Seminar Proceedings

Water Quality Control

Conducted by

Oregon State University
WATER RESOURCES RESEARCH INSTITUTE

Fall Quarter 1964

Corvallis, Oregon

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JANUARY 1965
PREFACE

An important function of the Water Resources Research Institute is to provide for training of students in the many aspects of water resources. Members of the Institute supervise the research efforts of graduate students and teach both undergraduate and graduate level courses applicable to water resources.

A water resources minor is offered under the guidance of the Institute for master of science or doctor of philosophy degree candidates in established disciplines. Courses offered in this minor cover all categories of water knowledge and include, as a requirement, a water resources seminar which is conducted by the Institute each quarter excepting summer session.

This publication is the proceedings of the Fall 1964 seminar series, which was designed to provide the participant with a general understanding of the entire field of water quality control including the complexities and interdisciplinary nature of this subject. Guest lecturers were specialists from many of the agencies and organizations having a direct interest and responsibility in the field of water quality control.

Corvallis, Oregon
January 1965

Malcolm H. Karr
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Of all the natural resources that bless this nation, water has probably exerted more influence on our cultural, economic and industrial development than any other single force. It was the availability of clean water to sustain life and supply household needs, water to supply fish for food and water for transportation that encouraged the early settlers to establish their communities along the natural water-courses of the eastern part of the continent.

Exploration of the west was hastened when Napoleon sold Louisiana to the United States, for this opened a vast new area for trade. Lack of a transcontinental transportation system to link the east to the west made it necessary to rely on an ocean route around Cape Horn. This was long and time consuming, so it was inevitable that efforts would be made by both the congress and eastern industrialists to shorten this distance by discovery, if possible, of an internal continental trade route. One of the objectives of the Lewis and Clark expedition, therefore, was to determine whether suitable navigable water courses existed that were near enough to one another to tie the west and east together for trade purposes. Unfortunately the Rocky mountains were a too formidable barrier between the Missouri and Columbia rivers, and the Colorado was too far away to be useful.

Since there was more than enough water to supply the demands of people and industry in the early years of the nineteenth century, there was no competition for its use, not even for transportation. The need to provide some measures for the management and control of water was recognized, but quality of water had not become a matter of concern. Practically nothing was known about the role of water in the transmission of disease, and the quantity of wastes discharged into watercourses was not of sufficient volume to exert any detrimental effect on fish or other aquatic life. Most of the interest, therefore, centered around proposals for improving navigation, the development
of harbor projects, and flood control. In fact, the Congress had been concerned about flood control for some fifty years before the Civil War, but did not establish the Mississippi River Commission until 1874.

With all the modern conveniences available today, it is difficult to imagine that a little over a century ago no public system designed primarily for the collection of sewage existed. Drains existed in some cities for the removal of surface rain water runoff, and these ultimately became the facilities for the disposal of other waste waters, both domestic and industrial. It was about 1855 that Chicago became the first city in the United States to enter into a contract with a consulting engineer for the design of a community system for collection of its domestic sewage.

As late as 1900 there were less than 1000 cities served by sanitary sewers and only 60 of these had provided some form of treatment or disposal. Concern over water quality had begun to develop, but time lag before something was to be done about it proved extremely slow. This may have been due to the fact that methods for treatment were not too well developed, and consisted of three general types that had been imported from either England or Germany, such as broad irrigation, chemical precipitation and intermittent sand filtration.

It is reported that the first system for disposal of sewage in this country consisted of broad irrigation which was installed by the State Insane Asylum at Augusta, Maine in 1872. The same kind of system was also installed at Cheyenne, Wyoming in 1883.

One would think that the invention of the microscope by Van-Leeuwenhoek in 1676 would have advanced knowledge as to the role of water in the transmission of disease. Almost two centuries elapsed, however, before the work of Pasteur, Koch, Lister, Cohn, and others gave scientists a better understanding of the science of microbiology. These and subsequent developments focused attention on water as a medium in the transmission of disease. One of the first giant steps in this direction was Dr. John Snow's epic study of cholera associated with an outbreak originating in an area where water had been taken through the Broad Street pump in London in 1854. In this instance, the well, contaminated from a nearby cesspool, was related to almost 700 deaths from cholera. The epidemic of cholera, which occurred in Hamburg, Germany in 1892, dramatically illustrated how intestinal diseases could be transmitted by water and at the same time demonstrated the effectiveness of water treatment in the prevention of such diseases. The City of Hamburg used as its source of water supply untreated water from the River Elbe. Altona, a city adjacent to and
downstream from Hamburg, also used water from the Elbe contaminated by sewage from that city. Since Altona's water was purified by sand filters, only 516 cases of cholera were reported in that city while Hamburg had some 18,000 cases of the disease and over 8000 deaths.

Sewage and industrial wastes created other problems such as sludge deposits that interfered with water oriented recreation, and odors and other aesthetically objectionable conditions that affected the enjoyment of living. Undoubtedly some of these led to the enactment of the first laws in the nation on water pollution control by the state of Massachusetts in about 1872.

With the establishment of the Lawrence Experiment Station in Massachusetts in 1880, American scientific ingenuity began to bring its talents to bear on water pollution control. The station's research and investigations of the sewage treatment, biological and bacteriological processes, particularly those related to filtration, activated sludge, contact beds and sludge digestion, set the stage for improved domestic waste treatment in the future. Work on the characteristics and treatment of industrial wastes was undertaken by the Station in 1895.

In the meantime, industry was making giant strides in providing the goods and products needed by the nation's increasing population. The development of rail transportation supplemented water routes for shipping and made it possible to bring more raw materials to manufacturing centers for processing.

The availability of fossil fuels probably played an important part in retaining industrial production in the east and midwest for many years. With the discovery of oil and gas in other regions, the development of hydro-electric power, and the extension of railroad services, industry could locate its operations nearer to the source of raw materials. Water pollution also moved west and south with industry.

There was such a wide variety of industrial products that the characteristics of waste waters and their effect on streams, while not too readily noticed at first, ultimately presented a set of complex circumstances some of which still remain to be solved. Some of these include acid mine drainage, fines from coal washing, phenols from coke production, organic materials and chemicals from tanneries, pulp mills, food processing, metal manufacturing, silt from mining, and dyes and grease from textile production.
Plastics, pesticides, synthetic detergents, nuclear reactors, nylon, rayon and synthetic rubber, and a host of other such products, had not yet come into being and their impact on pollution was not to be recognized until later.

In the early years of the twentieth century, serious outbreaks of water-borne disease created an urgent demand for the protection of water supplies from contamination by domestic sewage. Destruction of fish and the contamination of shellfish by pollution established the need to protect aquatic life. Finally, the appearance of many streams was becoming so objectionable that demands were being made to have such nuisances abated, even in a period when the nation was still largely rural and the industrial expansion resulting from two periods of wartime activity still lay ahead.

Most major streams at that time still provided a substantial amount of water for the dilution of wastes and generally most waste treatment plants were designed to take full advantage of the self-purification capacity of the water receiving wastes. The practice continued for a period of about fifty years until it was finally recognized that dilution was no longer a solution for pollution.

In spite of all these developments, only a few states enacted any legislation dealing with the control of pollution. Generally, early state laws were designed to take care of problems as they arose and usually provided protection for an individual stream for some particular beneficial use. More sophisticated laws did not appear until later. Even federal attention to water pollution control somewhat followed the state pattern. Earliest federal laws on the subject included the Rivers and Harbors Act of 1899, the Public Health Service Act of 1912, and the Oil Pollution Act of 1924. Congress apparently considered the possibility of enacting laws governing water pollution control, but for a long time failed to take decisive action. Under the Public Health Service Act of 1912, however, the Service was authorized to initiate studies of pollution in navigable streams, particularly as it related to the transmission of disease to man. This resulted in the establishment of a field station in Cincinnati, Ohio. The work of this productive group greatly broadened knowledge of the science of water pollution and paved the way for more intensive work in the Ohio river basin which was to come more than a quarter of a century later.

The first comprehensive federal water pollution control act was not adopted until 1948. Even then support for such activities was not strong. While activities instituted under this law were extended until 1953 they were severely reduced for lack of appropriation in 1950.
Interest was revived, however, and by 1956 the original act was amended and made permanent. It was again amended in 1961.

In the period 1900-1960 the United States population increased from 76 million to 180 million and industrial production rose from an index of 13 to 109, far outstripping expectations. Public support for the control of liquid waste discharges, and for the development of new methodology to keep abreast of other problems of water pollution control remained meager, however, with a rising tide of interest becoming apparent only during the past decade. Even without considering the mathematics involved with the newly developed water-using household appliances, simple deduction would quickly reveal the fact that more people and more production require more water and produce more liquid wastes to befoul public waterways.

During these years, agriculture had become a consumer of large quantities of water, too. In 1902 when Reclamation Act was adopted, private enterprise was supplying water to some 9.5 million acres of land. With federal participation in the program, irrigated lands have now increased to 37 million acres with an average use of 104 billion gallons of water daily.

Since the cessation of World War II, we have witnessed our greatest population and industrial growth. Industry has dispersed to all parts of the country, and so have people. The development of new industrial products and agricultural practices which have been changed by new chemical products have created new pollution problems. That competition for water has now reached a critical point was not readily accepted until these facts were publicly recognized:

1. Expanding cities will require more water to supply the needs of their rapidly growing urban complexes.

2. Industry will require more water to sustain its expansion and extension.

3. Agriculture will require more water to produce more food for a steadily increasing population.

4. Leisure time affords an opportunity for more people to participate in water oriented recreation. This will require a reserve of water of high quality.

5. Water reserves of high quality must also be provided to sustain an abundance of fish and other aquatic life.
6. Increased amounts of water will be required for steam power production, transportation, and water quality control.

These, coupled with the knowledge that, (1) there is a relatively fixed amount of water supply, and (2) there is an uneven seasonal and geographic distribution of water, clearly emphasize the need for prompt and effective action.

Neither the states nor the federal government were prepared to cope with these developments, and, therefore, they were not equipped to deal with resulting pollution problems technically, legally, socially, or economically. Actually, we had been attempting to meet this set of new and complex problems with tools designed to be used twenty-five to thirty years ago.

An examination of some of these basic facts will serve to bring this dilemma into sharper focus. For example, the nation can usually expect an average rainfall of about 30 inches. This means that we can plan on about 4,300 billion gallons of water per day from rainfall. About 3,100 billion gallons of this amount is lost through evaporation and transpiration. A substantial portion of the remaining amount occurs as floods and returns to the ocean before it can be used.

It has been estimated that the total amount of fresh water available today is about 315 billion gallons daily. By 1980 the total dependable supply that can be developed is 515 billion gallons daily. With engineering works, the maximum dependable supply of fresh water for any time will be about 650 billion gallons per day. On these amounts the people, industry and agriculture must depend.

To further complicate matters, the amounts of water we have discussed are not supplied evenly over the country. Seasonal variations also create equally formidable problems. Oregon is a good example of both principles. Rainfall here varies from 30 to 35 inches annually in the Willamette valley to 10 to 15 inches in the region east of the Cascades. In some areas in the Cascade and Coast Ranges, rainfall will reach 90 to 100 inches annually. Since most of the precipitation east of the Cascades falls as snow, the period of major runoff occurs in the late spring or summer. By contrast, most of the runoff in coastal streams and in those west of the Cascade range occurs during the fall and winter months. This means, then, that low flows occur during different seasons of the year and quite frequently during periods of extensive industrial and agricultural activity.
An increasing population, new and expanding industry, and an extension of agricultural activity would be expected to use more and more water. Water consumption has increased and can be expected to increase even more in the next forty years, as illustrated in the following table:

### Water Consumption in the United States 1900 - 2000

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity of Water Used (billion gallons daily)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>41</td>
</tr>
<tr>
<td>1945</td>
<td>150</td>
</tr>
<tr>
<td>1954</td>
<td>220</td>
</tr>
<tr>
<td>1960</td>
<td>355</td>
</tr>
<tr>
<td>1980</td>
<td>600</td>
</tr>
<tr>
<td>2000</td>
<td>1,000</td>
</tr>
</tbody>
</table>

Since the dependable supply of water is only about 515 billion gallons daily and the use predicted for 1980 is 600 billion gallons daily, re-use of water will become more of a necessity in some regions. It is almost inevitable that streams will continue to serve as the point of final disposal for liquid wastes. This means that this must be accomplished in such a manner that it will not interfere with or eliminate the use or re-use of any stream as it flows past each downstream city, industry, farm and recreation area.

In the face of rising water consumption and the necessity for providing water of high quality, attention must be directed to the magnitude of the water pollution problem and the steps that must be taken to reduce it. Domestic sewage and liquid industrial wastes have always been constant and troublesome sources of pollution and will continue to be so for many years to come.

The situation related to domestic sewage can best be illustrated by the table at the top of the following page:
The residuals estimated to be discharged into public waters for 1970 and 1980 anticipate that the present rate of sewage treatment plant construction will continue and that 80 per cent removal of oxygen consuming pollutants will be accomplished. Should we fail to meet these objectives, the residual population equivalents are estimated to be 85 and 114 million, respectively. Even the lower figures of 78 and 70 do not represent any substantial gains over stream loadings for 1950.

It is interesting to note that if the present rate of industrial waste treatment works construction continues and an 80 per cent reduction in population equivalent can be achieved for 1970 and 1980, the lower figures on waste loading will obtain. If this pace and progress is not maintained, waste loads that are four times those estimated will occur.

Current waste treatment methods will not remove 100 per cent of all pollutants. Flow augmentation during periods of low stream flows will therefore be required. The Senate Select Committee on Water
Resources estimated that it will be necessary to provide 522 billion gallons per day for flow augmentation in 1980 and 700 billion gallons per day by the year 2000. The storage requirements involved are 315 million acre feet by 1980 and an additional 127 million acre feet by 2000.

These probable future conditions should be enough to stagger the most ardent conservationist, but there are also special problems in water pollution control that add to the burden. These include radioactivity, heat, urban and rural land drainage silt, irrigation return flow, and pollution from navigation. Conventional methods of water and waste treatment now in use are not suitable to provide the full protection against radioactive materials that are necessary. More effective treatment and control of these wastes at the source appears to be the most practical solution.

Electric power production has doubled every ten years since 1900. It may be expected to double again by 1970. Heat pollution can also be expected to double in the next ten years. Added to this must be the increases in temperatures of surface waters that will occur naturally in impoundments for hydro-electric power, irrigation, navigation, water supply and flood control.

Fertilizers and pesticides from land drainage have, on numerous occasions, already indicated that they will have a rather formidable effect on the quality of water to be used for recreation, water supply, and aquatic life.

Highway and dam construction, logging, forest and brush fires, and other land use practices create conditions which lead to soil erosion. The result is an increase in stream sediment loads, which in some river basins have reached major proportions.

Irrigation return flows have for many years been recognized as detrimental to water quality in the West. They carry important minerals leached from the soil through which they flow, and the use of these waters again and again often makes them unsuitable even for irrigation.

Another condition that has grown to substantial magnitude in the past decade is the problem of urban land drainage. Each year more land is converted to use for streets, housing, highways, airports, automobile parking, commercial and industrial buildings, and shopping centers. The surface runoff from these lands is almost
100 per cent, and contains a wide variety of substances almost too numerous to mention. Included, however, would be such materials as oils, organic material, trash, soil, fertilizers, and pesticides used by weekend gardeners, industrial dusts, and other waste products. Recent studies have shown the pollution potential of this sort of runoff to be highly significant.

And finally, there is the matter of pollution from ships. While this is really nothing new, it must be recognized as a growing condition that must be corrected. Bilge water, garbage, oils and sewage from boats all exact their toll on water quality and can no longer be ignored.

Future lecturers in this seminar series will discuss the facets of water quality control in more detail. If this lecture has prepared the foundation for their discussions, then my mission has been fulfilled.
The synthetic organic chemicals which we will be considering today are chemical facts of life in western civilization, and undoubtedly are here to stay. In this framework, we refer not only to the pesticides, which we will consider later, but to all of the synthetic organic chemicals that this complex society is using. Unquestionably a great deal of these chemicals finds its way to the water resources. It does not necessarily follow that because some of these synthetic organics get into water that they will have reached a threshold level—and that level we don't know yet for many of these chemicals—at which impairment of water quality becomes serious. It is true that at high levels, any one of these synthetic organics is a serious contaminant.

Among the synthetics that may get into water are the industrial wastes, with which I suppose most of you are at least generally familiar. The substance might be a by-product of an organic synthetic plant, for example, a phenol. Phenols at a fairly high level become a serious contaminant, because of their toxicity and their objectionable odor, and, of course, the flavor they impart to the water. In addition, there are the social wastes. This is the waste from man's individual activities—the detergents, let's say, that enter the sewage system from home consumption, or the half bottle of insecticide that the urban homeowner pours down the drain in order to dispose of it. One could go on enumerating quite a list of such synthetic organics as waste products that may get into water.

The chemicals to which we give our primary attention here are the pesticides or agricultural chemicals and the problems that might be encountered as a result of their entering into water. At this juncture it should be noted that little is known about the effect of a good many of these substances on water quality. It does not follow that simply because there is a trace of a chlorinated hydrocarbon in water that this is going
to be harmful to man. It may be objectionable to have any foreign organic in water, but I think we are being somewhat unrealistic if we think we can avoid any sort of contamination. I would hasten to add that we should bend every effort to avoid contamination of water with these organic pesticides, but I think we should not exaggerate the danger where a few tenths of a part per billion of DDT, or 2,4-D, might appear in water.

Turning now to examine these chemicals, we find that there is quite an array of pesticides and they can be classified in several ways. One of the most common classifications and one which perhaps many of you employ is that based on use. Thus they may be listed as insecticides, fungicides, herbicides, nematocides, growth regulators, solvents, and so on. For purposes of this discussion, it would be more precise if we look at the classification of these chemicals by their chemical makeup.

One of the first groups of pesticides encountered—and incidentally, will embrace virtually all of the classifications of use—are the chlorinated hydrocarbons (see Figure 1). The chlorinated hydrocarbon grouping actually is very broad. All that the term indicates is that the molecule or chemical contains, among other things, carbon, hydrogen, and chlorine, or better, we should say, a halogen.
The properties of the chlorinated hydrocarbons vary widely. In the class known as chlorinated hydrocarbons will be found substances ranging in water solubility from a few parts per billion to complete miscibility. The compounds of low solubility are usually those containing only carbon, hydrogen, and chlorine; such as DDT, aldrin and hexachlorocyclohexane.

Further examples of the chlorinated hydrocarbons are those compounds containing in addition to C, H, and Cl, oxygen and other atoms. In this class we find the chlorophenols, chloronitrophenols, acids, esters, aldehydes and ketones. These compounds have different physical, chemical and biological properties than do those materials containing only C, H, and Cl. For example, highly oxygenated chlorinated hydrocarbons will be much less persistent in the environment. By way of illustration, one might compare the persistence of 2,4-D, an acid, to that of DDT. 2,4-D is relatively unstable, readily attacked by microorganisms, undergoes chemical reactions in the environment, all resulting in rapid destruction. In contrast, DDT is highly resistant to attack by virtue of its chemical stability.

Among other chemicals that are included in the chlorinated hydrocarbons or halogenated hydrocarbons, are low molecular weight, chain hydrocarbons. The materials are used as fumigants since they are highly volatile. This group is represented by ethylene dibromide, chloropropenes and methyl bromide. These materials, by virtue of their high vapor pressure, do not persist long in the environment, nor are they likely to be a serious water contaminant. The only way something like ethylene dibromide or dichloropropane would be a serious contaminant in water would be if deliberately introduced for the control of some organism.

The next group of compounds to be considered are the organic phosphates. While the organic phosphates vary in structure and properties, the wide differences found in chlorinated hydrocarbons are not to be observed here. The organic phosphates have a characteristic grouping in the ester linkage as illustrated in Figure 2. The ester linkage is one of the "weak points" of the organic phosphates. It is at this point that they may be attacked by water or enzymes, converting the malathion to harmless products. Unfortunately, mammals can't do this with all of the organic phosphates. Those that resist the attack prove to be quite toxic.

Because of inherent instability, organic phosphates are rarely serious contaminants. However, there have been reports lately of
traces of parathion found in runoff of streams in the South, where parathion was used for control of insects. The level of parathion was in the order of a few billion, probably below any dangerous level.

Another group of organic chemicals used as pesticides are the carbamates (see Figure 2). Representatives of all types of pesticides are found in the class of carbamates. The chemistry and properties of the carbamates can be illustrated by the insecticide Sevin and the herbicide CIPC. In both cases, it will be noted that the carbamates are esters of a special type of acid. As esters, they have two significant properties, namely ease of hydrolytic attack at the ester linkage and a relatively high vapor pressure. Other properties militate against this class of compound having a long persistence in the environment thus becoming a serious contaminant.

The next group of compounds to come to our attention are the hetero-
cyclic compounds. These are compounds characterized by having nitrogen in the ring, for example, the herbicide ATA or amino triazole. These heterocyclic compounds vary from being quite unstable to being very stable. Some of them, such as the triazines, which are both alkylated and halogenated are very stable and could get into water supplies.

Another compound of recent vintage belonging to the heterocyclics is the herbicide tri-chloro amino picolinic acid. Picloram, as it is called, is highly persistent because of chemical stability and this, coupled with its mobility in water, could easily lead to contamination of ground water.

Figure 3 also shows some metallo-organic compounds. Here we see mercury and arsenic as among the most common metals in the biocidal metallo-organic pesticides. The limited use of this class of chemical fortunately minimizes the problem of contamination.

Among some of the most potent chemicals are those containing a
nitro group such as nitrophenols. For the most part, they are quite toxic substances, but not particularly persistent because of the chemical reactivity of the nitro group. For example, it can be reduced to the less toxic amino group. This occurs with parathion, for example, when you feed it to a cow. Surprisingly enough you find that a cow isn't nearly as susceptible to parathion as many other organisms. The reason for this is simply that the nitro group on the phenyl ring of parathion is reduced to the amino group in the rumen of the cow; consequently, a great deal of the toxicity is lost.

The following table attempts to summarize some of the properties of the different compounds. From such information we would hope to predict the possibility of contamination. With this and a knowledge of the biological behavior, we can estimate the degree of toxic hazard and certain conditions. For example, we note that chlorinated hydrocarbons are quite stable and knowing their propensity to accumulate in fat, we would reasonably expect them to be concentrated in the food chain. The carbamates, on the other hand, would not be expected to do so despite their ready destruction by hydrolysis.

Hydrocarbons, such as kerosene, xylene and so on, are generally liquids or soluble organics, moderately volatile and generally not considered particularly stable under ordinary environmental conditions. The hydrocarbons will usually be lost from water by co-distillation with water vapor.

The next table is a rating of toxicity. This data was compiled for laboratory animals and can be used only to indicate possible toxicity to other species. Actual toxicity will vary markedly from one organism to another. It is interesting to note the wide differences in toxicity between compounds of the same chemical class, however.

The next table (p. 20) is a summary of the biochemical lesions produced by the different classes of compounds. You will note that chlorinated hydrocarbons generally have as the primary target organ the liver. Other organs are also affected, but it is the liver that is the primary target. The organic phosphates, as you know, exert their toxicity in the blood and brain by inhibiting the enzyme cholinesterase. Similarly, you will note other classes of compounds produce a characteristic biochemical lesion.

An important consideration in regard to organic chemicals and water quality is that of the behavior of the chemical in the environment. This is determined by physical laws that can help us to predict such behavior. For example, one of the most important factors relating to the
<table>
<thead>
<tr>
<th>Class</th>
<th>Physical State</th>
<th>Solubility</th>
<th>Vapor</th>
<th>Chemical Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Chlorinated Hydrocarbons</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>Liquid</td>
<td>Fats</td>
<td>High</td>
<td>Breaks down in light</td>
</tr>
<tr>
<td>DD</td>
<td>Liquid</td>
<td>Fats</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>DDT</td>
<td>Greasy Solid</td>
<td>Org. &amp; fats</td>
<td>Low</td>
<td>Stable</td>
</tr>
<tr>
<td>Aldrin</td>
<td>Solid</td>
<td>Org. &amp; fats</td>
<td>Low</td>
<td>Stable</td>
</tr>
<tr>
<td>2, 4-D</td>
<td>Solid</td>
<td>Org.</td>
<td>Low</td>
<td>Stable except in soil</td>
</tr>
<tr>
<td>2. Hydrocarbons</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Kerosene, etc.)</td>
<td>Liquid</td>
<td>Org.</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>3. Carbamates</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sevin</td>
<td>Solid</td>
<td>Org. &amp; fats</td>
<td>Some</td>
<td>Moderate</td>
</tr>
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<td>CIPC</td>
<td>Liquid</td>
<td>Org. &amp; fats</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>EPTC</td>
<td>Liquid</td>
<td>Org. &amp; fats</td>
<td>Mod. high</td>
<td>Fairly stable</td>
</tr>
<tr>
<td>4. Organic Phosphates</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parathion</td>
<td>Liquid</td>
<td>Org. &amp; fats</td>
<td>Moderate</td>
<td>Hydrolyses</td>
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<td>Malathion</td>
<td>Liquid</td>
<td>Org. &amp; fats</td>
<td>Moderate</td>
<td>Hydrolyses</td>
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<tr>
<td>5. Heterocyclics</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Aminotriazole</td>
<td>Solid</td>
<td>Water</td>
<td>Low</td>
<td>Light &amp; micro organism decompose</td>
</tr>
<tr>
<td>Simazine</td>
<td>Solid</td>
<td>---</td>
<td>Low</td>
<td>Stable</td>
</tr>
<tr>
<td>Nicotine</td>
<td>Liquid</td>
<td>Water, acid</td>
<td>Moderate</td>
<td>Moderately stable</td>
</tr>
<tr>
<td>6. Miscellaneous</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotenone</td>
<td>Solid</td>
<td>Org. &amp; fats</td>
<td>Low to moderate</td>
<td>Decomposed by light</td>
</tr>
</tbody>
</table>
### TABLE 2
TOXICITY RATINGS FOR AGRICULTURAL CHEMICALS

<table>
<thead>
<tr>
<th>Chemical or Product</th>
<th>Human Toxicity Rating</th>
<th>Acute Oral Toxicity to rate (LD50-mg./kg.)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2, 4-D</td>
<td>3</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>2, 4, 5-T</td>
<td>3</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>1080 (Sodium Fluoroacetate)</td>
<td>6</td>
<td>1.7</td>
<td>Used only by licensed personnel.</td>
</tr>
<tr>
<td>Alphanap</td>
<td>3</td>
<td>8,000</td>
<td></td>
</tr>
<tr>
<td>Aldrin</td>
<td>4-5</td>
<td>50-60</td>
<td></td>
</tr>
<tr>
<td>Aliphatic Hydrocarbons (kerosene)</td>
<td>3</td>
<td>--</td>
<td>Primarily hazardous when ingested in large quantities.</td>
</tr>
<tr>
<td>Alletrins</td>
<td>3</td>
<td>680</td>
<td></td>
</tr>
<tr>
<td>Amine Methyl Arsonates (AMA)</td>
<td>4</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Amino Triazole</td>
<td>1</td>
<td>14,700</td>
<td></td>
</tr>
<tr>
<td>Antu</td>
<td>2</td>
<td>6-8</td>
<td>Selective on rats and dogs. Not toxic to humans.</td>
</tr>
<tr>
<td>Aromatic Hydrocarbons (Xylene)</td>
<td>4</td>
<td>--</td>
<td>Same as Aliphatic.</td>
</tr>
<tr>
<td>Arsenic Trioxide (white arsenic)</td>
<td>6</td>
<td>10-13</td>
<td>Human toxicity varies widely due to individual susceptibility and slow solubility of white arsenic. Toxic dose for humans is 0.1 - 0.5 grams.</td>
</tr>
<tr>
<td>Borascu (Borax)</td>
<td>3-4</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td>Captan</td>
<td>2</td>
<td>9,000-13,000</td>
<td>Oral ingestion of 1 teaspoon has been fatal to susceptible individuals. Also hazardous as vapor in atmosphere at concentrations of 25 ppm or greater.</td>
</tr>
<tr>
<td>Carbon Tetrachloride</td>
<td>5</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Ceresan</td>
<td>5</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Chloro DIPC</td>
<td>3</td>
<td>1,500</td>
<td></td>
</tr>
<tr>
<td>CMU (Monuron)</td>
<td>3</td>
<td>3,700</td>
<td></td>
</tr>
<tr>
<td>Dalapon</td>
<td>2-3</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td>DDT</td>
<td>4</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Diazinon</td>
<td>4</td>
<td>85-135</td>
<td></td>
</tr>
<tr>
<td>Dicumarol</td>
<td>6</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Dieldrin</td>
<td>4-5</td>
<td>60-90</td>
<td>Dangerous primarily on repeated doses. Relatively larger single exposures can be tolerated.</td>
</tr>
<tr>
<td>Dinitro Ortho Secondary Butyl Phenol</td>
<td>5</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Disodium Methyl Arsonate Hexahydrate (DSMA)</td>
<td>4</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Ethylene Dibromide</td>
<td>4</td>
<td>(Males) 146 (Females) 420</td>
<td>Also may be toxic as vapor with maximum safe threshold level in air for humans at 25 ppm.</td>
</tr>
<tr>
<td>Chemical or Product</td>
<td>Human Toxicity Rating</td>
<td>Acute Oral Toxicity to Rats (LD50-mg./kg.)</td>
<td>Comments</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>-----------------------</td>
<td>-------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Ethyl Mercury Phosphate</td>
<td>5</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Ferbam</td>
<td>2-3</td>
<td>17,000</td>
<td></td>
</tr>
<tr>
<td>Freon (Propellants)</td>
<td>3</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>IPC (Propham)</td>
<td>3</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>Kelthane</td>
<td>3</td>
<td>app. 800</td>
<td></td>
</tr>
<tr>
<td>Lindane</td>
<td>4</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>Malathion</td>
<td>3</td>
<td>500-2,000</td>
<td>(Depending on purity and solvents used.)</td>
</tr>
<tr>
<td>Maleic Hydrazide</td>
<td>2-3</td>
<td>2,300-7,000</td>
<td>(Depending on formulation.)</td>
</tr>
<tr>
<td>Methyl Parathion</td>
<td>5</td>
<td>9-25</td>
<td>(Depending on purity.) Also has high vapor toxicity, which is absent with parathion.</td>
</tr>
<tr>
<td>Naphthalene acetic acid</td>
<td>3</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>Parathion</td>
<td>6</td>
<td>3</td>
<td>Has delayed action which greatly increased hazard. Readily absorbed through skin.</td>
</tr>
<tr>
<td>PCNB</td>
<td>3</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Pentachlorophenol</td>
<td>4</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>Phenyl Mercuric Acetate (PMA)</td>
<td>8</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Pyrethrins</td>
<td>4</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Red Squill</td>
<td>3-4</td>
<td>200-1,000</td>
<td>Selective on rats with little toxic effect on most humans.</td>
</tr>
<tr>
<td>Rotenone</td>
<td>4</td>
<td>132</td>
<td></td>
</tr>
<tr>
<td>Sevin</td>
<td>3</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>Simazin</td>
<td>3</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>Sodium Chlorate</td>
<td>4</td>
<td>12,000</td>
<td>Lethal human dose is somewhat above 5 grams.</td>
</tr>
<tr>
<td>TEPP</td>
<td>6</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Thimet</td>
<td>6</td>
<td>1.75</td>
<td>Has severe vapor hazard also.</td>
</tr>
<tr>
<td>Toxaphene</td>
<td>4-5</td>
<td>69</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 3

Toxic Action of Chemicals

<table>
<thead>
<tr>
<th>Compound</th>
<th>Primary Target Organ</th>
<th>Biochemical Lesion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorinated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrocarbon</td>
<td>Liver</td>
<td>Oxidative phosphorylation cytochromes</td>
</tr>
<tr>
<td>DDT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toxaphene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic Phosphates</td>
<td>Blood, brain</td>
<td>Choline esterase</td>
</tr>
<tr>
<td>Carbamates</td>
<td>Blood, brain</td>
<td>Choline esterase</td>
</tr>
<tr>
<td>Heterocyclics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amino Triazole</td>
<td>Thyroid</td>
<td>Catalase, oxidases</td>
</tr>
<tr>
<td>Coumarin derivatives</td>
<td>Blood</td>
<td>Clotting time</td>
</tr>
<tr>
<td>Phenols</td>
<td>Liver, others</td>
<td>Oxidative phosphorylation</td>
</tr>
</tbody>
</table>

TABLE 4

Chemical Properties and Behavior of Herbicides

<table>
<thead>
<tr>
<th>Compound</th>
<th>Sol. in H₂O Mg/L</th>
<th>Latent heat of solva</th>
<th>Adsorption</th>
<th>Leaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>2, 3, 6-Trichlorobenzoic Acid</td>
<td>7700</td>
<td>1.6</td>
<td>Slight</td>
<td>Ready</td>
</tr>
<tr>
<td>3 Amino 2, 5-dichlorobenzoic acid</td>
<td>630</td>
<td>2.8</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>2 Methoxy 3, 6-dichlorobenzoic acid</td>
<td>7900</td>
<td>1.9</td>
<td>Slight</td>
<td>Ready</td>
</tr>
<tr>
<td>2, 4-D</td>
<td>605</td>
<td>6.1</td>
<td>Strong</td>
<td>Mod. Resistant</td>
</tr>
<tr>
<td>Isopropyl-N-3-chlorophenyl carbamate</td>
<td>103</td>
<td>~ 4.9</td>
<td>Mod. Strong</td>
<td>Moderate</td>
</tr>
<tr>
<td>S-Ethyl-di-n-propylthiol carbamate</td>
<td>375</td>
<td>~3.9</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Phenyl Dimethyl Urea</td>
<td>3850</td>
<td>3.9</td>
<td>Moderate</td>
<td>Mod. Resistant</td>
</tr>
<tr>
<td>Dichlorobenzynitrile</td>
<td>45</td>
<td>2.8</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Dimethyl-Tetrachloro</td>
<td>5.6</td>
<td>12.4</td>
<td>Very Strong</td>
<td>Resistant</td>
</tr>
</tbody>
</table>
behavior of chemicals in the environment is absorption. This process, which is an equilibrium process, influences the amount of chemical that can be leached into water or evaporated into the air. It has been discovered that the amount of energy ($\Delta H$) required to drive a chemical into solution in water is also related to the strength with which that chemical will be adsorbed. With this and other data obtained in the laboratory, the behavior of a chemical in the environment can be estimated. From this we can speculate as to the probability of a material becoming a contaminant of water.

Now, finally, let us address ourselves to the question, "Can pesticides be used safely?" The answer is that they can be, but this requires both proper chemical and proper application.

Let me illustrate the proper choice of a chemical by one example. Down at Clear Lake in California there was a problem with a particularly annoying insect. The biologists, charged with eliminating the nuisance, selected a chlorinated hydrocarbon insecticide of very low mammalian toxicity with which to treat the lake. The insect control was highly successful, but the other organisms in the lake concentrated the chemical in their bodies. As these organisms served as food for fish, toxic levels of chemical appeared in the fish, and, when the fish, in turn, were consumed by the Western Grebe, many of these fine birds were killed. Control of the insect was still needed, but the danger to other organisms could not be tolerated. The answer to the problem lay in selecting another chemical which, while effective on the insect, would afford no danger to the other organisms. A team of scientists studying the problem came up with such a compound in one of the organic phosphates. This compound had the advantage of high toxicity to the insect and rapid breakdown, thus offering no opportunity of toxicity to the rest of the biota. In this example we can see that chemicals can be used safely by intelligent application of the knowledge available to us. Numerous other instances where application of our scientific knowledge will enable us to make a choice of chemicals that will afford less hazard to our resources may be found, water or other resources.

It is appropriate in closing to remark that pest control, by whatever means, is afterall aimed toward the benefit of man. In the final analysis it is the manipulation of the ecology to favor man's desires. We can manipulate with chemicals as we have been doing; we can manipulate it by the introduction of a pathogen, a parasite, or a predator for the organism we wish to control, or we can manipulate this ecology by varying crop rotation, culture, etc. The temptation is strong for workers in any one of these fields, whether biologists or chemists, that the first line of defense against these pests is the
particular method of his specialty. Such an assertion is error; there is no single first line of defense. Rather, man must use all of his ingenuity to manipulate his environment to produce his food and preserve his resources. He cannot afford the luxury of impetuous and ill-advised action that would curtail production of food for the world's starving masses nor befoul his essential water resources. Intelligent and resourceful action will preclude both disasters.
Comparative Importance of Infectious and Chemical Agents in Water Quality Control

1. While such factors as pH, hardness, opacity, biological oxygen demand, tastes and odors may have important implications for commercial, industrial, and agricultural uses as well as for human nutrition; the factors of overriding importance in water quality control for all waters likely to be used directly by man should be the presence or absence of chemicals, bacteria, protozoa or viruses in a concentration which endangers or enhances human health or nutrition.

Examples: One single water-borne outbreak of typhoid in a United States town of 8,000 produced over 1,000 cases of typhoid and 114 deaths. Reference 1(a). Adding a nutritionally adequate amount of fluoride ion to the Portland, Oregon City water supply could have saved the Portland residents upwards of $3,000,000.00 during the past 20 years. Reference 5.

2. While a great deal is understood and much has been accomplished in water quality control relating to the prevention of disease associated with the presence of pathogenic microorganisms and toxic chemicals, the improvement of human health and prevention of disease through control of the presence of trace elements important to human health is only in the beginning stages of investigation. References 1, 2, and 4.

Bacterial Contamination

1. Asiatic cholera is an acute diarrheal disease caused by ingestion of Vibrio Comma—the etiologic agent. In 1854, even before Vibrio Comma had been identified as the causative agent, John Snow investigated an outbreak in a London, England parish of about 36,000
population. In this outbreak, over 700 deaths occurred. Snow was able to demonstrate the cause of the epidemic as contamination of a public water supply (the Broad Street pump - drawing water from a 28' brick and mortar-lined dug well) by a defective private home cesspool which drained into the supply. Although cholera has been absent from the U.S.A. for many years, the disease is still endemic and intermittently epidemic in the Orient. The disease has a high mortality. With the speed of modern transportation, it could be easily reintroduced here. References 1(b) and 9(a).

2. Typhoid fever is an acute, prolonged fever caused by ingestion of the rod-shaped bacillus Salmonella typhi. Human cases and carriers spread the disease through contamination of food and water. Water quality control and proper disposal of sewage have done much to reduce the incidence of this disease in the U.S. since the time of the Plymouth, Pennsylvania outbreak in 1908 (referred to earlier). Thirty-nine U.S. waterborne outbreaks of typhoid involving 506 cases were reported to the U.S. Public Health Service from 1946-1960. Illustrative of these was the Milton-Freewater, Oregon outbreak of 6 cases of typhoid fever. In this 1960 outbreak the town's public water supply became the vehicle of spread when feces of a human typhoid carrier contaminated the City water through a broken municipal sewer line in proximity of a defective well used as an auxiliary source of the city water supply.

A 1959 typhoid fever outbreak of 14 cases and 1 death in Keene, New Hampshire was traced to contamination of surface water in the municipal watershed by feces of a human case. The municipal water was protected only by filtration. This outbreak emphasizes the importance of protecting watersheds from contamination by humans. References 2 and 3.

3. Bacillary Dysentery is an acute diarrheal disease caused by various bacilli of the Shigella group such as Shigella sonnei, Shigella flexneri, and Shigella dysenteriae. It is usually not a serious disease except for infants and debilitated persons; however, it is a highly prevalent illness still too frequently spread through contaminated water. Oregon had an outbreak of 34 cases at a summer resort in 1953 associated with contamination of a surface water supply due to overflow from a plugged septic tank drain line and inadequate manual chlorination of this semi public water supply. Since many of the bacillary dysentery outbreaks are mild and the causative organisms somewhat difficult to culture, it is probable that this disease is grossly underreported. Reference, unpublished reports of the OSBH.

4. The number of less common bacterial pathogens to be spread through water supplies is large but the number of cases produced appears to be relatively small.
Tularemia is a systemic febrile disease caused by the microorganism Pasteurella tularense. It is more commonly spread through manual contact with infected wild rodents or by the bites of mosquitoes, deerflies, and ticks. Nevertheless, Pasteurella tularense has been recovered from presumably pure surface water supplies and two human cases in Klamath County, Oregon in 1958 were traced to a poorly constructed dug well contaminated by infected wild rodents. Reference 10.

Leptospirosis is a systemic febrile disease of man due to infection with any of several species of leptospires such as Leptospira pomona, L. icterohemorrhagiae, and L. canicola. Contamination of domestic water sources with leptospira is probably common since the urine of infected wild rodents (especially rats) and domestic animals such as dogs, cattle and hogs, not infrequently enter these water sources and the presence of leptospira in such surface water supplies has been demonstrated. Human cases due to ingestion of such contaminated waters probably occur but rarely, due to the fact that the acidity of the human stomach is lethal to leptospira. A number of outbreaks associated with swimming in such contaminated water have been reported. Reference 12.

An interesting but apparently rare acquisition of skin tuberculosis through an abrasion contaminated with tubercle bacilli (Mycobacterium tuberculosis) in a public swimming pool was documented in British Columbia several years ago. Such an incident—although isolated—makes one wonder if it may be possible to contract pulmonary tuberculosis through swimming in contaminated swimming pool waters. Such possibilities remind us of the value of filtration and chlorination of public swimming pool waters.

Although it is well known that gastrointestinal disorders may be produced by a wide variety of species of Salmonella bacteria other than the typhoid bacillus and such pathogenic bacteria have been isolated from public waters used for drinking and swimming in New Mexico, it is unlikely that water is a significant source of human Salmonella infections. This is due to the fact that (in contrast to the typhoid bacillus which may produce human infections when only a few bacilli are ingested) human Salmonellosis infections usually do not occur unless a large number of the salmonellae are ingested. It usually requires multiplication of the organisms (as in food-borne outbreaks) for infection to take place. Reference 6.

Attention should be called to the fact that large numbers of cases of human gastroenteritis seem to be associated with the ingestion of waters grossly contaminated with non-specific bacteria (or perhaps viruses) of fecal origin. Reference 7.
Contamination with Protozoa

1. Amoebic dysentery is an acute or chronic, intestinal or systemic disease due to ingestion of the protozoon Entamoeba histolytica. While other protozoa may occasionally be implicated in human infections, the outstanding example of this class of water-borne diseases is the 1933 Chicago outbreak. In this outbreak over 700 clinical cases of amoebic dysentery in 206 cities were traced to two Chicago Hotels where cross connections permitted sewage to contaminate the hotel water supply. Although local cross connections were responsible for this outbreak, it is important to know that chlorination of public water supplies is not an effective measure to prevent Amoebic dysentery. The cysts of Entamoeba histolytica are resistant to usual chlorine concentrations. Coagulation and filtration is a much more effective measure against the spread of this disease. References 9(b), 13, and 14.

Weibel et al (Reference 2) listed only two outbreaks of Amebiasis in their review of 228 reported water-borne outbreaks in the United States from 1946 to 1960. One of these was instructive in that it incriminated the mode of spread as a leaky factory water main which passed through a sewer manhole while under negative pressure. Reference 19.

2. Contamination with other protozoa — As in the case of amebiasis, diseases associated with other intestinal protozoa such as Giardia lamblia and Balantidium coli, have infrequently been recognized in water-borne outbreaks.

Contamination with Animal Parasites

Cercarial dermatitis or "Swimmer's itch" is a comparatively common nuisance disease contracted by swimmers in certain natural bathing places (chiefly fresh water lakes) of North America. The Schistosome responsible for this mild skin irritation (similar to the skin irritation caused by nettles or a mild case of poison oak) is related to but a different parasite from the one causing the more serious systemic old-world Schistosomiasis. The parasite causing "swimmer's itch" in Oregon has a complicated life cycle involving ducks and snails so occurs only in natural bodies of water and is not a problem in artificial swimming pools or domestic water supplies. Reference 11.

Contamination with Viruses

The subject of waterborne viral diseases is of unusual interest because of the evidence that at least some viruses are resistant to the common methods of filtration and chlorination used for protection of domestic water supplies. Reference 15 and 16.
1. Infectious Hepatitis — This is a common systemic disease prominently affecting the liver. It is believed to be caused by one or more filterable viruses. Although perhaps most commonly spread by some form of personal contact, there is ample evidence that water-borne outbreaks of this disease occur quite frequently.

For example, in a preliminary listing of water-borne outbreaks of disease reported in the United States during 1961, five of eleven listed were outbreaks of infectious hepatitis. Oregon has had several outbreaks of this disease associated with contaminated drinking water. One outbreak (in 1949 at Glide, Oregon) involved 125 cases associated with a public school well which was cross connected with a semi public supply serving private residences adjacent to the school and subject to contamination from both raw water from the North Umpqua River and an unprotected private dug well.

A recent outbreak involving more than 40 cases occurred in connection with a bowling alley in Marion County, Oregon during 1961. Epidemiological evidence indicated that a drilled well supplying the bowling alley had become contaminated with the excreta of a case through a septic tank disposal system in proximity to the well. Reference 17.

Perhaps the largest and most instructive outbreak of water-borne Infectious Hepatitis occurred in Delhi, India during November 1955 to January 1956. Over 29,000 cases with frank jaundice occurred in this city of 1,600,000 population which had a modern water treatment plant including filtration and chlorination. This outbreak was so well investigated and instructive that it would be very worthwhile to read the reports on it (References 8(a) and (b)). Suffice it to say here that a flood changed the course of a river used for the city water supply so that sewage normally discharging 700 feet downstream from the municipal water intake reversed its flow and entered the city water intake. Filtration and chlorination of the city supply was apparently adequate to prevent an outbreak of bacterial or parasitic infections, but did not prevent the water-borne spread of hepatitis.

2. Other Viral Infections — Although poliovirus has been recovered repeatedly from raw sewage, there is comparatively little evidence that water-borne outbreaks of poliomyelitis with paralysis occur. A number of outbreaks have been described in which pharyngoconjunctival fever (due to one or more strains of adenovirus) have been associated with public swimming pools and bathing places. One probable epidemic of this type occurred in association with a Roseburg, Oregon public swimming pool. Type 3 adenovirus, colon bacilli, typhoid bacilli, and bacillary dysentery bacilli are probably all destroyed in water at 25° C
and pH 7.0 with free chlorine of 0.2 parts per million in 10 minutes or less. Thirty minutes contact time with 1.80 parts per million of chlo-ramines was required under similar conditions to destroy Type 3 ade-noviruses, colon bacilli, typhoid bacilli and Shigella bacilli. Some other viruses such as infectious hepatitis virus appear to be more resistant. References 18, 15, and 16.

Toxic and Nutritive Qualities of Chemicals in Water

Only 3 of Weibel's list of 228 water-borne disease outbreaks known to have occurred in the United States during the 15 year period 1946-1960 were attributed to toxic chemicals. Two of these were of arsenic poisoning and the other from copper. All were associated with private water supplies. In spite of the rarity of such reports, the possibility of toxicity from chemicals naturally occurring or introduced into drinking water should receive some attention.

1. Toxicity — It is well known that fluoride ion in excess of 2-4 parts per million in domestic drinking water may be responsible for disfigured teeth (dental fluorosis).

Arsenic poisoning may occur either from naturally occurring ground water or be accidentally or intentionally introduced into water supplies. The U. S. Public Health Service has set 0.05 parts per million as the maximum allowable concentration of arsenic in drinking water supplies. In an unpublished study by Goldblatt et al from the Lane County (Oregon) Public Health Department, naturally occurring arsenic was found in about 30 wells tested in concentrations ranging from 0.0004 to 1.63 parts per million. Most of these were properly protected drilled and cased wells with depths of 60 to 245 feet. Since chronic arsenic poisoning is very difficult to recognize by medical examination and since natural waters containing excessive amounts of arsenic have been demonstrated in this state, care should be observed in choosing water sources which do not contain excessive amounts of this toxic chemical.

It has also been demonstrated that otherwise potable water may be contaminated with toxic quantities of copper and lead by passage of the water through copper and lead pipes under certain conditions. Obviously surface water may also become contaminated with these minerals from the use of insecticidal and fungicidal sprays used in proximity to water sources or from industrial plants.

Nitrates and nitrites in naturally occurring waters have been identified as the cause of methemoglobinemia in infants. This is a type
of poisoning in which the normal hemoglobin (red coloring matter) of the blood is converted to methemoglobin—a stable compound which cannot carry oxygen to the tissues. Fatal cases of this illness due to ingestion of water containing nitrates in excess of maximum allowable concentrations have been described in a number of areas in the United States.

Fluorides, nitrates, copper, arsenic and lead by no means exhaust the list of toxic chemicals which may occur naturally or be artificially introduced into public water supplies, but are cited as examples of the variety of problems of chemical hazards which may arise in connection with water quality control. We should not leave this subject without brief reference to the subject of biological warfare. The subject of the intentional introduction of such substances as botulinus toxin (a biological poison produced by the anaerobic growth of the bacterium Clostridium botulinum) is one which is outside the scope of this discussion. Nevertheless, it reminds us that we have to guard against intentional as well as accidental contamination of public water supplies. Radioactive elements in water is another aspect of importance which I am not qualified to discuss.

2. Nutritive Qualities of Chemical in Water — The best known example of the value of certain chemicals in water supplies for human nutrition—namely the value of 1.0 part per million of fluoride ion in preventing dental decay was referred to earlier in this paper. Very little is known about the importance of other chemicals in naturally occurring waters to human nutrition.

Iodine in trace quantities is known to protect against endemic goiter (enlargement of the thyroid gland in the neck).

Studies should be conducted to determine the importance of other naturally occurring chemicals in water as there is evidence to suggest that several may have equally or more important effects on human nutrition as do iodine and fluorides. Reference 4.
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Material presented at this session was based on the article "Stream Life and the Pollution Environment" by ALFRED F. BARTSCH and WILLIAM M. INGRAM. That article is reproduced on the following pages with the permission of W. A. Hardenbergh, Editor, Public Works Publications, Ridgewood, New Jersey.
INCREASED field investigations over the past 10 years, directed toward the abatement of pollution, have prompted this pictorial presentation to show the impact of pollution upon the stream environment and in turn upon the stream life, or biota. The illustrations were developed initially for use in training sanitary engineers and supporting scientists at the U. S. Public Health Service's Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio.

To show schematically the effects of pollution on biota, raw domestic sewage has been chosen as the pollutant. With such a waste, the lowering of dissolved oxygen and formation of sludge deposits are the most commonly seen of the environmental alterations that damage aquatic biota. Fish and the organisms they feed on may be replaced by a dominating horde of animals such as mosquito wrigglers, bloodworms, sludge worms, ratted maggots and leeches. Black-colored gelatinous algae may cover the sludge and, as both rot, foul odors emerge from the water and paint on nearby houses may be discolored. Such an assemblage of abnormal stream life urges communities not to condone or ignore pollution, but to abate it without delay. This biotic picture emphasizes that pollution is just as effective as drought in reducing the utility of a valuable water resource. They help to make clear that pollution abatement is a vital key to the over-all problem of augmenting and conserving waters of this land.

No two streams are ever exactly alike. In their individualism streams differ from each other in the details of response to the indignity of pollution. In the following paragraphs, and in the charts they describe, the hypothetical stream is made to conform exactly to theory, showing precisely how an idealized stream and its biota should react in a perfect system. In reality, of course, no stream will be exactly like this although the principles shown can be applied with judgment to actual problems that may be encountered.

ASSUMED CONDITIONS

The stage for discussion is set in Figure 1. The horizontal axis represents the direction and distance of flow of the stream from left to right. Time and distance of flow downstream are shown in days and also in miles. The vertical scale of quantity—or more accurately, concentration—expressed in parts per million, applies to dissolved oxygen and biochemical oxygen demand at distances upstream and downstream from the origin of the sewage discharge, which is identified as point zero. Here, raw domestic sewage from a sewered community of 40,000 people flows to the stream. The volume flow in the stream is 100 cubic feet per second, complete mixing is assumed, and the water temperature is 25°C. Under these conditions the dissolved oxygen (D.O.) sag curve reaches a low point after two and one-quarter days of flow and then rises again toward a restoration similar to that of upstream, unpolluted water.

The biochemical oxygen demand (BOD) curve is low in upstream, unpolluted water, increases at point 0 from the great charge of sewage and gradually decreases from this point downstream to a condition suggestive of unpolluted water. BOD and D.O. are so interrelated that the dissolved oxygen concentration is low where BOD is high, and the converse also is true. Green represents clean water; orange, a zone of degradation; red, a zone of active decomposition; and blue, a zone of recovery.
EFFECT OF REAERATION

Figure 2 represents an interpretation of the two principal antagonistic factors that have to do with the shape of the D.O. sag curve. The biochemical and other forces that tend to exhaust D.O. supplies, called collectively the process of deoxygenation, would reduce such resources to zero in about a day and one-half if there were no factors in operation that could restore oxygen to water. The river reach where D.O. would be completely gone would occur about 18 miles downstream from the point of discharge of sewage from the municipality. However, with reaeration factors at work, there is appreciable compensation for deoxygenation, and in this way the actual contour of the oxygen sag curve is determined. Thus, the low point of the curve is not attained at one and one-half days of flow at mile 18 with a zero D.O., but in reality is reached at about two and one-quarter days of flow at about mile 27. The D.O. here does not go to zero, but to 1.5 ppm.

If the population of the city remains fairly uniform throughout the year, and the flow is relatively constant, the low point of the D.O. sag curve can be expected to move up or down the stream with fluctuations in temperature. In winter, one can expect to find the low point farther downstream than shown. In other seasons, if temperatures exceed the 25°C upon which the charts are based, D.O. will be depleted more rapidly and drastically with the low point farther upstream.

The reach of any stream where the D.O. sag curve attains its low point obviously is the stream environment poorest in D.O. resources. It represents a place where aquatic life that may need a high D.O. can suffocate or from which such life may move to other stream areas where the D.O. resources are greater.

EFFECT OF LIGHT

The upper graph of Figure 3 illustrates fluctuations of dissolved oxygen that may occur over a 24-hour period at a single point in a stream with average density of aquatic greenery such as planktonic algae or larger submerged plants. For sake of explanation, any point in the recovery zone would exhibit such diurnal D.O. variations. The lower graph shows only linear changes in D.O., and gives no indication of the daily variation in availability of this vital gas that may occur at any single selected point.

If this selected point is in the recovery zone at mile 72, one can see from Figure 3 that D.O. varies from a low of about 80 percent saturation at 2:00 a.m. to about 140 percent at 2:00 p.m. Diurnal variation such as this is a result of photosynthesis chiefly in algae but in other plants also. During daylight hours these plants give off oxygen into the water in such large quantities that if the organic wastes are not sufficient to use up much of the D.O. in oxidizing sewage, the water commonly becomes supersaturated at some time during daylight hours. In addition to giving off oxygen, the photosynthetic process results in the manufacture of sugar to serve as the base from which flows the nutritional support for all stream life. The process of photosynthesis can be illustrated schematically as:

$$6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$$

This action proceeds through the interaction of the green pigment, chlorophyll, contained in living plant matter, of sunlight, carbon dioxide, and even water to form the raw materials into a simple sugar and surplus oxygen.

While photosynthesis occurs, so also does respiration which proceeds 24 hours on end irrespective of il-
lumination. In this well-known process O₃ is taken in and CO₂ is given off. The algae, during daylight may yield an excess of oxygen over and above their respiratory needs, the needs of other aquatic life, and the needs for the satisfaction of any biochemical oxygen demand. Under these conditions, surplus oxygen may be lost to the atmosphere. During hours of darkness photosynthesis does not occur and gradually, the surplus D.0. that was present is used up or reduced by algae, fish, various insects, clams, snails and other aquatic life in respiration, and by bacteria in satisfaction of the BOD. That is why oxygen resources are poorest during early morning hours. During hours of darkness, a stream is typically dependent on physical reaeration for its oxygen resources after exhaustion of the “bank of dissolved oxygen”, that was elevated to supersaturation levels by aquatic plants.

Obviously, on stream sanitary surveys where organic wastes such as domestic sewage are pollutants, it is important to sample each station over 24 hours at intervals that are appropriate to reveal information on diurnal D.0. variations. If this is not done and station 1 is sampled consistently around 8:00 a.m. and station 6 around 5:00 p.m. over a weekly or a monthly survey, critical D.0. concentrations will not be found. If interval sampling over 24 hours cannot be done because of workday restrictions, reversing the time of sampling from the upstream to the downstream station on alternate days will at least show variations of D.0. that one can expect through an 8-hour workday.

EFFECT OF ORGANIC MATTER

The bottom graph of Figure 4 illustrates reasons for the decrease in the BOD curve progressively downstream and offers an explanation for the depression in the oxygen sag curve. On this graph there has been superimposed, in white, the shape of the log curve of bacterial growth rate. Accelerated bacterial growth rate is a response to rich food supplies in the domestic raw sewage. During rapid utilization of food, bacterial reproduction is at an optimum, and utilization of D.0. becomes fairly proportional to the rate of food oxidation.

The upper graph illustrates, in principle, the progressive downstream changes in nitrogen from the organic form to the nitrate form. It demonstrates the initial high consumption of oxygen by bacteria that are feeding on proteinaceous compounds available in upstream waters in freshly discharged domestic sewage. With fewer and fewer of these compounds left in downstream waters, the BOD becomes reduced and the D.0. increases. Fat and carbohydrate foodstuffs rather than proteins could have been chosen just as well to show this phenomenon.

The nitrogen and phosphorus in sewage proteins can cause special problems in some receiving waters. Experience has shown that increasing the amount of these elements in water can create conditions especially favorable for growing green plants. In free flowing, clear, pebble brooks they appear as green velvet coatings on the stones or as lengthy streamers waving gently in the current. They are not unattractive and even, in the poetry of Nature, are complimented by the name “mermaid’s tresses”. These plants are not like the troublesome ones which occur mostly in more sluggish streams, impoundments or lakes, especially when they are artificially fertilized by sewage. In the clean brook, they not only are attractive and natural to see, but also they are a miniature jungle in which animals of many kinds prey upon each other with the survivors growing to become eventual fish food.

In more quiet waters, the algal nutrients in sewage are picked up for growth by less desirable kinds of algae. With great supplies of nitrogen and phosphorus made available, free-floating, minute blue-green algae increase explosively to make the water pea soup green, smelly and unattractive. In some unfortunate localities, nuisance blooms of algae have become so objectionable that waterfront dwellers have had to forsake their homes and see their property depreciate in value. The problem has been studied at a number of localities, and some studies are still in progress. Special legislation has even been formulated requiring that sewage treatment plant effluents not be discharged to susceptible lakes solely because of the algal nutrients they contain. Sometimes, under conditions not well understood, some blue-green algae develop poisons capable of killing livestock, wildlife and fish. Fortunately, such occurrences are rare. It is completely clear that sewage disposal and biological responses of even such lowly plants as algae go hand-in-hand sometimes to plague the desires of man.

![Figure 4](image-url)
suspended solids is not conducive to algal production. Thus, except for slimy blue-green marginal and bottom types, algae are sparse in this reach. In order to grow well algae need sunlight, and here it cannot penetrate the water effectively. Also, floating solids that settle out of the water carry to the bottom with them floating algae that drift into the polluted zone from clean water areas upstream.

Blue-green algae that may cover marginal rocks in slippery layers and give off foul odors upon seasonal decay masquerade under the names: Phormidium, Lyngbya, and Oscillatoria. Green algae that accommodate themselves to the putrid zone of active decomposition frequently include Spirogyra and Stigeoclonium. Gonphomena and Nitellopsis are among the diatoms that are present here.

Algae begin to increase in numbers at about mile 36. Plankton, or free-floating forms, steadily become more abundant and reach their greatest numbers in algal blooms some 40 to 60 miles farther downstream. This is where reduced turbidity, a lack of settleable sewage solids, final mineralization of proteinaceous organics to nitrate-nitrogen fertilizers, and favorable oxygen relations result in an ideal environment for growth of abundant aquatic plants.

Algae that may be found abundantly here may be represented by the blue-green genera Microcystis and Anabaena; the pigmented flagellates are represented by Euglena and Pandorina; the green algae by Cladophora, Ankistodesmus, and Rhiizoclonium; and diatoms by Meridion and Cyclotella. Rooted, flowering, aquatic plants that form underwater jungles here are represented by the "water pest", Elodea, and various species of pond weeds known as Potamogeton. Such aquatic forests and meadows present an excellent natural food supply for the aquatic animals, and also serve them with shelter. Thus, commonly as plants respond downstream in developing a diversified population in the recovery and clean water zones, animals follow a parallel development with a great variety of species. In such reaches where the stream consists of numerous alternating riffles and pools, a great variety of fish are likely to occur.

In the reach where algae are scarce, from about mile 0 to mile 36, various moulds and bacteria are the dominant aquatic plants. Sphaerotilus filaments may abound in riffle areas at about mile 36 where physical attachment surfaces are available and where oxygen, although low, is adequate. Bacterial slimes may cover rocks and other submerged objects and bank margins. Such slimes have an abundant supply of available food in readily usable form of carbohydrates, proteins and fats and their digestion products. They are not bothered especially by high turbidities or by settleable solids. They do well living in the center of sludge or near it, in what to them is an "apple-pie" environment.

**BACTERIA AND THE CILIATES**

Associated with the bacterial slimes are certain ciliated protozoans that feed on bacteria and engulf small particles of settleable organic matter. Such ciliates are also found in aeration tanks of sewage treatment installations as a component of activated sludge and on the surface of rock in trickling filter beds. Common ones are Epistilis, Vorticella, Colpidium, and Stentor. Figure 6 illustrates the interrelations between bacteria and animal plankton, such as ciliated protozoans, rotifers and crustaceans. The quantities shown and the die-off curves for sewage bacteria in toto and for coliform bacteria separately
are theoretically accurate. The blue curve for ciliated protozoans and the green curve representing rotifers and crustaceans are more accurate in principle than in actual quantities.

After entering the stream as a part of the sewage, bacteria, including coliforms, reproduce to become abundant in an ideal environment. Here they feed on the rich organic matter of sewage and by multiplying rapidly offer a ready food supply for ciliated protozoans which are initially few in number. After about a day of flow the bacteria may be reduced through natural die-off and from the predatory feeding by protozoans. After about two days of flow, the stream environment becomes more ideal for the ciliates, and they form the dominant group of animal plankton. After seven days, the ciliates fall victim to rotifers and crustaceans which represent the principal microscopic animal life in the stream.

It has been long suspected that the efficiency of this sewage-consuming biological machine depends upon a close-knit savage society in which one kind of organism captures and eats another. Classical research of some time past showed that a single kind of bacterium mixed with sewage in a bottle could not do an efficient or rapid job of breaking down the sewage. Several kinds could do a better job, supposedly because one bacterial type, in acting upon parts of the sewage as food, prepared it for acceptance by another. With several bacteria a multilateral attack was made possible. But even a system like this is inefficient. Bacteria work best only when they are growing rapidly and they do this when they multiply frequently by splitting into two. It is important then that they not be permitted to attain a stable high and lazy population. In the bottle the task of stabilizing sewage goes most rapidly when ferocious bacteria-eating ciliates are introduced to keep the population at a low and rapidly growing state.

These relations between the bacteria eaters and their prey, discovered in the bottle, apply as well to efficient functioning of a modern sewage treatment plant. In some sewage treatment plants, examination is made routinely to see how the battle lines are drawn up between the bacteria eaters and their prey. It now becomes more obvious why sewage disappears so efficiently from the stream. It also is clear why the bacteria, the ciliates, the rotifers and the crustaceans increase, persist for awhile, and then decrease along the course of passage of the stream.

**THE HIGHER FORMS**

Figure 7 illustrates the types of organisms and the numbers of each type likely to occur along the course of the stream under the assumed physical conditions that were stated earlier. The green curve represents the numbers of kinds or species of organisms that are found under varying degrees of pollution. The orange curve represents the numbers of individuals of each species. In clean water above the city a great variety of organisms is found with very few of each kind repre-
sistent. At the point of waste entry the number of different species is greatly reduced, and they are replaced by a different association of aquatic life. This new association demonstrates a severe change in environment that is drastically illustrated by a change in the species make-up of the biota. However, this changed biota, represented by a few species, is accompanied by a tremendous increase in the numbers of individuals of each kind as compared with the density of population upstream.

In clean water upstream there is an association of sports fish, various minnows, caddis worms, mayflies, stoneflies, hellgrammites, and gill-breathing snails, each kind represented by a few individuals. In badly polluted zones the upstream association disappears completely or is reduced, and is replaced by a dominant animal association of rattailed maggots, sludge worms, bloodworms and a few others, represented by great numbers of individuals. When downstream conditions again resemble those of the upstream clean water zone, the clean water animal association tends to reappear and the pollution tolerant group of animals becomes suppressed. Thus, clean water associations of animals may form parameters around polluted water reaches. Such associations may be indicative that water is fit for multiple uses, while the presence of a pollution tolerant association of animals indicates that water has restricted uses.

Pollution tolerant animals are especially well adapted to life in thick sludge deposits and to conditions of low dissolved oxygen. The rattailed maggot, Eristalis tenax, is not dependent on oxygen in water. This animal shoves its “snorkel-like” telescopic air tube through the water surface film to breathe atmospheric oxygen. Thus, even in the absence of oxygen it is one of the few survivors where most animals have suffocated. Those who have worked around sewage treatment installations have probably observed the flesh or milkish colored rattailed maggot in the supernatant over sludge beds where dewatering performance was poor. Commonly associated with it in this supernatant over sludge beds are the immature stages of the well-known “sewagefly”, Psychoda, and wiggler of the sewage mosquito, Culex pipiens. The rattailed maggot turns into a black and brownish banded fly about three-quarters of an inch long, called a “bee fly” because it closely resembles a bee. It differs by having two wings instead of four and does not sting. Sludge worms, *Tubifex*, are dependent upon the dissolved oxygen in water; however, they are well adjusted to oxygen famine and commonly are found in water with as little as half a part per million. They are actually aquatic earthworms, cousins of the terrestrial earthworms found in lawns and used as fish bait. These worms feed on sludge by taking it into the digestive tract. In passing it through their alimentary canal, they remove organic matter from it, thus reducing the biochemical oxygen demand. Sludge worms one and one-half inches long and as thick as a needle have been observed to pass fecal pellets totaling five feet nine inches through the digestive tract in 24 hours. Fecal pellets that are extruded from the anal openings have on occasion been found to have a biochemical oxygen demand of one-half of that of sludge that was not “worked-over” by them. The sludge worms are then, “actually crawling BOD”, in that they incorporate sugars, proteins and fats that are present in sludge into their body cellular components. It may be difficult to visualize the magnitude of BOD removal that one worm, needle-thick in size and one and one-half inches long, can accomplish in relation to an extensive sludge deposit. However, when it is realized that from 7,000 to 14,000 of these worms may be found per square
foot of bottom surface in sludges, considerable work is done in removing BOD. By the same token, for example, wrigglers of sewage mosquitoes, Culex pipiens, that feed on the organics of sewage and emerge as adults to fly out of water represent BOD removed. In this instance it is "flying BOD" that is factually taken out of water, whereas the crawling BOD of sludge worms is not removed, but is recycled back as the worms die.

The worm-like body of organisms composing the pollution tolerant association of the rattailed maggot, sludge worms, blood worms, and leeches is an ideal type to have for successful living in sludge. As settleable solids fall to the bottom, such organisms are not trapped and buried in them to die, but by wriggling with their worm-like cylindrical bodies, manage to maintain their position near the surface of sludge in communication with the water interface. Sow-bugs that are shown in Figure 7 with the "wormy-horde" do have well-developed appendages, but their life may be marginal on stream bank areas and on the surface of rocks protruding from sludge covered bottoms. Thus, they are not buried by settleable solids.

The invertebrates shown in clean water do not form successful populations in streams where settleable solids sink to form sludge deposits. Because their appendages may become clogged with sludge as solids settle, they may be carried readily to the bottom and be buried alive.

### Population Fluctuation

Figure 8 shows that the population curve of Figure 7 is actually composed of a series of population maxima for individual species. The species form a significant pattern in reference to each other and to the varying strength of the pollutant as it decreases progressively downstream. Sludge worms such as Tubifex and Limnodrilus can better withstand pollution than other bottom invertebrates. Thus, they reach great numbers closer to the source than other bottom dwelling animals. In turn they are replaced in dominance by red midges, also called bloodworms or Chironomids, and then by aquatic sow-bugs, Asellus. The sludge worms and red midges are so numerous in contrast to the other organisms shown in Figure 8 that numbers of the latter are exaggerated 25 and 30 times to permit showing them effectively. Finally, when the effects of pollution have largely subsided in the environment, a variety of insect species represented by few individuals of each dominates the bottom habitat.

The story of pollution told here emphasizes that stream pollution and recovery may follow an orderly scheme under the influence of interacting physical, chemical and biological forces. Using streams as dumping places for sewage triggers the environmental and biotic changes that have been shown. These changes are not desirable. In most cases, in addition, they are hazardous to public health and otherwise impair the usefulness of valuable water resources. The needed remedy is to confine all of these interacting forces in an acceptable sewage treatment works so that this example of the Nation's water resources is protected for present and future use.

### Bibliography

Of the many natural resources which we enjoy here in Oregon none is more important than our public waters. This simple statement of fact has undoubtedly been repeated several times at previous sessions of this seminar. Therefore, it should hardly be necessary for me to have to present evidence to this audience to prove the truth of this statement. It would be well, however, to remind ourselves that Oregon's public waters are important not only because of their quantity but also because of their generally high quality.

Both the quantity and quality of the flow in a given river basin are to a major extent determined by the climatic characteristics and the size, nature and uses made of the watershed. Fortunately, many of our watersheds in the Pacific Northwest are still pretty much in their virgin state and, as a consequence, yield water of high quality. Some, however, through the years have been so modified by activities of man that their usefulness has been impaired. Because of this impairment, which has been due primarily to changes in quality, it has been necessary in recent years to give increased attention to improving the management of our watersheds.

The importance of clean waters has long been recognized by the people of Oregon. As early as 1889 the Oregon Legislature adopted a law declaring it illegal to pollute any public waters which are or may be used for domestic or livestock watering purposes. By statute it has for many years been the public policy of the state of Oregon to maintain reasonable standards of purity of all our inland, coastal and ground waters not only for the protection of public health but also for the recreational enjoyment of the people, the economic and industrial development of the state, the protection of property, and for the conservation of human, plant, aquatic and animal life.
Under this broad policy we have the responsibility (1) to preserve the excellent quality of water where it still exists in nature and (2) to restore and maintain the quality of water in those areas where degradation has in the past been allowed to take place. In order to carry out these responsibilities effectively it is necessary that there be a thorough understanding of the effects caused both by nature and by activities of man.

To help promote this understanding a special publication entitled "Watershed Control for Water Quality Management" was printed in April 1961 by the watershed protection committee of the Pollution Control Council of the Pacific Northwest Area. Much of the following information has been taken from this reference.

As previously indicated the physiography, geology, climate, soil formation and plant cover of a watershed are all significant factors in the determination of stream flow and water quality.

Because of their elevation the Coast and Cascade Mountain Ranges in Oregon produce a fairly high annual rainfall in the watersheds located in the western part of the state. Since most storms move inland from the Pacific Ocean the Cascade Range also causes a decrease in precipitation in the basins in the eastern part of Oregon.

West of the Cascades the bulk of the precipitation occurs from October to May. The summers usually are quite dry. During the summer the stream flows drop fairly low except in basins where the upper watersheds are high enough to produce significant snow packs in the winter. These well-known facts are presented here only to point out that although the Pacific Northwest is generally considered to be an area with an abundance of fresh water, there are certain areas which are always deficient in quantity and many others which each year experience seasonal shortages. In contrast to these area and seasonal low flows are the short period high stream flows caused by such factors as intense rainfall, rapid snow melt, steep terrain, impervious soil formations and removed plant cover.

Low stream flows aggravate the effects on water quality caused by activities of man on the watershed. High stream flows can by themselves result in impaired water quality by eroding soil and causing excessive turbidity and siltation.

A fairly wide range in water quality can be observed in different streams of the state due to the difference in geology. The Coast Range area in southern Oregon includes sandstones and other sedimentaries, metamorphic peridotite and serpentine, and shale. To the north it
includes old volcanic basalts and breccias, sandstones and conglomerates. The Cascades include a variety of volcanics. In the Columbia Plateau portion much of the windlaid material is pumice. The geology of the basin is often reflected in the amount and composition of sediment in the stream, or in the minerals in solution.

Because of their geology the majority of Oregon streams are not highly mineralized. Some of them, such as those on the west slope of the Cascades, have a very low mineral content. Certain of these latter streams may on occasion be milky white in appearance due to the natural turbidity caused by the presence of glacial flour.

One of the most important physical characteristics of a watershed is its soil formation. The erodibility of soils, their infiltration characteristics and their ability to withstand use can greatly influence water quality. Fine-grained readily eroded soils are conducive to high turbidity and siltation. Loam soils of open texture permit water to infiltrate rapidly and release it slowly to streamflow. Clay soils, on the other hand, slide easily when wet and often cause excessive turbidity and sediment loads in streams. Each type of soil may present a special problem. Their classification is necessary for proper management of land uses if water quality is to be protected.

Another very important physical characteristic of a watershed from the standpoint of water quality control is the amount and type of plant cover. In the Pacific Northwest the plant cover ranges from the dense spruce rain-forest along the coast to the sagebrush desert of the Cascades.

The rate of movement of water either across or into the ground surface is influenced greatly by the amount and type of plant cover present.

Good vegetation cover shields the soil against the beating and eroding action of intense rainfall. It also helps to maintain and improve soil infiltration capacity and permeability. Without this protection the soil surface can become puddled and sealed by the beating action of rain. The water will then run off rapidly into the stream and will erode away the upper layers of the soil as it goes. The stream flow will build up sharply to a high peak carrying with it a high load of eroded sediment. As the sediment settles out it provides a further sealing action.

Organic litter accumulations on the soil surface which develop with good plant cover also help to prevent puddling and sealing and to maintain high infiltration rates. Both on the surface and incorporated into the soil body, organic matter protects against erosion. Because of its contributions to soil structure and the protection it affords to the
soil surface, organic matter is very important to watershed management.

Plant roots penetrating the soil increase the porosity and provide additional means of temporary storage, thus helping to regulate the rate of stream flow.

In the upper watersheds plant cover is important for still another reason. It will control snow storage and melt rate thereby affecting, to a small but significant degree, both total yield and distribution of flow.

Though plant cover takes a portion of the water resource for use in its own growth, it more than makes up for this consumption by the protection which it gives the watershed. Without plant cover there is too much water at some seasons and not enough at others. Floods alternate with drought. The water that is available will often be too turbid and sediment-laden to be of beneficial use. Good plant cover serves both to regulate and to cleanse the stream flow.

Having given some consideration to the physical characteristics and the actions of nature which influence water quantity and quality, our attention should now be directed to the effects of activities of man on watersheds.

From the discussion thus far it is evident that the use that is made of the land can greatly affect the physical characteristics of the watershed. Conversion of forest land to waste or even to cropland removes the protective vegetation cover and bares the soil to erosion. Cultivation can change soil characteristics to reduce infiltration and increase runoff and erosion. Heavy grazing use on range land can compact the soil and greatly reduce infiltration in addition to removing much of the protective plant cover. Urban and industrial developments, roads and streets, all present large impervious areas that increase the amount and rate of runoff. Harvesting the timber from forest land opens the cover and affects the storage and melt rate of snow. It can also disturb the normal soil conditions, thereby causing erosion with resultant turbidity and sediment in the stream particularly during periods of heavy surface runoff. The blockading of streams by logs, brush and similar debris following careless logging operations can cause serious damage to fishery resources.

In Oregon some 30,000,000 acres, or about half of the land area, are covered with forests. They are used not only for timber production, but also for grazing by domestic stock and game animals, for mining, for important wood products industries, and for recreation. Timber
harvesting and grazing in the past have had the greatest impact on the land although forest fires have also contributed significantly to changed land conditions.

The proper conservation, development and utilization of the forestry resources are vital to the economy of the state of Oregon. It is just as vital, however, that it be controlled so that it will not interfere with the state's water resources. Unless properly conducted and managed the harvesting of timber and the production of various wood products can result in serious impairment of water quality.

The principal water pollution problems caused by lumber and wood products industries include:

(1) Excessive turbidity and siltation resulting from improper logging practices and poor location or construction of access roads in the upper watersheds.

(2) Oxygen depletion due to decomposition of the organic matter contained in pulp mill wastes, press water from hardboard production, and overflow or drainage from log ponds.

(3) Conditions toxic to fish and other aquatic life caused by discharge of certain concentrated pulp mill wastes, special preservative compounds used in the production of plywood and other wood products, and pesticides used in controlling infestation.

(4) Slime growths due to nutrients contained in pulp, hardboard and plywood mill effluents.

(5) Floating debris and bottom deposits due to pulp and insulating or hardboard wastes, hydraulic barker effluents, and to log storage and transportation.

(6) Blockading of streams by logs, brush and other debris.

Some idea of the magnitude of the pollution problem caused by this industry can be gained from the fact that presently throughout the state there are 500 or more sawmills, more than 100 plywood and veneer mills, some 9 or 10 fiberboard plants, 6 sulphite pulp mills, 1 neutral sulphite pulp mill, and 5 kraft pulp mills.

Because of the large number of logging contractors who are engaged in the harvesting of timber throughout the state, it has not been possible
for the limited staff of the state water pollution control agency, the Oregon State Sanitary Authority, to exercise close supervision over their operations. Under such circumstances it has been necessary to rely upon education and voluntary cooperation. Fortunately this approach has proved to be quite successful, particularly since 1956 when the first draft of the previously mentioned bulletin on watershed control was published by the Pollution Control Council of the Pacific Northwest Area.

Prior to that time there had been numerous cases where logging, road construction and related operations on upper watersheds had caused gross pollution in streams used as sources of public water supplies. Some of those early cases involved operations being conducted under the jurisdiction of the state and federal forestry agencies as well as by private interests. In other cases, even the cities themselves who owned and operated the water supplies did not take adequate precautions to see that their source of water was not damaged by such operations.

In recent years, however, methods have been devised for the harvesting of timber and the construction of access roads on watersheds of public water supplies so as not to cause damage to this highest of use of our water resources. In certain areas the properly conducted timber harvesting has even been beneficial rather than harmful to the public water supply use. Examples of logging operations which have been properly planned, carefully conducted and well managed include those on the Corvallis, McMinnville and Portland municipal watersheds.

In these particular operations the locations of cutting areas and road networks have been correlated so as to minimize disturbance to the terrain. Cutting boundaries, landings and spur roads are laid out in accordance with the conditions of topography, soil types, and climatic factors in order to take into account the effects of snow accumulations and melt and to handle drainage so that muddy and turbid waters are kept out of stream beds. Skid roads are never run in channels or down channel banks. Where it is not possible to lift logs across stream channels with a slack line, temporary measures such as log or metal culverts are used to prevent scouring of stream banks and excessive turbidity in the stream. Logging equipment is not used in stream beds. When logging is performed near stream channels the trees are felled uphill, and slash and debris are kept out of the watercourse. Logging debris has to be removed from stream channels with as little disturbance as possible to the stream bed and banks.

Logging roads are generally located as closely as possible on
contour with side ditches constructed to carry water to spreading areas.

Much of the forest land in Oregon is either state or federally owned. Now whenever contracts are entered into for timber harvesting the managing agencies always include provisions for adequately protecting the water resources.

In Oregon the biggest and most difficult water pollution problem associated with the forestry industry has been that caused by the liquid wastes from the pulp and paper mills. The 6 sulphite mills presently operating in the state have capacity to produce 800 tons of pulp per day. Based on oxygen demand the wastes from these 6 mills are equivalent to the raw sewage from 2,800,000 persons. The 5 existing kraft mills in the state produce an average of 2,400 tons of pulp per day with the resulting liquid wastes having a population equivalent of 420,000 persons.

The specific effects on water quality that have in the past been caused by these mills are: (1) Oxygen depletion in the South Santiam River below Lebanon and in the main Willamette River in the Portland harbor, (2) slime growths in the McKenzie River below Springfield, in the South Santiam below Lebanon, in the main Willamette below Albany and in the tidal reach below Oregon City, and in the lower Columbia River, the latter caused primarily by wastes from mills located in the state of Washington, (3) bottom deposits and resultant floating sludge rafts in the slough adjacent to Minto Island at Salem, in the South Santiam below Lebanon, and in the main Willamette below Newberg and below the Willamette falls, and (4) odor nuisances in the McKenzie River below Springfield and along the ocean front at Newport.

Pursuant to orders from the Oregon State Sanitary Authority the pulp mills since 1952 have employed special facilities or practices for disposal of their wastes in order to abate or alleviate their pollution. The 5 sulphite mills in the Willamette Basin have used impoundment, barging and concentration by evaporation for reduction of oxygen demand from their strongest pulping wastes. By these means they have effected BOD reductions during the critical stream flow months (June to October, inclusive) ranging from about 65% at 3 of them to 85% at one and to better than 90% at the other. To abate the odor and slime nuisance in the McKenzie River the kraft mill at Springfield has used recycling of process waters, improved in-plant controls and land disposal by spray irrigation. For control of odor and foam nuisances at Newport the kraft mill at Toledo has installed surface aerators for oxidation of odor producing constituents and improved detection, diversion and temporary storage facilities for handling unusually strong wastes.
Because the present facilities being used by the Willamette Basin pulp mills have not been adequate to restore and maintain the required degree of water quality in the river, these mills have recently been instructed by the State Sanitary Authority to provide additional or improved waste treatment works by not later than December 1966. Such facilities must provide for year-round removal of settleable solids and increased removal during the summer and fall seasons of their total oxygen demand. The officials of each of the companies involved are currently taking steps to comply voluntarily with these additional requirements.

Another watershed activity which can seriously impair water quality is the mining and processing of mineral resources. Included in this category is the mining and washing of sand and gravel, and the dredging or placer mining for gold and silver. Sand and gravel operations are conducted in practically every major drainage basin in the state. Unless properly conducted, they can cause excessive turbidity and siltation in downstream waters. Serious pollution of this type has in the past been caused in Bear Creek tributary to the Rogue River, in the Tualatin and Clackamas Rivers and in numerous other streams in the Willamette Basin and along the Oregon Coast. The resulting turbid conditions have been detrimental to fishing and other recreation and to domestic water usage. To prevent such pollution it is usually necessary that the mining operations not be conducted in the stream bed and that instead they be completely diked off from the stream flow. It is also necessary that the wash waters be impounded for efficient removal of settleable solids and excessive turbidity before being returned to the stream.

Placer mining which is conducted during the winter and spring months adjacent to small tributaries in the Umpqua and Rogue River basins in southern Oregon and in the John Day basin of Central Oregon have in recent years caused gross pollution in the form of excessive turbidity and siltation. Such conditions have been particularly damaging to fishing and in some cases to fish propagation.

Gold dredging operations which were formerly conducted in the Powder River basin destroyed practically all forms of aquatic life for several miles downstream. Fortunately, these operations were discontinued a few years ago and the stream conditions have again returned pretty much to normal.

Impairment of water quality can also be caused by agricultural activities such as land cultivation, irrigation, grazing, livestock feeding, and use of chemicals for fertilizer and pest or weed control. Land cultivation, if it results in soil erosion, can cause excessive turbidity and siltation.
Return irrigation waters and normal surface drainage from crop lands can add nutrients such as nitrates and phosphates which may trigger luxuriant algal growths in the downstream waters. These growths are sometimes so heavy that upon decomposition they deplete the dissolved oxygen from the river water. An example of this is the oxygen depletion in the lower waters of the Brownlee Reservoir in the Snake River. Nuisance algal growths of this type can also be caused by natural conditions as in the Upper Klamath Lake of Southern Oregon and the Owyhee Reservoir in Malheur County. In the relatively "unfertilized" Owyhee Reservoir blue-green algae populations each summer create "peasoup" conditions which occasionally are highly lethal to the resident warm water game fishes. The algal blooms which occur every summer from natural causes in Upper Klamath Lake resemble a slurry of grass clippings and on occasion have been responsible for fish kills in the downstream waters of the Klamath River.

Return irrigation flows are usually several degrees warmer than the source from which the water is drawn. This may adversely affect the water as fish habitat, or for industrial use.

The pollution caused by drainage of manure and other organic matter from livestock feeding lots can be injurious to downstream uses such as recreation, fish propagation, and domestic water supply. Locating feed lots where drainage will not reach a watercourse is usually the easiest and best solution to this problem. If this is not possible, then treatment of the drainage by means of a lagoon or other facility may be necessary.

Toxic chemicals used for weed or pest control by agricultural interests frequently find access to adjacent watercourses by accident or as the result of careless application to land. Numerous fish kills have been caused by such chemicals in Oregon during the past few years.

SUMMARY:

There are numerous activities conducted by man on watersheds which if not properly controlled or managed can greatly affect the water quality and thereby impair the use of such waters for beneficial purposes. To prevent water pollution it is therefore necessary to include proper development, conservation and utilization of the land as well as the water resources.

The watershed activities most frequently responsible for detrimentally affecting water quality in Oregon have been timber harvesting,
road and dam construction, pulp and paper production, and other wood products industries, mining and processing of mineral resources, land cultivation, irrigation, cattle grazing, livestock feeding, and use of toxic chemicals for weed and pest control.

The major forms of pollution have been excessive turbidity, siltation, organic bottom deposits, floating sludge rafts, oxygen depletion, nuisance slime and algal growths, bacterial contamination, conditions toxic to human, plant, aquatic or animal life, tastes or odors, and increased temperature.

Such pollution can impair the use of the waters for domestic or municipal purposes, for fish propagation, for recreation including fishing, swimming, water skiing and boating, for industrial purposes, for irrigation and livestock watering, can be a hazard to public health, and can be destructive to fish and other aquatic life.

Under the public policy of the state of Oregon such pollution must be prevented and controlled in order to maintain a reasonable degree of purity in all inland, coastal and ground waters.
Session 6

Radioactive Wastes

NATURE AND SOURCE OF RADIOACTIVE MATERIALS

Natural Radioisotopes

Of the 93 naturally occurring elements, 29 have radioactive isotopes that are found in nature (e.g., radioisotopes that existed before man began to produce them). Most of the natural radioisotopes (there are about 70 of them), occur among the heavy elements and are parts of a series of changes that atoms of U$^{238}$, Th$^{232}$, and U$^{235}$ undergo before they eventually become stable Pb$^{206}$, Pb$^{208}$, or Pb$^{207}$ respectively. Perhaps the best known of these isotopes has been Ra$^{226}$. A few radioisotopes also occur naturally among the lighter elements, and these include K$^{40}$ and C$^{14}$.

The natural radioisotope most often analyzed for in fresh water is Ra$^{226}$, and the amounts present reflect the Ra$^{226}$ content of the ore present in the watershed. In the United States, the highest concentrations reported are for Joliet, Illinois at \( \sim 6 \times 10^{-9} \) ppm. The surface of the Portland, Oregon area has a Ra$^{226}$ content of about \( 10^{-11} \) ppm, which is near the low for the United States.

Measurement of such small quantities by conventional chemical methods is, of course, impractical, but can be accomplished by detection of the radiation given off when the Ra$^{226}$ atoms change into atoms of Rn$^{222}$ (radon) (also radioactive). A concentration of \( 10^{-11} \) ppm of Ra$^{226}$ has about \( 2.6 \times 10^{7} \) atoms per liter, and about one of these \( 2.6 \times 10^{7} \) atoms disintegrates (changes) to Rn$^{222}$ each hour. In 1,620 years only half of the original \( 2.6 \times 10^{7} \) atoms remain (the "half-life" of Ra$^{222}$ is 1,620 years).

The unit used to measure the number of atoms that "disintegrate"
in a given interval of time is the "Curie". One curie = 2.2 \times 10^{12} disintegrations per minute. It was originally based on the disintegration rate of one gram of Ra\textsuperscript{226}.

Samples of natural water or biological material will contain only a very small fraction of the amount of radioactive material necessary for a curie, and it is more conventional to speak in terms of microcuries ($\mu$Ci) ($10^{-6}$ curie) or picocuries (pCi) ($10^{-12}$ curie). A picocurie means a disintegration rate of only 2.2 atoms per minute and can be measured only on high quality instruments that effectively exclude extraneous radiation from other "background" sources.

The "Curie" (disintegration rate) tells very little about the radioactive material present. A relatively large amount (1 gram) of Ra\textsuperscript{226} is necessary to produce one curie and some of the Ra\textsuperscript{226} atoms present initially are still present after several thousand years. On the other hand, At\textsuperscript{218} (another radioisotope of the U\textsuperscript{238} series) is very unstable, as evidenced by its half-life of two seconds, and the amount necessary to produce one curie has essentially all disappeared in less than one minute. Further, the curie tells nothing about the amount of energy released when the atoms disintegrate. This energy is a most important parameter in amount of radiation dose received by living organisms (or any material) in the vicinity, and thus, the potential biological effect.

The potassium found in nature contains about 0.01% of the radioisotope K\textsuperscript{40}, which has a half-life of 1.3 \times 10^9 years. Each gram of potassium has enough K\textsuperscript{40} to produce 1,900 disintegrations per minute or about $10^{-3}$ $\mu$Ci. A man of average size contains in his body about 130 grams of K and thus about 0.1 $\mu$Ci of K\textsuperscript{40}. Aquatic life, as well as all other life forms, contain K\textsuperscript{40} which delivers a major fraction of the "background" radiation they receive, and most of the "background" count when samples are measured for their content of radioactive materials.

**Man-Made Radioisotopes**

The discovery (in 1938) that U\textsuperscript{235} could be split (fissioned) when bombarded with neutrons, with the release of vast amounts of energy, led to the atomic bomb and to the technology of atomic power production. These techniques increased the potential for radioactive materials in streams because:

1. The demand for natural uranium to provide the basic fissionable material resulted in the establishment of mills to process
uranium ore. Such ore contains Ra and other natural radioactive materials associated with uranium ore, and these natural radionuclides may be leached from the tailing piles of the mills into nearby creeks or rivers.

2. When the \( \text{U}^{235} \) fissions (either in an atomic bomb or in a reactor) the resulting "fission products" are radioactive — most of them are "artificial" radioisotopes because they did not previously exist in nature. These fission products (which include such radionuclides as Sr\(^90\), Cs\(^{137}\), and I\(^{131}\)) can enter streams from:

a. Fallout from bomb debris in the atmosphere.

b. Liquid effluents from atomic energy facilities that process uranium (or other materials) that have undergone fission.

c. Ground water that seeps into streams from underground facilities used to dispose of liquid wastes that contain fission products.

3. When \( \text{U}^{235} \) (and some other nuclides) fission, neutrons are released that strike other nearby materials and (if the neutron is captured) these "target" materials are transformed into radioisotopes. These "neutron activation products" are also, for the most part, radionuclides that never before existed in nature. They include such things as Zn\(^{65}\), Co\(^{60}\), P\(^{32}\), U\(^{239}\). (The Hanford plants were built to produce a new fissionable material — plutonium-239. Ordinary U\(^{238}\) is "neutron activated" to U\(^{239}\) in the reactors. The U\(^{238}\) rather quickly decays to Np\(^{239}\), and then to Pu\(^{239}\). The Pu\(^{239}\) is separated from unused uranium and fission product debris in chemical processing plants. The purified Pu\(^{239}\) can be used as weapons material or reactor fuel in the same way as the fissionable U\(^{235}\).)

Neutron activation products are formed in the cooling water of reactors. In the case of the old Hanford reactors, the cooling water is sent directly to the Columbia River. In power reactors of contemporary design, the coolant is used to make steam and is recirculated, so that there is no direct release of the activation products to rivers.

Neutron activation products are also formed when atomic devices are exploded because neutrons strike the materials that contain the device, or the ground or sea. The fish of the Pacific Test Area have been found to contain greater quantities of activation products, especially Zn\(^{65}\), than fission products.
4. The production of radionuclides in reactors, either as fission products or as neutron activation products, created a supply of these materials that could be used by industry, hospitals, or research workers in both the physical and life sciences. Some small fraction of the material supplied to the users eventually becomes waste and some of the waste may enter surface waters via sewers or packages disposed to sea.

RELATIVE AMOUNTS OF RADIOACTIVE WASTES AND THEIR CONTROL

High-Level Wastes

By far the greatest amount of radioactive waste results when the spent fuel elements from reactors are dissolved at the chemical plants in order to recover the unused uranium or the newly created plutonium. Here, the fission products are separated from the materials to be recovered and are sent to large underground storage tanks. Millions of gallons containing billions of curies of fission products are now contained in such tanks.

Great care is taken to assure that the high-level wastes stored in the tanks does not get into the environment (e.g., leak out into the ground and reach the water table). Several methods for converting the liquids now sent to tanks into solids that can be stored in isolated spots (such as salt mines) are now in the pilot plant stage. No one is considering the disposal of this high-level waste to the environment.

Intermediate-Level Wastes

Although most of the fission products can be concentrated into high-level wastes and stored, it is impractical to "purify" all of the aqueous process streams to a point where no radioactive atoms can be measured. For example, the condensates from the evaporation of high-level waste still contain significant concentrations of radionuclides. These "intermediate" wastes are usually sent to pits (that are covered) from which the liquids gradually seep into the ground. Most of the radioactive materials are retained by fixation on the soil minerals. Careful watch is maintained and, if long-lived radioactive material begins to break through into the ground water, the site is abandoned. At major atomic energy sites, the volume going to such pits each day may amount to hundreds of thousands of gallons containing tens of curies. If such pits are not favorably located in respect to the ground water and nearby streams or lakes, they can be the most significant source of radioactive materials to surface waters. Such pits are not characteristic of the waste systems of contemporary power reactors.
Low-Level Wastes

Large volumes of cooling water are used by atomic reactors and fuel processing plants. Because of the large volumes (millions of gallons per day) the effluent streams must usually be returned directly to the river or lake from which they were drawn. These main coolant streams ordinarily remain uncontaminated but prior to discharge they may receive small amounts of "low-level" wastes from floor drains, "bleed lines", or other minor sources. For contemporary power reactors the radioactive material amounts to, at most, a few curies per year. (The Hanford reactors, with a single pass cooling system, are a notable exception.)

The cooling water effluent from power-producing reactors is apt to be the type of radioactive waste that will most often come to the attention of biologists and pollution control officers in the next several years. Such cooling waters will undoubtedly contain trace amounts of activation products, but the concentrations will be so small that identification, or even detection will be difficult.

The effluent water from the Hanford reactors contains a variety of neutron activated radioisotopes that are created in the cooling water as it passes directly through the reactor. Most of the radioactivity present comes from very short-lived isotopes and has disappeared by the time the river flows out of the Hanford reservation. Some radioisotopes do have half-lives that are long enough so that they can still be detected at the mouth of the river, however. The dominant ones are Cr$^{51}$, P$^{32}$, Zn$^{65}$ and Np$^{239}$. Nowhere in the river is the concentration of radioactive materials high enough to create any health hazard to either people or aquatic life.

Other categories of "low-level" liquid waste include the solutions that are discarded from hospitals and research institutions and some water from nuclear powered ships.

EFFECTS OF RADIATION ON MAN AND AQUATIC LIFE

The Mechanism of Damage

When the radiation given off by radionuclides (or by x-ray machines or other sources of ionizing radiation) strikes living tissue, much of the energy is dissipated in reaction that produces radicals and excited molecules in the protoplasm of cells. If this ionization is sufficiently intense, or occurs in certain vital sites within the cell, the cell can be killed or, more likely, injured so that it can not divide and thus reproduce itself.
With moderate doses of radiation, not enough individual cells are
damaged to affect the organism as a whole—except, perhaps, by life
shortening. Cells damaged by radiation are replaced by new ones,
as normally occurs with any injury to the body. If, however, the
radiation dose and the associated tissue damage is so great that the
repair process of the body can not replace the injured cells promptly,
the function of the organ may be impaired (e.g., production of blood
cells by the bone marrow).

If a source of radiation (such as Ra226 or Sr90) remains fixed in
a particular site (such as the bone) for a long period of time, the
"irritating" effect on the adjacent tissue may lead to tumor formation.

In the case of reproductive cells (sperm or ova) genetic damage is
also possible. This can happen if the effect on a reproductive cell is
not so great that the cell is killed (and thus can not enter into repro-
duction) but great enough to alter a chromosome or gene that can be
passed on in subsequent cell divisions.

Radiation induced injuries are largely nonspecific. The same effects
can be produced by many other agents, both physical and chemical.

Radiation Dose Versus Effect

The unit of dose received from ionizing radiation is the "rad" which
is established at 100 ergs per gram. The biological effect of a rad is
much the same for x-rays, gamma and beta radiation, but is more
severe for an equivalent amount of absorbed energy from alpha parti-
cles and some other types of radiation. Another unit of dose, the
"rem", is used instead of the "rad" where it is appropriate to work
in terms of biological effect rather than just physical measurements
(as made with instruments).

If a person's entire body is subjected to a single massive exposure,
doses in the range of 300 to 500 rads (rems) will cause severe "radia-
tion sickness" and about half of the people so exposed will die. Fish
are not quite as sensitive as people and about twice as much radiation
is required to produce the same effect. Generally speaking, lower
forms of life are more resistant to radiation than the higher forms,
and \(10^5\) or \(10^6\) rads are required to kill algae and bacteria.

The rate at which the dose is delivered is also important. If a
large dose is acquired gradually over a number of months or a year,
there may be no discernible effect at all.
The somatic effects of acute doses on the order of 100 rems can readily be measured in man. The effects of acute doses of less than 25 rems are very difficult to detect, (a diagnostic x-ray series of the gastro-intestinal tract may result in doses approximating 15 rems).

**Limits of Exposure**

The persons who are apt to receive the greatest exposures under normal circumstances are those that work with x-ray machines (or other similar sources), and those who work in atomic energy plants or laboratories. The exposure received by such people can be measured with good accuracy and controlled by administrative procedures. To oversimplify, it is limited by federal regulations to 5 rems per year. A worker could receive such an exposure every year without developing any symptoms that would be clinically discernible.

For members of the general public, prudence has prompted the establishment of limits for exposure that are about one-tenth of those allowed the persons whose occupations involve some exposure, e.g., 0.5 rem to the total body each year. Because some individuals in a population will receive more exposure than others, the limit is reduced to one-third if the average of a population group is used as base—e.g., 0.17 rem per year. These limits are for exposure that is in addition to natural background and exclude that received for medical reasons (an ordinary chest x-ray involves an exposure of about 0.05 rems). Natural exposure (from K\(^{40}\), Ra\(^{226}\), cosmic rays, etc.) are usually in the range of 0.1 to 0.2 rem per year in various parts of the United States. Some areas of the earth have alluvial deposits of monazite-bearing sands (rich in thorium) where the natural background is much higher. The dose rate to the people of one village in Brazil is estimated to be as high as 12 rem per year—over 20 times that established as the limit for persons who live near atomic energy plants in the United States.

**EXPOSURE PATHWAYS**

**Types of Exposure**

Radiation exposure, either natural or from artificial sources, can be classed as either:

1. **External** - that received from a source external to the body such as an x-ray machine or cosmic rays.
2. **Internal** - that received from substances taken into the body by breathing, or with food or beverages.
Unless a person is in very close proximity to a very large source of radiation (e.g., a worker that actually handles sources of radiation), the exposure received from external sources will be trivial. The potential for internal exposure certainly warrants much more consideration in connection with radioactive liquid wastes.

**Water Use**

Some potential for exposure exists for each way that water is used downstream from the point of release of liquid wastes. Whether or not any of these potentials is of significance is inseparably associated with the kinds of radionuclides present, their concentrations, how the water is treated, and in some cases, the ecology of the area. The types of water uses that are most apt to have some significance are:

1. Use for drinking.
2. Use for production of food fish.
3. Use for irrigation of crops or pasture.

**Drinking Water**

A larger number of people are apt to receive some water-borne radioactive materials via their drinking water than via other routes. Substantial fractions of most radionuclides present in raw water are removed by conventional treatment plants, however.

**Fish**

The chemical composition of fish is relatively consistent and is the result of selective accumulation of certain elements that at one time were in solution in the surrounding water. Most of this selection and accumulation is done by the algae and invertebrate organisms that form the food web of the fish. Radioisotopes are handled by the food web in the same way as the stable isotopes of the same element. Thus, many radioisotopes tend to be rejected by the biota, because they are of no nutritional or physiological value. A few nuclides are the radioisotopes of biologically essential elements, however, and these are avidly removed from the water by the biota and incorporated into protoplasm. Phosphorus-32 and zinc-65 are two such radioisotopes.

If the supply of the radioisotopes in the water is continually replenished, and the abundance of the stable element is limited, then the concentration of the radioisotope in the fish may be thousands of times greater than in the water. People who consistently eat fish will obviously take in more of the biologically concentrated radioisotopes from this source than from drinking the water.
Irrigation

Irrigation systems of the spray type are more effective in transferring water-borne radionuclides to crops or pastures than rill-type systems. If the water is applied directly to the surfaces of the plants (as by spray) the radioactive materials will remain as a deposit on the surfaces or enter the plant through the leaves. On the other hand, if the water is applied to the soil (as by rills), a large proportion of most kinds of radionuclides will be retained on the soil particles and reach the roots of the plant only after prolonged holdup and appreciable dilution by similar elements already present in the soil.

As in the case of aquatic food webs, the radioisotopes of some biologically essential elements can be passed along a food chain that starts with the irrigated pasture. Zn$^{65}$, Cs$^{137}$, I$^{131}$ and P$^{32}$ for example, can be passed from pasture grass to cows and from the cow's milk to man. For a few radionuclides, the irrigation route may be a more important source of supply to man than drinking water derived from the same river. If fish are harvested in abundance from the same river, however, they will most likely be the greatest potential source of radionuclides to man.

LIMITS VERSUS EFFECTS ON AQUATIC LIFE

The marked accumulation of certain radionuclides by aquatic organisms has caused some conjecture as to whether or not fish or their food supply might be adversely affected by radioactive waste at concentrations in the water that would be acceptable for humans. At this time, relatively few studies are available that bear directly on this question, but the evidence strongly indicates that radiation damage to aquatic life will not be the limiting case. It has been shown that concentrations of P$^{32}$ in water that meet drinking water standards might be too high (by about an order of magnitude) to provide adequate protection against radiation damage to the fish. However, if the fish accumulated enough P$^{32}$ so that radiation damage would be manifested, then they would be far too radioactive to be used as food by humans. If the concentration of P$^{32}$ in the water is kept at such a level that people can eat the fish regularly without exceeding the permissible rate of intake, then the fish will not receive enough radiation to result in a discernible effect.

P$^{32}$ is but one of many radionuclides that may be present in low-level radioactive waste streams. Nevertheless, it appears to be one that is near the top of the list of nuclides that would approach limitation on the basis of fish, rather than human exposure.
In short, until some firm evidence to the contrary is found, there appears to be no need for concern for radiation damage to aquatic populations (or terrestrial population), so long as the fish (or animals) are maintained in a status that permits them to be used for human food.

SUGGESTED READING


Some time ago, when Mr. Karr asked me to consider speaking to you today on the effects of heat on watershed usage, I was happy to take advantage of the opportunity, not only to pass along the impressions that I have gained during my own industrial experience with environmental factors, but also to have an opportunity to collect and review my thinking in this critical area. Since heat or its measurement as temperature form a sort of universal parameter in practically all of the life processes surrounding us, a discussion of the effects of heat necessarily ends up as an interdisciplinary review of a great many independent technical and economic factors.

At this particular time more and more serious researchers are examining the question of waste heat input or entrapment. However, despite this concentration of effort, very few well integrated conclusions are readily apparent. It is obvious that local effects on small streams with restricted drainage serve to focus attention on the study of heat dissipation, but when integrated into a large basin drainage system, the over-all effects are somewhat less palpable. In our discussion today I will attempt to illustrate technical factors related to the following four points:

1. The effects of heat on the planning and justification of industrial plants and process conditions will be of increasing importance in both public and private areas. Increased attention on heat related problems will undoubtedly force improved administration of the overall balance between capital formation and recreation industries.

2. The temperature of municipal water supplies will become a matter of public interest in terms of the optimization of water supply cost, the reduction of chemical taste and odors arising
from both chemical and natural pollution, and other esthetic factors.

3. In keeping with improved attention to the definition of technical problems, the legal aspects of stream regulation related to increasing thermalism will require significant development.

4. Lastly, but perhaps most important, improved attention will need to be directed at defining temperature as a parameter in research studies of every nature. This is essential in order to provide a reasonable basis for the economic calculations involved in industrial process development and financial planning.

In order to provide a background for some of the examples, I believe it is worthwhile to go over the general state of knowledge regarding heat as a parameter. First of all, the question of heat itself must be placed in proper perspective. There is a field of thought which seeks to infer that the quality of heat somehow depends upon process it originated from. For instance, we hear people speak of gas heat being more moist, or electric heat being drier, or even nuclear heat having somewhat different characteristics than fossil heating.

For the sake of setting the record straight, it is essential to consider human perception of heat as the subjective reaction to variations in internal energy. The laws of thermodynamics permit us to assign precise values of internal energy which we nominally call the temperature. While these internal energy values profoundly affect chemical and physical reactions, by themselves they offer no distinguishing characteristics other than that of measured on the thermodynamic scale. It follows that the origin of heat is quite independent of its effects in the presence of isolating barriers such as heat transfer surface. The rejection of heat to a stream from a nuclear source twice isolated by heat transfer surface and intermediate circulating fluid is indistinguishable from that of a conventional steam power plant. What is significant is the degree of containment of the process rather than the heat origins.

For example, in a single pass production reactor of the type at the Hanford plant, greater than 99.9 per cent of the heat rejected passes a heat transfer surface barrier. The balance of heating developed directly in the water by decay of activation reactions probably could not even be measured by direct methods.

Clearly, then, the emphasis must be placed on separation of the
variables—and development of further sophistication in reviews of the multiplicity of events related to heat rejection processes.

If we are satisfied that this position regarding the universal character of heat is correct, let us proceed to examine some of the effects of the common everyday problems with which we are involved.

If waters are warmed, the rate at which organic materials decompose, and the rate at which microorganisms die and are replaced by succeeding generations, are generally increased in keeping with this increased life activity. In this increased decomposition activity, the rate at which oxygen is consumed and the rate at which carbon dioxide is evolved go up with increasing temperature. Conversely, the solubility of gases declines. In addition, the overall process of self-purification of streams tends to increase, although this is an extremely general statement.

Measurements of the survival of plankton and microorganisms passing through industrial processes involving sudden temperature increases usually show a rather dramatic and usually fatal effect. The death of plankton in turn may produce a regional rise in biochemical oxygen demand as a result of the accelerated formation of decaying materials. It is also true that dissolved oxygen concentration caused by reaeration of streams increases geometrically at about 1-1/2 percent per degree C. However, even as this occurs, the dissolved oxygen concentration of the water at saturation declines, and the rate at which organic matter consumes oxygen also rises. This produces the net result that oxygen deficits appear early in the downstream flow of a warmer stream than its equivalent during colder seasons.

It is also true that small increases in water temperature tend to provide a more congenial condition for the multiplication of microorganisms in a high nutrient media, however, natural water usually provides a rather lean diet. Many tests have indicated that it is safe to generalize in saying that increased stream temperatures improve the rate at which critical counts of microorganisms related to disease in man are eliminated in lakes and streams. This topic is currently receiving considerable attention with promise of additional sophistication in separation of variables and possible rejuvenation of microorganism counting as a measure of stream pollution. Within limits, the transitional influence of temperature on the rate reactions appears to be of the variable of primary significance.

Along these same lines it is interesting to examine the effects of changing temperature of the effectiveness of chlorine as a disinfectant
for potable water. These effects have been studied for many years by a great many industrial and public authorities. It is usually generally true that greatly increased quantities of chlorine are required as temperature decreases in the range of 25 to 4 degrees C.

However, both the pH of the water and the presence of nutrients play a part in determining the overall activity of disinfectants. Further, there are few cases, if any, on record giving a great deal of insight into the non-seasonal effects on a standardized pathogen with only temperature as the variable parameter. Since the formation of free chlorine residual is also temperature dependent, the question of the chemistry versus the biology is unresolved.

Another effect which is of considerable concern to the public consumer of water is the matter of taste. It is generally observed that increased water temperature increases taste problems resulting from the residual algae remaining after treatment. While it is commonly believed that the growth of algae is stimulated by warm water specific definition of the various types must be made in order to provide a better definition of the floral spectra. The grass green algae are most abundant in water supplies during the summer but are seldom found in winter. The seasonal distribution of the blue-greens is similar but the maximum growth occurs later in the season and they often show a great increase after a period of sustained warm weather. Since the blue-greens appear to provide most of the problems as regards taste and oxygen depletion in high nutrient waters, improved understanding of the role of temperature in the acclimatization of these species is essential. In areas where excessive nutrients exist sufficient glue-green blooms occur to cause mechanical fouling in addition to significant progress towards eutrophy.

Perhaps the most highly publicized effect of temperature on life forms is that on fish. A substantial amount of research effort has gone into the relationship of temperature to the propagation of desirable and undesirable species. Undoubtedly much more will continue to be done as thermal problems are better defined. As an engineer, I can only highlight fish problems superficially; but as a continuation of an interdisciplinary concept of this discussion a review of heat effects on various fish forms is probably appropriate. Figure 1, prepared from an original paper by J. Alabaster appearing in International Journal of Air and Water Pollution, shows the results of a statistical study conducted under the auspices of government operated power industry. You will note a relatively constant relationship between the 100 and 1,000 minute mean life times of the various sample species used in the experiment. The data show rather conclusively the better adaptability of the perch type fish forms over the salmonoid forms such as
trout, and the high adaptability of the carp-like specie of which the European tench is an outstanding example. At the lower right you will see some points indicating the discharge temperatures of some major utility facilities and their relationship to the life expectancy of these three statistical groups. These stations use various combinations of direct and indirect cooling cycles which involve additional problems with sudden temperature changes.

With the data of Figure 1 in mind, it is probably safe to make some additional generalizations in this area. Studies indicate that temperature changes produced in short periods of time are frequently fatal to smaller fish because they are unable to move away from the area affected. This influence of size on the sensitivity of fish forms to temperature changes is quite critical, particularly in terms of migratory species in tributary streams with restricted flows. Some research has tended to make a case for sensitization of pathogens in regions of higher temperature through which migratory fish pass. Other work conducted at the Hanford project has failed to support this contention or suggested other relationships. There have been, however, some occasional correlations which indicate that retention of migratory fish in water which has been held in reservoirs for long periods at warmer temperatures shows increases in fish disease from yet unexplained causes.

Cooling water passed through power station condensers is frequently warmed as much as 10 degrees C. It is evident that poorly mixed effluents will disturb normal river conditions, particularly in streams with restricted flows. In addition these heated effluents by virtue of high temperatures and temperature fluctuations alone are statistically lethal to trapped trout and even coarse fish acclimatized to normal river temperature. However, small free living fish are affected to a lesser extent and larger fish appear to be able to swim away without difficulty.

The effects of temperature on fish forms increases dramatically in the presence of low dissolved oxygen and high CO₂ conditions. Here is an excellent case where proper definition of temperature as a parameter is necessary in order to draw conclusions which are meaningful and free of subjectivity.

I believe it is safe to generalize by saying that erection of power stations and dams on tributary streams will undoubtedly affect the natural life forms. Species which formerly thrived will disappear or be replaced by other less desirable species. The price of this evolution is one of those paid by the increasing pressure of civilization.
Until more efficient heat engines which minimize heat rejection to the environment are invented, the economical factors of such rejection should include an appraisal of the value of any fish forms which are affected.

Increasing temperature in streams introduces additional problems in appraising the fluid mechanics of reservoir and stream behavior. Since the density of water decreases rapidly with increased temperature, stratification effects become of great importance in the analysis of advected heat. Recent fluid mechanics studies by Yih which were confirmed by Debler in laboratory troughs, and Harlamann in TVA reservoirs, have also been confirmed by the author in detailed studies of Lake Roosevelt. They permit the prediction and correlation of the depth of density currents in reservoirs with relatively low flow-high volume characteristics. However, in long narrow reservoirs like Lake Roosevelt sufficient kinetic gradient is required to pass restricted portions that density currents can be upset when thermal gradients are too small. Stratification reduces the volume available for dilution and may concentrate cooler oxygen depleted waters in the lower levels of dam reservoirs. Artificially induced density currents could be a means of reducing this effect or the transient effect of heat slugs.

Thermal gradients complicate reservoir and stream heat budgets by introducing two region flow patterns. Further, horizontal velocity distribution causes transport of advected energy more rapidly than uniform mixing theories would predict. The combination of these with the added knowledge of the existence turbulence instability appears to offer a fertile field for fluid mechanics scientists for years to come.

Stratification effects can, however, be turned to good advantage by permitting erection of skimmer walls, wiers, and other hydraulic works which permit selected use of lower cooler water on streams where higher temperature surface water would cause some loss in efficiency. An excellent example of this type exists in the Clinch River on the TVA system and has been extensively publicized.

Effects of temperature on the operation of water treatment facilities provide an interesting and complex field of research all by themselves. It is generally stated in standard references that flocculation is retarded by cooler temperatures and that the length of filter runs also decreases because flocculation formed at the cooler temperature is finer and tends to penetrate into the filter media. As an overall generalization may be true. However, some examples exist where quite the opposite has occurred, and in our experience with water treatment on the Hanford project we find temperature of relatively
low significance in assessing the relative efficiency of our flocculating process. It is suspected that mixing may have a higher importance than temperature in determining flocculation characteristics. One interesting outgrowth of the research work at Hanford also indicates that the age of the turbidity is relatively important in determining the end result of filtration. Satisfactory water quality is maintained with relatively less alum per unit of turbidity removed during high flow seasons than during low flow seasons.

A classic example performed by Velz indicated sharp disagreement with the theory that flocculation is improved as temperatures increase. Rather, Velz found that alum requirements increased with temperature and were strongly related to the pH of the treated water. At similar temperatures of 20-25 degrees C the optimum pH was near 5.8, while in winter at 8-14 degrees C the optimum pH was near 6.7. Undoubtedly further research is necessary and will probably indicate that accumulation of electrical charge on suspended material is of primary importance in determining efficiency of flocculation process. Aeta potential measurements at Hanford show promise, but far from conclusive correlations. Improved isolation of temperature effects by themselves or as a parameter needs to be done before really meaningful information is available. This is especially true in view of the development of improved filtration processes involving multiple density filter bed media and polyelectrolyte filter aids.

Having completed this extremely brief review of the overall effects, let us examine a typical heat producing industrial process of a turbine generator plant. The laws of thermodynamics tell us that no engine can be more efficient than a reversible engine operating between given temperature limits. From this simple statement we can conclude that the lower the exhaust or rejection temperature the higher the efficiency of our heat engine. While this generalization is profoundly true, it is affected by the character and quantity of the fluids involved in an actual engine and may require considerable modification in practice. Figure 2 illustrates a large single shaft turbine generator steam cycle, consisting of a high pressure stage, intermediate pressure stages and low pressure stages, all on a single shaft. In this particular example there are seven stages of feed water heating by extraction from the various expansion stages. In a plant of this type feed water is heated from condensing temperature up to as high as 450-500 degrees F before injection into the boiler. Each feed water heater involves a temperature gradient across the prime surface which makes the detailed economic analysis of the effects of one or two degree temperature decrease at the low end of the cycle become somewhat involved. Further, the effects of windage losses in the final stages of the low pressure turbine are more of an
aerodynamic rather than thermo dynamic problem.

In Figure 3 we see the effects of various types of cycles on the efficiency of modern stages and a postulated economic advantage. Changes in the high pressure or upper limit of the cycle are relatively easy to evaluate because all of the variables are controllable and become a question of the proper balance of resources and raw materials.

Figure 4 is a generalized illustration of the effect of varying cooling water temperature on the ratio of cooling water required to the steam condensed, also related to the absolute pressure. The chart clearly indicates that large increases in cooling water are required in order to obtain extremely low vacuum. The normal range of water flows is from 60 to 90 pounds per pound of steam condensed. Within this region the effects are relatively linear.

Figure 5 summarizes the overall effects of plant economy as a function of condensing pressure for varying feed water temperatures. This plot is developed for a plant using eight stages of feed water heating but varying steam pressures. In general it can be seen that increases of feed water temperature decreases the gain from vacuum increase somewhat. The loss of 1-1/2 inches of mercury vacuum to a system of 400 degrees F feed water temperature is still in the neighborhood of .3 of 1 per cent of the plant heat rate. This item alone, over a twenty year period, is worth in excess of $50,000 figured at $2.00/bbl for heavy oil.

It is evident then that the detailed analysis of temperature effects on industrial machinery, particularly heat engines, is extremely involved and is an intrinsic part of the management responsibility of the owner-operator. Serious changes in overall plant efficiency can adversely affect the payout of plants in highly regulated industries where rigid economic supervision by public authorities such as the Federal Power Commission is imposed. Once built and optimized the changes occasioned by large stream temperature changes cannot be easily absorbed and often appear as important factors in the early obsolescence of such equipment.

On the other hand in the chemical industry, close optimization of heat transfer as related to steam temperature has never been a vital factor in the justification of plants. Such plants are generally depreciated over rather short time intervals and are more sensitive to a whole host of more significant process conditions. An exception to this case is the new desalinization process industry which may be somewhat more involved with the question of heat rejection or the
temperature of feedwater. Very little work has been done on the optimization of desalinization of plants subject to varying input temperatures. Many of these plants can be expected to be combined with steam turbine generation facilities which are highly dependent upon inlet water temperatures for competitive operation. It appears essential that future work in the field of desalinization include some emphasis on the long range economic impact of inlet water or heat rejection temperatures before too much optimization is done on the current process knowledge.

Occasionally there arises a case where a heat producing industry, such as a large power plant, is forced to operate on a stream with a limited flow rate, sometimes only a fraction of the condenser water flow. Figure 6 shows the pondage and holding pattern for a station of this type. Generally the hydraulics of the receiving stream are altered in order to permit a circulatory mixing pattern which will permit the station to go through the peak daily operating period, generally between 7:00 AM and 8:00 PM, before the hot effluent recirculates back into the intakes. Such a holding pool allows surface evaporation and convective heat transfer to perform a more effective job in reducing downstream temperatures. Incorporation of skimmer walls and other means to direct resulting stratification patterns is also used to improve the flow pattern. The Alden Hydraulic Laboratory has conducted extensive work with circulating pondage of this type in studies for power plants in New England.

Even in large main stream plant installations such as Hanford plant the operation of the plant is affected by neighboring facilities which introduce effects of economic significance. In Figure 7 we see a typical installation of a once through reactor at Hanford. The effluent stream is directed to the center of the river and proceeds for several miles downstream eventually to disappear by eddy division. The existence of several plants of this type along the stream plus the bank discharge of other effluents from back washing processes and leaking effluent facilities introduces other advected heat sources which appear along the shores.

In Figure 8 we see the action of the stream in passing by a plant intake and again note a circulatory pattern which serves surface water through the plant intake along with a considerable amount of circulating bank water from the location immediately downstream. As river flows are fluctuated sharply by upstream dam operations the recirculation problem changes rapidly involving temperature changes of two or more degrees C, in short periods of time to the plant process. Figure 9 shows a historical pattern of a six day period involving such operation.
In this particular case the reactor process concerned is relatively difficult to adapt to rapid temperature changes, with the net result that power levels require adjustment to somewhat higher mean intake conditions than would otherwise be the case. The net result is a decreased effectiveness of the process. This case is cited as an illustration of potential problems when multiple use operation of stream resources is increased.

Erection of dams and reservoirs provides another instance where the creation of potential heat problems requires a great deal of additional analysis in order to determine precise effects on existing facilities and future facilities. A great deal of material is available which indicates that on streams with relatively high reservoir volume to stream flow ratios the natural result of erection of such reservoirs is to decrease mean temperature of discharge water. This has been pointed out on the TVA Dam system where a thriving bass fishery has been depleted by the construction of these dams, although some success is being sustained in development of a substitute trout fishery. Other researchers performing statistical analysis on undisturbed streams have developed correlations which indicate that over a sufficiently long period of time, very little change in stream temperature can be expected in terms of departure from the overall statistical mean. Such efforts are more difficult to perform on large streams such as the Columbia.

Figure 10 shows the results of one study made with currently available data. It illustrates in curve A, representing the three year average of temperature from the Priest Rapids gauge falls well within the high and low limits for the ten years between 1947 and 1957, indicating no obvious overall effect from erection of Wanapum, Priest Rapids and Rocky Reach during the intervening period. In addition, while not plotted on this figure, stream temperatures measured before 1938 also fall within the high-low range for the 1947-1957 period, indicating that even Grand Coulee may have only marginal effect on the mean downstream conditions. However, a detailed review of the individual temperature data of the downstream exits of these various facilities, showed an increasing tendency for sharp variations from the mean to occur over relatively short periods of time. The varying independent activities of reservoir operators causes heat storage effects which if coincided with activities of other operators can cause a rather severe heat cycle. Such a cycle occurred in 1964 where the incidental manipulation of the various reservoirs for maintenance caused a two degree increase and followed by a sharp drop in stream flow temperature in less than one week. Such a variation is of low significance to most of the parameters which we have discussed today but the potential
exists that such resonant reactions from the increasing multiple use of Columbia River water such as pump storage and long term Canadian storage may involve transient effects of serious consequences. In addition the detailed heat budget analysis of the storage of the river below Grand Coulee Dam does indicate that under stable operating conditions general heating of the river does occur although probably to a lesser extent than investigators such as Raphael have predicted.

By way of summary it is probably desirable to develop some generalized thoughts on the overall question, heat as a potential pollutant. At the present time there appear to be a very few instances within the continental United States, other than on small restricted flow streams, where entire river basins are currently suffering from a thermal problem. It appears rather that the thermal problem as it potentially develops, will turn out to be a question of transient analyses of the most difficult form rather than one involving equilibrium, air-water mass transfer relationships generally used.

As a general observation the present concept of cooling water as a riparian use may require some evolutionary modification. Riparian owners have a right to a reasonable beneficial use of a stream provided that the stream is allowed to flow on untouched in quantity and quality, except for such alteration resulting from reasonable beneficial use. Obviously, the determination of reasonable beneficial use is significant to the question. One proposed definition for reasonable use of a stream is that which does not raise the stream temperature above prescribed limits associated with retention of desirable wildlife and does not otherwise interfere with its ability to assimilate organic or inorganic waste. There are, however, problems to be faced where a cooling use involves the width of the stream and perhaps some distance downstream. Under such a condition a detailed case study is the only way to define the desirable conditions, chart the economic impact both on the proposed investor and the surrounding communities.

Generalized use of cooling towers while probably inevitable, is probably not an ideal solution. It is often possible to show by detailed analysis that more water is wasted by windage, loss from holding ponds and surface evaporation than from pondage type, direct cooling systems. In the long run improved means for defining the relative importance of varying water uses must of necessity be evolved. As stated previously this is one of the costs of increased industrial use which limits the freedom of each of us to erect the facilities we desire for some individual purpose.

Out of consideration of all of these things it appears to point up
the need for additional research in three vital areas. First, of primary importance is improved attention to heat budgets and the mathematical treatment of air-water transport phenomena. A great many existing studies, including some of my own, were previously based on the concept of uniform mixing of internal energy changes occurring from surface phenomena. This concept was made rational by the apparent lack of stratification in most of the larger streams currently under study. The erection of a number of dams on the Columbia River and further developments in the mathematical prediction of density currents has pointed up the need for more sophisticated treatment of transport relations. A program currently under development by the author and expected to be published shortly, may form the basis for others to continue development work in this vital area.

Secondly, a closer identification of the specific changes associated with the temperature parameter is necessary. Practically all of the existing studies are involved with the changes of several parameters at one time and as such permit little freedom in their use for temperature studies alone. This approach must recognize the basic interdisciplinary nature of heat in order to provide background data for this type study.

Thirdly, there is a great need for improved standardization and methods of economic analysis for identification of the significant economic factors involved. Most of the classical methods of analysis were created years before the impact of environmental studies on plant optimization began to be felt. It is necessary in considering the evaluation of facilities such methods as the Present Worth method to consider varying environmental factors which cause shifting of optima and reduced profitability. The various techniques of linear programming will undoubtedly be of some assistance. However, appropriate attitudes and input data will be necessary to any successful financial analysis.

Finally, to close, the question of temperature in streams must be faced from a sociological viewpoint. The impact of increased industrialization along with the increased need for recreation facilities, provides the technical need for a rational synthesis. What are needed are appropriate guiding factors, a constructive attitude, and a sincere appreciation of the total broad needs of the community in order to develop perspective that will yield the optimum social result.
FIGURE 1
COMPARISON OF INCREASES IN TEMPERATURE LETHAL TO FISH
FROM - ALABASTER I. J. A. W. P. VOL. 7

Median Lethal Rise of Temperature OR Mean Difference of Temperature between Normal River and Effluent.

Some Typical Station Practice on Small Streams.
FIGURE 2
GENERALIZED ILLUSTRATION OF A LARGE SINGLE SHAFT TURBINE PLANT HEAT BALANCE

EQUAL Extractions FROM L.P. TURBINES TOTAL FLOWS ARE SHOWN.

LEGEND
H, h = Enthalpy, Btu/Lb
T = Temperature
# = Flow, Lb/Hr
P = Pressure, Psia

1.603,812#
SLEEP=1025.6 H
CEP=1039.9 H
2.0' Hg. ABS.

101.1°
69.1h
1130.9H
130.978H
1158.6H
1.835,085#
2846#
1199.6H
1133.82H
1330.9H

342,000 KW @ 3.5''
3600 RPM
2400 PSIG 1000/1000°F
FIGURE 3
PLANT HEAT RATE AND SAVINGS RELATED TO STEAM CONDITIONS

Evaluated for:
250 MW Output
Oil at $200/BBL

Throttle Pressure - psig

<table>
<thead>
<tr>
<th></th>
<th>Plant Heat Rate - BTU/Net KWH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1050/1000</td>
<td>9300</td>
</tr>
<tr>
<td>1050/1000</td>
<td>9200</td>
</tr>
<tr>
<td>1050/1000</td>
<td>9100</td>
</tr>
<tr>
<td>1050/1000</td>
<td>9000</td>
</tr>
<tr>
<td>1050/1000</td>
<td>8900</td>
</tr>
<tr>
<td>1050/1000</td>
<td>8800</td>
</tr>
</tbody>
</table>

Annual Savings, Dollars

| 250,000 |
| 200,000 |
| 150,000 |
| 100,000 |
| 50,000  |
| 0       |
FIGURE 4
COOLING WATER AND TURBINE EXHAUST RELATIONSHIP

Absolute Pressure - Inches Hg

<table>
<thead>
<tr>
<th>4.8</th>
<th>4.2</th>
<th>3.6</th>
<th>3.0</th>
<th>2.4</th>
<th>1.8</th>
<th>1.20</th>
<th>0.60</th>
<th>0</th>
</tr>
</thead>
</table>

Cooling Water Exit Temperature or Saturated Steam Temperature

°F  °C
122/50
113/45
104/40
95/35
86/30
77/25
68/20
59/15
50/10
51/5
32/0

Temperature Approach to Exit Steam

Inlet Water Temperatures

Cooling Water Ratio

#/Hr Cooling Water
#/Hr Steam Condensate

Normal Range
FIGURE 5
RELATION OF PLANT HEAT RATE TO CONDENSING PRESSURE AT VARYING
FEED WATER TEMPERATURE

% Reduction in Heat Rate-over
Non-Extraction Operation

Condensing Pressure - Inches Hg

Feed Water Temp. of
400
360
320
280
FIGURE 6
DISCHARGE PATTERN FOR A POWER PLANT WITH LIMITING STREAM FLOW AND RECIRCULATION PONDAGE

1200 AF PONDAGE

INTAKE

200 cfs 70°F

Barrier

Discharge 400 cfs 90°F

8 AM

Weir

8 PM

200 cfs 72°F

Barrier

Discharge 400 cfs 90°F

90°F

2 AM

200 cfs 68°F

Discharge 200 cfs 75°F

80°F
FIGURE 8
TYPICAL PATTERN OF CIRCULATION IN A PUMPING FOREBAY

Shoreline

Thalweg

Columbia River 20' Depth

20' Depth

Bank Groundwater Discharge

Plant Intake
FIGURE 9
VARIATION OF PLANT INTAKE TEMPERATURE WITH FLOW FROM PRIEST RAPIDS DAM

Main Stream

Temperature

Av.

Temperature

Av.

Temperature

Av.

Temperature

Av.

Temperature

Av.

Temperature

Av.

Temperature

Av.

Temperature

Av.

Time - Hours

Flow MCFS

Flow MCFS

Flow MCFS

Flow MCFS

Flow MCFS
Before beginning a discussion of waste treatment methods, it may be well to consider for a moment why we are concerned about waste discharges into our public waters. Early in the twentieth century, few people were alarmed over the pollution of our watercourses and little was heard about water shortages. But at that time, we were using only about one-sixth as much water as we do today.

The amount of available water for our use is strictly limited. If the average annual rainfall were evenly distributed over the continental United States, it would be about 30 inches, or 4,300 billion gallons daily. Seventy-two per cent, or about 3,100 billion gallons of this is lost through evaporation or transpiration. About one-half of the remaining 1,200 billion gallons is lost to floods which quickly return the water to the oceans. The maximum dependable supply which we can ever hope to develop by engineering works is about one-half the average total runoff or about 650 billion gallons daily.

The demand for water, on the other hand, has increased at a rate which exceeds the national population growth rate. From 1900 when water use amounted to about 40 billion gallons per day, the demand increased until it caught up with the developed supply in about 1958. From that time on the water use in this country has exceeded the supply by an increasing amount. It is estimated that by the year 2000 we will be using over 1,000 billion gallons daily, but the supply will remain fixed at 650 billion gallons per day.

Many streams in the nation are already used a number of times by cities and industries before the water reaches the sea and this reuse of water will become more common as the population growth and industrial expansion continue. We have reached the point, in many localities, where conventional treatment of municipal and industrial wastes is
inadequate to protect the downstream users. We must not only provide more treatment plants, but we must keep pace with technological advances by learning how to treat entirely new types of wastes. Even as recently as 25 years ago there were no radioactive wastes, no synthetic detergents, almost no organic pesticides, and water use was only half what it is today. Adequate waste treatment is now essential to the continued growth and progress of man.

Most of the major categories of wastes that are encountered have been discussed in previous sessions of this series. Synthetic organics, infectious and toxic agents, oxygen-consuming wastes, watershed activities, radioactive wastes, and heat are all potential pollutants that may have adverse effects on water quality. Because of time limitations, this discussion will be primarily concerned with treatment methods for oxygen-consuming wastes and destruction of infectious agents, with a brief review of some of the newer methods which have been suggested for removal of synthetic organic and some inorganic chemicals.

One of the earliest known treatment works in this country was the broad irrigation system employed at the Maine Insane Asylum in 1872. The wastes were spread on the ground at rates estimated at 10 to 20 inches per year.

Chemical precipitation followed by sand filtration was another early method. A coagulant, usually ferric chloride, ferric sulfate, or alum, was added to the waste and the waste then passed through a flash mixer for about a minute, then through a slow mix or flocculator for 20 to 30 minutes, then through a settling tank or clarifier with a detention time of about 2 hours, and then the clarified waste was passed through a sand filter. This treatment method was effective in removing suspended matter, but produced large volumes of chemical sludge that were difficult to dewater. This process is used at several places even today because of the ease of starting and stopping the plant. It does not depend upon the development of a biological growth for its effectiveness.

Intermittent sand filtration was often used for waste treatment, particularly in small communities, and consisted of about 30-inch beds of coarse sand through which settled sewage was passed to a tile under-drain system beneath the beds. The sewage was applied intermittently to these beds by sewage siphons or pumps, and it was common practice to dose one bed for 1 day and then switch the flow to an adjacent bed or beds for 1 or 2 days. Normally the sewage loading on intermittent sand filters was 100,000 to 120,000 gallons per day per acre. Only settled sewage could be applied to these sand filters if clogging were to be avoided. This system is still used occasionally today as a waste.
treatment for very small flows although it is not as widely used as septic tanks.

One of the earliest forms of sewage treatment still in use today for individual homes is the septic tank which is simply a large closed tank of sufficient size to permit low velocities for the removal of sewage solids by settling and with sufficient storage capacity for bacterial decomposition of this sewage sludge. Subsurface disposal of the effluent through an underground tile system is usually employed. These septic tanks are not satisfactory for larger sewage flows because of the large tank capacity required and the fact that anaerobic decomposition of the sewage sludge interferes with efficient settling of the fresh sewage flowing through the tank.

The Imhoff tank is an improvement over the septic tank in that a separate flow-through compartment for settling is provided in the top portion with a longitudinal slot in the bottom of this settling compartment to permit separated solids to fall into the lower compartment. This tank provides for about two hours' detention in the settling compartment and 90 days' or more detention for the sewage sludge in the lower compartment. About 20% of the surface of the tank is open to the lower compartment to permit dissipation of the gases formed during digestion. The Imhoff tank has some disadvantages since it is not practicable to heat the digestion compartment because of the common walls with the flow-through compartment and some odors escape from the surface of this tank. It is economical since both clarifier and digestion processes are incorporated in one tank and Imhoff tanks are still in limited use today, especially in small communities.

In many communities, the so-called primary treatment is used. "Primary treatment" is a term used to describe a form of treatment in which the sewage is subjected to plain sedimentation plus solids disposal. The effluent is usually chlorinated to destroy pathogenic bacteria. The raw sewage solids are normally anaerobically decomposed in a separate digester and then dewatered on sludge drying beds. Primary treatment results in only a partial removal of pollutants—about 50 to 60% of suspended solids, but only 30 to 50% of the biochemical oxygen demand (BOD), and almost no removal of the dissolved organic and inorganic compounds.

It may be advisable at this point to explain that BOD, or biochemical oxygen demand, is a measure of the polluting strength of a waste. The BOD is determined by measuring the amount of oxygen consumed by microorganisms in decomposing a sample of the waste
over a fixed time, generally 5 days, at a constant temperature of 20°C. This determination is often used to predict the effect a quantity of waste will have on the oxygen balance in a receiving stream, and is used as a design parameter in selecting the size of new aerobic treatment plants and to determine the efficiency of existing plants.

The average sewage composition figures normally used in design include a flow of 100 to 125 gallons per capita daily, 0.17 pound per day of BOD per capita, and 0.20 pound per day of suspended solids per capita. Preliminary treatment units normally provided in any treatment process include grit removal facilities consisting of a long, narrow, manually-cleaned channel in which the sewage flow is reduced to a velocity of 1 foot per second to permit settling of inorganic particles without settling of organic solids. These channels are usually 50 to 100 feet long or they may consist of rectangular tanks to which compressed air is supplied to maintain a spiral velocity of about 1 foot per second within the tank. To maintain nearly constant sewage velocity regardless of channel depth, a proportional weir or Parshall flume is often installed, and this device can be used for flow measurement.

The preliminary treatment facilities also normally include either bar screens or sewage grinders for the removal of large objects from the sewage flow which could harm plant pumps or other mechanical equipment. Oftentimes these units are installed at the end of grit removal channels.

Clarifiers used to separate settleable and floatable solids are simply flow-through tanks of sufficient size to reduce the waste flow velocity to the point where the larger suspended solids will separate by gravity. Conventional design calls for a detention time of 2 hours and an average tank depth of 8 to 10 feet. Small, simple plants may employ tanks which have steep, hopper bottoms which depend on gravity to move the sludge to central withdrawal points. Larger plants use clarifiers with relatively flat bottoms in which a slow-moving rake or plow moves the sludge to a point in the tank from which the sludge is withdrawn through a pipe to sludge treatment facilities.

Clarifiers may be round or rectangular, with horizontal or vertical flow, and some of the newer rectangular tanks combine some of the features of both horizontal and vertical flow. Settled sludge may be removed at frequent intervals or continuously to prevent a build-up of sludge to the point where anaerobic decomposition may occur within the sludge mass, causing gases to form which may float portions of the sludge to the tank surface causing odors and interfering with sedimentation. Most mechanically cleaned clarifiers are equipped with
skimming devices to remove grease and other floatables. Preaeration is sometimes employed in the entry portion of the tank to improve settling characteristics of the waste.

Primary treatment provides little actual treatment to sewage or waste except a removal of the larger settleable and floatable solids, which improves the appearance of the waste effluent in the receiving stream. A large diluting flow must be provided by the receiving stream if the waste is to be assimilated without creating adverse effects.

The principal method in use today for the treatment of sludge removed by the clarifier is anaerobic digestion. The sludge is held in a closed tank at an elevated temperature for an extended time. Anaerobic bacteria in the digester break down the organic solids into methane and other gases and produce a stable, inoffensive sludge which is easily drainable. Raw sludge may be $2\frac{1}{2}$ to 5% solids and amount to 40 to 80 cubic feet of wet sludge per day per 1000 persons. Digestion will change the sludge from about 70% to about 40% volatile solids.

In batch digestion of sludge three separate phases may be observed. First, an acid formation stage which lasts about 2 weeks at 60°F during which organic acids are formed. The second phase of digestion is a period of acid regression lasting about 3 months. During this phase active digestion is starting and much gas is formed which contains a high percentage of carbon dioxide. Considerable foam may form during this phase. The third phase is known as alkaline fermentation which usually lasts about 1 month. During this stage the sludge is highly buffered and maintains a pH of 7.0 or above, and the biological activity gradually decreases. The gas formed at this stage contains a higher percentage of methane.

In actual practice digestion is a continuous process with raw sludge added in small amounts at frequent intervals. When proper digestion is established, the contents of the tank are at a pH near 7.0 and digestion occurs at a moderate rate with production of sludge gas containing about 70% methane and 30% carbon dioxide. The digestion process is highly temperature dependent. For example, at 50°F digestion takes about three times longer than at 90°F. The optimum temperature for anaerobic bacteria in digesters is about 95°F and, at this temperature, digestion will be practically completed in 20 to 25 days. It is possible to reduce digestion time below this figure by elevating the digester temperature to about 125°F at which point thermophilic organisms become active, but digester control is very
difficult. At this point foaming conditions are often experienced and digester temperature must be controlled to a very narrow range.

Unheated digester tanks are not efficient and should not be used except for the very smallest communities. In most cases, very little digestion takes place in unheated tanks and these are not much more than storage tanks.

Digester tanks are heated by direct steam injection into the sludge, by transfer of heat from hot water through coils installed inside the digester, water jackets around mixing devices, or heat exchangers located outside the digestion tank.

It has lately been recognized that mixing is essential to ensure rapid and complete digestion. In the past, external circulating pumps were used to provide some mixing of tank contents, but because of the high density of the sludge, very little actual mixing occurred. Common practice now is to install draft tube-type mixers in the digester to provide a high turnover rate. These are propeller-type mixers which move 5,000 to 10,000 gallons per minute of sludge. The draft tube in which the propeller is located may be provided with a water jacket to incorporate digester heating.

Single digesters are not efficient since raw sludge must be added at frequent intervals which in turn displaces a like amount of supernatant which will be of very poor quality if the digester is properly mixed. It is, therefore, much more desirable to have two digesters, the first stage of which is maintained at optimum temperature and provided with turbulent mixing while the second stage digester receives the overflow from the first and provides quiet settling within the tank to separate the digested sludge from a clear supernatant liquid.

Sludge gas is produced during digestion at a rate of about 1 cubic foot per capita. This gas is combustible and contains from 600 to 700 B.t.u.'s per cubic foot. The gas is usually burned in a boiler to provide heat for the digester, but in larger plants the gas may be used as fuel in gas engine generators for the production of plant electricity.

After digestion, the sludge is normally withdrawn to open beds for air drying. These may be sand beds or asphalt paved, generally with an area of 1 square foot per capita. After dewatering, the sludge may be used as a low-grade fertilizer or as land fill. Larger cities often provide for vacuum filtration of digested sludge using cotton or wool blankets on a vacuum drum. Occasionally cities will provide
equipment for flash drying and incineration of the digested sludge. In this process the sludge must be dried to 10% moisture or less before it will burn. This has the advantage of reducing the sludge volume to about 1/50 of the original volume.

Newer processes in use in large cities use wet oxidation of the raw sewage sludge in place of conventional digestion. The Zimmerman process, as it is known, uses a combination of high pressure and temperature to oxidize the volatile organic solids while still in the liquid state. This is a highly efficient sludge disposal method, but requires a large capital investment and highly technical operation to ensure continuous operation of the system. A different process suspends the sludge in a fluidized sand bed at high temperature to oxidize these sewage solids. This system operates at low pressure, but additional air must be provided to maintain sufficient oxygen in the system.

The preceding discussion has described primary treatment processes as those which involve simple clarification of the sewage with sludge treatment and disposal. As indicated previously, primary treatment will remove only about 35% of the oxygen-consuming organics from sewage and in most locations today this degree of treatment is inadequate. Secondary treatment includes all of the primary treatment units plus additional facilities to provide biological treatment of the settled sewage. The secondary units consist of trickling filters or activated sludge tanks or modifications of these processes.

Trickling filters are simply open beds of rocks, 1 to 4 inches in diameter, normally 3 to 10 feet deep. Sewage is sprayed evenly over the top of the bed and permitted to trickle through the filter to a tile underdrain collector system. The underdrain is an open channel system to permit easy movement of air through the filter. The rock provides a surface area for the growth of an aerobic biological film which utilizes the finally suspended organics in the sewage as a food source.

Low rate trickling filters are hydraulically loaded at 2 to 4 million gallons per acre per day (mgad) or at 0.3 to 0.6 mgd per acre-ft. BOD loadings on low rate filters range from 200 to 400 pounds per day per acre foot or 0.1 to 0.2 pound per day per cubic yard. Low rate or standard rate filters, as these are often called, receive a single pass of the sewage and no facilities for recirculation around the filter are required. A secondary treatment plant utilizing low rate filters will be 75 to 90% efficient in BOD removal and 70 to 90% efficient in suspended solids removal. These filters may serve as a breeding place for small filter flies which create local nuisance conditions around the
plant, but the flies can be adequately controlled by recirculation to maintain continuous application of the sewage to the filter or sometimes controlled through the use of insecticides. Trickling filters should always be followed by secondary clarifiers to remove the growth that sloughs off the filter and is suspended in the filter effluent.

High rate trickling filters are similar to the low rate units, but are designed with smaller volume of rock and equipped with pumps to recirculate flows around the filter up to three times the plant inflow rate. The construction is identical to the low rate unit, but hydraulic loadings are much higher. Normal application rates may range from 15 to 30 mgd or 2.5 to 4.0 mgd per acre foot. The organic loading varies from 1800 to 3000 pounds of BOD per day per acre foot or 1.2 to 3.4 pounds per day per cubic yard. The efficiency of high rate filters can be as high as that from standard rate units if two-stage operation is provided. The high rate filters do not provide as much nutrification to the sewage effluent as the low rate units.

The activated sludge process is also a biological oxidation system, but in this system the active growth of organisms is suspended in a tank of sewage rather than attached to a stationary surface as in rock filters. To maintain adequate oxygen levels for the support of the biological growth, compressed air is pumped into the sewage, or mechanical aerators agitate the surface of the tank to permit transfer of oxygen from the atmosphere. The activated sludge process is more efficient than trickling filters, the construction cost is approximately the same, but the process needs more careful attention to operation than trickling filter plants. This type of plant has very little headloss compared with trickling filters, which may be an advantage in site location.

The aeration tank is normally installed after the primary clarifier and is a rectangular tank from 10 to 15 feet deep, large enough to provide from two to six hours' detention to the average plant flow. If the plant uses diffused air for mixing and to provide oxygen, the air flow rate is usually $\frac{1}{2}$ to $1\frac{1}{2}$ cubic feet of air per gallon of sewage. The activated sludge growth will give a brown, turbid appearance to the tank and will usually maintain 1,200 to 3,000 ppm suspended solids in the tank. To operate efficiently, there must be a proper balance between the activated sludge organisms, the food supply, and the oxygen levels. The organic matter in the sewage or waste provides the food source which is uncontrolled, but the concentration of organisms can be controlled by limiting the amount recirculated to the aerator and the air supply can be physically controlled. The aerator must be followed by a secondary clarifier to permit the separation of the acti-
vated sludge growth from the treated sewage before discharge to the receiving stream. A portion of this sludge removed in the secondary clarifier is returned to the head of the aerator to seed the incoming sewage and to maintain the proper population of organisms in the tank, and the excess sludge is wasted to the head of the primary clarifier for additional settling and transfer to the digestion process.

Several modifications of the activated sludge process have been used in which the amount of air supplied to the aeration tank is varied throughout the tank length, or the sewage may be admitted to the aeration tank at various points throughout its length. These modifications are attempts to maintain an even distribution of organisms, food supply, and air. The most efficient plants are equipped with mechanical mixers to provide violent mixing throughout the tank and thus maintain uniform loadings.

Almost all present-day sewage treatment plants, whether primary or secondary, are equipped with chlorination facilities for the destruction of infectious bacteria remaining in the sewage after treatment. Gaseous chlorine is the most common disinfectant and it is applied as a gas or in water solution to the sewage so as to provide adequate mixing and then the sewage is retained in a tank for about 30 minutes before discharge to the receiving stream. The kill of microorganisms is not instantaneous, but follows a logarithmic curve. Organic matter and some inorganic compounds combine with the chlorine and reduce its effectiveness. For this reason, less chlorine is required to adequately treat secondary than primary treatment plant effluent. Disinfection is usually adequate if the chlorine residual is 0.2 to 0.4 ppm after a 30-minute detention time. Chlorine is a highly effective disinfectant against nonspore-forming bacteria such as those causing typhoid fever, but viruses such as those causing infectious hepatitis are quite resistant and the cysts of amoebic dysentery and beef tapeworm are almost unaffected by normal chlorine dosages.

Many other treatment processes have been attempted with varying degrees of success, and one worthy of mention here is the sewage lagoon. Lagoons have been used with success in dry climates and are adaptable to smaller communities where low-cost land is available. The sewage lagoon is a shallow pond usually not over 4 feet in depth with a surface area of about 1 acre for each 100 persons connected to the system. Sewage is discharged near the center of the lagoon with no primary treatment. Wind induced currents are relied upon for mixing and prolific growths of algae occur and assist in maintaining adequate oxygen supplies for the aerobic bacteria which decomposes the sewage. This system effectively reduces the organic content of
the sewage if the lagoon is not overloaded. An additional lagoon cell is usually provided to permit some separation of sewage effluent from the algae before discharge to the stream. The lagoon effluent is sometimes chlorinated to protect downstream waterusers.

Most industrial waste treatment plants are similar to sewage treatment plants if the waste is organic in nature, but many times earthen basins are substituted for concrete tanks to reduce plant costs. Most plants producing inorganic or toxic wastes have developed special chemical treatment processes for the reduction of their specific waste loads.

Final disposal of plant effluents is usually to a nearby watercourse. For cities located along the coastline, ocean outfalls are often used. These provide for waste disposal by dilution and dispersion, but should not be considered as a substitute for treatment. At least primary treatment and chlorination should be provided before discharge to an ocean outfall. There is always some onshore movement so that the outfall must be sufficiently long to adequately dilute any of the wastes which may eventually come back to the shore.

New York City has adopted a standard that ocean outfalls must be of sufficient length that shoreline contamination will not result in a most probable number (MPN) of bacteria of 1000 per 100 ml or greater. Ocean outfall disposal is quite expensive; for example, a 30-inch pipe will cost between 50 and $100 per foot to install, and maintenance of the outlet diffusers may be a continuous and expensive item.

The cost of sewage treatment varies with the type of treatment plant constructed and the population. Per capita costs for some typical plants in two-size ranges are shown in the following table:

<table>
<thead>
<tr>
<th>Per Capita Cost of Treatment</th>
<th>1.0 mgd</th>
<th>5.0 mgd</th>
</tr>
</thead>
<tbody>
<tr>
<td>8,000 Population</td>
<td>40,000 Population</td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>$28</td>
<td>$18</td>
</tr>
<tr>
<td>Standard Rate Filter</td>
<td>37</td>
<td>23</td>
</tr>
<tr>
<td>High Rate Filter</td>
<td>34</td>
<td>20</td>
</tr>
<tr>
<td>Activated Sludge</td>
<td>36</td>
<td>22</td>
</tr>
</tbody>
</table>

These costs vary for different regions of the country, but the figures cited are typical of recent construction costs in the northwest.
Because of new types of wastes being produced today, including inorganic and synthetic organic chemicals, and because of our rapidly increasing demands for water, we are approaching the time when the need for reuse of our water resources will require treatment beyond that provided in conventional secondary treatment facilities. Some of the special wastes which create treatment problems include synthetic organic pesticides which are extremely toxic to aquatic life; for example, the toxicity to fish may be measured in a few parts per billion instead of the normal measurement units of parts per million. Some of the waste chemical fertilizers either lost from chemical plants or washed from agricultural lands may produce prolific algal growths in the watercourses which cause taste and odor problems in downstream water supplies. The enormous use of household detergents has caused foaming problems in receiving streams and even ground water supplies since these materials are not removed by conventional waste treatment plants. Metallic salts are highly toxic to both human and aquatic life and phenols discharged to the streams create serious taste and odor problems in water supplies.

Intensive research is underway to test many suggested methods of advanced waste treatment and to determine methods of reducing the typically high construction and operation costs. One method showing great promise is adsorption on activated carbon. This process utilizes sand or other fine grain filters for pretreatment of secondary treatment effluent using high coagulant dosages and then passage of the sand filter effluent through activated carbon columns or beds. This process removes phosphates and about 80% of the soluble organic material in secondary treatment plant effluent. The cost of this process currently is in the range of 5 to 10¢ per 1000 gallons. A full-scale plant using this process is under construction at South Tahoe, California.

Electrodialysis has been tested and found effective in removing inorganic ions. The cost of this process is currently 15 to 20¢ per 1000 gallons, and to be effective, organics must be first removed. Membranes used in this process may have to be regenerated by acids and solvents.

Foam separation shows promise since it is inexpensive, costing only about 2¢ per 1000 gallons. In this system some detergent is purposely added to the treatment plant effluent and air is bubbled through the waste to produce foam. The foam can be skimmed from the effluent and contains from 30 to 40% of the organics present in an activated sludge effluent. An air to liquid ratio of 5 to 1 is used and
the foam will be 1 to 2% of the plant flow. In current pilot plants this foam is being recirculated to the aeration tanks.

Evaporation has been considered as an advanced waste treatment method because of recent emphasis on sea water evaporation methods. Since the total solids in sewage and waste effluents is much less than the total solids in sea water, it appears likely that evaporation of wastes may cost as much as 30% less than sea water evaporation. Treatment by freezing may have some application and this could be accomplished at about half the cost of sea water freezing. Other experimental methods of advanced waste treatment include extraction with solvents, reverse osmosis, ion exchange, and oxidation.

In summary, waste treatment is an essential responsibility of all users of our water resources. Our use of water already exceeds the developed supply and it is estimated that when our relatively fixed national water supply is fully developed near the end of this century, the fresh water needs will be nearly double the supply. Our traditional methods of gravity settling and biological treatment of wastes then become inadequate to preserve the necessary high quality of these water resources for multiple reuse. We, therefore, are seeing, and will continue to see, increased emphasis on advanced waste treatment methods that will remove more of the inorganic ions and organic pollutants present in ever larger amounts in the waste streams being returned to their watercourses of the nation.
In view of my current, primary interest in management aspects of fish conservation, my remarks are restricted to information that has been developed by research workers with references to my experience on the application to management. These pertain primarily to the fishery problems of the Northwest and, particularly, salmon and steelhead of the Columbia Basin.

Generally, water quality problems affect wildlife to a lesser extent than fish in the Northwest. Some local toxicity problems develop that affect waterfowl and there is, of course, an increasing use of pesticides which affect waterfowl as well as upland and big game.

My personal association with waterfowl toxicity has been limited. One interesting problem was the mortality of swans on the delta area of Coeur d'Alene River in Idaho. Coeur d'Alene River carries wastes from mines and processing mills in the upper basin and deposits them in the delta. Although mining activities have been reduced in recent years, deposits of earlier days have played a part in killing swans which feed on the delta. With their long necks, swans feed deeper than other birds and reach deposits of heavy metals well below the surface. The problem was serious enough in past years to cause an annual mortality of swans.

Water quality standards must be necessarily high in the Northwest because of the requirements for fish and wildlife in this area. We are accustomed to clean, cold, fresh water, and we are not willing to accept the lower standards of quality found in other parts of the United States where requirements for warm-water fish are less rigorous. Oxygen tolerance levels of salmon and trout are generally accepted in a neighborhood of 5 ppm, but we strive toward a more
desirable minimum of 7 ppm. We will be forced by encroaching civil-
ization to lower standards soon enough, but we should not voluntarily
lower them to invite contamination and pollution of our water supplies.

The present status of our water quality in the Northwest gener-
ally is good; however, there are few areas that are really problems to
fish. They are few and we can almost pinpoint them individually.

Water quality problems in the Columbia Basin, as far as fish
are concerned, are not so much a question of mortality caused by
toxins as they are a matter of gradual change that affect the total
fish population and contribute to the deterioration of the total fish
population.

A few mining areas contribute wastes that are toxic. Gravel
removal for commercial use is often detrimental in the destruction of
spawning areas and increasing turbidity. Dredge mining has been a
real problem in the past. At present there are few, if any, dredges
operating in the Northwest. Our main problem with dredging at the
moment concerns the rehabilitation of streambeds to enable fish to
spawn. Dredges have completely destroyed many good spawning
streams, and very little rehabilitation has been attempted by the
dredging companies. Research under contract with Oregon Game
Commission is now developing methods of restoring such streambeds
to usable condition, especially in the John Day system.

The heavy silt load of some streams is serious. Logging is
accompanied by soil erosion, faster runoff, and heavy silt loads.
Although the effect is not often recognized, it is certainly widespread.
Experiments have demonstrated the loss of eggs and bottom food
organisms to be as much as 100% in gravel near fresh slide areas.

Sphaerotilus is a nuisance product of pollution, primarily from
pulp mills. Its occurrence is prominent in the Columbia River down-
stream from the Camas mills and in the Yakima River. Commercial
fishermen in affected areas of the Columbia are forced to discontinue
fishing at some seasons of the year because their nets are so com-
pletely fouled from fibrous mats of Sphaerotilus. In the Yakima
River many fish screens in the irrigation diversions become clogged
with Sphaerotilus and must be removed at times, allowing young
migrants to pass into irrigation ditches and become lost.

The migratory habits of salmon and steelhead and the instinct
which brings them back to a parent stream from which they hatched
are not fully understood. We do know, however, that many factors
control their migration. These apparently include geographic orientation, celestial navigation, as well as recognition of organic odors and tastes of water. The latter pertains to our analysis of water quality problems and is of real significance.

Experimentally we can artificially flavor the water supply where young fish are raised. They become accustomed to this even though it is not natural and, when they return as adults two to four years later, they recognize this treated water and seek it in preference to the natural water that is untreated.

Another example is a recent study conducted by our Fish Passage Research Program at Spring Creek National Fish Hatchery across the Columbia from Hood River. In one experiment, several hundred adult chinook that arrived at the hatchery to spawn in the fall were transported to other locations 13 miles upstream and 15 miles downstream. These fish were treated so that part of them could no longer smell and an equal number could no longer see. About 25% of the fish that were released downstream, and still could smell, returned to Spring Creek Hatchery, but only 2% of those returned that could not smell but still could see. Of the fish that were released upstream, about 20% of those that could smell returned downstream to the hatchery; whereas, none returned that could no longer smell but still could see. These results emphasize that the olfactory sense of salmon plays a prominent part in their homing instinct.

Water affected by pollutants, temperatures, or nontoxic chemicals could have considerable influence on the migratory habits of salmon leading many of them astray to such an extent that they may never spawn.

Oxygen is easily influenced by pollution. In some places this deterioration is enough that the lack of oxygen becomes a complete block to the migration of fish. In the lower Willamette River the oxygen content often dropped in past years to zero. Recent improvements in water quality control and increased dilution by regulated flows from storage dams upstream have brought favorable results. The oxygen content sometimes even now drops to as much as 2.5 ppm which holds up the free movement of salmon in late summer. Continual effort is being put on this problem by Oregon Sanitary Authority, and we expect further improvement to the extent that we propose to construct a new fishway at Willamette Falls for use during the late summer season at a cost of $2 million.

The heavy organic load of the Snake River caused by irrigation returns, food processing plants, and sugar factories has created a
problem in Brownlee Reservoir that was recognized by research of
the last three years by the Bureau of Commercial Fisheries. We
have discovered that the deposition and decomposition of organic
matter is sufficient in the upper end of the reservoir to create an
oxygen deficiency block about 15 miles downstream which prevents
the free passage of downstream migrant salmon through the reservoir.
Even though the block is eliminated later in the season, many fish are
delayed long enough to lose their migrating urge and they never leave
the reservoir. Thus, regardless of the efficiency of fish passage
facilities at the dam, if the fish never reach them, the run fails.

Pesticides are presenting a newly recognized problem that we
do not fully understand. Occasionally, we are confronted with heavy
mortality, but we do not have enough background experience to estab-
lish sound standards to protect the fish. One interesting example in
Madison River, Montana, was a heavy mortality of trout several
months after forest spraying occurred. Apparently, the accumulation
of residue in bottom organisms for several months built up to a point
where the fish were killed, as they fed on them, whereas the initial
spray was not toxic.

Temperature is the one feature of water quality that concerns
us most at the present time in the Columbia Basin. You have heard
some features of this problem in an earlier seminar from Dr. Jaske
of General Electric Company. We have serious apprehension about
the future of the Columbia River system because of increased temper-
ature expected from impoundments and steam generation of power
from atomic energy.

The temperature of the Columbia River is increasing slowly
because of water resource development. This trend is slow and
gradual, but it is insidious and certainly the salmon runs are being
influenced. The plasticity of salmon is sufficient that they can adjust
to many changes in environment but, if these changes are too great or
too rapid, they cannot accommodate them.

Some temperature thresholds are fairly well defined. One ob-
server has stated that if salmon start spawning in temperature of 58°F
to 60°F we can expect an egg survival of 81%. If they start spawning
in water of 60° to 63°F, the survival is reduced to 69%. Another ob-
server notes that 50% of eggs will die at a temperature of 57.5°F;
whereas, 100% will die at 60°F.

We generally recognize that 60° is an important threshold. Eggs
in water offer 60° invariably experience heavy mortality. The optimum
temperature is in the low 50's. Adults that are resting in pools and
awaiting the ripening of their eggs should not be in water with temperature over 60°. We prefer an upper limit of about 55°. Young salmon can be reared in higher temperatures under carefully controlled conditions, even as high as 70°. In such water their growth rate is fast, but they may also encounter increased disease problems.

Disease is more prevalent in higher temperatures. We expect a heavy mortality from a disease called Columnaris at temperatures over 60° and certainly over 70°. The Snake River has temperatures as high as 80°, and we have been warned by pathologists from University of Washington that an epidemic could start easily. The effect of temperature increases may not be fully apparent in nature, but it becomes a serious problem in hatcheries where fish are confined to small areas. The mortality in nature may never be conspicuous, but, at the same time, it could easily affect the population trends of salmon and steelhead.

In the Columbia River and its main tributary, the Snake, there is being constructed a continuous series of dams and impoundments from Bonneville to the Canadian border and up the Snake above Boise. Such impoundments do increase the water temperatures, although some high dams may have a cooling effect if operated with that objective in mind. We are told by Dr. Jerome M. Raphael of the University of California that the Columbia River in the neighborhood of Wanapum and Priest Rapids Dams increases approximately at a rate of 1°F in 50 miles without impoundments and 1°F in 20 miles with impoundments. Wanapum and Priest Rapids Dams are estimated to increase the temperature 1 1/2°F in the month of August. If a similar increase is reflected at all dams of the Columbia, the result could be tremendous by the time the river reaches Bonneville.

Steam generation with atomic energy is forecast to increase significantly in the Columbia Basin. One engineer has stated that cooling water for this purpose could conceivably increase the temperature of the Columbia as much as 17°F.

At Oxbow Dam, on Snake River, adult fall chinook held in artificial facilities for spawning purposes have suffered greatly from high temperature. In the fall of 1962 the loss of these fish was near 75% when temperatures were well above 70°F. In 1963 this loss was about 55% when temperatures were in the 60's.

Control of temperature in the Columbia is being studied. We hope to obtain some relief from dams such as High Mountain Sheep, Dworshak, Grand Coulee, Arrow Lakes, and Mica in Canada. We believe it is
possible to reduce the temperature several degrees at the mouth of
the Snake River by proper manipulation of High Mountain Sheep stor-
age to release cold bottom water during critical summer months.
Similar improvement is conceivable in the Columbia River as a re-
sult of storage in Canada.

We are endeavoring to research this problem in cooperation
with other agencies to determine means of getting the greatest benefit
possible from water storage at high dams.

The correction of these water quality problems would go a long
way to assure perpetuation of the salmon in the Columbia River.
Solutions for fish passage are being found for both adult and down-
stream migrants, but we are seriously worried about the deteriora-
tion of water quality. More time and energy must be devoted to solv-
ing these problems. There are many conflicting interests in the
basin, and, although we believe that conservation of salmon ranks
among the most important, other interests have their place.

As an example of the potential value of a tributary of the Colum-
bia, we can look at the Willamette River. If the Willamette Falls is
provided with a satisfactory fishway so that fish can pass upstream
during the late summer months and the water quality of the Portland
Harbor is improved so that fish can migrate through it satisfactorily,
we anticipate an increased salmon run that will be at least four times
the present. The increase in commercial catch could be as much as
200,000 salmon and the increase in the sport catch, 120,000. The
value of this increase is conceivably as much as $3.8 million a year.
The Federal Water Pollution Control Act directs the Secretary of the Department of Health, Education, and Welfare to prepare comprehensive programs for the elimination or reduction of pollution in surface and underground waters, and specifies that, in preparing these programs, due regard shall be given to the improvements required to conserve waters for all legitimate purposes, including public water supplies, propagation of fish and wildlife, and recreational, agricultural and industrial uses. The preparation of these programs is to be undertaken in cooperation with other federal agencies and with affected state and local interests. The Act also requires that in the planning of any reservoir by the Corps of Engineers, Bureau of Reclamation, or other federal agencies, consideration be given to the inclusion of storage for the regulation of streamflow for the purpose of water quality control, but specifies that such streamflow regulation shall not be used as a substitute for adequate treatment. The need for, and the value of, storage is to be determined by these agencies with the advice of the Secretary of Health, Education, and Welfare. The possible need for flow regulation storage must, therefore, also be considered in preparing these comprehensive programs.

This directive naturally raises questions regarding what is meant by a "comprehensive" program, what is involved in preparing one, and of just what is expected to be accomplished by one. The following discussion, in the form of a series of questions and answers, attempts to explain the need for, and the nature and objectives of these programs.

What do we mean by "Comprehensive" Water Pollution Control Planning?

Comprehensive planning simply means all-inclusive planning. As such, it is concerned not only with the physical entities involved, such
as the water and land resources in a whole region or basin, but also
with the social patterns, the political structure and the economic back-
ground and activities which characterize the area for which planning
is being conducted. Thus, planning for Comprehensive Water Quality
Management Programs means planning for all of those present and
future water needs and uses in an entire river basin or region in
which water quality plays a role.

Such planning must give consideration to all sources of water,
all needs for or uses of water, all effects of such use upon the quality
of the water, and the interaction of all of these elements upon each
other. It must take cognizance of the interests of the political subdivi-
sions and other institutions of the area, its legal and social patterns,
its economic resources and potentialities, and its esthetic preferences
and community values. The objective sought is the preservation or
improvement of the quality of the waters of the basin or region in such
a way as to insure continuing optimum benefit for the basin as a whole
at minimum economic cost.

Why is Comprehensive Water Management
Planning Necessary in the First Place?

Any study of the water resource problem will indicate that as we
move into the future, we must anticipate a rapidly increasing use of
water in the face of an unchanging supply. In the past, increasing
demands for water have been met more or less locally in most areas
by impounding water which otherwise would escape uncontrolled to the
sea. Reliance on this method may still be possible in most areas for
a few more years, but in the long run, our limited supplies will re-
quire that we reuse water several times as it moves downstream. In
some areas, this is already necessary. The maintenance of water
quality is the key to this reuse.

Quality determines the usefulness of water. A satisfactory
quality is a basic requirement for all water use. Enough water may
be available to permit the economic and social growth of an area, but
unless the quality of that water is reasonably satisfactory for the
intended use, this growth potential will go unrealized, and the public
health may also be endangered.

With water being withdrawn for use repeatedly as it flows from
the headwaters to the sea, the water quality problems of the future
will be complex. Each use causes some degradation of quality, and
natural phenomena further aggravate this situation. Our growing
population and industries are using increasingly larger quantities of
water and are producing greater quantities of wastes, both absolutely
and relatively, while the distances between points of water use and waste discharge are being reduced. Thus, some answer is required to the question of how to control the discharge of polluting wastes into waters which must be used over again by other users downstream.

With continued growth, and increasing use of water for all purposes, there will thus be an increased need to provide treatment of all waste waters before returning them to the stream for further use to the maximum degree economically possible. It will also be necessary to bolster the ability of streams to assimilate the wastes remaining after treatment, by augmenting the flow of the stream through additional releases from storage, in those situations where, after adequate treatment, the wastes impose too great a load on the stream under natural low flow conditions. These additional releases from storage must be provided for. Since all of the uses of a stream, both in terms of withdrawals and returns, and of instream uses, mutually affect each other, it becomes obvious that a comprehensive basinwide plan of development and management is required if all of these uses and demands are to be met most economically, efficiently, and equitably. It is also apparent that such a plan must anticipate future requirements and conditions as well as recognize existing conditions.

What Policies have been Formulated for the Administration of this Program?

The legislative history preceding the enactment of a law usually forms the base upon which the policies and principles for its administration are formulated. In the case of the above-mentioned act, the legislative history appears to indicate that it was the policy of Congress that:

1. Water quality management is an integral part of the concept of planning for comprehensive river basin development; in this sense, quantity and quality are inseparable components.

2. Water resource developments should be visualized as large comprehensive systems of interrelated, interlocking land and water components rather than as individual, isolated or purely local undertakings.

3. Unless there is a definite reversal in the present population growth pattern, or a revolutionary scientific or technological breakthrough in water use and waste water treatment techniques, which would make it possible to use less water, or reuse water oftener, full development of water resources in all basins will ultimately (100-200 years) be required.
4. While current studies may not be able to disclose fully the economic justification and timing for this total future water use, such total use should, nevertheless, be assumed as an eventuality in planning a development.

5. In developing federal reservoir sites, every effort should be made to conserve their full potentialities for optimum development including a provision for the future water needs of municipalities and industries and the maintenance of satisfactory water quality.

6. Primary effort in water pollution abatement should be oriented toward the reduction or elimination of polluting wastes at the source by means of waste treatment plants or other means.

7. Flow regulation is not to be considered a substitute for waste removal, but should be looked upon, rather, as a supplement to a program of adequate treatment.

8. In providing storage for municipal or industrial water supply, the necessity of providing additional water for the dilution of the treated waste effluents resulting from its use should be recognized.

9. The costs of waste treatment or removal should rest first with those producing the wastes; but, beyond this, the costs of storing dilution water producing widespread benefits should be non-reimbursable.

What Considerations are Involved in Planning a Comprehensive Program?

The following summarization of the principal data collection and evaluation processes involved in preparing a comprehensive program will provide an insight into the scope of these studies. At least six considerations or areas of investigation and analyses are required.

Consideration No. 1. How much Water is Available, and What is its Pattern of Occurrence?

Hydrologic analyses and investigations are required to answer this question. Analysis of existing streamflow, ground water, and rainfall records within the drainage basin of the river in question is the first step in this phase of the study. Existing data of this type are, in many instances, insufficient, however, and it may be necessary to undertake additional field measurements. The end result is a determination of the total amount of water the basin can be expected to furnish, the variations in the rate of its
occurrence, and the magnitudes and frequencies of these variations, both for flood flows and low flows. The ground water studies determine the location, quality, and dependability of ground water supplies, and show the extent to which they can be developed and relied upon to provide maximum yields. The usefulness and potential hazards of the disposal of waste through either subsurface injection or broad surface irrigation is also determined by these studies.

Consideration No. 2. What are the Existing Water Uses and Waste Water Discharges in the Basin?

It is necessary, in studying a river basin, to determine the locations, amounts, and reasons for all withdrawals of water from the basin, and of all return flows to the stream. All instream uses in the basin, such as fishing, boating, and other recreation, must also be determined. These inventories provide information on the amounts of water used and for what purposes, the location of withdrawals and of the existing water supply systems and treatment facilities. With these and other data developed by the demographic and economic studies, it is possible to project amounts, and, to some degree, the locations of future water supply requirements.

Water pollution inventories provide necessary information on the locations, kinds, amounts, and characteristics of all sources of pollution, including combined sewer overflows and discharges from municipal and industrial sewer systems and waste treatment facilities. These data, combined with those from other studies, provide the information on existing pollution loads, as a starting point for estimating future pollution loads, their location, and their potential effect on receiving water quality.

Consideration No. 3. What are the Physical, Chemical, and Biological Characteristics of the Streams, Lakes, and Estuaries of the Basin?

The existing physical, chemical and biological qualities and characteristics of the waters of the basin are determined by extensive sampling surveys and laboratory analyses. Where a lake or estuary is concerned, these investigations are extended to include special studies of an oceanographic character to determine such things as currents and stratification, as well as the other characteristics mentioned above. These data, together with the inventories and other studies show where water quality has deteriorated, the extent and cause of such deterioration, the mass movement of water in estuaries, the ability of given waters to recover from
pollution, and the protective measures required to maintain water quality objectives.

Hydraulic studies include measurements of velocity, depth, turbulence, stratification, effects of impoundments and regulating devices, and other physical characteristics of streams. These physical characteristics influence the capacity of the stream to assimilate wastes and a knowledge of them is essential to the reliable prediction of the effects of varying kinds and amounts of waste loadings on water quality.

Consideration No. 4. What are the Existing and Projected Future Population and Industrial Developments of the Study Area?

Population and economic data, together with other economic analyses, are used to prepare an estimate of future population and economic conditions in the basin. The economic data establish the historic trends in industrial, agricultural, and other developments in the basin in terms of type, size, location, and labor force. When coupled with other economic analyses, such as national trends, resource availability, etc., they provide the basis for forecasting future industrial developments, including projected size and distribution of labor force and job opportunities. Special studies are undertaken, where necessary, to determine probable kinds, amounts, and locations of specific industrial developments, as a basis for estimating industrial water needs.

The historical population figures establish the basis for projecting future populations in terms of growth, age groups, distribution, and movements, although economic and other factors must also be recognized in making these projections. The population studies are correlated with the economic and industrial projections, in preparing the estimates of future water uses and needs, and the amounts and kinds of resulting wastes. The geographic area covered by these economic and population studies is that area which is expected to be served by the water resources of the basin, rather than the drainage basin of the stream.

Consideration No. 5. What Geographic and Natural Resource Characteristics of the Basin Affect or Relate to Water Quality?

It is necessary to study the topographic, geologic, climatologic, and natural resource characteristics of the basin for several reasons. These studies provide an inventory of the location, kinds, and stages
of development of the natural resources of the basin. They are needed to determine the storage capacities of potential sites for impoundments for both water supplies and for water quality control storage. The natural resources data are used in conjunction with projections of population and industrial growth and distribution. Data on Land utilization and management practices are also useful in connection with water quality and quantity determinations.

Consideration No. 6. What will be the Amounts, Locations, and Characteristics of the Future Waste Water Discharges to the Stream?

The determination of future waste water discharges is based on the economic projections of populations and industries, coupled with data on trends in water use in homes, commercial establishments, public activities, and in various kinds of industries. From these projections, the location, kinds, and magnitude of required additional treatment facilities is developed and the resulting waste discharges to the stream determined. These estimates are based on the assumption that all wastes will be given treatment to the maximum degree which present technical knowledge and engineering practice indicates to be economically feasible. With respect to domestic sewage and similar organic wastes, this is usually taken to be about 85% removal of BOD at the present time, but this figure is expected to be greater in future years. Treatment required for other kinds of wastes depends upon the kind of wastes.

The estimates of volume, and kinds of wastes expected to be discharged to the stream are in turn used to determine the amounts of storage required to provide stream flow regulation for water quality control in the stream. However, the determination of these storage requirements is complicated by the demands upon the stream for water for all other purposes, and must be undertaken in conjunction with the overall water use determinations discussed below.

How is the Final Water Quality Control Plan Prepared?

The knowledge obtained from the series of complex and interrelated studies described in the six preceding sections give a picture of present and past conditions in the basin and of the possible future economy of the area to be served by the basin. Projections of the future economy are used to develop estimates of future water requirements and waste water discharges. A projection of probable future water quality conditions at various points along the water courses of the basin is then developed, using the estimates of waste discharge, runoff,
The development of this plan is an extremely complex process. Many combinations of water use and water quantity and quality control facilities are possible, and the objective is to ascertain the combination or combinations which appear to be most economical and acceptable. Because of this complexity and the time consuming character of the computations which would otherwise be required, mathematical models, computators, and the techniques and procedures of operations research are often used in developing the program to be finally recommended. The objective is to develop a comprehensive management program which in essence describes the alternative actions which can be taken to preserve the quality of water for beneficial uses. In describing the alternatives, the costs and benefits of water pollution control actions are evaluated.

How are Comprehensive Program Studies Undertaken?

The accomplishment of the various detailed and complex surveys, investigation and analyses, and the fitting together of the results of these efforts to produce an acceptable water quality management program for an entire river basin is a formidable undertaking requiring several years and a high degree of organization to undertake.

Many of the Federal, State, and local agencies possess essential information on particular facets of the study, and skilled staff for gathering needed additional data. Others have an intimate knowledge of water needs and water management problems in the basin, and of the legal and administrative structures which are controlling. Therefore, while the Public Health Service employs and organizes a substantial staff of scientists and engineers to deal with many of the aspects of the study, such as biological and chemical sampling and analyses of water, the inventorying of water supply and sewage treatment facilities, the study of currents, and dispersion characteristics, and the use of mathematical models and other techniques for marshalling and analyzing the assembled data, it also enlists to the maximum degree possible, the assistance of many of these other agencies. Sometimes this is done by means of arrangements for reimbursing these agencies for expenses; sometimes these agencies are able to arrange for their share of the work through their own budgets. And where another agency is authorized to undertake a comprehensive survey in a basin covering its own sphere of interest, such as for flood control, or irrigation, advantage is taken of this situation to join with that agency in a partnership.
endeavor to the mutual advantage of both agencies.

To assure that there is full understanding on the part of all interests regarding the objectives of the study, and to insure that a maximum degree of cooperation from all of these interests is achieved, an advisory committee, consisting of representatives of the important federal and state agencies is also organized. Various technical working committees are also created, where this procedure is advantageous. Finally, where needed expert knowledge, guidance or assistance is not readily available from within the various affected agencies, consulting services are solicited from private firms, individuals, universities and other learned institutions. This latter practice applies particularly to the assembly and analysis of economic data, and to certain operations research and computer processes required in arriving at a decision regarding the program to be recommended.

What Benefits Result from Comprehensive Water Pollution Control Studies?

Completion of comprehensive water pollution control studies should not only result in the development of long range plans for the abatement or control of pollution in the principal river basins of the nation, but should also provide a basis for achieving optimum use of the waters for all purposes. More specifically, these plans should result in an understanding or knowledge of:

1. The projected demands upon surface and ground waters for all purposes, such as municipal and industrial usage, cooling, waste dilution, irrigation, fishing, water oriented recreation and general improvement of the environment.

2. The capturable supplies of water available to meet these demands, and the capacity and location of potential storage sites required to hold this water.

3. The location and kinds of waste loads expected to be imposed upon the streams, lakes, and estuaries.

4. The individual characteristics of each stream or estuary which govern the way in which its waters react to waste loads.

5. The quality of water necessary for each of the beneficial uses and the control system required to achieve such quality, including the degree of treatment which wastes must be given, and the regulation of the river system necessary to assimilate treated waste effluents.
6. Based on the foregoing, the water reuse potential of the waterway and, therefore, the ability of the waterway to meet the projected demands, including the alternative choices available to the water users, if all demands upon the river for water cannot be satisfied.

7. The optimum potential population and industrial development which the river can support, within the known limits of the art and science of water quality management and use.

8. The cooperative inter-relationship which must exist or be brought into being between all water users in the area or region served by the river, in order to achieve optimum development.

9. A tentative time schedule for the construction of the various facilities required to meet the various water needs and use of the basin.

Properly drawn, the comprehensive plan can serve as an analogous model for the agencies concerned with the control and management of the waters of the basin. Thus, upon completion, a comprehensive pollution control plan should provide the Public Health Service with a sound basis for meeting its own responsibilities for conducting the pollution control and research operations and the technical, financial assistance, and enforcement programs provided for in the Water Pollution Control Act. It should also provide valuable water pollution control guidelines for the Congress in connection with the authorization of water resources programs and projects, and for other federal, state, interstate, and local agencies which have direct responsibility for the construction of facilities and the management of the waters of river basins, in connection with the carrying out of their respective programs.

What Governs the Selection of Projects:

The criteria by which dates are chosen for undertaking comprehensive program projects are based upon:

1. Urgency of need to integrate comprehensive water pollution control planning with other water resource development planning, including state and federal agency construction schedules;

2. The need to take advantage of opportunities to collaborate with federal, state, interstate and local groups;

3. The need to resolve critical water problems where pollution has curtailed water uses; and
4. The need to establish anti-pollution measures where imminent municipal growth or industrial development poses a serious threat to water quality.

Where have Comprehensive Water Pollution Control Studies been Started?

Earlier lectures in this seminar series on "Water Quality Control" have traced the problem of water pollution from its simpler aspects of a half-century ago to the more complex problems of urbanization and industrialization that must now be overcome. The discussions on substances that cause pollution, their effects on beneficial water uses, the effectiveness of conventional treatment methods, and the implications of comprehensive planning for water quality control should have given each of you a little better appreciation of the magnitude of the job that remains to be done if pollution is to be prevented or controlled. It is now time to give consideration to the manner in which this knowledge is put into practice. The responsibility for the control of water pollution in the United States is shared along five broad lines as follows:

The State has the primary responsibility for water pollution control. In Oregon the responsible agency is the State Sanitary Authority. It establishes standards for water quality within its area of jurisdiction, conducts surveys and investigations, collects and evaluates data, provides technical assistance to local government and industry, supports research, and applies the appropriate State laws and regulations, including enforcement.

Local governments construct and operate municipal sewage treatment works, provide consultation and technical assistance to industries they serve, and enforce their own regulations and ordinances.

Industries are responsible for control of their own pollution. They institute inplant measures for waste reduction and construct and operate waste treatment or disposal facilities if they do not have access to a municipal sewer system. They conduct research to
University are responsible for conducting research and training scientific manpower needed by other jurisdictions. They also provide technical services and consultation.

The Federal government has a leadership role to play in water pollution control. It supports and supplements the programs of the other four levels. It conducts research and investigations, collects and analyzes data on a national basis, provides technical assistance and training to states, local governments, and to industries. It develops comprehensive water supply and pollution control programs and coordinates these with the states and with the water resources programs of other federal agencies. It carries out the enforcement provisions of the Federal Water Pollution Control Act. It provides grants for (1) State program development; (2) as incentives to municipalities for the construction of sewage treatment works; and (3) for research, demonstrations and training.

While the fundamentals of these program responsibilities have remained essentially unchanged, increases in urban population, new and expanding industry, and the development of new chemical products have required the institution of more sophisticated techniques and the adoption of stronger laws. More emphasis is now being placed on research, special studies, public information, and enforcement.

Time does not permit a thorough explanation of each of these responsibilities in depth. Our interest today is concerned with the administration of water pollution control programs. The remainder of the discussion, therefore, will be devoted to those activities essential to the implementation of water pollution control programs, and to some of the problems that are inevitably encountered along the way.

The backbone of any water pollution control program is the law under which the responsible agency operates. Such laws may fall into two categories. One is a basic statute which: (1) enunciates the policy of the State relative to water cleanliness; (2) establishes the agency legally responsible for administration of water pollution control and outlines its powers and duties; (3) provides guidelines for the adoption of regulations governing water quality criteria, waste treatment and disposal, administrative procedures, etc.; (4) outlines the basis on which hearings may be held and orders entered; (5) provides the procedure for instituting legal action when necessary to abate pollution or to enforce administrative order to abate pollution.
The second group of laws is generally designed for the special protection of specific waters or water uses. Examples of these in Oregon include:

1. The protection of Lake Oswego from sewage pollution.

2. The preservation of the Deschutes River and its tributaries, and the upper McKenzie River as sources of drinking water supplies.

3. The protection of certain streams in Benton and Yamhill counties for water supply.

4. The prohibition of swimming in some irrigation canals where the water must be used for drinking purposes.

5. The prohibition of the discharge of certain materials into streams that will cause the streams to be unfit for drinking water supplies or that will damage fish and aquatic life.

Laws in this category provide specific penalties for violation, and, in Oregon's case, represent some of the state's first efforts to control pollution of public waters. Responsibility for enforcement, however, was divided among several agencies and in some instances no responsibility was placed at all.

While many of these laws were quite adequate at the time they were adopted, and served usefully for many years, it must be recognized that advances, improvements, and changes have occurred in the judicial arm of government, just as they have in the executive and legislative branches. For example, the first comprehensive water pollution control law in Oregon was adopted in 1939. While it followed the basic principles which were outlined earlier, some of its provisions were quite broad. It provided authority for the adoption of regulations but did not specify any subject areas for which such regulations could be promulgated. The authorization for hearings and entry of orders was not related to any established procedure, for there was none. These deficiencies became apparent, as the law was applied in several situations, and were remedied by subsequent amendments.

This means then that all state laws governing pollution control must be reviewed periodically to remove weaknesses that become apparent as a result of experience and court decisions. To cope with today's rapidly moving industrial and urban investment, legal provision should be made for the responsible agency to move promptly and decisively to halt pollution that seriously impairs the use of public waters for beneficial purposes.
Until Congress adopted the Federal Water Pollution Control Act in 1948, federal activity in water pollution was authorized in three laws: the Rivers and Harbors Act of 1899, the Public Health Service Act of 1912, and the Oil Pollution Act of 1924.

One segment of the Rivers and Harbors Act prohibited the discharge or deposit of refuse into navigable waters, except that which flowed in a liquid state from streets or sewers. Obviously this was designed to prevent hazards to navigation.

The Public Health Service Act of 1912, among other things, authorized investigations of water pollution related to transmission of disease to man.

The Oil Pollution Act of 1924 was intended to control the discharge of oil in coastal waters to prevent damage to aquatic life, harbors and docks, and recreational facilities.

The first Federal Water Pollution Control Act adopted in 1948 was limited to a trial period of five years. After that time it was to be reviewed and revised on the basis of experience. The Act was extended for a 3-year period in 1953, but no revisions were made.

The Federal Water Pollution Control Act of 1956 was the first permanent legislation on the subject and extended and strengthened the 1948 law. The new law:

1. Reaffirmed the policy of Congress to recognize, preserve, and protect the primary responsibilities and rights of the States in preventing and controlling water pollution;

2. Authorized continued Federal-State cooperation in the development of comprehensive programs for the control of water pollution;

3. Authorized increased technical assistance to States and intensified and broadened research by using the research potential of universities and other institutions outside of Government;

4. Authorized collection and dissemination of basic data on water quality relating to water pollution prevention and control;

5. Directed the Surgeon General to continue to encourage interstate compacts and uniform State laws;

6. Authorized grants to States and interstate agencies up to
$3,000,000 a year for 5 years for water pollution control activities;

7. Authorized Federal grants of $50,000,000 a year (up to an aggregate of $500,000,000) for the construction of municipal sewage treatment works;

8. Modified and simplified procedures governing Federal abatement actions against interstate pollution;

9. Authorized the appointment of a Water Pollution Control Advisory Board; and

10. Authorized a cooperative program to control pollution.

Amendments to this Act in 1961:

1. Extended Federal authority to enforce pollution abatement in intrastate as well as interstate or navigable waters and strengthened the enforcement procedures;

2. Increased the annual authorization for Federal financial assistance to municipalities for construction of waste treatment works to $80 million in 1962, $90 million in 1963, and $100 million for each of the four following fiscal years 1964-1967;

3. Intensified research toward more effective methods of pollution control; authorizing for this purpose annual appropriations of $5 million up to an aggregate of $25 million and authorizing the establishment of field laboratory and research facilities in, among others, seven specified major areas of the Nation;

4. Extended for seven years, until June 30, 1968, and increased from $3 million to $5 million per year the Federal financial support of State and interstate water pollution control programs;

5. Authorized the inclusion of storage in Federal reservoirs for regulating streamflow for the purpose of water quality control;

6. Designated the Secretary of Health, Education, and Welfare to administer the Act.

A comparison of the provisions of State and Federal laws will indicate that the day-to-day task of pollution control still falls within the realm of State activity, with the Federal government placed in a strong supporting role, chiefly in the areas of financial and technical
assistance, research, comprehensive river basin planning and, when necessary, enforcement.

Normally, enforcement action has been a responsibility of State or interstate agencies. Insufficient staff, lack of legal guidance or authority, disagreement as to the standards of water quality to be achieved, and, in some cases, reluctance to proceed for economic reasons, can result in time-consuming delays in an abatement program. In the case of interstate or navigable waters in or adjacent to any state or states, pollution which endangers the health or welfare of any persons is subject to abatement under the Federal Water Pollution Control Act. The procedures for conferences, hearings, and court action are well defined and may be invoked by the Secretary of Health, Education, and Welfare on his own initiative or upon the request of the governor of any state, or a state water pollution control agency, and under certain conditions upon the request of a municipality. To date, 32 Federal enforcement actions have been initiated and these have resulted in agreement on the required corrective measures in every instance where the actions have been completed. Some agreements are awaiting studies that are now in progress.

While the law provides the foundation on which a water pollution control program can be planned, the effectiveness of such a program will depend upon the ability of the administering agency to maintain seven fundamental activities on a sound and substantial basis. These are:

1. The recruitment and training of a competent, highly qualified technical staff composed of as many scientific disciplines and technical skills as may be required to discharge legal and administrative responsibilities.

2. The development of facilities such as laboratories, field stations, and research units sufficient to support the total water pollution control effort.

3. The collection and collation of data on (a) the physical, chemical, and biological characteristics of surface, underground, and coastal waters; (b) the volume and characteristics of waste effluents discharged into such waters; (c) the hydrology and hydrography of waters under surveillance; and (d) such other information as may be required for sound planning.

4. Based on the data collected and evaluated, the development of a comprehensive plan for the prevention, control, or abatement of pollution by wastes effluents and from other sources.
5. An aggressive information program to keep the public advised of the nature and extent of water pollution control problems, what has been done to correct them, what needs to be done about them, and the fiscal and legislative support required to accomplish desired objectives.

6. Initiation of the special studies or research necessary on problems for which current technical knowledge does not provide answers.

7. Initiation of enforcement action to bring about compliance when voluntary cooperation or other means to achieve abatement fail.

The selection and training of a water pollution control staff is one of the administrator's most important responsibilities. Keen ingenuity and judgment must be exercised to determine the nature, magnitude and timing of the various work assignments, to separate routine operations from those of special importance, and balance these with the financial resources available to employ the staff required. The agency is seldom in a position to do everything that needs to be done at the time it should be done, so priorities and appropriate staffing schedules must be developed.

Once this is done, staff requirements and supporting services can be determined. The number and grade of engineers, aquatic biologists, microbiologists, chemists, technicians and clerical and administrative personnel needed make up only a part of the budgetary requirements. Field sampling equipment, office and laboratory equipment, office and laboratory supplies, and travel provide the remainder. The administrator must be prepared, however, to adjust programs in line with appropriations, for the latter do not always meet needs or come up to expectations. Since it is not always possible to employ highly specialized personnel for short time assignments, outside resources such as other state or federal agencies, universities, and sometimes private industry must be drawn upon to furnish needed technical assistance.

As assembly of a staff begins, plans must be made for orientation training so that each member is aware of the nature and extent of the control program, its missions and objectives. It is equally important that each member of the staff, including secretarial and clerical, recognize the contribution his particular skill will make toward the attainment of established objectives. Short term, specialized training is necessary to bring professional staff up to date on new developments, and long term formal academic study may be required to permit some professional employees to extend their areas of responsibility.
One key aspect of any water pollution control program is the reporting of significant events in a manner that will be readily understood by those who will read or hear of them. Technical reports are essential to the proper distribution of new information to the scientific community. These should be prepared with care and precision. It must be remembered, however, that these same reports are of no value to lay people unless the facts they contain are presented in familiar and understandable language. The importance of properly interpreting programs, problems, what is being done and why, and what needs to be done, cannot be over emphasized. This requires special skills which most scientists do not possess, and these tasks should be assigned to those whose training and experience equip them for the task.

The development of public support at the local level for the water pollution control effort can be a most difficult task. It becomes even more complex when support is needed to resolve a river basin problem involving several states. Almost every intelligent individual is "for" the control of water pollution, but to get this support organized in an effective and decisive manner so that the legislative branch of government is impressed with the necessity for substantial financial and legal support is another matter. While scientific and engineering judgment is important in matters of water pollution control, it must be remembered that the impact of these judgments on the socio-economic situation must also be evaluated by professionals in those disciplines.

Disagreement as to objectives and needs, the reluctance of many individuals to express opinions, and the complexities of control procedures have all contributed to an apparent inability in the past to develop a united effort. With the advent of better comprehensive planning for river basin development, backed by close coordination on the part of the agencies involved, these discrepancies are gradually being overcome. With the aid of the press, radio, and television; conservation organizations; civic groups; professional, technical, and public administration societies; industry organizations; and others, the need for clean streams is beginning to be presented in a manner as to keep the individual citizen informed of regional water pollution problems, and what needs to be done about them.

A great deal remains to be done, and we are faced with a situation where new pollution problems are being created at a rate faster than solutions can be obtained. All levels of responsibility in the realm of water pollution control must rapidly accelerate their efforts if substantial accomplishment is to be made. Otherwise we may well find
ourselves in the same philosophical frame of mind as "An Indian at the Burial Place of His Fathers" so aptly described by William Cullen Bryant in his poem of this title when he wrote of the change in water supply brought about by unwise land use practices:

"The springs are silent in the sun

   The rivers, by the blackened shore

   With lessening current run;

   The realm our tribes are crushed to get

   May be a barren desert yet."