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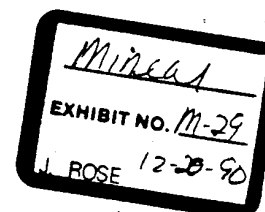
AIR FORCE MANUAL

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SEWERAGE, REFUSE AND INDUSTRIAL WASTE

INDUSTRIAL WASTE



DEPARTMENT OF THE AIR FORCE

AIR FORCE MANUAL
No. 88-11
CHAPTER 6

DEPARTMENT OF THE AIR FORCE
WASHINGTON 25, D. C., 19 June 1955

FOREWORD

The information and instruction contained in this manual are published for the guidance of all Air Force personnel and construction agencies responsible for Air Force construction.

BY ORDER OF THE SECRETARY OF THE AIR FORCE:

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Part VIII

SEWAGE AND WASTE DISPOSAL

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INDUSTRIAL WASTES

6-01 **SCOPE.** Industrial wastes are the liquid wastes derived from industrial activities as distinct from domestic or sanitary sewage. The purpose of this manual is to present information on industrial wastes originating at military installations. As an introduction to the subject of industrial wastes, the closely related topics of water pollution control principles, programs, planning and state relations are discussed briefly. Subsequent sections deal with other important aspects of the problem, including water pollution control standards, hydrology, waste surveys, gaging, sampling, analysis, treatment (or correction by other means) and effluent disposal. Because of the varied nature of industrial waste problems, principles rather than practice are emphasized.

6-02 **WATER POLLUTION CONTROL PRINCIPLES.** Water pollution may be defined as the unreasonable impairment of water quality as a result of discharge of wastes into the water. Unreasonable quality impairment occurs when the waste discharge produces quality changes sufficient to interfere with subsequent beneficial use of the water receiving the waste. Thus, a basic characteristic of water pollution is damage, and the objective of water pollution abatement is the prevention of damage to water resources. This objective may be achieved by reduction of the waste load by treatment or industrial process revisions.

a. Water Uses. Water uses fall into the following broad categories: municipal and private water supply, industrial water supply, agricultural water supply, fish and wildlife propagation, recreation, aesthetic enjoyment, and disposal of liquid wastes. Water for human consumption is invariably assigned the highest use priority. Priorities assigned to other uses vary depending on locality.

b. Pollution Damage. Examples of damage associated with the discharge of industrial wastes into natural waters are shown in the following table.

Table I.
Water Pollution Damage

<i>Effect of industrial waste</i>	<i>Examples of water use affected</i>
Discoloration.....	Public water supply
Sludge Deposits.....	Navigation
Floating oil, solids.....	Recreation
Toxicity.....	Public water supply
	Aquatic life
	Agricultural use
Taste and odor.....	Public water supply
Increased mineral content.....	Public and industrial water supplies
Oxygen depletion.....	Aquatic life
	Recreation
Corrosion.....	Public water supply
	Navigation
	Subaqueous structures

c. Water Quality. Water quality is judged on the basis of concentration of constituents in the water as, for example, parts of the constituent per million parts of water (ppm). With certain exceptions (oils and solids), concentration of a pollutant is a function of receiving water volume, so whether or not serious quality damage results from a waste discharge depends to a great extent

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on the availability of a firm supply of dilution water in the receiving stream or other water body. Wastes discharged during periods of relatively high stream flow may not produce noticeable effects on water quality whereas the same amount of waste discharged during low flow conditions may result in serious damage to down-stream water uses. Obviously, effective mixing of the wastes with the receiving water is an important consideration.

d. Use of Water Resources for Waste Disposal. There is general agreement with the principle that water pollution should not be allowed to interfere with the water uses important to a region. On the other hand, there is also general agreement with the thesis that the use of a natural water-course for the receipt and transportation of industrial and other wastes is as necessary and legitimate as its use for other purposes, subject always to the important limitation of no resultant unreasonable interference with other beneficial water uses. The premise that natural waters have some capacity to assimilate wastes and that this capacity should be utilized in the interest of economy is also a generally accepted one. These principles are not inconsistent with one another. Conflicts which may arise as a result of use of a stream for waste disposal can be satisfactorily resolved by the institution of waste correction methods usually involving some degree of waste treatment. Waste correction by treatment or other means is frequently necessary for the protection of water resources, thus permitting their maximum beneficial use and re-use. No rules can be set forth as to the extent of waste correction required. Each problem, existing or potential, requires expert, individual study and evaluation in the light of the industrial operations involved, type, strength and volume of wastes, dilution water available, stream self-purification and stream uses.

6-03 WATER POLLUTION CONTROL PROGRAMS. Historically, authority for water pollution control has been vested in the various states. The Federal Government, through the Congress, and inter-state agencies (created by the states themselves) have asserted only limited control over water pollution. In general these agencies work closely with and through the various states.

a. Federal Activities. One section of the Navigation Act of 1899, which is in force today, prohibits the deposit of all kinds of refuse, other than that flowing from streets or sewers in a liquid state, into navigable waters and their tributaries. The Federal Oil Pollution Act of 1924 relates to the pollution of coastal waters by oil. The first comprehensive Federal water pollution control law was enacted in 1948. The Federal Water Pollution Control Act (Public Law 545, 80th Congress, 1948) places major responsibility for Federal water pollution control activities in the hands of the U. S. Public Health Service, a part of the Department of Health, Education, and Welfare. This law encourages research, investigations and demonstrations on the part of the Public Health Service. Enforcement provisions are limited to pollution problems of an interstate nature. The policy carefully specified in the first section of the Act is to recognize, preserve, and protect the responsibilities and rights of the states in controlling pollution.

b. State Activities. State water pollution control activities traditionally have been associated with the protection of public health. While health considerations remain of the highest importance, it has been recognized generally that other phases of the water pollution problem also deserve attention. This has led, in recent years, to the broadening and strengthening of state laws and appurtenant rules and regulations, and in some states, to the establishment of water pollution control boards separate from the state department of health. Consequently, in some states, there may be division of authority between the state health department and the state water pollution control agency.

c. Program Objectives. While water pollution control statutes and program administration vary widely among the states, the primary objective of state water pollution control activities is the protection of the waters of the state from the harmful effects of waste discharges. Basic considerations in the achievement of this objective are determination of water uses and establish-

ment of pollution control standards for the protection of these uses. In general, water use determinations are made and standards established only after the conduct of water pollution surveys, public hearings, and publication of findings.

6-04 PLANNING FOR INDUSTRIAL WASTE DISPOSAL. In view of the complexity of industrial waste problems, it is essential that waste disposal receive expert attention in the early stages of development of manufacturing or other processes and in the location, lay out, and design of works for the employment of new or existing processes. Failure to give consideration to waste disposal in the early stages of project planning and design may have serious consequences. The problem will have to be faced eventually and in the absence of specific advance planning, the solution may be extremely difficult and expensive and may interfere with production. Early consideration of waste disposal by specialists in this field will minimize subsequent problems of waste collection, treatment and disposal and will thus contribute to the overall efficient operation of the facility involved. There are many technical problems involved in the efficient segregation, collection, treatment, and disposal of industrial wastes. The solution of these problems requires specialized knowledge of chemical, biological, and physical principles and, in addition, the ability to translate these principles into engineering plans and specifications. For a specific situation detailed information is required on receiving-water quality, self-purification capacity, quantity and uses, and on waste sources, waste characteristics (chemical, biological, physical), waste volumes and flow patterns. Collection and analysis of these data and the development of an economical solution to the problem require careful field investigations, detailed office studies and design competence. A background of successful practice in the waste disposal field is essential to an understanding of the problems and to the efficient organization and conduct of the field and office studies required to solve them.

6-05 COOPERATION WITH STATE AGENCIES. Industrial waste disposal should be discussed with the state water pollution control agency as a part of preliminary project planning. (Executive Order 10014, 3 November 1948, requires cooperation with state agencies having statutory authority in water pollution control.) Information should be furnished to the state indicating insofar as practicable the characteristics and quantities of industrial wastes to be handled, type of correction believed to be needed, and the approximate point of waste discharge. The state agency should be requested to supply data as to water uses that might be affected, water quality standards, effluent standards and any other pertinent state requirements. In such matters usually more rapid progress will be made if initial activities are handled through conferences with top state personnel. Thorough exploration of the waste disposal problem with representatives of the state pollution control agency will lead to a mutually satisfactory solution.

a. Reports, Plans, and Specifications. As previously noted the primary objective of the state water pollution program is protection of the waters of the state from the harmful effects of waste discharges. While the method of achievement of this protection is of secondary importance to the state agency, the state will expect reasonable assurance that waste treatment or disposal facilities or other corrective measures provided will function satisfactorily and that their operation will not create a public nuisance. The state agency, therefore, may request submission of reports, design data, plans, and specifications, for treatment and disposal facilities. Within limits imposed by military security such requests should be met on the basis that plans, etc., are furnished to the state for information only and are not subject to formal review and approval by the state.*

b. Permits A prevalent characteristic of state requirements is a permit to discharge wastes into the waters of the state. Usually it is required that applications for such permits be accompanied by design data, plans, and specifications pertaining to waste-handling facilities. As previously indicated, plans, etc., may be furnished to the state for information,¹ but permit application forms should not be executed.

*Numbers shown in this manner refer to references listed at end of this chapter or to footnotes.

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c. *Policy.* The exigencies of military operations and security may preclude strict adherence to all of these recommendations relative to cooperation with the state pollution control authority. Nevertheless, the guiding principle as to state relations should be the fullest cooperation possible with the state agency having jurisdiction to the end that pollution damage to water resources will be minimized.

6-06 WATER POLLUTION CONTROL STANDARDS. State pollution control standards now in general use may be divided into two broad categories,² namely, effluent standards and water quality standards. Effluent standards refer to the wastes themselves and may restrict the strength and/or amount of waste that can be discharged at a given location or may specify the percentage removal of a specific pollutant that must be accomplished by treatment or other methods, such as process changes. Water quality standards deal with the quality of the receiving water and are based on limiting concentrations for specific substances in the water receiving the wastes. Both "effluent standards" and "water quality standards" are useful administrative devices. Both have their supporters and opponents and each has technical and administrative advantages and disadvantages. As a practical administrative matter, it is often advantageous for a state to make use of both types. The principal objection to effluent standards has been that, if arbitrarily applied, they may not take into account ability of the receiving water to dilute and assimilate the wastes. Their arbitrary application to waste disposal situations other than those for which they were specifically designed may result in objectionable under-correction in some instances and uneconomical over-correction in others. Recently there has been a trend in the direction of the establishment of receiving water quality standards as a basic control measure. While numerous water pollution control agencies continue to use effluent standards, these are generally derived from receiving water quality standards which in turn are based on the requirements of existing or anticipated water resource uses.

Standards for effluents or receiving water quality must be reasonable. They should realistically reflect actual water quality needs. Achievement of equity in establishing the simplest stream standards is a difficult task and each river reach presents new problems. Uniformity throughout the country should not be expected and is not desirable. Equitable standards for industrial waste disposal are especially difficult to establish. In contrast to domestic sewage, industrial waste disposal may present many unusual technical problems. The effects of sewage pollution are generally fairly rapidly dissipated by the forces of self-purification. While the same may be true for some industrial wastes, others pose serious problems in receiving waters by reason of extreme toxicity, taste- and odor-producing characteristics, color, etc., combined with unusual persistence. Furthermore, in the establishment and subsequent judgment of standards of receiving water quality, antagonistic and synergistic effects of various components of industrial wastes must be considered. Synergism is especially important in connection with the effects of industrial wastes on fish and other aquatic life for through synergistic effects the toxicity of a substance may be increased many times. Although some metal ions are antagonistic in that they lower the toxicity of poisonous metals, of greater concern is the fact that some ions are synergistic. Mixed solutions of their salts are much more toxic than simple solutions of corresponding concentration. For example, minnows which withstood for 8 hours, 8.0 ppm of zinc alone or 0.2 ppm of copper alone succumbed within 8 hours in a mixed solution containing only 1.0 ppm of zinc and 0.025 ppm of copper.³ Thus water quality standards which at first glance appear to be unrealistically restrictive may be perfectly valid and reasonable. The state water pollution control agency is often confronted with the problem of considering numerous and varied waste sources and the fact that mixtures of wastes in the stream may produce damage out of proportion to what might be expected on the basis of a summation of the individual waste loads. In general, state water pollution control agencies recognize the inherent variability of stream flow and natural water quality and the many technical difficulties associated with the exact establishment of receiving

water quality or effluent standards. Consequently, water quality or effluent standards, whichever used, are **generally** viewed from the state control agency's standpoint as desirable aims and not necessarily **absolutely** rigid controls. Industries which have made a vigorous effort to solve their waste problems have received full cooperation from state agencies and have been allowed adequate time for the solution of the administrative, technical and financial problems involved in planning and constructing industrial waste correction works.

McKee² and others have prepared a comprehensive review of the literature on water quality criteria for the California State Water Pollution Control Board. This is one of the best publications on the subject. Recommendations of the Surgeon General, Department of the Army, are presented in appendix A. Examples of various state water quality and effluent standards are given in appendix B. Also presented in this appendix are data on the toxicity of certain chemicals to aquatic life.

6-07 **HYDROLOGY.** The amount of dilution water available has an important bearing on the extent of waste correction required. Consequently waste disposal studies must include careful consideration of the hydrology of the receiving stream with particular reference to the probability of recurrence of low flows. Waste load, waste concentration in the stream, and stream flow are related as follows:

$$L_x = 5.4 C_x Q$$

where

L_x = lbs. of waste constituent "x" discharged daily in the waste

C_x = concentration of "x" in the stream, after mixing of waste and stream flows, in parts per million (ppm)

Q = combined stream and waste flow in cubic feet per second (cfs)

This equation indicates that for a given water quality standard (C_x), the allowable waste load (L_x) is proportional to stream flow (Q). Obviously for a given value of C_x , low stream flows will require correspondingly low waste loads. It is the low flow, therefore, that to a great extent determines the maximum degree of industrial waste correction required. Low stream flows vary from year to year in accordance with drought severity. Analysis of stream flow records will provide an estimate of the frequency of occurrence of low flows of various magnitudes. For example, a stream having an annual average flow of 500 cfs may have a weekly mean low flow of only 100 cfs on the average of once every 3 years. Once in 10 years the weekly mean flow may be as low as 20 cfs and once in 50 years the flow may be as little as 5 cfs. Obviously treatment requirements based on a 50-year low flow (average expectancy, once in 50 years) would be much more severe than those determined from the 10-year low flow (average expectancy, once in 10 years). Establishment of the low flow return period to be used in determining degree of treatment is a matter for judgment on the part of the state pollution control agency. For sizable streams, weekly or bi-weekly mean flows having an average return period of about once in 5 to 20 years may be selected. However, in some instances, requirements may be much more stringent. The return period selected and the period over which the low flow is to be averaged (daily, weekly, bi-weekly, monthly) will be governed by the consequences of temporary failure, during a severe drought, to meet the established standard.

6-08 **INDUSTRIAL WASTE SURVEYS.**⁴ The general objectives of an industrial waste survey are the determination of the sources, characteristics, flow patterns and volumes of liquid wastes discharged to the natural drainage with a view to establishing a sound basis for treatment of the wastes, by-product recovery from them, or waste reduction or elimination by process modification. Requirements of intelligent waste survey planning are familiarity with the industrial processes used, operating schedules, sources of individual wastes, raw materials and plant industrial sewer system. In order for the results of a survey to be of maximum value it is necessary that they

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be correlated with production records obtained during the survey period. This will enable waste load estimates to be prepared for production rates other than those in effect at the time of the survey. Prior to initiation of sampling-gaging studies a preliminary survey should be made. The purpose of this survey is to establish and to estimate probable characteristics and quantities of wastes. Data obtained from a survey of this type are of great value in organizing subsequent phases of any industrial waste investigation.

a. *Duration of the survey.* This will be governed by factors such as plant operating schedule, number and variety of waste-producing operations, and number of independent points of waste discharge. The guiding principle should be to continue the survey long enough to register the effects of all waste-producing operations. This may require as much as one week (exclusive of time required for preliminary arrangements) for small plants and as much as 2 or 3 weeks at large installations. The survey period each day should extend over the entire operating schedule. If the plant operates 8 hours a day, the survey should cover the full 8-hour operating period with due consideration to clean-up operations which sometimes extend for several hours beyond the normal operating period. (Clean-up may contribute as much to the waste problem as normal operations.) For a plant which operates 24 hours per day the survey should extend over the full 24-hour period.

b. *Waste Load.* Waste load is usually expressed in terms of pounds (or 1,000 pounds) of waste constituent discharged in the waste stream in a specified time period; for example, pounds of sulfuric acid per 24 hours. Material balances are often useful in approximating loss to waste. However, an accurate estimate of waste load can be obtained only from a knowledge of two factors: (1) *strength of waste*; that is, concentration of the material in the waste, as determined by chemical analysis of representative samples; (2) *volume of waste* as determined by flow measurement.

c. *Strength.* Generally waste strength (concentration of constituents) is expressed in terms of parts (by weight) of the substance per million parts (by weight) of the liquid waste. The term "parts per million" is commonly abbreviated "ppm." Most wastes have a specific gravity close to 1.0. For such liquids, strength in parts per million (ppm) is numerically equal to strength expressed in milligrams per liter (mg./liter). For wastes with a specific gravity significantly different from 1.0, results in mg./liter may be converted to ppm by dividing the mg./liter value by the specific gravity of the waste. A correction is generally required when the total solids content of the waste exceeds about 5,000 ppm.

d. *Volume.* Waste flow rates may be expressed in any convenient unit. However, gallons per minute (gpm); gallons per day (gpd); or million gallons per day (mgd) are the most generally used units.

6-09 **PRINCIPLES OF WASTE FLOW MEASUREMENT.** The complex network of piping and sewers in many industrial plants presents challenging flow measurement problems. Almost every conceivable measurement method may have to receive consideration. However, the majority of measurements are made at sewer outfalls, or in sewers or other gravity channels flowing partially full. Consequently, open channel flow is emphasized in the following section. The presentation presupposes a basic knowledge of hydraulics. Inasmuch as gaging and sampling are closely associated, thought must be given to the latter in connection with the establishment of gaging stations.^{1,2,3}

a. *Safety.* Safety is an important consideration in connection with gaging and sampling of waste flows, and care should be exercised in locating stations so as to minimize hazards. However, it is frequently necessary to establish sampling-gaging points in manholes or other poorly ventilated, potentially dangerous locations. In the absence of proof, acquired by repeated testing of the air within such structures, that the atmosphere is safe, a hazard should be assumed to exist. The greatest danger lies in deep manholes or pump wells. The hazard may exist in the form of poisonous gas, such as hydrogen sulfide, chlorine or hydrogen cyanide or explosive gases, such as methane, gasoline vapor,

or carbon monoxide. (The latter is also a treacherous chemical asphyxiant). In addition there is always the possibility that the atmosphere may not contain enough oxygen to support life. Physiologically inert and nonexplosive gases such as carbon dioxide and nitrogen may readily produce a deadly atmosphere in a manhole or other poorly ventilated structure by diluting the oxygen to a level that will not support life. Obviously, a conventional gas mask is of no value in such a situation. Self-contained breathing apparatus would be acceptable, but in general a hose mask which is suited for unlimited time of use against any poisonous gas or oxygen-deficient atmosphere is the best type of equipment. In some instances it will be possible to produce a safe atmosphere by providing artificial ventilation by means of portable blowers or air compressors. A safety harness, rope, and explosion-proof light in addition to gas-protective equipment are essential when entering unventilated structures. A two-man sampling-gaging team is required under such conditions.

b. *Accuracy.* Waste flows should be measured as accurately as possible consistent with the significance of the waste stream receiving attention and reasonable expenditure of time and funds. Extreme accuracy in gaging is not required in view of the inherent variability of waste flows and their heterogeneous nature. The characteristics of the waste are certain to introduce errors in sampling and analysis, and extreme accuracy in gaging will not, therefore, improve overall results. Flow measurement accuracy of the order of ± 10 percent is generally satisfactory. Expensive gaging installations are seldom warranted as a part of the waste survey. The significance of any waste stream in relation to the overall waste load, waste treatment, and water pollution depends on its concentration as well as its total volume. Obviously a small flow of dilute waste will not have pronounced effects, especially when combined with a large volume in the main waste stream. Hence rapid, relatively simple methods for measurement of its flow are usually satisfactory. On the other hand, small volumes of very strong wastes may have an important influence on waste load and waste treatment, and the expenditure of the additional time required for careful, replicate flow, as well as concentration measurements may be justified. Manual gaging of waste flows requires frequent observations of the measuring device. Observations should be at least at hourly intervals for fairly uniform waste flows. Where there is considerable flow variation, half-hour or quarter-hour readings should be made.

c. *Preliminary Estimates.* Rough estimates of maximum, minimum, and average flows are often necessary for the determination of the size and type of temporary gaging installations required. If the plant water supply is metered, data on metered water use should be obtained. Usually such data will give information only as to total water used in a certain time period. This will furnish a basis for an estimate of average waste flow but little information as to maximum and minimum flow rates which are important in flow measurements. Maxima are likely to be several times as great as the average, and it is generally not feasible to estimate maximum rates from total water use. Maximum-to-average ratios sometimes employed in connection with sanitary sewage flow rates are useless in predicting industrial waste flow patterns. In most cases a reconnaissance covering selected sampling-gaging stations will be necessary for estimating the range in flow rates. Repeated observations, employing one of the simpler methods of flow measurement described in the following section, will be necessary to establish the approximate magnitude of peak and minimum flows. Knowledge of plant operating schedules is obviously essential in connection with the timing of these observations.

d. *Flow measurement methods.* Depending on the situation any of the following methods of flow measurement may be found useful.

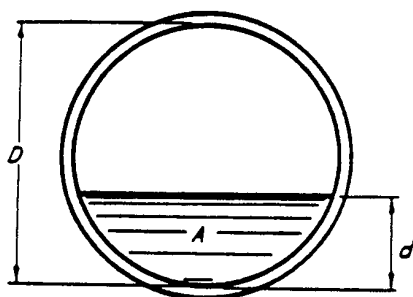
(1) *Velocity-area.* Wood blocks, large corks, oranges, dyes, etc., may be used to determine surface velocity in partially filled conduits. Mean velocity is obtained by multiplying the surface velocity by 0.85. Application of the mean velocity to the cross-sectional area of flow will give a good approximation of the flow rate. Cross-sectional area must be measured at the time the velocity is determined. (Flow cross-sectional area in circular sewers may be readily obtained by

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measuring depth of flow and referring to table II). Velocity in open channels can also be measured means of pitot tubes and pygmy-type current meters.

Table II.

Cross-Sectional Area of Liquid in Pipes at Various Depths of Flow



D = diameter of pipe - inches
d = depth of flow - inches
A = cross sectional area - square feet

Depth of flow (d) inches	Cross-sectional area (A)—square feet				
	Pipe diameter (D)—(inches)				
	6"	8"	10"	12"	15"
0"					
1/4"	.0078	.0089	.010	.011	.012
1/2"	.014	.016	.019	.020	.023
3/4"	.022	.025	.029	.031	.036
1"	.030	.035	.040	.043	.048
1 1/4"	.038	.045	.051	.057	.064
1 1/2"	.048	.057	.064	.071	.080
1 3/4"	.058	.069	.076	.086	.097
2"	.068	.080	.090	.10	.12
2 1/4"	.078	.093	.11	.12	.13
2 1/2"	.088	.11	.12	.14	.15
2 3/4"	.098	.12	.14	.15	.17
3"	.11	.13	.15	.17	.20
3 1/4"	.12	.15	.17	.19	.22
3 1/2"	.13	.16	.19	.21	.24
3 3/4"	.14	.17	.20	.23	.27
4"	.15	.19	.22	.25	.29
4 1/4"	.16	.20	.24	.27	.31
4 1/2"	.17	.22	.26	.29	.33
4 3/4"	.17	.23	.27	.31	.36
5"	.18	.24	.29	.33	.38
5 1/4"	.19	.26	.31	.35	.41
5 1/2"	.19	.27	.32	.37	.43
5 3/4"	.20	.28	.34	.39	.46
6"		.29	.36	.41	.48
6 1/4"		.30	.38	.43	.51
6 1/2"		.31	.39	.45	.54
6 3/4"		.32	.41	.48	.56
7"		.33	.42	.50	.59
7 1/4"		.34	.44	.52	.62
7 1/2"		.35	.45	.54	.64

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Table II.
Cross-Sectional Area of Liquid in Pipes at Various Depths of Flow—Continued

Depth of flow (d)—inches	Cross-sectional area (A)—square feet				
	Pipe diameter (D)—(inches)				
	6"	8"	10"	12"	15"
8"35	.47	.56	.67
1/448	.58	.69
1/249	.59	.72
3/451	.61	.74
9"52	.63	.77
1/453	.65	.79
1/254	.67	.82
3/454	.68	.84
10"55	.70	.87
1/471	.89
1/273	.92
3/474	.94
11"75	.96
1/476	.99
1/277	1.01
3/478	1.03
12"79	1.05
1/4	1.07
1/2	1.10
3/4	1.11
13"	1.13
1/4	1.15
1/2	1.16
3/4	1.18
14"	1.19
1/4	1.20
1/2	1.21
3/4	1.22
15"	1.23

(2) *Channel size-slope.* Knowing channel size, slope, and depth of flow, discharge may be estimated by the Manning or Kutter formula in conjunction with a chart of the hydraulic elements of the conduit. The Kutter or Manning "n" may be assumed to be 0.013 for all but the roughest channels.

(3) *Volumetric methods.* It is sometimes possible to measure average flow rate over a fairly short time period by determining the time required to raise the water level a known distance in a tank or basin of known area. Existing tanks, basins, and pump wells can be used by drawing the tank, etc. down, then closing the outlet and determining the rise rate over the tank area. Free discharge at the inlet end must continue during the test. For the measurement of small flows accurate results can be obtained readily by noting the time required to fill a previously calibrated container, such as a drum or bucket. (The container can be easily and accurately calibrated by weighing empty, filling with water and reweighing. Capacity in gallons is obtained by dividing the pounds of the water by 8.3.) The container should be of such size that at least 10 seconds are required to fill it.

(4) *Weirs.* Because of their simplicity, economy, and ease of installation, weirs are widely used for waste flow measurements. Head values may be measured manually or recorded continuously by clock-operated stage recorders.

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(a) *V-notch weirs.* The 90° triangular V-notch weir is generally the most useful weir for waste survey work. For small flows this weir gives a greater head reading than does a corresponding rectangular weir. It is therefore well suited to the measurement of varying waste flows between about 25 and 500 gallons per minute. For flows between 500 and 4,500 gpm, it is at least as accurate as any other type of weir.⁹ Its primary disadvantage is that at high flow rates it requires considerable head. Critical dimensions are shown in figure 1. Table III, based on the King⁹ formula, also gives head in inches and corresponding flow rates in gallons per minute. Heads below 0.2 ft., about 2½ inches, have to be measured very carefully in order to obtain even approximate flows. (Flows corresponding to head values of less than 2½ inches are shown in parentheses.) Also at a head value of less than 0.2 ft. the nappe may adhere to the crest thus invalidating the discharge-head relationship. Where the peak discharge is no more than 25 gpm, a 90° V-notch weir cannot be expected to give very accurate results. The 60° V-notch weir possesses somewhat better characteristics for gaging flows in the range 10 to 50 gpm. Its formula is $Q = 1.41H^{3/2}$ for Q in cfs and H in feet.⁹ Table IV gives flow in gallons per minute corresponding to various head values in inches.⁹ Flows corresponding to head values of less than 2½ inches are shown in parentheses. Critical dimensions are given in figure 1.

(b) *Rectangular weirs.* Rectangular weirs may be used where a V-notch weir would require too much head. Rectangular weirs are especially well suited to the measurement of very large waste flows. Two types are available; the contracted rectangular weir and the standard suppressed rectangular weir. Recognized formulae for these types are as follows:

Standard contracted rectangular weir;¹⁰

$$Q = 3.33H^{3/2} (L - 0.2H)$$

(End contractions should be at least 2.5H)

Standard suppressed rectangular weir;¹⁰

$$Q = 3.33LH^{3/2}$$

where

Q = discharge in cfs (negligible velocity of approach.)

L = Length of weir in feet (L should be at least 3H)

H = head on weir in feet

Extensive tables relating head and discharge for rectangular weirs are available.^{9 10}

(c) *Weir installations.*^{9 10} The following precautions should be observed in weir installations in general:

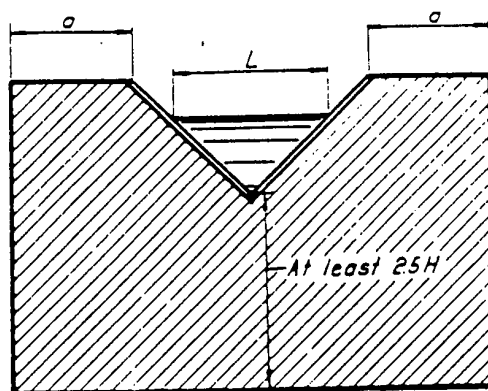
Select a weir to suit the situation. Minimum head should preferably not be less than 0.2 feet, and the maximum head no more than approximately 2 ft. Maximum head will usually be the controlling factor. Weirs are not well suited to the measurement of significant waste streams having flow rates consistently at or less than 10 gpm.

The weir plate crest should be sharp or at least square-cut. Unbeveled plates up to one-eighth inch thick may be used if square cut. Thicker plates should be beveled and placed with the high edge upstream.

The height of the crest above the channel bottom should be at least 2.5 times the expected maximum head. This reduces velocity of approach to a negligible value. So far as practicable, weirs should be installed to make velocity of approach negligible. Where this is not feasible, correction for velocity of approach is required.¹⁰

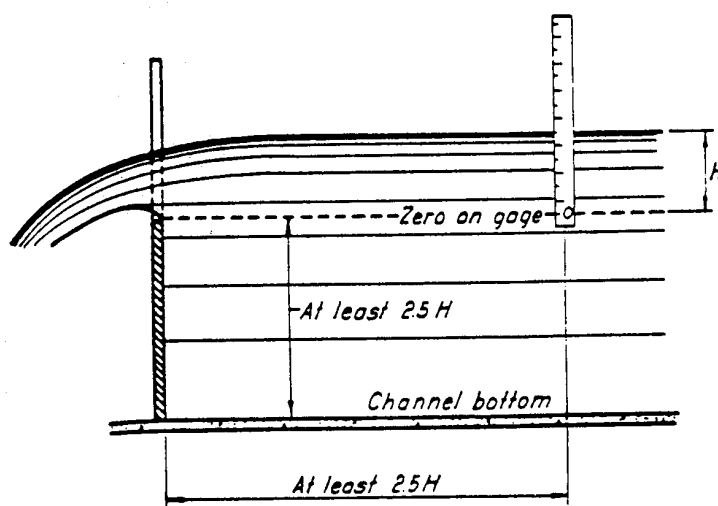
The approach channel should be straight, nearly level and as free from disturbing influences as possible for a sufficient distance upstream to insure quiet flow. A stilling box may be required to meet this condition.

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L = width of notch at water surface - maximum H .
 a = width of end contractions - not less than $\frac{3}{4} L$.

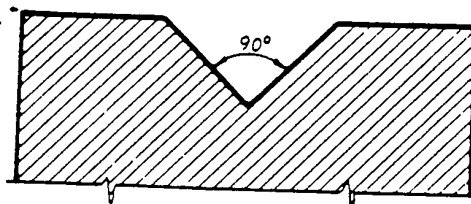


SECTION THROUGH APEX OF NOTCH

Figure 1. Critical dimensions V-notch weirs.

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Table III.
Discharge Over 90° V-Notch Weir



$$Q = 2.52 H^{3.47}$$

(Q in cfs; H in feet)

$$Q = 1130 H^{3.47}$$

(Q in gpm; H in feet)

Note: H should be measured at least 2.5 H upstream from weir plate. (See Figure 1 for other important dimensions.)

Head (H) inches	Discharge (Q) gallons per minute (gpm)	Head (H) inches	Discharge (Q) gallons per minute (gpm)	Head (H) inches	Discharge (Q) gallons per minute (gpm)	Head (H) inches	Discharge (Q) gallons per minute (gpm)
1"	(2)	6"	204	12"	1,130	22"	5,060
1 1/4"	(4)	6 1/4"	225	12 1/4"	1,250	22 1/4"	5,340
1 1/2"	(6)	6 1/2"	247	13"	1,380	23"	5,640
1 3/4"	(9)	6 3/4"	276	13 1/4"	1,520	23 1/4"	5,950
2"	(12)	7"	300	14"	1,650	24"	6,280
2 1/4"	(17)	7 1/4"	332	14 1/4"	1,810	24 1/4"	6,580
2 1/2"	24	7 1/2"	354	15"	1,970	25"	6,900
2 3/4"	30	7 3/4"	383	15 1/4"	2,120		
3"	37	8"	413	16"	2,310		
3 1/4"	45	8 1/4"	451	16 1/4"	2,480		
3 1/2"	53	8 1/2"	486	17"	2,670		
3 3/4"	65	8 3/4"	520	17 1/4"	2,880		
4"	76	9"	555	18"	3,080		
4 1/4"	88	9 1/4"	594	18 1/4"	3,290		
4 1/2"	100	9 1/2"	632	19"	3,530		
4 3/4"	114	9 3/4"	684	19 1/4"	3,760		
5"	129	10"	725	20"	4,000		
5 1/4"	149	10 1/4"	815	20 1/4"	4,250		
5 1/2"	166	11"	910	21"	4,500		
5 3/4"	183	11 1/4"	1,040	21 1/4"	4,770		

The weir must be ventilated. Air must have access to the underside of the waste stream as it passes over the weir.

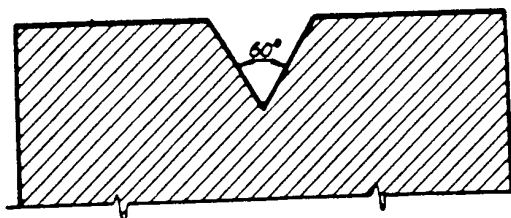
All flow must pass over the weir. Seal off leaks between the weir plate and the supporting structure and between the latter and the channel sides.

The weir must be level, plumb and perpendicular to the direction of flow.

Head measurements should be made upstream from the weir a distance of at least 2.5 times the expected maximum head on the weir. Carefully "zero in" the head measuring gage. "Zero" on the gage must be exactly level with the weir crest.

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Table IV.
Discharge Over 60° V-Notch Weir *



$$Q = 1.41 H^{3/2}$$

(Q in cfs; H in feet)

$$Q = 633 H^{3/2}$$

(Q in gpm; H in feet)

Note: H should be measured at least 2.5 H upstream from weir plate. (See Figure 1 for other important dimensions.)

Head (H) inches	Discharge (Q) gallons per minute (gpm)	Head (H) inches	Discharge (Q) gallons per minute (gpm)	Head (H) inches	Discharge (Q) gallons per minute (gpm)	Head (H) inches	Discharge (Q) gallons per minute (gpm)
1"	(1.3)	4"	40	7"	164	10"	401
1 1/4"	(2.2)	4 1/4"	47	7 1/4"	179	10 1/4"	452
1 1/2"	(3.5)	4 1/2"	54	7 1/2"	195	10 1/2"	508
1 3/4"	(5.1)	4 3/4"	62	7 3/4"	212	10 3/4"	568
2"	(7.2)	5"	71	8"	229	11"	633
2 1/4"	(9.6)	5 1/4"	80	8 1/4"	248	11 1/4"	700
2 1/2"	12	5 1/2"	90	8 1/2"	267	11 1/2"	772
2 3/4"	16	5 3/4"	100	8 3/4"	287	11 3/4"	848
3"	20	6"	112	9"	308	12"	929
3 1/4"	24	6 1/4"	124	9 1/4"	330	12 1/4"	1,014
3 1/2"	29	6 1/2"	136	9 1/2"	352		
3 3/4"	34	6 3/4"	150	9 3/4"	376		

The weir and approach channel must be kept reasonably clean. Sediment or debris on the upstream side or scale or rust on the weir plate may seriously affect the weir's accuracy.

(5) *Parshall flume.* This measuring device is described in the Engineering Manual, Part VIII, Chapter 3, *Sewage Treatment Plants*. It is particularly suited to permanent gaging installations. ~~Flow~~ Head of head is small and the device is self-cleansing. Velocity of approach, which may be an important factor in the operation of weirs, is less important in the case of the Parshall Flume. The flume is considerably more difficult and expensive to construct than a weir.

(6) *Salt dilution method.* This method is useful when hydraulic or other conditions make it impractical to employ other measurement devices. No measurements of area or distance are needed. Disadvantages are that considerable equipment is required and for high flow rates, salt requirements are excessive. The method cannot be employed where the normal chloride content of the waste stream fluctuates rapidly. The method is applied as follows:

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Determine the "normal" chloride content of the waste. This is accomplished by sampling and analysis of several samples of waste prior to the addition of salt. Results should be averaged and expressed in ppm as sodium chloride (NaCl). Call this result "N."

Add concentrated salt solution of known strength at a known uniform rate to the waste stream. The rate of addition should be sufficient to produce at least a 20 ppm increase in chloride concentration. Express salt solution concentration in lbs. of salt (as NaCl) per gallon of solution. Call this value "C." Express solution feed rate in gpm. Call this "q."

At a point downstream far enough from point of salt addition to insure mixing, collect samples for chloride analysis. As before, analytical results should be in terms of ppm chloride expressed as sodium chloride. Call this result "D."

Flow rate "Q" in gallons per minute is computed from:

$$Q = \frac{120,000qC - qD}{D - N}$$

Generally the term "qD" is so small in comparison with the other term in the numerator that it can be neglected. The formula then becomes

$$Q = \frac{120,000 qC}{D - N}$$

where

Q = waste flow rate—gpm

q = salt solution flow rate—gpm

C = salt solution strength—lbs. NaCl per gal

D = salt concentration in mixture of waste and salt solution—ppm as NaCl

N = normal salt concentration in the waste—ppm as NaCl

(7) *Metered water supply.* Waste flows from individual processing units may in some instances be measured by temporarily installing a metering device on the water supply line. Frequent readings of totalizing meters will provide information as to the flow pattern.

(8) *Other flow measurement methods.* Various other flow measuring devices may be found useful. These include venturi tubes, nozzles of various types, orifices, and parabolic flumes. These are described in the literature on waste disposal,^{11, 12} various handbooks on hydraulics, and manufacturer's publications. The venturi tube possesses many advantages but is relatively expensive. Orifices are low in cost but are not suited to the measurement of wastes containing suspended solids. The Kennison nozzle and the parabolic flume are adaptable to the measurement of wastes high in suspended matter.

6-10 PRINCIPLES OF WASTE SAMPLING. Securing representative waste samples is one of the most difficult aspects of industrial waste survey work. Industrial wastes are seldom homogenous. They frequently contain material in suspension as well as in solution. Their characteristics reflect the nature of the process materials used and their composition may vary widely within the space of a few minutes. Sampling methods have to be adapted to the needs of each situation. Factors which influence sampling are chemical and physical character of the wastes sampled, waste quality and waste flow variations, laboratory analyses required, and use to be made of the analytical results.

A well-organized sampling program properly coordinated with other activities can contribute greatly to the collection of valuable data. On the other hand, a haphazard program may invalidate the results of the entire survey. Good practice requires attention to sampling consistent with that devoted to gaging and analysis.^{3, 6}

a. *Grab Samples.* As the name suggests, a grab sample is a manually collected single portion of the waste.¹ The analytical results on a grab sample indicate concentration of the constituents at the time the sample was collected. Grab samples serve as spot checks and are useful in studying variations in waste quality. Grab samples are essential for those analytical determinations which should be made promptly such as dissolved oxygen, chlorine demand, residual chlorine, temperature, etc.

b. *Composite Samples.* Individual samples collected at, say, quarter-hourly intervals over a 24-hour period will, when properly combined, yield a single sample representative of the entire day's waste flow. Such a sample is termed a 24-hour composite sample. (Theoretically a 24-hour composite sample may be viewed as being the same as a single sample collected from a thoroughly mixed impoundment of the entire day's waste flow). In order for a composite sample to be truly representative, the individual portions which make up the composite must be combined in volumetric proportion to the flow rate noted at the time each is collected. Failure to composite according to flow can lead to large errors in subsequent load calculations. The 24-hour composite sample is generally the most satisfactory for use in determining B. O. D. and solids loadings and for loadings due to other constituents in industrial wastes of fairly uniform quality. For highly variable wastes such as those encountered when there is batch discharge of different kinds of strong wastes, a composite based on a shorter time interval may provide better information. It is, therefore, frequently desirable to composite over 2-, 4-, or 8-hour periods in addition to a 24-hour period.

It must be understood that the act of compositing automatically masks the abnormalities in waste characteristics. The longer the compositing period the greater the masking effect is likely to be. This is particularly true in the case of highly variable chemical wastes. Chemical reactions may occur within the composite sample which can render conclusions based solely on the analysis of such a sample completely erroneous. For example, where both acid and alkaline wastes are involved, a composite may indicate only a slightly acid, slightly alkaline, or even a neutral condition. Hourly grab samples would have shown both strong acid and strong alkaline characteristics. These extremes could cause serious damage in the receiving stream, and such damage could not be predicted from analysis of a composite sample alone.²

The following examples illustrate the method of combining grab samples in volumetric proportion to flow to provide 24-hour and 8-hour composite samples. (In these examples, it is assumed that preliminary observations have indicated that hourly sampling-gaging intervals are adequate to provide a representative composite.)

c. *Manual Compositing.* Manual compositing requires the following steps:

Collection of "grab" samples at regular intervals.

Simultaneous determination of flow rates.

Compositing of the grab samples in proportion to the observed rates of flow.

The last step will be expedited and mistakes avoided if a table is prepared showing the volume of the grab sample to be added to the composite container for each flow rate in the expected range.

d. *Sampling Interval.* Normally the interval between sample collection for grab or composite samples should not be greater than one hour. More frequent sampling (15- or 30-minute intervals) is often desirable. In general, the more frequent the sampling (and flow measurement) the more accurate the information obtained will be.

e. *Batch Sampling.* If the industrial operation involves periodic rapid discharge of batch tanks of spent solutions, these should be subjected to special study. Normally this will require measurement of tank volumes, rates of discharge and analysis of representative samples. The full effects of batch discharge may be missed by composite and grab sampling of the main waste stream. (Rapid discharge of significant volumes of strong wastes may produce undesirable "slug" effects at treatment works.)

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Example 1

Twenty-four Hour Composite Sample

Time	Observed rate of flow	Size of portion for composite sample
0700.....	80 gpm	240 ml.
0800.....	80	240
0900.....	75	225
1000.....	100	300
1100.....	130	390
1200.....	110	330
1300.....	80	240
1400.....	85	255
1500.....	95	285
1600.....	110	330
1700.....	120	360
1800.....	125	375
1900.....	100	300
2000.....	120	360
2100.....	110	330
2200.....	100	300
2300.....	100	300
2400.....	90	270
0100.....	80	240
0200.....	75	225
0300.....	80	240
0400.....	95	285
0500.....	80	240
0600.....	75	225
Sum.....	2295	6885 ml.

Total flow

$$= (60) (2295) = 137,700 \text{ gal./24 hrs.}$$

$$= 138,000 \text{ gal./24 hours (rounded)}$$

Example 2

Eight-Hour Composite Sample

Time	Observed flow rate	Revised flow rate	Size of portion for composite sample
0800.....	60 gpm	(1) (60) = 30 gpm*	150 ml.
0900.....	80	80	400
1000.....	110	110	550
1100.....	120	120	600
1200.....	90	90	450
1300.....	40	40	200
1400.....	100	100	500
1500.....	130	130	650
1600.....	100	(2) (100) = 50**	250
Sum.....		750	3750

Total flow in 8 hrs. = (60) (750) = 45,000 gal.

*60 gpm flow assumed to persist from 0730 to 0830 or for only 1/2 hour during 8 hour composite period (0800-1600).

**100 gpm flow assumed to persist from 1530 to 1630 or for only 1/2 hour during 8 hour composite period. (0800-1600).

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*f. Preservation of Samples.*¹¹ Most wastes exhibit some degree of instability, and the best insurance against change in sample characteristics is prompt analysis. Where this is not feasible, various methods of preservation may be used. However, it must be recognized that preservatives may cause serious interference with subsequent analysis. Consequently chemical preservatives should be used only after discussion of the problem with laboratory personnel. As a guide to preservation methods the following information is presented. For additional information see *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes*.¹²

Refrigeration is the most generally satisfactory preservation method. Temperature should not exceed 4° C. (39° F.).

Formaldehyde is not recommended as a preservative because it interferes with many analytical determinations.

Samples for the determination of B. O. D. must NOT be treated with chemical preservatives. Use refrigeration only. (BOD samples should be refrigerated during compositing.)

Samples for oxygen consumed (dichromate) may be preserved by acidifying with sulfuric acid to pH 2 to 3.

Nitrogen balance may be preserved for 24 hours by adding sufficient sulfuric acid to the sample to produce an acid concentration of 1,500 ppm.

Dissolved oxygen samples may be preserved for short periods (4 to 8 hrs.) by adding 0.7 ml. concentrated H₂SO₄ and 1 ml. 2 percent sodium azide solution to the dissolved oxygen sample bottle (250 to 300 ml). Preserved samples must be stored at the temperature of collection or water sealed and kept at 10°-20° C. Immediate analysis is preferable and is a requirement if the sample contains ferric iron.

Cyanide samples can be preserved by adding NaOH to raise the pH to 11.0+ and storing in a cool place.

Phenol samples can be stored up to 18 hours if treated with copper sulfate at the rate of 1.0 gram per liter of sample. Analysis should be completed within 24 hours after sample collection.

Sulfide samples (for determination of total sulfides) may be preserved by adding zinc acetate solution (240 grams/liter) at the rate of 2 ml. per liter of sample.

*g. Manual Sampling.*¹³ In manual sampling the following should be observed:

Be sure there is opportunity for thorough mixing of the wastes above the sampling point.

Collect samples as near mid-channel as possible.

Use a dipper or other convenient wide-mouthed container. Take a full dip of waste to get a representative sample.

Avoid skimming the surface of the waste or scraping the bottom on the channel.

Keep sample portions well mixed during compositing. Rapid measurement of individual portions is essential.

If there is visual evidence of unusual waste characteristics, make a note of it. Collect a grab sample.

Sample dippers and containers should be thoroughly cleaned prior to start of sampling.

Provide a complete sampling outfit for each sampling point.

Observe chemist's instructions regarding preservation of samples.

Develop a standard identification system. Each sample container should be identified before it is moved from the sampling point. Minimum identifying information should include date, time, origin, collection method, name of sampler, and observations as to unusual occurrences.

Remember that the reliability of a manually collected sample depends upon the care exercised by the sampler. Take time to instruct the sampling crews and stress the importance of their job.

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h. Mechanical Sampling. Various types of automatic mechanical samplers are available commercially. Where permanent sampling-gaging installations are to be provided, such equipment should receive careful consideration. Mechanical samplers are available which will collect composite samples proportioned according to flow. Mechanical samplers should be selected only after careful study of the characteristics of the waste. Although such devices possess many advantages over manual sampling, they also have certain limitations. Clogging and corrosion may present problems with certain types of industrial wastes. Routine maintenance, including daily cleaning, is usually required.^{9 6 11 12 13}

6-11 ANALYTICAL METHODS. Because of their complexity industrial wastes pose unusually difficult analytical problems. Problems of interference are frequently encountered and methods suited to the analysis of a particular waste may be inadequate when applied to another. It is, therefore, frequently necessary to modify standard procedures. Preliminary tests are often required to determine the modifications needed. Generally time and money will be saved if the whole problem of sampling and analysis is discussed in advance with the chemist who will make the analyses.

The best reference work on analytical procedures is *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes*.¹² Part II covers physical and chemical examination of sewage, treatment plant effluents, and polluted waters. Part III covers physical and chemical examination of industrial wastes.

6-12 WASTE LOAD CALCULATIONS. Waste load is readily computed from the following formula:

$$L = \frac{(8.34)(S)(V)(C)}{1,000,000}$$

where

L = waste load in pounds of a specific constituent discharged in a specified time period "T"; e. g. lbs. 24 hours, lbs. 8 hrs. etc.

V = total volume of waste in gallons discharged in time "T."

C = concentration of the constituent in the composite sample in parts per million (ppm) (Sample composited in time "T").

S = specific gravity of the waste sample. (Normally this = 1.0 for all practical purposes and specific gravity can be ignored except in the case of very strong wastes.)

For S = 1.0

$$L = \frac{(8.34)(V)(C)}{1,000,000}$$

For "V" in gallons discharged in 24 hours (T), "L" is in terms of lbs. per 24 hours; for "V" in gallons discharged in 8 hours (T), L is in terms of lbs. per 8 hours, etc.

Example 3 (continuous discharge)

Assume that analysis of the 24 hour composite sample illustrated in Example 1, paragraph 6-10b, showed sulfuric acid in concentration of 1250 ppm (expressed as H₂SO₄).

From Example 1, volume, V = 138,000 gallons, T = 24 hours, therefor—

$$L = \text{lbs. H}_2\text{SO}_4 \text{ per 24 hours} = \frac{(8.34)(138,000)(1250)}{1,000,000} = 1440$$

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Example 4 (continuous discharge)

Assume that analysis of the 8-hour composite sample illustrated in Example 2, paragraph 6-10b, showed the following:

Sulfuric acid = 850 ppm (as H_2SO_4)
Cadmium = 60 ppm (as Cd^{++})
Chromium = 50 ppm (as Cr^{+++})
Zinc = 35 ppm (as Zn^{++})

Then the 8-hour load, L, in respect to the various substances, would be—

$$H_2SO_4 = \frac{(8.34)(45,000)(850)}{1,000,000} = 320 \text{ lbs.}$$

$$Cd^{++} = \frac{(8.34)(45,000)(60)}{1,000,000} = 23 \text{ lbs.}$$

$$Cr^{+++} = \frac{(8.34)(45,000)(50)}{1,000,000} = 19 \text{ lbs.}$$

$$Zn^{++} = \frac{(8.34)(45,000)(35)}{1,000,000} = 13 \text{ lbs.}$$

Example 5 (batch discharge)

Assume a 1,000-gallon tank of waste sulfuric acid solution is discharged periodically. Analysis of a representative sample of the tank's contents indicates that the acid concentration is 8.4 percent H_2SO_4 by weight. The specific gravity of the waste is 1.06. As 8.4 percent by weight is equivalent to 84,000 ppm

$$L = \text{lbs. } H_2SO_4 / \text{batch} = \frac{(8.34)(1.06)(1,000)(84,000)}{1,000,000} = 744$$

If this batch had been discharged along with the other waste considered in Example 3, the volume would have been increased from 138,000 to 139,000 gallons per 24 hours or about $\frac{1}{2}$ of 1 percent. The load would have been increased from 1440 to 2184 lbs. of H_2SO_4 per 24 hours or approximately 51.5 percent. Thus a concentrated waste batch while increasing volume by less than 1 percent would have increased load by more than 50 percent.

6-13 EFFECTS OF INDUSTRIAL WASTES ON SEWAGE WORKS. Industrial wastes may have deleterious effects on systems designed exclusively for the collection and treatment of sanitary sewage. Problems associated with the discharge of industrial wastes into sanitary sewer systems are reviewed briefly in the following sections.¹⁷

a. *Inadmissible Wastes.* The following should be excluded from the sanitary sewer system to the maximum possible extent:¹⁷

- Gasoline, solvents, other volatile hydrocarbons, fuel oil, paraffin.
- Ashes, sand, cinders.
- Tar, plastics, other viscous substances.
- Lubricating oils and grease.
- Metal scraps, wood scraps, rags, glass.
- Acetylene generation sludge.
- Lime-soda water softener sludge.
- Toxic, corrosive, malodorous liquids. (See subsequent sections)
- Toxic, corrosive, explosive, malodorous gases.

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b. Volume Control. Industrial wastes often exhibit wide variations of flow rates. This factor alone may make it inadvisable to admit them directly to sanitary sewers. Rapid discharge of industrial wastes may overload sewer lines, pumping stations, and treatment works. Regulation of the rate of industrial waste discharge is often a requirement for successful combined handling of sewage and industrial wastes.

c. Strength Control. Industrial waste strength may fluctuate widely. Excessive industrial waste concentrations may produce shock loads at sewage treatment plants with resultant interference with biological treatment processes. Regulation of industrial waste discharge to iron out concentration (as well as volume) peaks is often required.

d. Temperature Control. High waste temperatures may damage sewer joints as well as accelerate decomposition of sanitary sewage making it septic and malodorous. The maximum temperature of significant volumes of industrial waste should not exceed 150° F. Pre-cooling is indicated for high temperature wastes.

e. Oil and Grease. These should be removed to the maximum practicable extent prior to discharge to the sewer system. Substantial amounts of soluble cutting oils may pass through treatment works causing objectionable conditions in receiving streams. Special pretreatment methods are required for wastes containing significant amounts of soluble cutting oils. Excessive amounts of lubricating oils and grease may cause sewer clogging and are certain to cause trouble at sewage treatment plants. A maximum concentration of 100 ppm is suggested for admissible oils and grease.¹⁷ Grease and oil separators represent the minimum in pretreatment where oil and grease are a problem.

f. pH Control. Excessive acidity or alkalinity of industrial wastes may alter the pH of the sewage to the extent that biological treatment processes will be harmed. Excessive acidity will also cause corrosion damage at pumping stations and treatment works. Alkaline wastes may react with sewage producing objectional sludge. For admission to sanitary sewers, the pH of industrial wastes should be in the approximate range 6.0 to 9.0. Regulation of the waste discharge rate is generally desirable. Correction of acidity or alkalinity may be accomplished by pretreatment of the industrial wastes with appropriate neutralizing chemicals plus separation of any sludge formed. Where both acid and alkaline wastes are involved, judicious mixing of the two may provide the required pH correction.

g. Toxic Wastes. Approximate limiting concentrations of certain commonly-encountered toxic materials are given in the following table. These should be regarded as approximations and are presented merely as rough guides.^{18 19}

Table V.
Approximate Limiting Concentrations of Toxic Substances

Constituent	Concentration Sludge digestion* ppm	Concentration Activated sludge* ppm	Causing Interference in Trickling filters* ppm
Chromium.....	1-5	2-3	3
Copper.....	1-2	1	1
Cyanide (CN ⁻).....	2	2	2
Cyanide (HCN).....	1	2
Iron.....	(***)	(***)
Lead.....	0.1	0.1
Nickel.....	500**	1-3	1-3
TNT****	60	(****)	(****)
Zinc.....	20	(***)	(***)

*Concentration in sewage except as noted.

**Concentration in sludge.

***Interference.

****Interference. (8 percent by volume TNT wastes interfere with activated sludge process. Self purification of water is said to be slightly retarded by 0.5-1.0 ppm of TNT. Beyond 1.0 ppm deleterious effects occur.)

Recent work ²⁰ indicates that the toxicity of certain metals in order of decreasing toxicity is as follows:

Table V.I.

Toxic Metals Arranged in Order of Decreasing Toxicity ²⁰

Nickel
Copper
Cobalt
Cadmium
Chromium (trivalent Cr³⁺)
Zinc
Chromium (hexavalent Cr⁶⁺)
(Basis of toxicity: 5-day oxygen demand)

*h. Synthetic Detergents.*²¹ Excessive quantities of synthetic detergent materials may cause serious operating difficulties at sewage treatment plants. One of the most troublesome problems has been frothing of aeration tanks at activated sludge plants. Synthetic detergents produce persistent emulsions with the result that grease and oil removal by primary units may be less effective. It also appears that synthetic detergents will interfere to some extent with solids removal in primary tanks. As a result, a higher B. O. D. load will be transferred to secondary treatment units. Effluents of sewage treatment plants receiving high detergent loads will be rich in available phosphorus. (Synthetic detergents contain a high proportion of phosphate compounds.) This will increase the fertility of receiving waters and may result in algae growths of nuisance proportions.

i. Solids. Solids in industrial wastes may be organic or inorganic and may be in a dissolved, colloidal or suspended state. Suspended solids of high specific gravity and in high concentration may interfere with flow in sewer systems and cause clogging and other operational difficulties at pump stations and treatment plants. Examples of wastes which contain a high proportion of inorganic suspended solids are those from lime-soda ash water softening plants and those derived from the cleaning of vehicles. Rinse water from ion exchange water treatment devices contains a high proportion of dissolved inorganic solids. Wastes unusually high in putrescible organic solids (suspended, colloidal or dissolved) will usually accelerate decomposition in the sewer system with resultant odor and corrosion problems. Significant volumes of such wastes are likely to produce serious operating difficulties and effluent deterioration at conventional sewage treatment plants.

6-14 COMBINED SEWAGE-INDUSTRIAL WASTE TREATMENT. Although industrial wastes generally exhibit characteristics which are objectionable from the standpoint of sewage treatment, it does not follow that it is not feasible under some circumstances to handle such wastes at sewage treatment works. The dilution afforded by the sewage itself may render the effects of the industrial wastes unobjectionable. If dilution is not sufficient, pretreatment of the industrial wastes may be required to reduce waste strength to an acceptable level. Regulation of discharge of industrial wastes is often a useful and economical solution to problems posed by combined treatment. This serves to equalize the waste load and volume and may be correlated with sewage flow to take advantage of dilution afforded by the latter. Each situation requires individual study. Such a study should answer the following questions: ^{17 22 23 24}

Will the industrial waste damage the sewer system?

Is the chemical nature of the waste such that it will respond to treatment by conventional sewage treatment methods?

Will the industrial waste promote anaerobic decomposition of the sewage and thereby create odor and corrosion problems?

What is the industrial waste-sewage dilution ratio?

Will the added volume of industrial waste create a hydraulic overload in the collection system or at the treatment plant?

Is the character of the waste such that it will interfere with the treatment process?

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Are the sewage treatment plant units adequate to handle the additional load?
How will the additional load affect the sewage treatment plant effluent and the receiving stream?

6-15 PRINCIPLES OF WASTE CONTROL.²³⁻²⁵ The objective of industrial waste control is protection of water resources from pollution damage. Often treatment of the wastes is required to achieve this objective. However, it is emphasized that treatment itself is not the objective; treatment is the means, not the end. Waste treatment is one means of reducing waste load, but other methods of waste load reduction may be equally effective and much more economical. These include process changes to obtain partial or complete elimination of the waste; segregation and independent disposal of low-volume, high-strength wastes; recirculation of waste water, etc. Waste prevention, reduction and salvage possibilities should be studied carefully before a decision is reached as to the extent and type of treatment works required. Waste prevention and salvage may prove profitable in some cases because of recovery of valuable process materials and water savings. Even in the absence of salvage values and substantial water savings, waste prevention is worthwhile because it is certain to effect a saving in treatment costs. *Waste treatment costs money; waste prevention saves money.* Principles of waste control are presented in the following subparagraphs:

a. *Process Changes.* Process changes may result in the reduction or virtual elimination of liquid wastes. The application of this principle is usually difficult; nevertheless, the possibilities should be thoroughly explored. Process changes may in the long run represent the best and cheapest solution to the waste problem.

b. *Reduction of Waste Volume.* Reduction of waste volume will generally increase concentration, but normally the overall result will be a saving in treatment costs. Volume reduction may be accomplished by a number of means.

(1) *Re-use of waste water.* This often requires treatment of the recirculated flow.

Example: cooling, sedimentation, filtration and re-use of TNT-bearing shell washout water.

(2) *Control of rinse water.* Check rate of flow of clean water to rinse tanks and reduce to minimum consistent with process requirements. The possibility of substituting low-volume, fine-mist spray methods for dipping methods should be investigated. Substitution of a still rinse and subsequent use of the still rinse water as process solution make-up may prove advantageous. Counter-current washing instead of batch washing may be beneficial in reducing waste volume and equalizing strength.

(3) *Segregation of cooling water.* Substitution of surface condensers for barometric condensers will avoid contamination of large volumes of cooling water. The condensed waste, usually small in volume may be handled by an alternate disposal method.

(4) *Segregation of storm water.* The entrance of storm water into the waste disposal system upstream from the treatment processes obviously would increase the volume at times and thus increase the waste treatment problem.

c. *Reduction of concentration of contaminants.* Concentration of contaminants may be decreased by the following means.

(1) *Improvements in plant housekeeping and maintenance.* Check for oil, chemical solution, water, etc. leaks. **Repair valves, pumps etc.**

(2) *Segregation of strong wastes.* Small volumes of concentrated wastes may be intercepted in containers or sumps not connected to the plant sewer. These may be returned to the process or disposed of by alternate means, such as burning.

(3) *Reduction of carry-over.* Carry-over ("dragout") of chemical solutions from treatment tanks to rinse tanks may be reduced by installation of drain racks and drain boards at or adjacent to treatment tanks.

(4) *Neutralization.* Acid and alkaline wastes may be used to neutralize one another.

5) *Re-use of material.*

Example: Purification and re-use of "soluble" oil used in machining operations.

6-16 **COLLECTION OF WASTES.** Proper collection of wastes is an important aspect of industrial waste disposal. Collection may present difficult problems, particularly at existing industrial plants that are discharging untreated wastes through numerous outlets. Planning for waste collection should begin with a study of individual waste sources. In general, clean water streams (cooling water) should be segregated from waste streams that require treatment. Normally uncontaminated cooling water can be discharged to storm sewers or to the nearest water course. Wastes requiring preliminary treatment (e.g. chromate wastes, by special methods) should not be allowed to mingle with the main waste stream. Consideration should be given to possible adverse effects of high temperature, acid or alkaline wastes on pipe and joint materials and pumps. As a part of the collection system it is frequently desirable to provide one or more equalizing tanks. Such tanks will serve the dual purpose of suppressing flow surges and quality variations. (This is important in connection with treatment plant operation.) Where pumping is required, equalization may be sometimes accomplished in the pump station wet well.

6-17 **INDUSTRIAL WASTE TREATMENT.** Wastes from industries reflect the raw materials and processes employed by industry and are as complex and diversified as the industries themselves. There is no standard method for treating industrial wastes. Each industrial plant effluent presents a special treatment problem. Industries manufacturing identical products and employing the same processes, but located in different regions probably will not require the same type and extent of waste treatment, for availability of dilution water and water uses vary from area to area. In many instances extensive laboratory and pilot plant studies are required to determine the kind of treatment needed for a particular waste. The following paragraphs of this chapter deal with treatment processes principally in terms of various unit operations. Depending on waste characteristics, combinations of these basic procedures, when applicable, may be utilized to provide the required degree of treatment. Some of the basic treatment methods are presented briefly in the following subparagraphs.

a. *Solids separation.*

(1) **Racks and screens.** Bar racks (also termed bar screens) having relatively wide spacings (1" to 1.5") are often used at sewage treatment plants. These may be hand- or mechanically-cleaned and their principal function is the protection of pumps and treatment units from damage and clogging resulting from large solids, rags, etc. carried by the sewage. Such devices will serve a similar protective role at an industrial waste treatment plant. Their use is indicated ahead of pumping stations.

Revolving drum or disc screens having openings from one sixteenth inch to approximately one quarter inch may be suited to preliminary treatment of wastes containing coarse solids. Certain types of screens are self-cleaning. Other require the use of water jets or brushes.

(2) **Grit removal.** Wastes from ordnance and vehicle repair depots are likely to contain considerable grit as well as dirt and grease. Washing and steam cleaning are important sources of these waste components. Grit is objectionable because of its tendency to clog sewers and cause rapid wear on pumps and sludge removal mechanisms. Grit is also harmful to plants employing sludge digestion. The grit accumulates in the digester and may clog sludge draw-off piping. Wastes containing an excessive amount of grit should be segregated and subjected to grit removal treatment prior to discharge to sewer systems, pumping stations or waste treatment units. (Grit chamber design for sewage treatment works is described in Engineering Manual, Part VIII, Chapter 3, *Sewage Treatment Plants*.)

(3) **Sedimentation.** Sedimentation, plain or assisted by the addition of flocculating chemicals, is useful in connection with the treatment of most industrial wastes. Sedimentation will produce a substantial reduction in the suspended solids content of a waste. Sedimentation of industrial

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wastes is usually accomplished in basins similar to those used for sewage treatment. Mechanical sludge and scum removal equipment is customarily provided. Sedimentation tank overflow and weir rates need to be considered carefully. Rates suited to sewage treatment may be used as a guide but adjustments will be required if the settling characteristics of the industrial wastes differ appreciably from those of sanitary sewage. (Principles of sedimentation basin design for sewage treatment plants are given in Engineering Manual, Part VIII, Chapter 3, *Sewage Treatment Plants*.)

Batch sedimentation in fill and draw tanks, while seldom used for sewage treatment, is useful for various industrial wastes, particularly for chemical wastes, such as those produced by metal finishing processes.

Solids removal efficiency of sedimentation units can be improved by employing various coagulating chemicals, such as ferrous sulfate, aluminum sulfate (filter alum), ferric chloride, ferric sulfate, etc. Lime or sulfuric acid may be used for pH adjustment. Activated silica may be employed as a coagulant aid. Successful application of chemical coagulation methods requires facilities for rapid and slow mixing of the chemicals with the waste. The presence of oil in the wastes will retard floc settling, and allowance must be made for this in the design of settling basins. Coagulation characteristics of a waste cannot be predicted with accuracy. Usually pH adjustment is required to secure optimum conditions for floc formation. Experiments, employing a laboratory stirrer, are necessary to determine correct chemical dosage and optimum pH. Use of chemicals will substantially increase the sludge volume from sedimentation units.

(4) *Flotation*. Suspended material, such as oil, grease and other substances having a specific gravity less than that of water tends to separate by floating. Fine particles and some flocculent material having a specific gravity greater than that of water settle, but at a very low rate. Flotation methods offer a useful means of treating wastes containing low specific gravity and slow settling materials. Flotation may be accomplished in simple gravity separators or by the use of dissolved air flotation devices.

(a) *Gravity separators*. An example of a gravity separator of proven usefulness in oil removal is the device developed by the American Petroleum Institute.^{31, 32} This is often referred to as the "API Separator" and consists of a long, narrow, relatively shallow, baffled basin equipped with a continuous skimming and scraping mechanism. Free floating oil is readily separable in a basin of this type. Dispersed oil which will coalesce rapidly is also removed. However, emulsified oil which coalesces slowly will not be reduced appreciably. Where emulsions are encountered pre-treatment to break the emulsion is indicated.³³

(b) *Dissolved air flotation*.^{34, 35, 36} As applied to waste treatment this type of flotation involves production of many small air bubbles within the waste. These attach themselves to the suspended particles causing them to float to the liquid surface. The floating material is skimmed from the surface by mechanical means and the clarified liquid is removed from the flotation tank through submerged outlets. Flotation units have been applied to a variety of industrial waste treatment problems. Emulsified oils, washing machine wastes, paint spray booth wastes, and wastes containing soluble oils have been successfully treated by dissolved-air flotation methods. The efficiency of the process may be improved by the addition of flocculating chemicals, such as alum and activated silica, and surface active agents. Clarification in air flotation units is quite rapid. This permits a fairly high operating rate and consequent economy in space requirements.

b. *Biological Oxidation of Organic Substances*. Destruction of organic components of many industrial wastes may be accomplished by biological oxidation. Wastes which, when properly seeded with biological life, exhibit a biochemical oxygen demand are amenable to biological oxidation. However, not all organic wastes can be treated by biological processes. (A notable example of an organic waste which is not susceptible to biological attack is "red water" from TNT manufacture. This waste has resisted all attempts to treat it by biological methods.) When applicable, biological methods provide an efficient method of treatment. Biological processes are

customarily preceded by treatment units for the removal of a substantial proportion of suspended matter.

(1) *Trickling filters.*⁴¹ Trickling filters similar to those employed for domestic sewage are useful for the treatment of organic industrial wastes which exhibit a normal biochemical oxygen demand. Both standard and high-rate trickling filters are employed. Recirculation generally proves advantageous. Trickling filters are rugged, reliable treatment devices that are relatively easy and inexpensive to operate. In general they provide the best type of biological treatment for industrial wastes or for combined treatment of sanitary sewage and industrial wastes. (Design criteria for trickling filters, as used in the treatment of sanitary sewage, are given in Engineering Manual, Part VIII, Chapter 3, *Sewage Treatment Plants*.)

(2) *Activated sludge.* The activated sludge process has been applied to a limited extent to the biological oxidation treatment of organic industrial wastes.⁴² The process is sensitive to shock loads and toxic substances and requires extremely careful operating control. Consequently its use for industrial waste treatment except under unusual circumstances is not recommended.

c. *Neutralization.* Strong acid or alkaline wastes generally require neutralization before final disposal. (See figs. 2 and 3.) Neutralization is frequently complicated by accompanying chemical reactions which produce sludge. Where both alkaline and acid wastes are involved, mixture of the two in a suitable receiving tank is generally advantageous. In such instances only the excess acid or alkali requires the addition of a neutralizing chemical. Most industrial wastes requiring neutralization are acid in character. Acid wastes derived from metal pickling and finishing operations and the manufacture of explosives usually pose the greatest problems.

(1) *Spent pickling acids.* Various acids, including sulfuric, nitric, hydrochloric, phosphoric, hydrofluoric, are used for metal pickling. Sulfuric acid is the most widely used and treatment of spent sulfate pickling solutions has been extensively studied.^{43 44 45} High calcium lime (quicklime or hydrated lime) is the alkaline agent most commonly used for neutralization of spent pickle liquor. This type of lime reacts readily and is usually easy to obtain. Neutralization is carried out by feeding lime slurry to the spent pickle liquor contained in an acid-proof tank equipped with an agitator. Lime requirements are estimated from the "acid value" of the pickle liquor and the "basicity factor" of the lime. Both of these terms are determined by chemical analysis.^{46 47} The "acid value" is a measure of the total acidity of the pickle liquor and the "basicity factor" measures available alkalinity of the lime (or other alkaline agent) in terms of grams of calcium oxide (quicklime, CaO) per gram of lime or other agent. Chemicals other than lime can be used and the following table lists other alkaline agents.

Table VII.
Approximate Basicity of Various Alkaline Agents^{48 49}

Agent	Basicity Factor (Expressed as equivalent grams of CaO per gram of agent)
Sodium hydroxide.....	0.69
Sodium carbonate.....	0.51
Hydrated Lime, High Calcium.....	0.71
Hydrated Lime, Dolomitic.....	0.91
Quicklime, High Calcium.....	0.94
Quicklime, Dolomitic.....	1.1
Limestone, High Calcium.....	0.49
Limestone, Dolomitic.....	0.56

Sodium hydroxide is normally too expensive for use as a neutralizing agent. Sodium carbonate (soda ash) is easily handled but is also fairly expensive and has the additional disadvantage of forming soluble iron compounds.⁵⁰ Pulverized limestone is relatively cheap, but reaction rate is a function of particle size. Unless the limestone is ground to pass a 100-mesh or finer screen its full

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neutralizing power will not be realized unless a long reaction time is provided. Dolomitic lime reacts at a lower rate than high calcium lime but has a somewhat higher neutralizing power. The reaction rate for dolomitic lime or any other neutralizing agent can be increased by raising the temperature of the reaction mixture and by adding an excess of the agent. Important pickle liquor neutralization products are hydrated metal oxides plus the salt of the pickling acid employed. Where steel is pickled in sulfuric acid and lime is the neutralizing agent, the products are hydrated iron oxides and calcium sulfate. These substances are found in the slurry formed by the neutralization reactions. This slurry is commonly disposed of by lagooning. Slurries formed by simple neutralization of spent acid derived from steel pickling settle slowly and cannot be dewatered readily.^{33, 34} A controlled oxidation process has been developed which decreases sludge volume and increases filterability.^{35, 36} This process employs a conventional alkaline neutralizing agent and consists of feeding the alkaline agent and the pickle liquor into an aerated reaction vessel. Temperature should be maintained above 170° F. and vigorous aeration should be provided. If lime

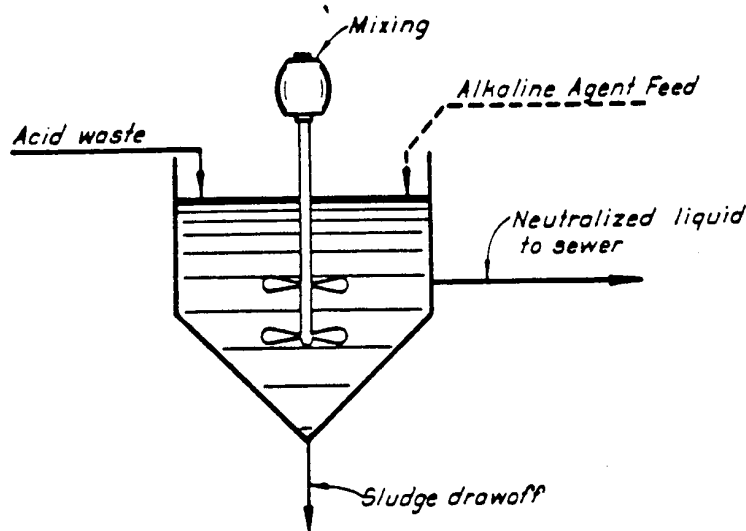


Figure 2. Batch neutralization of acid wastes.

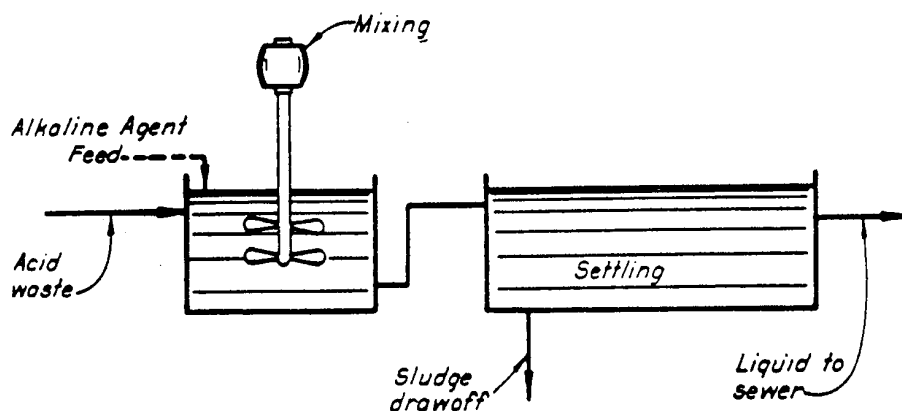


Figure 3. Continuous neutralization of acid wastes.

is the neutralizing agent, the sludge will contain, in addition to ferroso-ferrie oxide, a high proportion of calcium sulfate. The process can be operated on a continuous basis.^{23 24}

(2) *Spent acid.* Neutralization of spent acid, such as encountered in the manufacture of smokeless powder, does not ordinarily pose problems of unusual difficulty. Calcium sulfate deposition in effluent lines of high calcium lime neutralizing plants has been encountered.²⁵ This difficulty was overcome by diluting the effluent with cooling water. Laboratory studies indicated that deposition could have been avoided by the substitution of dolomitic lime for high calcium lime. Dolomitic lime reaction products are more soluble than those of high calcium lime. Trickling of wastes containing a high proportion of sulfuric acid through beds of lump limestone is not a particularly effective method of treatment. The sulfuric acid reacts with the limestone and produces an impervious coating of calcium sulfate which inhibits further neutralization.^{26 28} Dilute acid wastes may be treated on upflow limestone beds if they do not contain other materials such as iron which will precipitate on and inactivate the limestone.

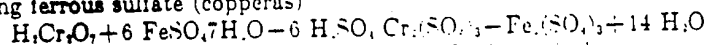
(3) *Metal-finishing wastes.*^{29 42} Treatment of metal-finishing wastes often involves removal of toxic substances (e. g., chromium) as well as neutralization. The important constituents of metal-finishing wastes are, in addition to the acids used for pickling, alkaline cleaners, solvents, and metal salts (chromium, cadmium, copper, zinc, aluminum, iron) derived from pickling, cleaning, anodizing and plating operations. The mixed wastes are usually acid in character and this is one of the important reasons for segregating waste cyanide solutions from other metal-finishing wastes.

Metal-finishing waste treatment commonly involves neutralization to a pH of approximately 8.0. The combined wastes, exclusive of those containing cyanide, are conducted to a suitable tank equipped for vigorous mixing (mechanical or air injection). A neutralizing and precipitating agent, usually lime, is then added in an amount sufficient to react with the acid and metal salts present. After completion of the reaction the metallic precipitates plus other insoluble reaction products are separated by sedimentation. The latter may be accomplished in the reaction tank if batch treatment is practiced or the neutralized waste may be discharged to a sedimentation basin, commonly a lagoon. (See subsequent discussion on lagoons.) Most of the heavy metals are removed by this type of treatment. It should be noted that zinc and aluminum are amphoteric materials and that too great an excess (high pH) of neutralizing agent will re-dissolve previously precipitated zinc and aluminum hydroxides.

(a) *Chromate waste treatment.*^{29 42} Chromium in the hexavalent form (Cr^{+6}) is not removed by simple neutralization treatment. For this reason it is generally advantageous to segregate chromate wastes for separate handling through the initial (reduction) stage of treatment. Successful precipitation of chromate wastes requires reduction of the chromium from the hexavalent (Cr^{+6}) form to trivalent chromium (Cr^{+3}). This can be accomplished by reduction under acid conditions using reducing agents, such as ferrous sulfate (copperas),* sodium metabisulfite, and sulfur dioxide. Following reduction, addition of an alkaline agent, such as lime, precipitates the chromium. See figure 4. Chemical reactions involved in chromium reduction and precipitation are as follows:

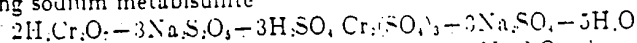
Reduction

Using ferrous sulfate (copperas)



(1 ppm Cr^{+6} requires 10 ppm $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, theoretical)

Using sodium metabisulfite



(1 ppm Cr^{+6} requires 2.8 ppm 97.5 percent $\text{Na}_2\text{S}_2\text{O}_5$, theoretical)

* Ferrous sulfate reduction can also be accomplished under alkaline conditions (up to pH 10).⁴³

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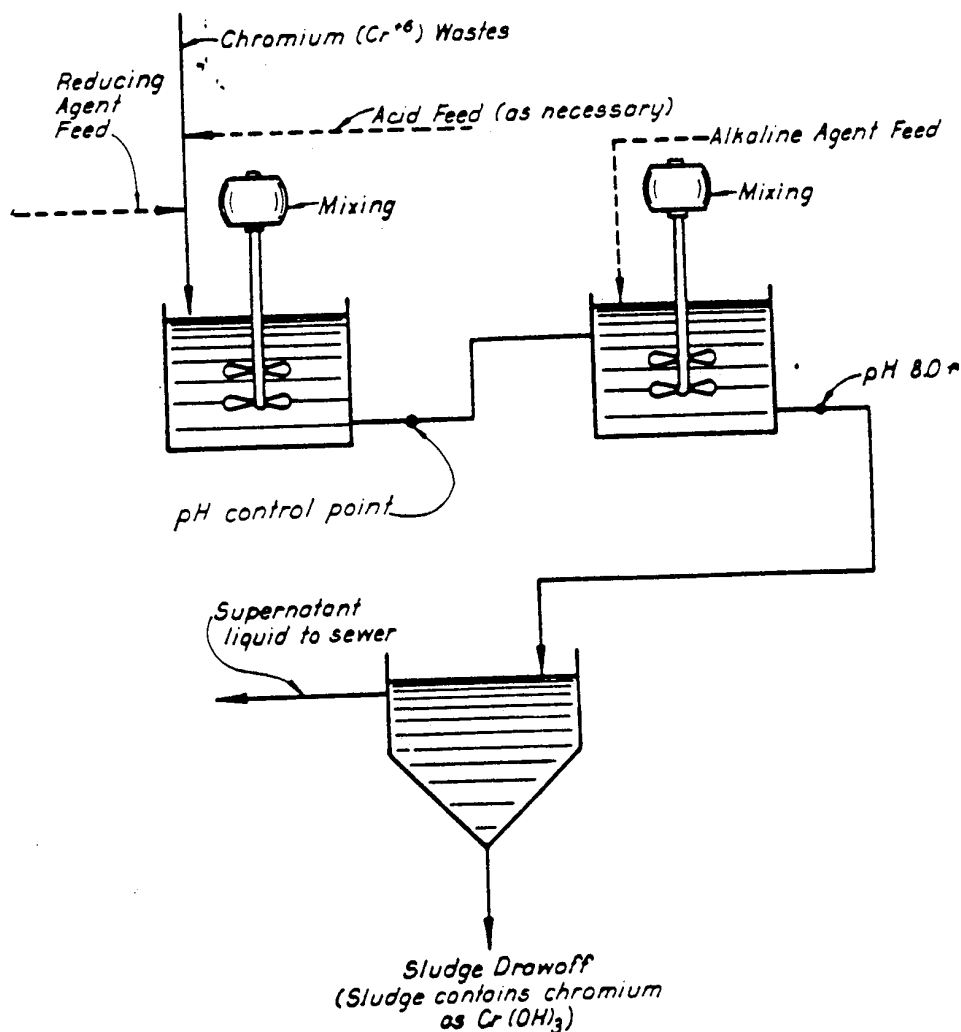
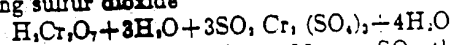


Figure 4. Reduction-precipitation treatment of chromium wastes.

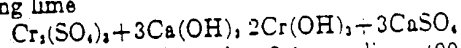
Using sulfur dioxide



(1 ppm Cr^{+6} requires 1.85 ppm SO_2 , theoretical)

Precipitation

Using lime



(1 ppm Cr^{+6} requires 2.4 ppm lime, (90 $\text{Ca}(\text{OH})_2$), theoretical)

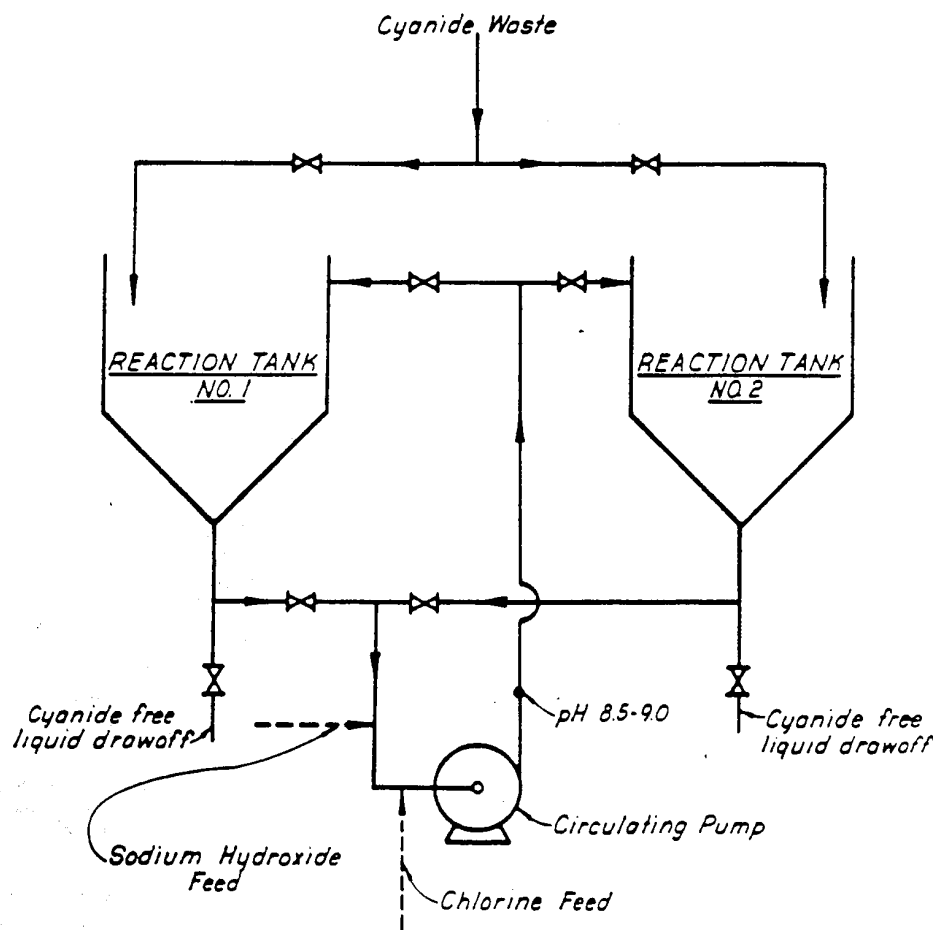
(Additional lime required for precipitation of iron if ferrous sulfate is used)

The reduction reaction rate for dilute chromium solutions (20 ppm or less) is low but can be speeded up by the addition of an excess of reducing agent. Once the chromium is reduced the waste may be

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combined with other metal-finishing wastes for neutralization and precipitation of the tri-valent chromium.

(b) *Cyanide waste treatment.* Acidification of cyanide solutions may produce deadly hydrogen cyanide gas. In addition, cyanide wastes require an entirely different treatment procedure. While numerous methods of cyanide waste treatment^{23, 24} are known and have been employed, the alkaline chlorination method is considered to be the most generally satisfactory method thus far devised. Chlorination under controlled conditions results in complete destruction of the cyanide. Batch or continuous flow treatment may be used; however, batch treatment is recommended for all except the largest installations. Batch treatment (fig. 5) offers the advantage of positive con-

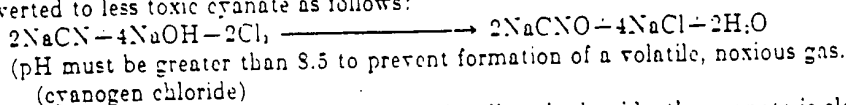


Note: Wastes diverted to reaction tank No.2 while treating in tank No.1 and vice versa.

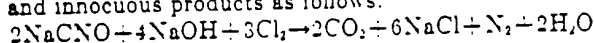
Figure 5. Alkaline chlorination treatment of cyanide wastes.

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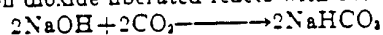
trol of effluent quality. No waste need be discharged until sampling and analysis indicate complete cyanide destruction. Application of the alkaline chlorination method consists of treating the wastes with sodium hydroxide to render them alkaline followed by chlorination for cyanide destruction. The latter reaction apparently takes place in steps. In the initial stage cyanide is rapidly converted to less toxic cyanate as follows:



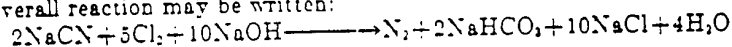
As more chlorine is added in the presence of sodium hydroxide, the cyanate is slowly oxidized to stable and innocuous products as follows:



Carbon dioxide liberated reacts with excess sodium hydroxide:



The overall reaction may be written:



The theoretical chlorine requirement is 6.33 pounds of chlorine per pound of cyanide (as CN^-) destroyed. In practice, other constituents of the waste exert a chlorine requirement, so the actual amount of chlorine needed will exceed the theoretical, approaching 10 pounds of chlorine per pound of cyanide destroyed. Sodium hydroxide (caustic) requirements are reported to approach 1 pound per pound of chlorine used. Sufficient sodium hydroxide is required to maintain the pH of the reaction mixture at the proper value. The optimum pH range is 8.5 to 9.0. Alkalinity of the raw wastes will influence sodium hydroxide requirements. Automatic pH control is desirable. (For small scale operations chlorine may be applied in the hypochlorite form. Use of alkaline hypochlorites provides automatic upward adjustment of pH.) Chlorination of cyanide wastes must be carried on under conditions of vigorous mixing. At least 1 hour should be allowed for completion of the reactions. Temperature should be maintained below 120° F. Alkaline cyanide wastes may be collected at the treatment site in one of two holding tanks, each of which should have a capacity equal to a day's waste flow. Wastes are recirculated in one of the tanks and caustic and chlorine added until all cyanides including metallic cyanide complexes are destroyed. (pH may have to be lowered by addition of acid or excess chlorine to insure destruction of metallic cyanide complexes.) While one tank is filling, the contents of the other are being treated and treatment is continued until analysis indicates that all cyanide has been destroyed. After destruction of the cyanide the alkaline waste water may be mixed with other waste streams. (The residual alkalinity in the treated cyanide waste may be useful in neutralizing acid wastes.)

d. Miscellaneous Treatment Methods.

(1) *Adsorption.* Adsorption on activated carbon or other materials having adsorptive capacity offers a means of treating small volumes of certain organic wastes. The principal application has been in connection with TNT shell washout wastes. One study ¹⁴ indicated that black garden soil would remove approximately 0.1 percent of its weight of TNT when the wastes were filtered through it. Granular activated carbon may be used as a filter medium; however, the previously cited report ¹⁴ indicates that the mixing of powdered activated carbon with the TNT waste is more effective than filtering the waste through carbon. From 100 to 300 pounds of activated carbon are needed for the treatment of 50,000 gallons of TNT (alpha) waste water. The large quantities of carbon required make this type of treatment economically unattractive for plants producing large volumes of waste. Fly ash containing 10 to 25 percent carbon has been used at one ordnance plant for the treatment of TNT waste waters. Approximately 100 pounds of fly ash are required for the treatment of 500 gallons of waste. Fly ash may show considerable variation in adsorptive capacity.

(2) *Ion exchange.*⁴⁴ Treatment of wastes by ion exchange is a relatively new process which shows promise for material recovery and water conservation, as well as waste load reduction. A possible application is to metal plating rinse waters. Ion exchange, like many other treatment methods, is fundamentally a process of concentration. All material removed from the waste by ion exchange methods will be present in the exchanger regenerating solution. The latter, unless re-used, will require treatment prior to final disposal. However, the volume of the regenerating solution will be only a fraction of the total volume of waste passed through the ion exchange unit. Metal recovery from the regenerating solution may be economically worthwhile. Ion exchange methods are also applicable to the purification of electroplating baths.

(3) *Evaporation.* Evaporation using multiple-effect evaporators or other methods is generally a costly method of waste handling, especially if large quantities of waste are involved. Ordinarily evaporation should not receive consideration as a large scale waste-treatment-disposal method unless a thorough study of other waste-handling possibilities has indicated no feasible alternative method. To date, the principal application of large-scale evaporation has been to "red water" (sellite waste) from TNT manufacture. The results of one investigation⁴⁵ have indicated that TNT-sellite-waste volume averages 1.11 ± 0.19 (std. dev.) gallons per pound of TNT produced. Color averages $220,000 \pm 49,000$ (std. dev.) color units⁴⁶ as measured by platinum-cobalt standards.⁴⁷ At one ordnance plant TNT wastes, after pH adjustment, are conducted to multiple effect evaporators. Evaporation yields a concentrate containing 30 to 35 percent solids which is burned in rotary, oil-fired incinerators. The ash is a marketable material of high sodium sulfate content. Cost of "red water" disposal by this method varies from approximately 0.6c to 1.0c per pound of TNT produced. (Solar evaporation is considered in a subsequent paragraph.)

(4) *Chlorination.* (TNT Wastes.) Recent experimental work⁴⁸ has indicated that fresh TNT sellite waste can be chlorinated directly in a column. Treatment with about 9,000 ppm of chlorine reduced the color by more than 90 percent. The residual yellow color in the chlorinated waste is reported to be similar to that found in natural waters and much less objectionable than that of the raw waste. Work on this method of "red water" treatment is continuing.

(5) *Incineration.*⁴⁷ Incineration is a good means of disposing of combustible material, such as waste oil, solvents, solids. Open burning areas are commonly employed for this purpose. For the disposal of large quantities of waste by burning, a specially constructed incinerator will probably be required. Careful design and operation of incinerators are necessary to avoid creation of an air pollution problem. (See Engineering Manual, Part VIII, Chapter 4, *Incineration*.)

(6) *Catalytic oxidation.* A catalytic oxidation method of waste treatment has been developed by one large chemical manufacturing company.⁴⁹ This is reported to be a worthwhile process for the treatment of dilute aqueous wastes containing a variety of organic chemicals. Operating conditions have been established and effective catalysts developed.

(7) *Lagoons.*^{49 50 51 52} Lagoons are extensively used in connection with waste treatment, sludge disposal, and effluent disposal. Low cost and ease of construction make lagoons an attractive means of waste handling, and their use, under favorable circumstances, is encouraged. Certain disadvantages of lagoons and precautions in connection with their use should be noted. Seepage from lagoons may create a very serious ground water pollution problem. In many areas the soil is relatively impervious and seepage presents no problem; however, in others the soil may be quite porous and considerable downward percolation may occur. (See fig. 6). If the wastes contained in the lagoon are nontoxic and low in mineral matter, seepage may not be objectionable. However, highly mineralized or toxic wastes are likely to cause serious damage to ground water.^{53 54 55} Lagoon seepage is an insidious type of pollution. The damage to the ground water may not be discovered for months or years, and correction is extremely difficult. Where porous soils are encountered, lagoons, if used, should be treated to render the soil impervious.

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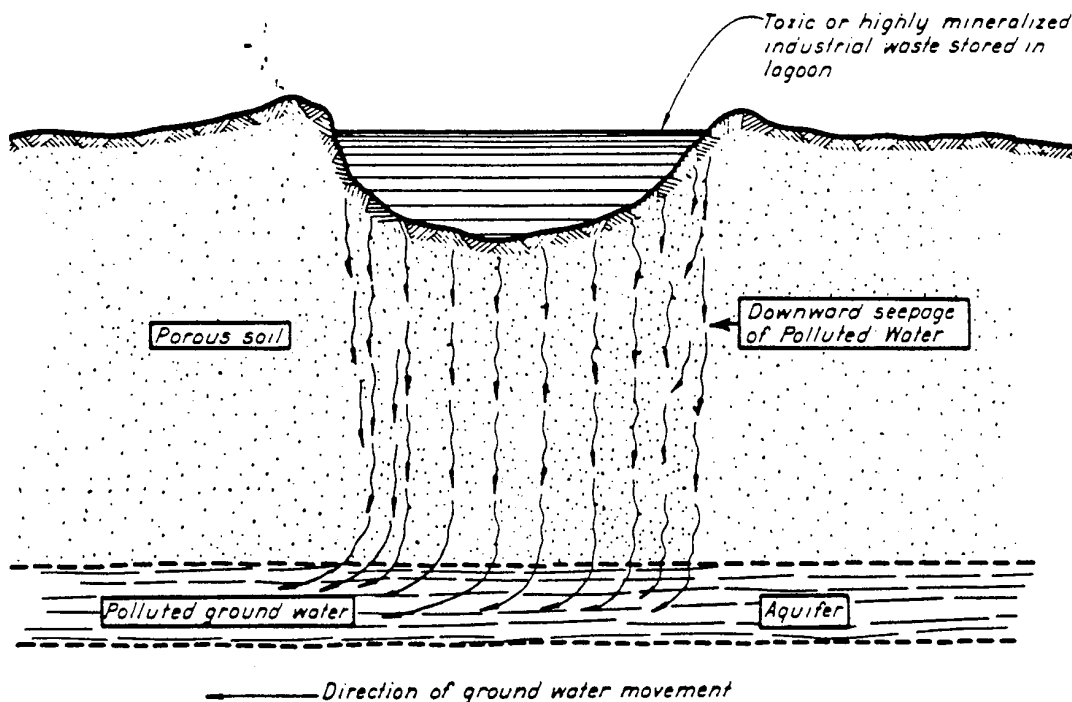


Figure 8 Ground water pollution by seepage through porous soils

e. *Sludge Treatment and Disposal.*²⁸ Disposal of sludge produced by waste treatment processes frequently poses problems as great as the treatment itself. The method of sludge treatment and disposal to be employed depends on the character of the sludge produced. Predominantly organic sludge, not containing toxic substances, may be handled by digestion methods similar to those used at sewage treatment plants. Digestion reduces sludge bulk leaving a stable, easily dried material. Drying of digested sludge may be accomplished in open beds or after chemical conditioning, by means of vacuum filters. Chemical sludges may be air-dried, filtered or centrifuged to reduce bulk and moisture content. Heat drying may be used for additional moisture reduction. Discharge to shallow lagoons is a commonly used method of chemical sludge disposal. This is generally a cheap, effective method of sludge handling. (See previous discussion on lagoons.) Residues from sludge drying operations may, if combustible, be destroyed by incineration. Noncombustible sludge residues may be used for fill or placed on dumps. Care must be exercised to see that drainage from the fill or dump area does not create a new water pollution problem.

6-18 EFFLUENT DISPOSAL.

a. *Re-use of Effluents.* The possibility of re-using all or part of the effluents from industrial waste treatment works should receive consideration. Even though additional effluent treatment may be necessary, its re-use as process water may be advantageous, particularly for industries operating in limited water resource areas.

b. *Dilution.* Discharge to the nearest water-course is the most common method of disposal of effluents from waste treatment works. Mixing of the treated effluent with the dilution water is frequently an important factor. Lack of mixing may result in the persistence of a fairly high concentration of effluent along the shore line with resultant adverse effects on aquatic life and down-

stream water uses. Failure to obtain adequate mixing of effluent and receiving water may make an otherwise acceptable effluent entirely unsatisfactory. When the effluent is discharged to a small stream, mixing generally presents no problem. However, if the discharge is to a large stream, obtaining good mixing may require the installation of special outlet structures designed to secure the maximum amount of dispersion of effluent with the flow of the stream.

c. *Controlled dilution.*⁴² Adjustment of rate of effluent discharge to rate of stream flow is generally advantageous. Application requires the construction of effluent storage ponds. (See previous paragraph on lagoons.) All or part of the effluent is retained in the ponds during periods of low stream flow. The stored wastes are released at a controlled rate when stream discharge is sufficient to provide a favorable dilution ratio. Rate of release may be adjusted to water quality requirements in the stream. Assuming an effluent high in chloride (Cl^-) is to be disposed of by regulated discharge, the allowable rate of release from storage can be computed from the equation—

$$q = \frac{Q(C-A)}{B-C}$$

where

q = effluent flow rate in cfs

Q = stream flow rate in cfs

C = maximum allowable ppm or chloride (Cl^-) in the stream below point of effluent discharge.

A = ppm chloride (Cl^-) in the stream above the point of effluent discharge.

B = ppm, chloride (Cl^-) in the effluent being released.

(See discussion in preceding paragraph on importance of mixing.)

d. *Solar Evaporation.*⁴¹ If study of rainfall and evaporation records indicates a favorable evaporation balance, solar evaporation may prove useful as a means for handling dilute wastes. Use of this method requires the construction of a system of shallow lagoons. (See previous discussion on lagoons.) Pretreatment for oil removal is necessary as oil films will retard evaporation. A high concentration of dissolved inorganic solids will also decrease the evaporation rate. (There will be a solids concentration increase as evaporation proceeds.)

e. *Irrigation.*⁴² Irrigation has been used to advantage as a means of sewage treatment plant effluent disposal. Irrigation has also been successfully employed for the disposal of food industry wastes, notably cannery wastes.⁴³ Other nontoxic industrial wastes might be successfully disposed of in this way provided climatic conditions are suitable and sufficient land is available. Surface, ridge and furrow, or spray irrigation methods may be used depending on local conditions.

f. *Disposal Wells.* Discharge of toxic, highly-mineralized industrial wastes into shallow wells is a hazardous procedure which is practically certain to result in serious pollution of the ground water resources in the vicinity of the well.⁴⁴ Consequently, such waste disposal practice is forbidden by state water pollution control agencies. While discharge of wastes into shallow wells has been universally condemned, properly constructed deep wells which extend well below usable aquifers have been successfully used for industrial waste disposal.⁴⁵ A notable application of this method is the use of specially constructed deep wells for the injection of oil field brines into subterranean formations. Hundreds of such wells have been in operation for 10 years or more and are satisfactorily handling the large volumes of highly mineralized water frequently encountered in connection with oil production.⁴⁶ Where they can be safely employed, properly constructed deep wells appear to offer an excellent means of disposing of industrial wastes that are extremely difficult and expensive to handle by conventional methods. Examples of such wastes are those containing a high proportion of stable constituents, such as sodium chloride or sodium sulfate. One large chemical manufacturing plant⁴⁷ has adopted this method for the disposal of waste water containing a high proportion of sodium chloride. Successful application of the disposal well method of waste handling requires a thorough knowledge of the geology and ground water resources of the area. Another

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prerequisite to successful disposal well operation is treatment of the waste to prevent clogging of the receiving subterranean formation. Such treatment may include aeration, coagulation, sedimentation, stabilization and filtration. Unusual care is required in disposal well construction. A disposal well used for chemical plant wastes has been described as follows: "

- "1. A 10½ in. steel casing has been cemented in at the 2,448 ft. level. This casing is lined with . . . a baked-on phenolic resin, to protect it against corrosion.
- "2. A 7-in. inner casing also . . . protected . . . extends from the surface to the 4,522 ft. level. It is cemented in from the 1,957 ft. level to the bottom.
- "3. A casing pressurizing system with automatic controls has been provided.

"In completing the well, a production string of 3½ in. o. d. . . . metal tubing, along with a packer and safety joint, is being installed. The . . . tubing is also protected . . . The bottom 100 ft. of casing is being perforated. There are at least 500 ft. of permeable unconsolidated sands that appear suitable to receive the wastes."

REFERENCES

1. Army Regulations 415-105; Air Force Regulations SS-10A. Par. 12. "Standards for Permanent Installations."
2. State (Calif.) Water Pollution Control Board (McKee) *Water Quality Criteria* (1952) Publication No. 3. Documents Section, State Printing Division, 11th and "O" Sts., Sacramento (14), Calif.
State (Calif.) Water Pollution Control Board (McKee) *Water Quality Criteria*, Addendum No. 1 (1954) Publication No. 3, Addendum No. 1, Documents Sections, State Printing Division, 11th and "O" Sts., Sacramento (14), Calif.
3. Doudoroff, Peter, and Katz, Max. "Critical Review of Literature on the Toxicity of Industrial Wastes and Their Components to Fish (II The Metals, as Salts)." *Sewage and Industrial Wastes* 25:802 (1953).
4. Metal-Finishing Industry Action Committee *Planning and Making Industrial Waste Surveys* (1952) Ohio River Valley Water Sanitation Commission, 414 Walnut St., Cincinnati (2), Ohio.
5. Black, Hayse H. "Procedures for Sampling and Measuring Industrial Wastes" *Sewage and Industrial Wastes* 24:45 (1952).
6. Hauck, Charles F. "Gaging and Sampling Water Borne Industrial Wastes" *ASTM Bulletin* No. 162, p. 38 (Dec. 1949).
7. Federation of Sewage and Industrial Wastes Associations *Occupational Hazards in the Operation of Sewage Works* (1944) Manual of Practice No. 1 Federation of Sewage and Industrial Wastes Associations, 4435 Wisconsin Ave., Washington (16), D. C.
8. King, Horace Williams. *Handbook of Hydraulics* (4th ed., 1954), McGraw Hill Book Co., New York.
9. Shaw, G. V., and Loomis, A. W. *Cameron Hydraulic Data* (11th ed., 3d prtg. 1942), Ingersoll-Rand Co. (N. Y.).
10. U. S. Dept. of the Interior, Bureau of Reclamation, *Water Measurement Manual* (1st ed., 1953), U. S. Gov't Printing Office, Washington, D. C.
11. Hite, Howard O. "Primary Devices and Meters for Waste Flow Measurements" *Sewage and Industrial Wastes* 22:1357 (1950).
12. Brown, Walter H., and Symons, George F. "Flow Measurement in Sewage Works," *Sewage and Industrial Wastes* 27:149 (1955) and 27:283 (1955).
13. *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes* (10th ed., 1955), American Public Health Association, 1790 Broadway, New York (19), N. Y.
14. Kline, Hubert S. "Automatic Sampler for Certain Industrial Wastes" *Sewage and Industrial Wastes* 22:922 (1950).
15. Kline, Hubert S. "Samplers for Industrial Waste Surveys" *Proc. of the Fifth Industrial Waste Conference* (Nov. 29-30, 1949), Purdue University, Lafayette, Ind.
16. Gray, S. C., Trost, R. J., and Moses, D. V. "Automatic Wastes Sampler" *Sewage and Industrial Wastes* 22:1047 (1950).
17. *Municipal Sewer Ordinances* (1949) Manual of Practice No. 3, Federation of Sewage and Industrial Wastes Associations, 4435 Wisconsin Ave., Washington (16), D. C.
18. Coburn, Stuart E. "Limits for Toxic Wastes in Sewage Treatment," *Sewage and Industrial Wastes*, 21:522 (1949).
19. Rudolfs, W. (et al.). "Review of Literature on Toxic Materials Affecting Sewage Treatment Processes, Streams and B. O. D. Determinations" *Sewage and Industrial Wastes* 22:1157 (1950).

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20. Heukelekian, H., and Gellman, I. "Studies of Biochemical Oxidation by Direct Methods. IV Effect of Toxic Metal Ions on Oxidation," *Sewage and Industrial Wastes* 27:70 (1955).
21. Thomas, Harold A., Jr. "Effects of Detergents on Sewage and Sewage Treatment at Military Installations." *Sewage and Industrial Wastes* 26:954 (1954).
22. Eldridge, E. F. *Industrial Waste Treatment Practice* (1st ed., 1942), McGraw-Hill Book Co., N. Y.
23. Estrada, Alfred A. (et al.). "Acceptability of Industrial Wastes in Public Sewers" *Sewage and Industrial Wastes* 27:40 (1955).
24. Heukelekian, H., and Orford, H. E. "Industrial Wastes in Municipal Sewers" *Sewage and Industrial Wastes* 27:49 (1955).
25. Dickerson, B. W. "Waste Control Begins With Process Operations" *Sewage and Industrial Wastes* 26:1463 (1954).
26. Swartz, Carl J. "Industrial Sewer Modification to Reduce Pollution" *Sewage and Industrial Wastes* 26:1468 (1953).
27. Anon. "Check List for Reducing Industrial Waste Costs" *Sewage and Industrial Wastes* 22:86 (1950).
28. Rudolfs, Willem (Editor). *Industrial Wastes—Their Disposal and Treatment* (1953). Reinhold Publishing Corporation, N. Y.
29. Besselièvre, Edmund B. *Industrial Waste Treatment* (1st ed., 1952), McGraw-Hill Book Co., N. Y.
30. Pomeroy, Richard. "Floatability of Oil and Grease in Waste Waters" *Sewage and Industrial Wastes* 25:1304 (1953).
31. *Manual on Disposal of Refinery Wastes* (5th ed., Vol. I, 1953), American Petroleum Institute, 50 West 50th Street, New York (20), N. Y.
32. Elkin, H. F., and Soden, W. E. "Gravity Separation of Oil" *Sewage and Industrial Wastes* 26:854 (1954).
33. Hathaway, C. W. "Treatment of Machine Shop Wastes Containing Emulsified Oils" *Sewage and Industrial Wastes* 27:198 (1955).
34. "Industrial Wastes Forum" *Sewage and Industrial Wastes* 25:706 (1953).
35. Beebe, Austin H. "Soluble Oil Wastes Treatment by Pressure Flotation" *Sewage and Industrial Wastes* 26:1314 (1953).
36. Osterman, Joseph. "Dissolved Air Recovery of Suspended Solids" *Sewage and Industrial Wastes* 27:209 (1955).
37. Harlow, I. F., and Powers, T. V. "Pollution Control at a Large Chemical Works" *Industrial and Engineering Chemistry* 39:572 (1947).
38. Hoak, R. D. *Disposal of Spent Sulfate Pickling Solutions* (1952) Ohio River Valley Water Sanitation Commission, 414 Walnut St., Cincinnati (2), Ohio.
39. Heise, Lorenz W., and Johnson, Milton. "Disposal of Waste Pickle Liquor by Controlled Oxidation and Continuous Lime Treatment" *Sewage and Industrial Wastes* 27:190 (1955).
40. Dickerson, B. W., and Brooks, R. M. "Neutralization of Acid Waters" *Industrial and Engineering Chemistry* 42:599 (1950).
41. Dickerson, B. W. "A High Rate Trickling Filter Pilot Plant for Certain Chemical Wastes" *Sewage and Industrial Wastes* 21:685 (1949).
42. Metal-Finishing Industry Action Committee *Methods for Treating Metal-Finishing Wastes* (1953) Ohio River Valley Water Sanitation Commission, 414 Walnut Street, Cincinnati (2), Ohio.
43. Ruchhoft, C. C., LeBosquet, M., and Meckler, W. G. "TNT Wastes from Shell Loading Plants, Color Reactions and Disposal Procedures" *Industrial and Engineering Chemistry* 37:937 (1945).

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44. Fadgen, T. J. "Operation of Ion Exchange Units for Treatment of Electro Plating Wastes" *Sewage and Industrial Wastes* 27:206 (1955).
45. McCall, Robert G. "Investigations of Variations in Flow and Color Concentrations of TNT Sellite Waste Waters" (20-24 July 1953), Proj. No. 1414E36-53. Dept. of the Army, Office of the Surgeon General, Army Environmental Health Laboratory, Army Chemical Center, Md.
46. Edwards, Gail P., and Ingram, William T. "The Removal of Color from TNT Waste" *Proceedings of the American Society of Civil Engineers*, Vol. 81, Separate No. 645 (March, 1955).
47. Anon. "Incineration Solves a Waste Disposal Problem" *Chemical Engineering* 55:110 (March 1948).
48. Green, Ralph V., and Moses, D. V. "Destructive Catalytic Oxidation of Aqueous Waste Materials" *Sewage and Industrial Wastes* 24:288 (1952).
49. Griffith, Charles R. "Lagoons for Treating Metalworking Wastes" *Sewage and Industrial Wastes* 27:180 (1955).
50. Van Heuvelen, W., and Sore, Jerome H. "Sewage Lagoons in North Dakota" *Sewage and Industrial Wastes* 26:771 (1954).
51. Henkel, H. O. "Surface and Underground Disposal of Chemical Wastes at Victoria, Texas" *Sewage and Industrial Wastes* 25:1044 (1953).
52. Stone, Ralph. "Land Disposal of Sewage and Industrial Wastes" *Sewage and Industrial Wastes* 25:406 (1953).
53. Sanborn, N. H. "Disposal of Food Processing Wastes by Spray Irrigation" *Sewage and Industrial Wastes* 25:1034 (1953).
54. Task Group Report. "Findings and Recommendations on Underground Waste Disposal" *Jour. American Water Works Assoc.* 45:1295 (1953).
55. Cecil, Lawrence K. "Underground Disposal of Waste Water" *Industrial and Engineering Chemistry* 42:594 (1950).
56. Lieber, Maxim, and Welsch, W. Fred. "Contamination of Ground Water by Cadmium" *Jour. American Water Works Assoc.* 46:541 (1954).

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APPENDIX A

SUGGESTED WATER QUALITY CRITERIA FOR STREAMS RECEIVING WASTES FROM MILITARY MANUFACTURING PLANTS AND REPAIR DEPOTS¹

The State agency that is responsible for pollution control may already have established water quality criteria, or it will probably have some policy for determining such criteria. The wastes from military installations, however, are sometimes almost unique, and the following criteria may be suggested to the State agency by the military authorities if the State has no information concerning these wastes:

- a. Alpha-TNT
 - In waters used for human consumption—1 ppm
 - In waters used by fish or animal life—5 ppm
- b. TNT Manufacturing Waste (Sellite Waste, Red Water)
 - In waters used for human consumption—20 ppm of color (platinum-cobalt standard)
 - In all other wastes—75 ppm of color (platinum-cobalt standard)
- c. RDX (Explosive)
 - This substance is virtually insoluble in water.
- d. Tetryl (Explosive)
 - This substance is virtually insoluble in water.
- e. Picric Acid
 - In waters used for human consumption—1 ppm
- f. Ammonium picrate
 - In waters used for human consumption—1 ppm
- g. Nitrate Nitrogen, expressed as N
 - In waters used for human consumption—10 ppm

¹ Source: Department of the Army, Office of the Surgeon General, Washington, D. C.

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APPENDIX B

EXAMPLES OF WATER QUALITY STANDARDS

PREFACE

This appendix presents quotations from various sources providing examples of water quality standards or criteria. *These are given for illustrative purposes only and it is emphasized that in general these criteria cannot be applied arbitrarily to specific situations.* Water quality criteria are being extensively studied and are certain to be changed from time to time. Furthermore, a standard suited to the needs of a stream in one area may be entirely inappropriate to conditions existing in another area. For guidance in specific situations, consult the state water pollution control agency having jurisdiction over the waste-receiving waters.

Example 1

(See Preface to Appendix B)

Recommended Water Quality Objectives for Critical Low Flows¹ of Miami River² from Dayton (Ohio) to the Mouth

Component	Tolerable Limits ³
Dissolved oxygen.....	Not less than 4 ppm
pH.....	Between 6.3 and 9.0
Chlorides (as Cl ⁻).....	Not over 250 ppm
Phenols ⁴	(Substantially complete removal ⁵)
Iron.....	Not over 5 ppm
Manganese.....	Not over 5 ppm
Zinc.....	Not over 15 ppm
Nitrates (as N).....	Not over 10 ppm
Cyanide (as CN).....	Not over 0.15 ppm
Lead.....	Not over 0.35 ppm
Copper.....	Not over 0.40 ppm
Chromium.....	Not over 2 ppm
Oils.....	(Substantially complete removal ⁶)
Free acid.....	None
Color and Odor.....	To be nonoffensive
Other toxic wastes, deleterious substances and high temperature liquids.	None alone or in combination with other substances in sufficient amounts to impair water usage.

¹ Low flow (7-day average) occurring on the average of one year in five (20 percent of the time).

² Refer to water quality in the stream except as noted.

³ Refers to effluents; i. e., the wastes themselves.

⁴ Tentative stream value for phenols not over 25 to 30 parts per billion especially during critical low flow periods in cold weather. (Phenol persists longer in cold water than in warm.)

⁵ Source: McDill, Bruce M. "Mobile Laboratory Survey of the Miami River" *Sewage and Industrial Wastes* 22:1464 (1952).

Example 2

(See Preface to Appendix B)

Toxic Wastes—Maumee River Basin (Ohio)^{1,2} (Excerpt)

Pending the results of studies and research now in progress by qualified technical groups, the following should serve as a guide to the reasonable protection of the waters of the basin:

¹ Critical flow is the minimum (7 day average) occurring on the average of once in 5 years.
² Source: McDill, Bruce M. "Pollution Study of the Maumee River Basin" *Sewage and Industrial Wastes* 24:1258 (1952).

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Component	Limit
Cyanide (as CN).....	Not over 0.15 ppm
Lead (as Pb).....	Not over 0.35 ppm
Copper (as Cu).....	Not over 0.4 ppm
Chromium (as Cr ⁺⁶).....	Not over 2.0 ppm
Cadmium (as Cd).....	Not over 0.4 ppm
Zinc (as Zn).....	Not over 1. ppm
Nickel (as Ni).....	Not over 5. ppm
Nitrate.....	Not over 10. ppm

It is emphasized that exceptions to these limits must be made where water uses require higher quality; and, further, that some of the substances mentioned may cause damage in lower concentrations than noted under certain conditions and in certain combinations.

Example 3

(See Preface to Appendix B)

Excerpts from New York Water Pollution Control Board's Quality Standards for Class A Waters¹

Items	Specifications
1. Floating solids, settleable solids, sludge deposits.	None which are readily visible and attributable to sewage, industrial wastes or other wastes or which deleteriously increase the amounts of these constituents in receiving waters after opportunity for reasonable dilution and mixture with the wastes discharged thereto.
2. Sewage or waste effluents.....	None which are not effectively disinfected.
3. Odor producing substances contained in sewage, industrial wastes or other wastes.	The waters after opportunity for reasonable dilution and mixture with the wastes discharged thereto shall not have an increased threshold odor number greater than 8, due to such added wastes.
4. Phenolic compounds.....	Not greater than 5 parts per billion. (Phenol)
5. pH.....	Range between 6.5 and 8.5.
6. Dissolved oxygen.....	For trout waters, not less than 5.0 parts per million; for nontrout waters, not less than 4.0 parts per million.
7. Toxic wastes, oil, deleterious substances, colored or other wastes or heated liquids.	None alone or in combination with other substances or wastes in sufficient amounts or at such temperatures as to be injurious to fish life, make the waters unsafe or unsuitable as a source of water supply for drinking, culinary or food processing purposes or impair the waters for any other best usage as determined for the specific waters which are assigned to this class.

The following comments and criteria are also applicable to class A waters: With reference to certain toxic substances as affecting fish life, the establishment of any single numerical standard for waters of New York State would be too restrictive. There are many waters, which, because of poor buffering capacity and composition, will require special study to determine safe concentrations of toxic substances. However, based on nontrout waters of approximately median alkalinity (80 ppm) or above for the state, in which groups most of the waters near industrial areas in this state will fall, and without considering increased or decreased toxicity from possible combinations, the following **may be considered as safe stream concentrations** for certain substances to comply with the above standard for this type of water. Waters of lower alkalinity must be specially considered since the toxic effect of most pollutants will be greatly increased.

Ammonia or Ammonium Not greater than 2.0 parts per million (NH₃) at pH 8.0 or above compounds.

Cyanide.....	Not greater than 0.1 part per million (CN)
Ferro or ferricyanide.....	Not greater than 0.4 part per million as Fe (CN),
Copper.....	Not greater than 0.2 part per million (Cu)
Zinc.....	Not greater than 0.3 part per million (Zn)
Cadmium.....	Not greater than 0.3 part per million (Cd)

¹ Source: Reference 2.

Example 4

(See preface to Appendix B)

Industrial Wastes—Quinnipiac River Valley (Connecticut)¹

(Excerpt)

All water-borne industrial wastes before being discharged to the Quinnipiac River and its tributaries shall be treated in an adequately designed and operated plant which will produce an effluent which, upon laboratory tests, will meet the following standards:

- a. pH between 6.5 and 8.5
- b. Color and turbidity not over 50 ppm.
- c. Suspended solids not over 30 ppm
- d. BOD not over 25 ppm
- e. Metals (dissolved) each not over 5 ppm
- f. Oils and greases not over 20 ppm
- g. Any water borne wastes of unusual character or volume not covered by the preceding standards will be considered as individual problems.

¹ Source: Reference 2.

Example 5

(See Preface to Appendix B)

Toxicity of Certain Chemicals to Fish and Fish Food¹

Substance	Concentration ppm	As	Test organism	Effect
Chromic acid.....	0.3	Cr	<i>Daphnia magna</i> *.....	Toxic
Hydrochloric acid.....	62	HCl	<i>Daphnia magna</i> *.....	Toxic
Nitric acid.....	107	HNO ₃	<i>Daphnia magna</i> *.....	Toxic
Sulfuric acid.....	88	H ₂ SO ₄	<i>Daphnia magna</i> *.....	Toxic
Strong acids.....	To pH 5.0	-----	Fish.....	Toxic
Cadmium chloride.....	0.01	Cd	Goldfish.....	Kills in 8-18 hrs
Cadmium sulfate.....	513	Cd	Minnows.....	Kills in 3 hrs
Copper sulfate.....	0.8	Cu	Goldfish.....	Kills in 24-96 hrs
Copper sulfate.....	0.04	Cu	<i>Daphnia magna</i> *.....	Toxic
Sodium chromate.....	0.1	Cr	<i>Daphnia magna</i> *.....	Toxic
Potassium dichromate.....	36	Cr	Goldfish.....	No effect in 108 hrs
Potassium dichromate.....	180	Cr	Goldfish.....	Kills in 3 days
Chromate (ion).....	20	Cr	Trout and minnows.....	Kills in 8 days
Chromate (ion).....	50	Cr	Sunfish, blue-gills.....	Not toxic in month
Chromate (ion).....	0.01	Cr	Micro-flora.....	Toxic
Ferric chloride.....	34	Fe	Goldfish.....	Kills in 1-1.5 hrs
Ferrous sulfate.....	37	Fe	Goldfish.....	No effect in 100 hrs
Ferrous sulfate.....	368	Fe	Goldfish.....	Kills in 2-10 hrs
Nickel chloride.....	4.5	Ni	Goldfish.....	Kills in 200 hrs
Lead nitrate.....	63	Pb	Goldfish.....	Kills in 80 hrs
Stannous chloride.....	626	Sn	Goldfish.....	Kills in 4-5 hrs
Zinc sulfate.....	25	Zn	Trout.....	Kills in 133 mins
Zinc (ion).....	0.3	Zn	Fish.....	Kills some fresh water fish
Sodium cyanide.....	0.3	CN	Minnows, catfish, carp..	No effect in 24 hrs
Potassium cyanide.....	0.04-0.12	CN	Goldfish.....	Kills in 3-4 days
Cyanogen chloride.....	0.08	CNCl	Fish.....	Critical
Potassium ferrocyanide.....	948	CN	Minnows, goldfish.....	Not lethal
Potassium ferricyanide.....	848	CN	Minnows, goldfish.....	Not lethal

* *Daphnia magna* is a representative fish food organism commonly found in streams.¹ Source: Reference 2a.

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Toxicity of Certain Chemicals to Fish and Fish Food—Continued

Substance	Concentration ppm	As	Test organism	Effect
Ammonia.....	2.5	NH ₃	Goldfish.....	Kills in 1-4 days
Ammonia.....	2.7	NH ₃	Fish.....	Lethal
Hydrogen sulfide.....	10	H ₂ S	Goldfish.....	Kills in 96 hrs
Sulfide (ion).....	3	S	Trout.....	Kills in 5 mins
Sulfide (ion).....	0.5-1.0	S	Fish.....	Critical
Potassium cyanate.....	264	KCNO	Trout fingerlings, adult minnows	No effect in 24 hrs
Sodium hydroxide.....	156	NaOH	<i>Daphnia magna</i> *.....	Toxic
Trisodium phosphate.....	52	Na ₃ PO ₄	<i>Daphnia magna</i> *.....	Toxic
Chlorine.....	0.05-1.0	Cl	Fish.....	Critical

* *Daphnia magna* is a representative fish food organism commonly found in streams.

† Source: Reference 28.

APPENDIX C

REPORTS OF INDUSTRIAL WASTE INVESTIGATIONS

An engineering report should define the waste collection and disposal problems and provide a sound basis for the detailed planning of any necessary corrective measures. While the report will have to be prepared to meet the needs of each situation, in general, the following topics should be covered:

- (1) Summary of Findings and Recommendations
- (2) Introduction:
 - Statement of objectives
- (3) Description of Industrial Plant and Processes Employed:
 - Location map
 - Plant layout
 - Process flow sheets
- (4) Process and Production Data:
 - Raw materials, chemicals, etc.
 - Production:
 - Present: average, maximum, minimum
 - Future: average, maximum, minimum
 - Production patterns: daily and seasonal
- (5) Waste Sources:
 - Description, flow sheets, plant sewer system layout, etc.
- (6) Waste Volume:
 - Survey data
 - Estimated volume under conditions of average, maximum and minimum production—present and future
 - Flow variation
- (7) Waste Characteristics (physical, chemical, biological):
 - Present—variations during day
 - Future
- (8) Waste Load:
 - Existing—at average, maximum and minimum production rates
 - Future
- (9) Existing Waste Correction and Disposal Methods:
 - Description of methods now in use
 - Evaluation of these methods
- (10) Receiving Stream:
 - Stream flow data
 - Water quality data
 - Stream uses
 - Pollution damages
 - State standards for waste disposal
- (11) Waste Correction Program:
 - Recommended program of waste prevention
 - Recommended program of waste treatment
 - Justification for recommended programs
- (12) Cost of Recommended Corrective Measures:
 - Estimate of installation costs
 - Estimate of operating costs

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APPENDIX D

TREATMENT FACILITIES FOR AIRCRAFT WASH WASTE AND SIMILAR WASTES AT U. S. AIR FORCE INSTALLATION

1. REQUIREMENTS. When authorized, facilities will be provided for the collection and treatment of wastes from aircraft washracks, motor pools and engine test cells and other alkaline wastes. (This appendix does not apply to the treatment of plating or like acid wastes, such as those generated at Air Materiel Command bases.) The plant should consist of a combination surge tank and grit chamber for primary treatment and, when determined to be necessary and authorized, secondary treatment facilities. The primary treatment units should be designed complete with all influent and effluent piping and pumps that may be necessary. Secondary treatment units may be either completely designed and constructed according to drawings and specifications or specified to be furnished on a performance guarantee basis and indicated schematically on the drawings.

a. The combination surge tank and grit chamber should have a holding capacity of 12,000 gallons when one washrack is to be served and 24,000 gallons when two or three washracks are to be served simultaneously. This tank should be provided with free oil collecting and removal facilities as applicable to the site location and constructed with a grit collecting hopper at the influent end. Normally, the grit hopper will be manually cleaned and mechanical equipment should not be provided for collecting and removing grit unless the waste is from other operations than plane washing and then only when the waste would contain sufficient grit to justify such equipment. In view of the tendency of the wastes to stratify, the surge tank should be provided with suitable facilities for stirring and mixing during treatment operations. Also means should be provided for skimming kerosene from airplane wash wastes. For this purpose, a manually operated slotted pipe or fixed or manually operated overflow weir where gravity flow is feasible or pumping facilities where gravity flow is not feasible should be provided and connected to a 500 gallon sump. Also pumping facilities should be provided for transferring the kerosene from this sump to the kerosene storage tank or "gunk" mixing tank. The transfer pump associated with the kerosene storage tank may be utilized for this purpose by providing suitable connecting piping when feasible. The skimming device should be provided in the surge tank except where motor pool or other alkaline wastes from other operations are treated in combination with aircraft wash wastes and it has been determined that the recovered kerosene will have absorbed sufficient contaminating matter to render it below the grade "B" level required for cleaning purposes. Where this condition exists a separate 5,000 gallon tank should be provided ahead of the surge tank to receive aircraft wash wastes only and the skimming device should be installed in this tank. Also, this 5,000 gallon tank and the kerosene recovery facilities should be provided where facilities for the treatment of aircraft wash wastes are not provided or contemplated.

b. The secondary treatment process should be flocculation and flotation by air under compression and the system should provide for continuous operation. The facilities should consist of inflow pumps, chemical mixing tanks, manually operated controls for wet chemical feed, flotation tank, and mechanical sludge collecting equipment for removing floated sludge from the surface of the liquid in the flotation tank. The inflow pumps should be provided with automatic start-stop control for operation at pre-set liquid levels in the surge tank. One pump should have full plant capacity and one should have half plant capacity. The influent connection or connections to the flotation tank should be so located and arranged as not to create detrimental turbulence at the surface. Connections for effluent of the liquid should be near the bottom of the tank and means should be provided for adjusting the liquid level as operational conditions require. Also, means should be provided for draining the tank. The sludge collectors should operate so as not to trap and carry over, with the sludge, water from below the sludge blanket. The tank should

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be provided with suitable sludge trough or hopper. In rectangular tanks the sludge skimmers should be spaced about four feet apart attached to roller chains and in circular tanks the sludge skimmers should be at least four in number and equally spaced. The flotation tank should be of metal plate at least three-sixteenths inch thick and provided with adequate bracing, either pre-assembled or assembled on the site. The secondary treatment facilities should have capacity of 75 gpm when treating the waste from one or two aircraft washracks and 150 gpm when treating the waste from 3 aircraft washracks.

c. The foundation structure for the secondary treatment system should consist of a concrete and/or steel grating platform designed and constructed to support the weight of the plant which will vary according to size of the indicated treatment equipment. The platform required for a 75 gpm capacity plant should approximate 20' x 40' with a design support requirement of approximately 12,000 pounds. In areas where official weather records indicate 20 or more hours of sustained temperatures of $\pm 20^{\circ}$ F. or lower, the plant should be inclosed in a newly constructed or existing structure applicable to operational requirements. New building construction should be entirely utilitarian and conform to the cleaning solvent and storage building shown on the current issue of Definitive Drawing No. 36-40-12—RI modified as required for local site adaptation.

d. Facilities will be necessary for transfer of wet sludge to a sanitary fill or other disposal area. Normally, the volume of sludge will amount to approximately 5 percent of the total aircraft wash waste flow and approximately 10 percent when motor pool, engine test cell and other alkaline wastes are included. Where piping to the point of disposal would not be practicable Dempster-Dumpster or similar watertight portable containers or tank trucks would be required for transportation of the sludge. Equipment of this type would be an item for the using service to furnish and should not be required to be furnished under the construction contract. Means for concentrating the sludge, such as a tank provided with adequate sampling cocks and piping connections for selective draw-off, may be necessary, depending upon the type of sludge transporting equipment that will be available. Also, where a tank truck is to be used, a holding tank or sump of adequate size to permit uninterrupted plant operation may be necessary. Determination should be made in consultation with the using service as to the type of equipment the using service will utilize for transportation of the sludge so that piping, pumps, holding tank and like facilities that may be required for loading can be included in the plant design.

e. The treatment system should be of as simple design as feasible for operation by unskilled labor with part-time supervision by skilled personnel. Complete written instructions for maintenance and operation of each waste-treatment installation should be furnished the using service. Engineering service should be furnished during initial start-up, instruction period and test run.

f. A one-year guarantee of all mechanical equipment against defects should be specified.

g. Where the secondary treatment facilities are specified to be furnished by the contractor on a performance-guarantee basis, the requirements for quality of plant effluent should be specified as follows:

Oil and grease.....	30 ppm maximum
Suspended solids (exclusive of oil turbidity and floc).....	30 ppm maximum

The specifications should require that the test samples be prepared and tested in accordance with the distillation-extraction method described in Volume IV, First Edition (1953), "Sampling and Analysis of Waste Water, API Manual on Disposal of Refinery Wastes," published by the API Division of Refining, 50 West 50th Street, New York, N. Y. The specifications should also require that the contractor furnish the instructions and engineering services mentioned in paragraph 1.e. above for a 10-day operating period during and after initial start-up. The contractor should furnish all necessary chemicals and operating labor during this period of service.

2. INFORMATION ON WASTES. The following information regarding waste matter and washing operations is for guidance of the designer and of the contractor when performance guarantee is required and should be included for that purpose in the specifications when and as appropriate.

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a. *Aircraft Cleaners and Solvents.* In general the compounds used for the exterior cleaning of aircraft are of the following three types:

Cleaning Compound (For Aircraft) (U. S. Air Force Specification 20015)

Steam Cleaning Compound (U. S. Air Force Specification 14128A)

Cleaner and Brightener Compound (Specification MIL-C-5410A)

The composition of these chemicals is not restricted by the specifications, but is optional with the manufacturer. Therefore, no definite formulation can be given for the solvents. However, the chemicals listed below can be expected in approved compounds under the above specification. The percentages given are normally the maximum which will be present and apply to the concentrated compound. All materials may not be present in any one compound.

(1) *Cleaning compound (USAF Specification 20015).*

	Approx. Max.
Potassium soap of mixed fatty acids.....	45%
Sodium Sulfonate.....	60%
Wetting agents (anionic or nonionic).....	10%
Kerosene of high-flash naptha.....	40%
Mineral oil or light lubrication.....	35%
Pine oil.....	35%
Butyl cellosolve.....	20%
Butyl carbitol.....	20%
Cellosolve.....	20%
Carbitol.....	20%
Butyl alcohol.....	5%
Diethylene glycol.....	10%
Cyclohexanol.....	2%
Higher alcohols.....	25%
Isopropyl or methyl alcohol.....	10%
Glycol.....	5%

This compound solvent is normally diluted one part to four parts kerosene or Stoddards solvent (Federal Specification P-S-661) and applied by atomizing spray. Rinsing is normally done with water at a pressure of 60 psi.

(2) *Steam cleaning compound (USAF Specification 14128).*

	Approx. Max.
Wetting agents--anionic.....	5%
Tetra sodium pyrophosphate.....	40%
Sodium tripolyphosphate.....	40%
Sodium dichromate.....	2%
Sodium bicarbonate.....	20%
Sodium carbonate.....	20%
Borax.....	30%
Sodium metasilicate.....	40%
Trisodium phosphate.....	10%

This solution is normally applied by steam gun in concentrations of approximately 0.5 percent and rinsing with water at a pressure of 60 psi.

(3) *Cleaner and Brightener compound (Specification MIL-C-5410).*

	Approx. Max.
Phosphoric acid.....	8%
Methylethyl ketone.....	20%
Oxalic acid.....	2%
Citric acid.....	2%
Methyl cellulose.....	2%
Wetting agents (nonionic).....	5%

The brightener is normally diluted with an equal volume of water and applied with brushes or mops. Rinsing is normally with clear water at low pressure. Brighteners are available com-

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mercially with up to 4 percent hydrofluoric acid or hydrofluosilicic acid or salts. These have not been previously approved for military use due primarily to the disposal problem of untreated wastes.

(4) Paint Remover, which is sometimes used for removal of exhaust stains contains substantially the following:

	Approx. Max.
Methylene chloride.....	70%
Ethylene dichloride.....	70%
Wetting agents.....	20%
Alcohols.....	18%
Cellosolve.....	6%
Methyl cellulose.....	3%
Amines.....	5%
Wax.....	5%

This solvent is normally applied undiluted and rinsed off with water.

b. Washing Operations.

(1) In general, washing operations are performed in the following manner:

(a) Pressure sprays of entire aircraft surfaces are made with the above-mentioned government-specified cleaners to loosen accumulated oil film, dirt and oxides. The cleaners contain oil-water emulsifiers, solvents, detergents and metal brighteners, such as kerosene, cresylic acid, tall oil, soap, isopropyl alcohol in varying concentrations. Mixtures as sprayed on aircraft normally consist of one part "cleaner" to from 8 to 10 parts kerosene.

(b) "Cleaner-coated" surfaces are subsequently brushed to facilitate loosening of foreign matter.

(c) The surfaces are finally hosed down with cold or hot water to thoroughly remove emulsified oil, grease and dirt from aircraft.

(2) Motor pool wastes are produced from vehicle washing operations and from the disposal of waste grease and oil. Engine repair shop wastes consist of wastes produced by cleaning motors and parts with oakite or other base chemicals. Engine test cell wastes are produced from engine and floor cleaning operations and are similar to plane washing wastes.

(3) Due to the operations described in subparagraphs a and b above, run-off waters are produced containing high entrainment of emulsified oils, greases, suspended solids and base chemical agents. Average flow of these wastes under customary washrack usage for the largest planes ranges from 0 to 25 gpm with peak flow of 75 gpm for one-half-hour to one-hour periods during hosing down operations. Quantity flows of wastes from motor pools, engine repair shops and engine test cells vary with each installation and must be determined in the field in order to arrive at design requirements for treatment facilities.

(4) The range of content and other conditions of these wastes normally will be as follows:

Oil and grease.....	800 to 5,000 ppm
pH.....	7 to 9
Temperature.....	1,600 to 3,500 ppm
Suspended solids.....	About 250 exclusive of grease and oil
Total solids.....	About 800 exclusive of grease and oil
Temperature.....	Approximately ambient

A more exact analysis of the waste to be treated should be furnished if feasible. This analysis should be of a carefully composited sample that would reasonably represent the effluent from the holding tank. If the waste is not existent at the specific project, analysis may be assumed from that of existing wastes at similar projects. Where the waste will be from aircraft-washing operations only and reasonably accurate data relative to such waste are not available, an oil and grease content of 1,500 ppm and other suspended solids of 250 ppm may be assumed.