WATER POLLUTION

DISPOSAL AND REUSE

(in two volumes)

Volume 1

by J. E. ZAJIC

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PREFACE

The interdisciplinary sciences are unquestionably the most difficult fields to teach and for the student to learn. Environmental science, which includes the study of water pollution, requires the development of talents and skills in many areas. In examining air, water, and soil pollution, or in evaluating natural resources and the population problem, no single subject can be said to be paramount. The student, researcher, or engineer must draw on a knowledge of chemistry, biology, mathematics, statistics, and hardware to solve problems involving the lithosphere, biosphere, atmosphere, and hydrosphere.

If all resources are reduced to the life supporting level, water, air, and energy are most essential. Water of varying degrees of purity is required by every form of life. Water makes up 85 per cent or more of the weight of most plants and animals. It follows that, where fresh water is a limiting factor, life forms are limited. No single compound or solvent has the diverse properties associated with this solvent. Since life processes are so dependent upon it, one cannot visualize life in space without an adequate supply of moisture.

These volumes do not treat the hydrosphere except as that subject relates to purification. Most water purification processes have been going on in nature from that distant point in time at which water became a dominant factor in the surface structure of the planet Earth. Distillation, condensation, filtration, freezing, thawing, and biological degradation of organic contaminants, and even flocculation and clarification, are actually natural phenomena.

In most instances, man has had to utilize these processes as arts, but gradually, through study, they are being reduced to a science. Water pollution control is, however, still an empirical field. It is in great need of basic study and much of the theory still remains to be established.

These volumes are written for anyone interested in water and its purification. Since any chemical in concentrated form in water can be toxic, the work starts with three chapters which lay a predicate for the prime toxic chemicals which man has encountered. Water quality is discussed from both a chemical and biological base. Since the study of water pollution has already drawn together certain terminology, this too must be introduced to the environmentalist at an early stage.

The remaining chapters are placed under either the biological (Vol. 1) or the chemical (Vol. 2) section. Where any biological operation is involved in contamination or purification, it is handled in the biological section. One finds, of course, that not all chapters fit neatly within the classifications used, and where conflict is encountered, my choice of handling is evident.

Likewise, not all the subjects handled in Vol. 2 are chemical. The Information Reliability chapter could have been placed in the first section, however, I believe it should be developed after one has acquired some experience with pollution problems. Similarly, settling reactions can be purely physical, and the same can be said for freezing and thawing; but these topics are discussed in the chemical section. An adequate discussion of the equipment used in water pollution would alone comprise a book, and only a few highlights are covered here. If one desires to be critical, there are many topics which are excellent game. I hope that this work will, nevertheless, contribute to the advancement of water pollution control from an art to a fully developed science.

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Chapter 1

WATER QUALITY

I. INTRODUCTION

Historically, the availability of good, potable water has been one of the major factors influencing the development of civilization. In probably the first recorded use of treatment facilities the ancient Chinese and Egyptians used crude methods of chemical coagulation to purify their water. All early methods were patterned after natural water purification systems occurring in nature.

Modern treatment had its beginning with the slow sand filter in England in the early 19th century. It was not until the latter part of the same century, however, that diseases of epidemic proportion were traced to water supplies. Since that time the activities of many thousands of scientists and engineers have been directed toward the development of water purification processes aimed at the elimination of adverse physical, chemical, and pathogenic constituents.

The best compendium on water quality criteria to date has been prepared by McKee and Wolf (1963). It not only gives the criteria for all of the States in the United States but also covers the Pollution Control Council of the Pacific Northwest, New England Interstate Water Pollution Control Commission, the International Joint Commission, etc. Water quality objectives for Ontario are discussed by Van Fleet (1968). Van Fleet's presentation is an excellent guide.

Other important documents relating to water management and legislation are:

1. Canada Water Act (1970),
2. Alternatives in Water Management (1966),
3. Recommended State Legislation and Regulation (1965),
4. Water Resources in Canada, reports 1-5 (1968).

In the United States the Water Quality Act of 1967 (PL 89-234), an amendment of the Federa' Water Pollution Control Act (PL 84-660), requires each state to establish water quality criteria for all interstate waters and to develop a plan for the implementation and enforcement of the criteria. In general, the standards must be such as to enhance the quality of natural waters for their "... use and value for public water supplies, propagation of fish and wildlife, recreational purposes, agricultural, industrial, and other legitimate uses. Numerical values are stated for quality characteristics where available and applicable. Biological or bioassay parameters are used, where appropriate" (Federal Water Pollution Control Federation, 1966).

To introduce the environmental engineer to some of the desired objectives in controlling water pollutants, some of the water quality criteria used in Canada and the United States are presented here. "Water Quality Objectives," guarantee a healthy populace and high rate of industrialization. Ontario's objectives were first established in 1964 and updated by amendment in 1967. Water quality criteria can generally be classified under the heading of bacteriological, physical and chemical.

II. BACTERIOLOGICAL CHARACTERISTICS

Coliform bacteria are regarded as indicators of fecal pollutions and of the presence of human pathogens. There are two methods in general use in the laboratory examination of samples for bacteriological quality; one is the most probable number (MPN) technique, used by the Department of Health, and the other the membrane filter (MF) technique. Details of these are treated separately.

A. Interpretation of Results

There is, however, a slight difference in the interpretation of the significance of actual numbers of coliforms indicated in each 100 milliliter (ml) portion. None of the samples having coliform organisms should have an MPN index greater than 10 per 100 ml, while in the MF technique none of the coliform counts should be greater than 4 per 100 ml. If samples of water approach or exceed these limits in consecutive examinations, then an immediate investigation should be initiated to locate and eliminate the source of the contamination. At the same time a series of "special samples" are required to determine the extent of contamination and the progress being made toward its elimination from the water supply. This special sampling continues until the bacteriological water quality proves to be satisfactory. "Special samples" are also required when more than 10% of the samples collected per month and tested by either the MPN or MF methods show the presence of coliform organisms.

A third method of analysis involves running a series of confirmation tests to confirm and definitely establish the presence or absence of a variety of pollution indicator bacteria. These specialized tests are required to identify pathogenic cultures as to genus and species.

B. Frequency of Sampling

Contamination is often intermittent and may not be revealed by the examination of a single sample. The examination of a single sample can indicate no more than the conditions prevailing at the time of sampling; a satisfactory result cannot guarantee that the observed conditions will prevail in the future. A series of samples over a period of time is thus required.

To ensure reliable results, samples should arrive at the testing laboratory within 24 hr of sampling or be refrigerated if delay is unavoidable. The sample should be collected directly into sterile bottles and not via a dipper or some other container. It should be stressed that the reliability of the results is wholly dependent upon the employment of proper sampling techniques and the care with which the samples are collected. The minimum number of samples required from specific sources are shown in Table 1.

TABLE 1

SAMPLING FREQUENCY

Description of source	No. of samples	Minimum frequency of sampling
Treated surface water	1 raw and 1 treated at plant	Once per week
Treated ground water	1 raw and 1 treated from each source	Twice per week
Untreated ground water	1 raw from each source and 1 from each point of entry into the distribution system	Once per week

The minimum number of samples to be collected and the frequency of sample collection from a distribution system are often based on the size of the population served (Table 2).

TABLE 2

SAMPLE FREQUENCY BASED ON POPULATION

Population served	Minimum number of samples per month	Minimum frequency of sampling intervals
Up to 1,000	2	Twice per week
1,001-100,000	10 + 1 per 1000 of population per month	Once per week
Over 100,000	100 + 1 per 10,000 of population per month	Once per day

The number of samples determined with the use of the above table should not include plant effluents whether treated or otherwise. The frequency and size of sampling should follow the guide adopted by the U.S. Public Health (1962) shown in Fig. 1.

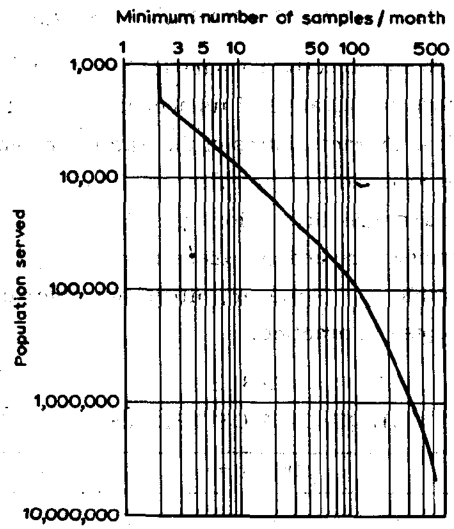

FIG. 1. Flow chart of activated sludge process.

As a typical example let us consider a municipality of 2400 persons with two wells providing treated ground water to the system. Bacteriological sampling would consist of the submission twice per month of a raw water sample from each of the sources of supply and a treated water sample from each of the points of discharge to the distribution system. In addition, a total of 12 bacteriological samples per month would have to be taken from various points in the distribution system. This would entail the submission of three samples per week in order to meet the sampling frequency requirement.

The responsibility for taking the required number of samples lies with the operating authority, whether it be a municipality or an individual who owns a private water supply. The total number of samples to be collected monthly may be examined by the Water Resources Commission, other government laboratories, water works authorities, or by commercial laboratories. "Special samples" are not included in the total number of samples required above.

III. PHYSICAL CHARACTERISTICS

Physical tests do not directly measure the safety of a water supply; however, they do give an indication of its acceptability. Thus, objectives governing the physical characteristics of the water are somewhat less stringent than those required for bacteriological control. The physical qualities of concern are turbidity, color, taste and odor, temperature and pH. [Except for temperature and pH, these results may be reported in parts per million, ppm (Table 3).] However, oftentimes other units have become established and accepted in practice.

TABLE 3

PHYSICAL QUALITY OF TREATED WATER [a]

Parameter	Objective	Acceptable Limit
Color, TCU [b]	< 5	15
Odor, TON [c]	0	4
Taste	Inoffensive	Inoffensive
Turbidity, JTU [d]	<1	5
Temperature, °C	<10	15
pH [e]	--	6.5-8.3

[a] To be examined according to the latest edition of Standard Methods for the Examination of Water and Wastewater (American Public Health Association, American Water Works Association, and Water Pollution Control Federation), or other acceptable methods as approved by the control agency.

[b] True Color Unit, platinum-cobalt scale.

[c] Threshold Odor Number.

[d] Jackson Turbidity Unit.

[e] Has significance in controlling corrosion and scaling tendency of the water.

A. Turbidity

Turbidity should average not more than 1 (turbidity) unit, although a Jackson turbidity unit of 5 is acceptable. At levels approaching 10 units the water may appear cloudy to the observer. Plants that provide complete treatment should routinely produce water than meets this objective. Ground water supplies will normally meet the objective without the need for treatment.

B. Color

Color should average not more than 5 (apparent color) units. Color does not occur too frequently in the natural waters, particularly in Canada. Leaching effect of the water on organic material found in certain watersheds may range beyond 50 units. Removal is possible with alum coagulation, sedimentation, and filtration.

C. Temperature

Temperature is a physical characteristic about which little can be done. The most desirable range is from 40-50^{o}F (4-10^{o}C). Higher temperatures tend to make water less palatable and reduce its suitability for air conditioning purposes. Temperatures above 80^{o}F (27^{o}C) are unsuitable and above 90^{o}F (32^{o}C) are unfit for public use.

IV. CHEMICAL CHARACTERISTICS

Under normal circumstances, analyses for chemical constituents need only be made semiannually. If, however, the supply is suspected of containing undesirable elements, compounds, or materials, then periodic determinations for the suspected toxicant or material should be carried out at more frequent intervals. Where experience indicates that particular substances are consistently absent from a water supply, semiannual examinations for these substances may be omitted on government approval.

A. Limits for Chemical Constituents

The chemical constituent concentrations in water may be broken down into two categories: those concentrations that can be tolerated if another, more suitable source is not available, and those concentrations that