcement. In other words, to successfully carry out a water quality control program by the public sector, in addition to the original legislation, adequate appropriations must be made to provide for staffing, monitoring, and enforcement activities of the executive branch to make the program meet the objectives desired by the public which, broadly stated, might be to protect the right of the individual citizen to enjoy access to unpolluted water.

This means that the water quality controversy cannot be assumed by the public to be resolved simply because it is receiving governmental attention.

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[18] Exceptions may occur, such as overcrowding of highways or other facilities. In contrast, *private goods* are those readily available through the market system in units small enough to be purchased by individuals. The consumption of private goods by an individual or small group generally precludes consumption of these goods by others. The benefits of private goods are limited primarily to the purchaser. The difficulty of pricing *public goods* in the market adds to the complexity of natural resource decisions. See: Lee R. Martin, *The Minnesota Agricultural Economist,* "Joint Products of Natural Resources," Sept. 1968.

[19] The interested reader may pursue this idea further in a popular basic economics text, Campbell R. McConnell, *Economics: Principles, Problems, and Policies,* Third Edition, Chapter 6, McGraw-Hill, New York, 1966.

FEDERAL RESPONSIBILITY

Federal Water Pollution Control Act

The basic federal legislation regarding water pollution is PL 84-660, popularly called the Federal Water Pollution Control Act, enacted in 1956. The basic act was amended in 1961 (PL 87-88), again by the Water Quality Act of 1965 (PL 89-234), and by the Clean Water Restoration Act of 1966 (PL 89-753).

The declaration of policy under the Act states that its purpose is

> "to enhance the quality and value of our water resources and to establish a national policy for the prevention, control, and abatement of water pollution." It declares policy to "recognize, preserve, and protect the primary responsibilities and rights of the states in preventing and controlling water pollution, to support and aid technical research relating to the prevention and control of water pollution, and to provide federal technical services and financial aid to State and interstate agencies and to municipalities in connection with the prevention and control of water pollution."

As originally enacted, the Surgeon General of the U.S. Public Health Service was authorized to make grants to any state, municipal, or interstate agency for the construction of necessary treatment works to prevent the discharge of untreated or inadequately treated sewage into interstate waters and their tributaries. The amendments of 1961 authorized the establishment and maintenance of research facilities and water quality studies. In addition, federal pollution abatement and enforcement authority was extended to all navigable water, if requested by a state or municipality (with concurrence of the Governor and State Water Pollution Control Agency) whether or not there was interstate pollution.

The Water Quality Act of 1965 authorized the Secretary of Health, Education, and Welfare to make grants to interstate, state, and local government agencies for research and development of improved methods of water quality management and increased the grant program for construction of sewage treatment works.

The Federal Water Pollution Control Administration, responsible for carrying out the federal water pollution control program, was created in 1965 within the Department of Health, Education, and Welfare and transferred to the Department of Interior in 1966.

A very significant provision of the Water Quality Act of 1965 is the requirement that states were to develop water quality criteria applicable to interstate waters within their state and develop a plan for implementation and enforcement of the criteria by June 1967. Progress on this aspect for Minnesota is summarized in a later section.

The Clean-Water Restoration Act of 1966 provided that the Secretary of Interior be authorized to make grants not to exceed 50 percent of the administrative expenses of a planning agency which is capable of developing an effective comprehensive water quality-control and abatement plan for a basin. In addition, the amounts which may be appropriated under the Act for water pollution control programs were increased.

In total, the Clean Water Restoration Act provides for financial assistance in three forms: for research and development of water quality control programs, for water pollution control programs, and for construction of sewage treatment works. The following table shows the annual federal appropriation for waste treatment facilities.

Table 2. Federal appropriations for waste treatment facilities

Fiscal year	Federal total authorization	Proposed allocation to Minnesota	Actual federal appropriation	Actual allocation to Minnesota
1966-67	$ 150,000,000	$ 2,743,250	$150,000,000	$2,743,250
1967-68	450,000,000	8,377,550	203,000,000	3,728,000
1968-69	700,000,000	13,072,100	214,000,000	3,931,000
1969-70	1,000,000,000	18,707,100	?	?
1970-71	1,250,000,000	23,402,350	?	?
	$3,550,000,000	$66,302,350		

Prior to July 1, 1967, grants under this program were generally limited to 30 percent of the eligible cost, or a maximum of $1.2 million per applicant on any one project. Under this legislation, the dollar limitation was removed. Also, provision was made for the federal share to be increased to 40 percent if the state agrees to pay not less than 30 percent for all projects funded. The federal share can also go up to 50 percent if the state agrees to pay at least 25 percent of all projects funded, and if enforceable water quality standards have been established for the waters into which the project discharges.

A bonus of an additional 10 percent of the federal grant can be awarded to any project that is part of a metropolitan area-wide plan, raising the possible federal contribution to 33, 44 or 55 percent.

The Clean Water Restoration Act also added the reimbursement provisions which said a community could actually proceed to construct sewage treatment works without a federal grant and then be reimbursed to the extent allowable, provided all appropriate state and federal requirements have been met from any such allotments the state receives prior to July 1, 1971.

The Minnesota Pollution Control Agency is responsible for processing applications for federal grants to local agencies for waste treatment facilities. Since the beginning of the grant program, requests each year have totaled approximately four times the funds available. In fiscal year 1968-69, Minnesota applications approximated $50 million in estimated construction costs with approximately $15 million requested in federal grants, while only $3.9 million of the latter was available.

Minnesota presently has no matching grant programs for local assistance for construction of waste treatment facilities.[20] The basic federal grant available is limited to 30 percent of the project cost, leaving 70 percent borne by local government. With a state matching grant of 25 percent and establishment of enforceable water quality stand-

[20] The 1969 session of the Minnesota Legislature failed to enact such a program. As of May 1969, at least 17 other states had enacted a state matching program.

ards, the federal grant could be 50 or 55 percent, leaving 20 or 25 percent of the cost of facilities to local government.

Thus far, Congress has not appropriated funds for the programs in the full amount authorized under the law. Because of competing demands for public expenditures at the Federal level, it is unlikely the maximum amount authorized for fiscal years 1970 and 1971 will be appropriated. Consequently, not all municipalities eligible for grants for waste treatment facilities will receive them.

Other Federal Responsibility

Grant programs besides the Federal Water Pollution Control Act include the following:

Consolidated Farmers Home Administration Act of 1961, as amended, is administered by the Farmers Home Administration (FHA), U.S. Department of Agriculture. Federal aid of up to 50 percent of the construction costs for sewage treatment works and sanitary sewers is available to Minnesota communities which have a population of less than 5,500 and are located in rural areas. Only 30 percent grants are offered to municipalities for sewage treatment construction in noneconomically distressed areas, to prevent being competitive with the program administered by the FWPCA. The Department of Commerce and Labor determines a distressed area for federal purposes. Loans are also available.

The Public Works and Economic Development Act is administered by the Economic Development Administration (EDA) of the Department of Commerce. Federal participation of 50 percent or more of the eligible construction costs of sewage treatment works and sanitary sewers is obtainable by communities located in areas designated by the Federal authorities as distressed. Loans are also available.

The Housing and Urban Development Act of 1965 is administered by the Department of Housing and Urban Development (HUD). The statute provides for up to 50 percent grants of the construction costs of sewer facilities which are not eligible for aid under the Federal Water Pollution Control Act. This financial assistance is available to municipalities over 5,500 population. Loans are also available. Any municipality may also apply for an advanced planning loan to retain a professional engineering firm to prepare a report on sewage facilities.

There are several other bases for federal activity in the area of water quality control.

In 1961, an amendment to the Water Quality Control Act provided

> "that in the survey or planning of any reservoir by the Corps of Engineers, Bureau of Reclamation, or other federal agency, consideration shall be given to inclusion of storage of stream flow for the purpose of water quality control."

This simply means that water quality control through dilution is an authorized function of dams constructed by the Corps of Engineers and other agencies.[21]

Other federal legislation includes the Oil Pollution Act of 1924 which prohibits the discharge of oil into coastal waters. The Water Quality Act of 1965 amended this act to prohibit discharge in inland navigable waters as well.

Executive Order 11288, issued July 2, 1966 prescribes procedures and standards governing the treatment of wastes resulting from activity of federal installations in the United States.

Public Law 88-379, the Water Resources Research Act of 1964, provides grants to universities and other institutions for research and educational activities in water resources. Substantial amounts of these funds have been allocated to projects directly related to water quality.

A significant step toward coordinated federal-state-local water resource planning and development was taken with the enactment of PL 89-80, the Water Resources Planning Act of 1965. Matters concerning water quality must be dealt with if planning activities are to serve the needs of the people of individual states and localities.[22]

STATE AND LOCAL RESPONSIBILITY

Minnesota Pollution Control Agency

At the state level, the primary responsibility for water pollution activities rests with the Minnesota Pollution Control Agency (MPCA), although some authority in matters relating to sources of domestic water supplies and public health remains the responsibility of the State Department of Health. The new agency replaces the Water Pollution Control Commission, established in 1945, and assumed all of the responsibilities in water pollution, in addition to new responsibilities in the field of air pollution, solid waste disposal, and land use as related to pollution. It meets monthly, has a full-time executive director and staff, and nine Governor-appointed part-time members.[23]

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[21] However, by administrative agreement with the Federal Water Pollution Control Agency, costs cannot be charged to water quality control unless at least 85 percent treatment is being provided at the sources affected. The practical effect of this agreement is to prevent polluters from passing responsibility for treatment on to the Federal Government.

[22] For a summary of Minnesota activity under this Act, see: John J. Waelti, *Minnesota Agricultural Economist,* "Statewide Water Resource Planning in Minnesota," Sept. 1968.

[23] The present part-time members include: Robert Tuveson, chairman, an attorney; Homer Luick, vice chairman, former vice president, Northwestern National Bank and former president, Minnesota Conservation Federation; F. Wayne Packard, president, Culligan Water Conditioning Company; Mace Harris, former vice president, Northwest Paper Co.; Steve Gadler, professional engineer; John Borchert, Department of Geography, University of Minnesota; Dr. Harold Anderson, medical consultant, Mayo Clinic; Milton Fellows, a farmer; and Mrs. R. C. Nelson, a housewife. The part-time members serve staggered 4-year terms, all expiring on February 15, two in 1970; two in 1971; two in 1972; and three in 1973.

The MPCA has the following powers and duties relating to water pollution:

Administering and enforcing all laws relating to the pollution of any waters of the state;

Investigating extent, character, and effect of pollution of waters of the state;

Regulating, establishing, and ordering pollution standards and the issue or denial of permits for discharge of sewage, industrial wastes, and other wastes; and

Planning activities with the State Planning Agency in comprehensive river basin planning.

It is the policy of the MPCA to encourage local government to initiate solutions to local pollution problems with technical assistance available from the state. If problems cannot be resolved satisfactorily locally, the agency must itself evaluate the problem, determine a proper solution, and carry it through by whatever means are required and available.

A chemist at the Minneapolis Office of the Federal Water Pollution Control Administration analyzes water samples for dissolved oxygen.

In 1961, Minnesota law provided for the establishment of sanitary regions and for the creation and administration of a water pollution control advisory committee and sanitary districts. Each congressional district of the state constitutes a sanitary region. The advisory committee consists of two members, appointed by the Governor, from each region. The committee's purpose is to assist the MPCA in the performance of its duties and to maintain a liaison between the agency and communities, industries, and persons concerned with water resources.

Minnesota Progress on State Water Quality Standards

The Federal Water Quality Act of 1965, described here, made mandatory the adoption of water quality standards of interstate waters by July 1967. If the individual states did not comply with this order, the Federal Water Pollution Control Administration could set standards.

In 1963 Minnesota began working on a general framework of criteria for classification and establishment of water quality standards which was well along by the time the Federal Water Quality Act of 1965 was passed.

Proposed criteria for classification for all interstate waters (about 4,000 miles) and establishment of standards were prepared and submitted for review and criticism at five public hearings from January through March 1966 at different locations throughout the state. These criteria were adopted in March 1967. In April 1967, five similar public hearings received and considered testimony and evidence bearing on the appropriate classifications for 4,000 miles of interstate waters and establishment of standards of water quality and purity. In addition, a plan of implementation and enforcement of these standards was presented in conformance with requirements of the Federal Water Pollution Control Act. The state subsequently adopted the classification, standards, and enforcement plan, and was able to meet the June 30, 1967 deadline set by Congress for interstate standards to the FWPCA.[24] Minnesota interstate standards were approved by the Secretary of Interior on June 18, 1968 with certain exceptions most of which have been resolved.

In addition to interstate water quality standards, water quality criteria and effluent standards for intrastate waters have also been established.

Key Role of Local Responsibility

Because so many decisions regarding waste treatment are made at the local level, local responsibility must play a key role in any pollution control program. Communities' realization of the negative impact of pollution on the local economy (especially in resort areas) and on the quality of the environment can provide additional incentive for the provision of necessary funds for waste treatment and pollution control at the local level.

County enforcement will be the key to the success of the new Minnesota Shoreland Zoning Ordinance (see footnote 27). Although the state will set minimum standards to control pollution of lakes, the county governments have the option of adopting more restrictive standards to meet their local requirements. Strict enforcement on the part of the counties will be needed if this new zoning ordinance is to be of help in controlling the pollution of state lakes.

In addition to responsibility for treatment of municipal and industrial wastes, other community activities are extremely important. Locally administered agencies such as the County Soil and Water Conservation Districts in Minnesota have knowledge of local conditions and access to technical skills (through cooperation of agencies such as the Soil Conservation Service) that are necessary to implement responsible land management practices which reduce pollution from excessive land runoff.

[24] A report on interstate water quality standards is to be made available to the public by the MPCA.

Enjoyment on the Rum River at Princeton, Minn.

"It is better to debate a question without settling it, than to settle it without debate." — Joseph Joubert

An Interpretation of the Controversy

Agreement on Principle — Controversy on Specifics

The technology for preventing most forms of water pollution is known. Everyone favors clean water. No one has ever signed a petition favoring pollution. Why, then, do serious water pollution problems exist?

There are several factors which explain but do not necessarily rationalize the existing situation. Part of the explanation may be that waste treatment works are public goods as explained earlier. It would seem that this should not be a reason for underinvestment. However, the argument has been advanced that because of the clear-cut exchange of benefits for specific voluntary payments realized with the purchase of private goods, and because of the compulsory element of taxation through which public goods are financed, there is a bias in favor of private goods at the expense of public goods. Hence, there is the irony of using modern, well-designed camping gear to camp alongside a polluted stream.

The validity of the public vs. private goods argument itself has been the subject of some controversy. However, there are several other relevant factors. Industry has traditionally located where there was an abundance of water and need for treatment was not at first evident. It is sometimes argued that industry is unable to bear the cost of treating its waste water, and to require this would force industry to seek other locations. It is sometimes argued, too, that high water quality standards might nullify the advantage of water-rich areas for attracting industry.

Again, these questions are subject to some controversy. It might be argued that with uniform water quality standards across the nation, heavy water-using industries would have no advantage in shifting locations, on this basis. The role of a high quality environment and recreational opportunities in attracting employees might at least partially compensate for higher costs involved in waste treatment. Even if the requirement of more thorough waste treatment raised costs to industry, and these costs were passed along to consumers as higher prices, it is conceivable that the public would willingly pay the higher prices in return for cleaner water.

Still another possible explanation for pollution problems is the *fallacy of limited decisions* — the belief that more decisions made by the public sector will necessarily limit those options available to the private sector. As pointed out earlier, key public decisions sometimes increase the options open to the private sector.

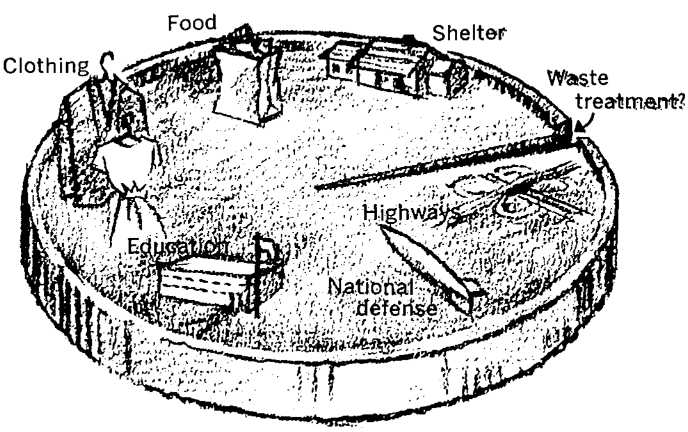
These issues are all part of the controversy. However, the real issue remains for discussion.

The Heart of the Controversy

The heart of the water quality controversy rests on the proposition that if conditions are to be improved, somebody must pay. Even in an affluent society, there are not enough resources to produce unlimited amounts of private goods such as food, clothing, shelter, automobiles, appliances, and public goods, such as national defense, schools, or highways. Although recent national economic policy has been significant in ensuring full employment of resources, the increased production of waste treatment facilities means that something else must be cut back. If wastewater is not treated, costs are in terms of lost recreational opportunities, increased costs incurred by downstream users, lost revenue from tourism, lowered property values, and a general deterioration in the quality of our environment. If wastewater is treated, and other measures are taken to maintain water quality, costs are either incurred in the form of higher taxes to individuals and business, or higher costs to industry (which may or may not be passed on to consumers, depending on the ability of the industry to do so).

With greater public responsibility in water quality control, resources are required not only for treatment of wastes *per se,* but for increased research, staffing, and equipment necessary to monitor and enforce standards and to develop more efficient ways of handling wastes.

Those who are involved in the water quality controversy face the immutable economic axiom that the increased use of fully employed resources for one purpose necessitates a reduced use for others.



Waste treatment must compete with many other uses of limited resources.

Organizing the Policy Issues

Although the matter of economics lies at the heart of the problem, there are many issues involved in the water quality controversy. To create some order for a rational discussion, three sets of problems may be outlined.[25]

The first set of problems revolves around methods of attaining various levels of water quality. This is an engineering, an economic, and an administrative problem. There are usually several alternative methods of maintaining water quality such as dilution, conventional treatment, and mechanical aeration. The design of waste treatment systems that are technically feasible as well as the development of new technology is a problem involving chemistry, microbiology, and engineering. Although there may be a number of technically feasible methods of maintaining water quality, the practical choice of systems is limited by costs. There will probably be economically superior designs with respect to location and capacity of treatment plants and other pollution control facilities along a given stream. Controversy may center on how the costs are to be shared or on the capacity of a system to maintain water quality at the desired level. Additional research is needed on technical problems such as eutrophication and disposal of agricultural wastes.

A second set of problems revolves around the question of level of water quality that should be attained. There may be agreement on the technically and economically feasible methods of maintaining water quality at alternative levels. However, there still may be considerable controversy regarding the proper level of water quality. For example, one faction may argue that it is best to make maximum use of the self-purification potential of a stream, minimizing the needed treatment facilities. Another faction may argue that wastes should be treated thoroughly to permit maximum recreational use of a stream. Others would argue that a logical solution is somewhere between these alternatives. A difficult problem to resolve involves the level of water quality to be maintained on reaches of streams in heavy industrial areas which are also near large, low income population centers.

This second set of problems is both economic and political. Thus far, this aspect of the controversy has been resolved through the political process as the benefits of water pollution control, mainly recreational and aesthetic values, are non-market in nature and difficult to measure by economic criteria. Even if these values are estimated by economists, it is society, rather than economists, which, properly, makes the ultimate decisions regarding allocation of resources.

The third set of problems involves institutional means by which water quality control policy can be implemented. These problems have economic, political, sociological, and legal implications. Even if there is general agreement on the proper level and means of maintaining water quality, the most idealistic plans for water quality control are of no value if they cannot be implemented and enforced.

Among the possible means for implementing water quality control policy are tax credits for industry which builds treatment facilities, laws requiring waste dischargers to treat wastes, and effluent charges by which a waste discharger, whether industrial or municipal, would pay a fee to a regional or state authority in relation to amount of waste discharged. These charges could be used to finance regional pollution control facilities. Each of these policy measures has its advantages and disadvantages and is subject to considerable controversy. In metropolitan areas such as the Twin Cities, the matters of financing, construction, and operation of sewage collection facilities is made more complex by controversy among numerous governmental units.

At the state and federal level, as well as the local level, the development of institutional means by which quality problems can be solved is important. *The ability of these institutions to successfully formulate and implement water quality control policy which is responsive to the needs and will of the public is at least as important as the development of more efficient and economical technology in changing controversy into constructive action for the improvement of water quality.*

Issues Facing the People of Minnesota

The ultimate objective of any water quality control policy must be to serve people. There are many explicit problems on which policies must be formulated while options are still available.

A problem which urgently requires attention is lakefront zoning in Minnesota. With over 80,000 lakefront homes in the state and the number growing rapidly each year, the remaining undeveloped lakeshore is rapidly dis-

[25] This outline is based on that proposed by Allen V. Kneese, *The Economics of Regional Water Quality Management*, Johns Hopkins Press, Baltimore, 1964.

appearing.[26] The manner in which lakefront is utilized will have important implications on lake water quality.[27] Once a haphazard pattern of development is begun and eutrophication accelerates, the process is, under present technology, impossible to reverse. Although even the most farsighted and comprehensive zoning program will not ensure preservation of water quality, the alternative is to permit events to develop without public policy guidelines.

The problem of stream water quality standards has already received some attention. The public will probably not make available sufficient resources to purify all waste water in the state enough to permit swimming and waterskiing. However, many would opt for cleaner streams than presently exist. Minnesotans must decide on a balance between stream standards desired and the resources required to achieve these standards. Especially, will public revenue be shifted from the state level to the local level to assist municipalities in waste treatment? The stream standards already set under auspices of the Federal Water Pollution Control Act represent a beginning. These standards will be subject to continual public review and revision.

Another problem yet to be resolved is the coordination of waste treatment facilities in the Twin Cities Metropolitan Area. Issues included the level of government needed and area of responsibility, functions of an agency responsible for regional sewage disposal, and payment formulae. The ultimate solution will depend partially on whether the Mississippi River is to be used for sewage dilution where convenient or whether only limited stretches, if any, are used for this purpose and the remaining sections kept of sufficient quality to permit fishing and other recreational activities.

The formation of more comprehensive water quality policies will require effective administration. The willingness of the people of Minnesota, as expressed through the legislature, to formulate a program and provide the funds for the necessary technical and legal staff will in large measure contribute to the state's success or failure in attaining the water quality objectives the public desires.

The state's problems in water quality control are greatly simplified because of its "top of the hill" location. Minnesota is the origin of waters — its major streams flow into other states. In other words, Minnesota's waters are polluted in Minnesota.

As with most controversial subjects, there are no simple or clear-cut, all encompassing solutions — only imperfect measures with which to try to solve complex problems. Alternative courses of action are still available but are becoming more limited each year. The people of Minnesota must decide.

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[26] A study on Minnesota Lakeshore Development is currently in progress in the Department of Geography under the direction of John R. Borchert, and another on Seasonal Home Ownership in Rural Areas in the Department of Agricultural Economics under the direction of Robert W. Snyder, both at the University of Minnesota.

[27] A law was amended by the 1969 Minnesota Legislature to require the Conservation Department to formulate by July 1, 1970, model standards and criteria for development of shoreland. Individual counties are to adopt shoreland conservation ordinances by July 1, 1972, or accept the model ordinance of the Conservation Department. (Amendment to Minnesota Statutes 1967, Chapters 105 and 396 by adding sections 394.25, Subdivision 2; and 396.03.)

Technical Terms Commonly Used in the Water Quality Controversy

Aerobic decomposition — A process of decomposition in which bacteria utilize oxygen in the breakdown of organic matter.

Algicide — Any material, substance, or compound which is fatal to algae or inhibits enough growth to be considered a potential means of control.

Algae — A broad class of microscopic plants which inhabit water. Although some forms of algae are necessary and desirable, excessive concentrations tend to discolor water and cause objectionable tastes and odors, severely limiting water's recreational uses.

Anaerobic decomposition — A process of decomposition in which breakdown of organic matter occurs by bacteria without the use of oxygen, resulting in production of hydrogen sulfide and other obnoxious gases.

Bacteria — A broad class of miscroscopic one-celled organisms. Bacteria provide a useful function in the decomposition of organic matter. The self-purification potential of streams depends on bacterial action.

Biochemical oxygen demand — (BOD). A measure of waste load represented by the amount of dissolved oxygen utilized in the aerobic decomposition of organic matter in water (usually over a 5-day period). The higher the expressed BOD, the greater is the waste load.

Coliform bacteria — Bacteria present in large numbers in humans and hence, in sewage. Because coliform bacteria are always present in relatively large numbers in sewage, because they may be detected with comparative ease, and because purification procedures which cause their elimination or destruction are equally effective against pathogens, the routine bacteriological analysis of water is concerned mainly with testing for the coliform group of bacteria.

Colloidal materials — Particles suspended in liquid which are intermediate between true solutions and suspensions.

Degradable wastes — Substances which are changed in form and/or reduced in quantity by the biological, chemical, and physical phenomena characteristic of natural waters. *Biodegradable* is a term specifically referring to decomposition by biological processes.

Dissolved oxygen — Refers to oxygen which is dissolved in water. Dissolved oxygen is essential for fish and other aquatic life and for aerobic decomposition of organic matter.

Effluent — An outflow of water such as from a septic tank or a waste treatment plant.

Enrichment — An increase in nutrients, mainly nitrates and phosphates, which fosters growth of algae and other plant life in water.

Eutrophic — Waters rich in nutrients.

Eutrophication — The process of aging of a lake; occurs slowly under natural conditions, but may be greatly accelerated by man's actions (sometimes referred to as *cultural eutrophication*).

Fallacy of limited decisions — The proposition that there are a limited or fixed number of decisions to be made by society and that if more decisions are made by the public sector, less are necessarily available to the private sector. This proposition is often not true as there are many examples where public policy has increased the options available to the private sector.

Hardness of water — A condition in which water contains high concentrations of mineral salts which interfere with lathering and cleansing properties of soap and cause incrustation of pipes and other plumbing fixtures.

Inorganic matter — Compounds that do not contain carbon and hydrogen.

Intangible costs and benefits — Costs and benefits which are not established through the price and market system. "Non-market" is sometimes preferred to the term "intangible." The loss of game fish through pollution is an example of an *intangible cost.* Boating and other recreational activities are examples of *intangible benefits* associated with water resources.

Limnology — The study of freshwater lakes and streams.

Nondegradable wastes — Substances that are not changed in form and/or reduced in quantity by the biological, chemical, and physical phenomena characteristic of natural waters. Although nondegradable wastes may be diluted by receiving water, they are not reduced in quantity.

Organic matter — Compounds which contain both carbon and hydrogen. Organic substances are the chief constituents of living things although many organic compounds can be synthesized.

Oxygen deficit — The difference between observed oxygen concentrations and the amount that would be present at 100 percent saturation.

pH — A technical measure of acidity or alkalinity. A pH of 7 is neutral, over 7 is alkaline, and under 7 is acidic.

Pollution — Waste materials in a watercourse which adversely affect water for any particular use, including aesthetic.

Primary treatment — Treatment of sewage to the extent that the heavier solids and flotable materials are settled out.

Private goods — Goods purchased by individuals through the price and market system which yield benefits primarily to the purchaser.

Productivity — In the context of water quality, this refers to the capacity of a body of water to produce algae and other aquatic life. Productivity increases as eutrophication proceeds although certain species, such as game fish, decline.

Public goods — Goods which are not readily available through the price and market system and which yield widespread benefits to society. Public goods are normally financed by taxes and other sources of public revenue and benefits are not limited to those who finance these goods. Waste treatment facilitates and sewer systems are examples of public goods.

Reaeration — The absorption of oxygen in water from the atmosphere. This phenomenon enables self-purification of streams by providing the necessary oxygen to bacteria.

Secondary treatment — Treatment of wastes beyond the primary stage, utilizing biological processes, to the extent that a portion of the remaining organic matter is decomposed before discharge of the effluent.

Self-purification — The process by which a stream is purified some time after receiving a waste discharge. This occurs in the decomposition of organic matter by oxygen-using bacteria.

Septic conditions — A term sometimes used to refer to conditions where dissolved oxygen is absent and decomposition is occurring anaerobically.

Social costs — Costs which are incurred by an individual or group but imposed on society as a whole.

Tertiary treatment — Treatment of sewage beyond the secondary stage to accomplish a very high degree of nutrient and/or BOD reduction.

Thermal pollution — The addition of heat to a lake or stream. An increase in water temperature fosters algal growth, reduces oxygen-holding capacity, and increases the rate of utilization of dissolved oxygen.

Turbidity — Cloudiness of water caused by presence of collodial matter or finely divided suspended matter.

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