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THE TREATMENT OF SOME CHEMICAL INDUSTRY WASTES *

By Thomas Powers

The Dow Chemical Company, Midland, Michigan

The Midland Plant of the Dow Chemical Company is one of the largest chemical plants in the country within one enclosure. Here the manufacture of over 400 products requires the use of some 250 million gallons of water per day which discharge to the Tittabawassee River having a minimum flow of 150 c.f.s. Pollutants in this river discharged from oil fields, municipalities, and industries are borne to the Saginaw River and thence to Saginaw Bay and Lake Huron (Figure 1). There

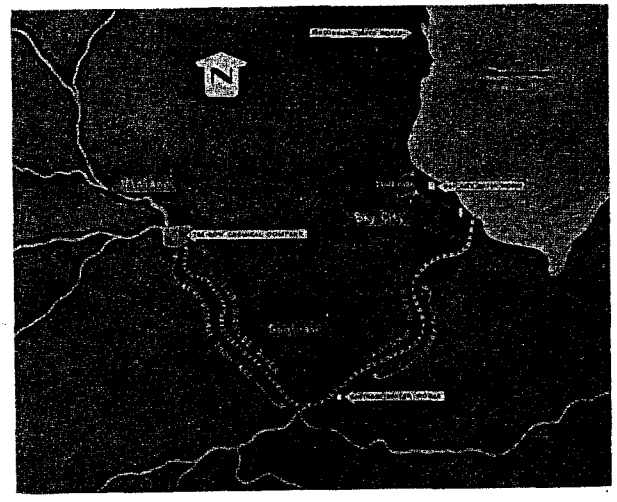


Figure 1.—Usage of Tittabawassee and Saginaw Rivers below The Dow Chemical Company plant at Midland, Michigan.

are many users of these receiving waters. The first use is agricultural for a 20-mile frontage. The city of Saginaw and many of its industries have the Saginaw River as a water source and also use it for wastes disposal. Almost the entire length of the Saginaw River between Saginaw and Bay City could be classed as recreational frontage

* Presented at Seventeenth Annual Meeting, F.S.W.A., Pittsburgh, Pa., October 13, 1944.

while the watercourse itself is open to lake boat commerce. Many of the industries in Bay City also use the river as a water source and for wastes disposal. The city of Bay City has its water source in Saginaw Bay some 4 miles from the mouth of the river. Saginaw Bay is a productive commercial fishing water and has miles of recreational frontage.

Waste waters from the Dow Midland plant requiring treatment total 75 m.g.d. Strong waste brines are stored in some 400 acres of ponds and released during periods of high flow by arrangement with downstream water users. The general plant wastes of 50 m.g.d. flow through some 40 acres of sedimentation ponds. Strong phenolic wastes require a 30-acre storage pond prior to treatment. A 50-acre pond is used to treat and cool a difficult waste resulting from the direct quench of cracked oil gases.

General Plant Wastes

The general plant wastes of 50 m.g.d. which are now settled in 40 acres of ponds before discharge to the river have a B.O.D. population equivalent of about 130,000. The wastes result from the manufacture of all products other than the phenolic type. The oxygen demand is created by such compounds as polysulfide, sulfites, alcohols, and many aliphatic combinations.

A treatment plant for these combined wastes is being studied. Experimentally it was found that activated sludge would do a creditable job of oxidizing this waste.

Specific Chemical Wastes

Too often investigators fail to evaluate the oxygen demand of certain chemical wastes. Polysulfide wastes resulting from the manufacture of a synthetic rubber and also from the treatment of cyanides have an immediate oxygen demand. Polysulfide rapidly oxidizes to thiosulfate as shown:

$$2Na_2S_x + 3O_2 = 2Na_2S_2O_3 + (x)S\downarrow$$

With the proper bacteria present the oxidation is completed:

$$2Na_2S_2O_3 + O_2 = 2Na_2SO_4 + 2S\downarrow$$

$$2S + 3O_2 + 2H_2O = 2H_2SO_4 + (282\ \text{calories})$$

These reactions should proceed in a two stage process since the oxidation of sulfur and thiosulfate results in an acid water which would release H_2S from the polysulfide if added, and the excess alkali contained in polysulfides would slow up the oxidation rates. It is believed that few activated sludge plants would be capable of receiving much polysulfide waste without seriously affecting the effluent because of the high oxygen demand.

The use of blowing-out towers has proved effective in removing certain low boiling organics such as styrene, ethyl benzene, chlorobenzol, alcohols and benzene.

Complete elimination of certain waste waters such as cracking process quench water has proved necessary.

The oxidation of organic matter, using bacteria as catalysts, is by far the cheapest method available. If an industry under severe pollution restrictions has gone as far as practical with biological treatment, what more can be done?

The oxidation of residual taste and odor pollutants can be accomplished chemically using chlorine, bromine or perhaps ozone. The control of oxidation by chlorine or bromine (Figure 2) must be exact or there is great danger of increasing the taste and odor.

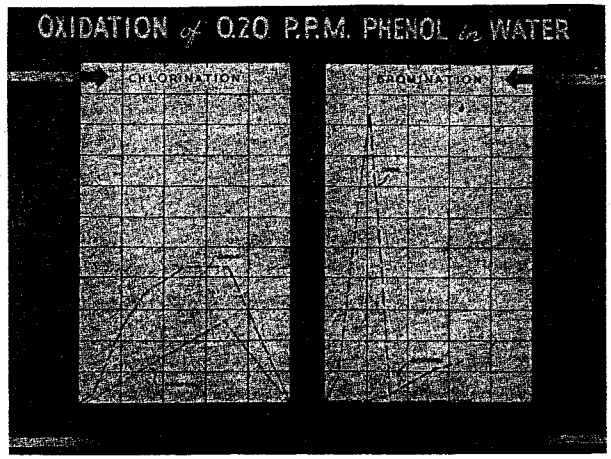


FIGURE 2.—Oxidation of 0.20 p.p.m. phenol in water by chlorine and bromine.

The adsorption of residual organics by activated carbon might also become feasible provided the biological or extraction process is carried to its practical limits.

The treatment of phenolic wastes has been the subject of many articles for the past twenty years. As Mohlman (1) pointed out years ago a pound of phenol requires 2.38 pounds of oxygen when completely oxidized to CO_2 and H_2O:

$$C_6H_5OH + 7O_2 \cdots 6CO_2 + 3H_2O$$

$$\frac{94}{1} :: \frac{224}{2.38}$$

Eldridge (2) concluded that inhibition of biological oxidation does not start until about 180 p.p.m. of phenol are present.

The cresols, aniline, salicylic acid and most of the lower substituted phenols are readily oxidized biologically. Within their range of solubility, the toxicity of phenolic compounds to bacteria (3) increases with the molecular weight (Figure 3). The fact that most of the higher substituted phenols are insoluble in acid solution should lead toward pretreatment of such wastes by acidification.

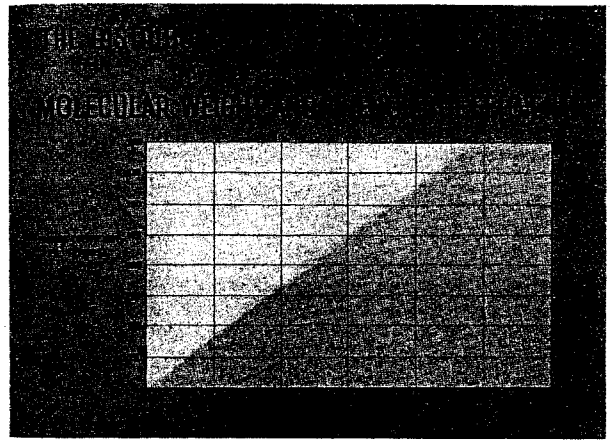


FIGURE 3.—The distribution of phenolic compounds with respect to their molecular weight and phenol coefficient.

PHENOLIC WASTE TREATMENT

The units for treatment of the phenolic wastes of the Dow Chemical Company are (Figure 4): strong waste storage pond, Dorr clarifier, four trickling filters, and an activated sludge plant and 50 acres of effluent ponds.

Strong phenolic wastes are pumped to the storage pond by all bronze open-impeller centrifugal pumps and Saran discharge lines. The pond is a treatment unit which serves to equalize flows and waste concentrations besides precipitating substituted phenols which are insoluble in acid solution. The volume of strong waste averages about 1.25 m.g.d. with a concentration of phenolics of about 600 p.p.m. The pH might vary between 2 and 4 and contain an acidity of 270 parts per million as HCl. Storage capacity of 42 million gallons permits control of feed to treatment process.

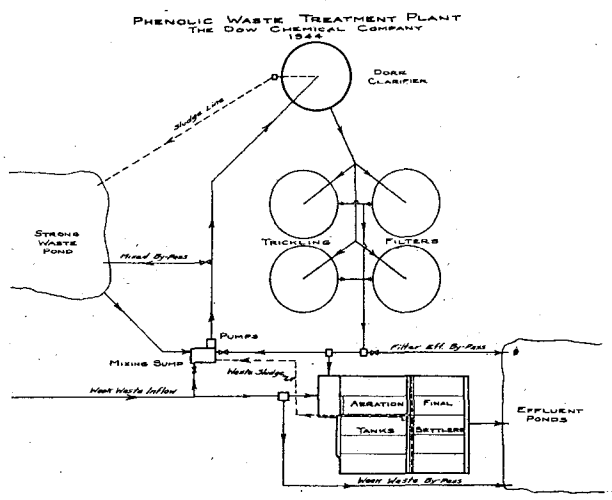


FIGURE 4.—Layout of phenolic waste treatment plant of The Dow Chemical Company at Midland, Michigan.

Weak waste flows of 12 m.g.d. in the winter and 20 m.g.d. in the summer contain from 5 to 1 p.p.m. of phenol. This waste is mixed with the strong wastes (and filter effluent recycle when necessary) and is pumped to the clarifier at a rate of 15 m.g.d. The clarifier at this plant serves to skim light oils and settle whatever heavy oils and precipitates are present. No phenol is removed in this unit (Figure 5).

It is possible to pump the mixed waste to the strong waste pond

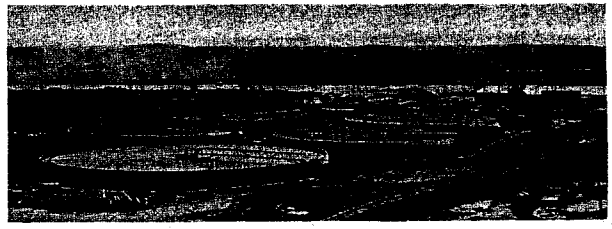


FIGURE 5.—Trickling filters and sedimentation unit treating phenolic wastes.

when weak waste concentration of acid, caustic or phenolics might create overloaded or toxic conditions. The underflow from the Dorr clarifier is lagooned in a portion of the strong waste pond. Overflow from the clarifier flows by gravity to the four trickling filters which are 142 feet in diameter on top with the 2½–3½-inch blast furnace slag media forming the outside wall on a 45 degree slope, which makes the bottom diameters 162 feet. The center gallery and complete bottom coverage of "Armcre" tile were designed to give maximum aeration (Figure 6). Motor driven, two-arm distributors are of ten-inch pipe



FIGURE 6.—Effluent gallery of trickling filters shown in Figure 5.

with eight-inch for the last ten feet. Water head on these units is sufficient to rotate them so that the motor serves as a speed regulator most of the time. The temperature of the mixed waste leaving these filters varies from 53 deg. F. to 95 deg. F. The pH of the mixed liquor is kept above 6.1 and below 8.0. The phenol concentration for normal feeds varies between 30–50 p.p.m. Concentrations higher than that are recirculated. The beds average 9.75 feet deep and obtain removals of phenol from 4.29 lbs. per 1000 cu. ft. at 56 deg. F. to 9.0 lbs per 1,000 cu. ft. at 83 deg. F. with a feed rate of 10.2 m.g.a.d. Removal of B.O.D. varies from 15.8 lbs. per 1,000 cu. ft. to 27 lbs. per 1,000 cu. ft. at the respective temperatures given.

The population equivalent of the B.O.D. load to this plant is about 125,000.

Activated Sludge Plant

The activated sludge plant (Figure 7) receives the filter effluent and excess weak wastes through a grit chamber. Return sludge is mixed with inflow at the effluent end of the grit chamber and the flow is directed to each of the 5 batteries. Three mechanical aerators in series in a 24-foot by 75-foot tank with a 15-foot depth, followed by a 24-foot width, 70-foot length and 10-foot depth settling tank, comprises one battery.

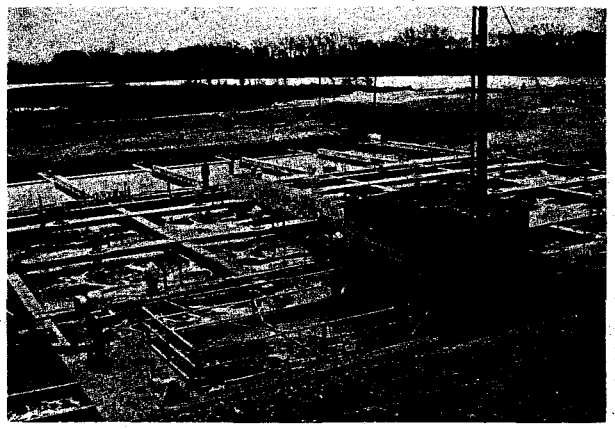


Figure 7.—Activated sludge plant treating phenolic wastes at Midland plant of The Dow Chemical Company.

Return sludge is delivered by slip pipes to a channel leading to screw pumps which lift the sludge to the channel set on top of the wall between No. 2 and No. 3 batteries.

The activated sludge plant has been found to be capable of oxidizing 1,300 lbs. per day of phenol or 3,300 lbs. per day of B.O.D.

The overall removal effected by various units is illustrated (Table 1). The final effluent to the river averages less than 0.4 p.p.m. of phenol.

The Dow Chemical Company has proceeded on the basis of eliminating or recovering wastes wherever possible and providing biological treatment where feasible. Each chemical plant must be studied separately and every waste evaluated with respect to its pollutant characteristics.

Table 1.—*Summary of Phenolic Waste Disposal—The Dow Chemical Company Midland, Michigan*
Removal of Phenol by Various Units

Month	Pounds of Phenol per Day				Over-all Per cent Removal
	Total Received	Removed by Filters	Removed by Activated	Removed by Ponds	
May '43	5152	3880	810	172	98.6
June	5745	4853	515	139	96.2
July	4775	3875	346	153	94.6
Aug.	4332	3184	523	299	95.8
Sept.	5703	4547	914	136	98.2
Oct.	3987	3217	590	73	97.1
Nov.	4063	2947	1011	55	98.9
Dec.	4040	2695	1316	55	98.0
Jan. '44	3999	2746	1188	32	99.3
Feb.	3892	2603	1193	60	98.8
March	4054	2655	1280	80	99.0
April	4496	3089	1234	117	98.8
May	5463	4805	540	61	98.9
June	4444	3996	334	43	98.4
July	4028	2651	294	41	98.9
Aug.	4499	3715	561	105	97.5

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INDUSTRIAL WASTES IN CONNECTICUT AND THEIR TREATMENT *

By William S. Wise

Chief Engineer, State Water Commission, Hartford, Conn.

Industrial wastes of a polluting nature are discharged into the waterways of Connecticut at the rate of about 100,000,000 gallons per day. These wastes vary enormously in character and it is estimated that their total pollution load upon the waterways is equivalent to that which would result from the sewage discharged untreated by all the municipalities of the state.

These wastes are produced by many different types of industries. The three largest groups are: (1) metallurgical; brass and copper, iron and steel, (2) textile, (3) paper board and allied products. The smaller groups are hat, leather, chemical, rubber, distillery, dairy, laundry, machine tools and others.

The amount of materials discharged in these wastes is in some instances startling. In 1941 a survey was made of the brass and copper heavy industries in the state to determine the amount of metals lost primarily in the pickling processes. During that year it was estimated that 1,560 tons of copper and 1,150 tons of zinc were discharged in the liquid wastes. This amounted to 2,675 lbs. of copper and 1,950 lbs. of zinc per 500 tons of processed material shipped. The pickling operations required the use of 10,250 tons of sulfuric acid, 1,440 tons of sodium bichromate and water at the rate of about 8,000,000 gallons per day.

Paper board and allied industries in this state discharge about 23 tons of pulp per day with 18,000,000 gallons of water; one plant alone loses over 5 tons of pulp per day in this manner.

In addition to the tangible loss of certain recoverable products there is the intangible loss caused by gross pollution of public waterways. The latter represents a real loss of considerable magnitude, even though it cannot readily be evaluated on a monetary basis. The increase in cost of obtaining satisfactory water for domestic and industrial uses; destruction of fish and aquatic life; effect upon recreational uses; damage to structures and land values; formation of deposits in stream channels; public nuisances, such as unsightliness and foul odors; and the effect upon public health; are all conditions which directly and indirectly affect the lives and welfare of all the people.

Industrial waste treatment has a two fold purpose, the abatement of pollution and the recovery or re-use of materials used in the manufacturing processes. A very important aspect of the problem confronting those desiring to improve the condition of waterways and those charged with the duties of pollution abatement is the decision as to the

* Presented at Seventeenth Annual Meeting, F.S.W.A., Pittsburgh, Pa., October 13, 1944.

degree of treatment necessary or justified. Nearly all industrial wastes can be treated by a process or combination of processes to a degree which will permit of their discharge into almost any watercourse. The limiting factor is the cost.

Because of the multiple uses made of watercourses, it is not practical to maintain all streams in a state of pristine purity, but to permit their use for indiscriminate disposal of wastes is unthinkable. The common law doctrine, whereby the riparian owner is entitled to the stream flow by or through his land undiminished in quantity and unpolluted in quality, has been modified in practice if not by law. There is an economic balance determining for what purpose a stream can or should be used.

The goal of an industrial waste treatment policy must be the restoration and maintenance of all watercourses in a reasonable condition of purity within the limits of physical possibility of attainment and that which is economically feasible. If this is to be done it is necessary to have in outline a comprehensive program for the guidance of administrative agencies and as a graphical picture showing how it affects each individual offender.

Program for Pollution Abatement

Pollution abatement programs on a watershed basis should be set up in accordance with certain fundamental considerations, among which are: conservation of water; stream size and characteristics; character and volume of wastes discharged; natural laws and self-purification; local conditions and needs; and multiplicity of uses made of the watercourse.

Conservation of Water

In certain industrial areas unsatisfactory conditions of surface waters for manufacturing purposes are a factor in the trend of industry toward developing ground water supplies to satisfy its needs. In some localities the draft on wells is critically taxing these limited supplies with the alternative of treating highly polluted river water or purchasing from utilities.

While not all waters can be conserved for only one type of use, it is obvious that the vital and limited water resources of a state or region are best conserved when rivers are so maintained and protected that they can meet, to the maximum extent possible, the varied demands of the area through which they flow.

Self-Purification of Streams (1) (2)

The natural factors of self-purification represent a tremendous economic asset, which should be used and not abused. The amount of organic matter thus stabilized is remarkable when the biochemical reactions are in equilibrium and allowed to proceed in an orderly sequence of stages of oxidation. However, when inorganic materials, acids, alkalies, toxic compounds, and excessive quantities of organic

matter reach the waterway with limited dilution, the results are putrefaction, odors, unsightly appearance and depreciation of property values.

Classification of Streams and Standards of Quality (3) (4)

Classification of all streams in a state or region based on restoring them to the best condition which is economically feasible provides reasonable standards to aspire to and supplies a logical foundation upon which to develop a pollution abatement program. Obviously, standards cannot be used as a mechanical device by armchair theorists to solve the complex problem of pollution on a rational basis. There is the temptation, in setting up standards, to make them all-inclusive, rigid and with many details that later are found to be conflicting and impractical of enforcement. This should be avoided.

Recognition must be given to three fundamental limitations: first, the fact that it is impossible to control, by standards or otherwise, the quality of water to fit the specific requirements for all uses; second, the great difficulty in sampling the wastes and the receiving water to determine whether the degree of treatment is meeting the requirements set forth in the standards; third, the impossibility of developing foolproof treatment plants which will continuously produce a uniform effluent, because of the number of unpredictable factors involved, such as failure of mechanical equipment, varying character and volume of wastes, natural conditions and the exceedingly important human element.

No single standard can be set for an entire state, region or country. One, satisfactory for a drainage basin in Connecticut, might not be applicable to another watershed or in another state or even for the entire course of a stream.

Work on the classification of streams in New England was started before the war and discontinued for the duration (5). The object was to set up, through joint action of the states, a reasonable classification for interstate streams and to have each state classify all streams wholly within its borders, in accordance with the same general plan. This classification divides the streams into four classes, designated as A, B, C and D, depending upon their existing and potential highest use and the quality of effluent which might be expected from reasonable and practicable treatment processes.

This classification has considerable merit because of its simplicity, flexibility, reasonableness and comparative ease of administration, and is particularly applicable to sewage pollution. It is probably impracticable to set up any classification which would be applicable to all types of industrial wastes. Therefore, flexibility is necessary to permit of discretionary requirements by the administrative agencies.

Treatment of Industrial Wastes

It is neither feasible to treat all types of industrial wastes so as to produce the same high degree of purity, nor reasonable to require the same degree of treatment for similar wastes which are discharged into streams of different size and characteristics. The logical course lies in the adoption of methods to fit the quality of receiving waters contemplated in a rational classification program.

Some wastes contain products of value recoverable at a comparatively low cost and permit a profitable re-use of the water; others are not amenable to high degrees of purification except at a high cost and do not yield products of value.

Mixing and Equalization

The majority of industrial wastes contain intermittent slugs of high concentration discharged with the more dilute wastes and wash waters. One department of a plant may discharge acid wastes, another alkaline wastes.

Mixing and equalization of wastes of this nature is frequently necessary as a first step for further treatment and occasionally is the only treatment required, particularly if ample dilution is available.

Some wastes contain minute or colloidal particles which do not settle because they carry electric charges of the same sign. Mixing this solution with another, the molecules of which carry charges of opposite sign, may result in a partial clarification of both wastes if precipitation is permitted.

Industrial Wastes and Sewage Treatment

The desire of some industrial officials to discharge wastes into municipal sewerage systems is natural and logical. However, the majority of industrial wastes cannot thus be accepted in plants using biological treatment processes without satisfactory pretreatment of the wastes.

A considerable amount of research work has been carried out to determine the effect of copper upon sludge digestion (6). It was found that a sewage containing 0.5 p.p.m. of copper produced a sludge containing over 100 p.p.m. While this investigation has been interrupted by the war, it has tentatively been concluded that the chemical nature of the copper, the presence of certain sulfates in the sewage and the concentration of solids in the sludge all have an effect upon the toxicity of the copper and its inhibitory effect upon digestion. In general, a decrease in the efficiency of sludge digestion can be expected when the constant amount of copper in the sewage exceeds 1 p.p.m.

It has also been found that when 200 p.p.m. of precipitated chromium is present in sludge the rate of digestion is noticeably reduced and when the concentration of chromium in sewage constantly exceeds 1 p.p.m. its effect is similar to that of copper (6).

Other toxic materials in plating solutions, such as nickel, cyanides, etc., also have an inhibitory effect upon biological treatment.

Wastes from a textile plant discharging dyeing and finishing wastes through an equalization and controlled flow system are satisfactorily handled at a sewage treatment plant where the sewage is chlorinated

during the bathing season (7). The wastes apparently have no serious effect upon sludge digestion and a detailed investigation disclosed the following reduction in chlorine demand of the wastes through its mixture with the sewage.

Sewage flow (average rate)	16 m.g.d.
Volume of wastes:	
Dilute	850,000 g.p.d.
Concentrated	50,000 g.p.d.
Chlorine demand of wastes:	
At mill	2,060 lbs.
At sewage treatment plant	1,300 lbs.

The chlorine demand of the various wastes at the mill ranged from 8 to 3,200 p.p.m.

At another plant it was found that textile wastes would probably not interfere with the operation of the sewage treatment plant if their discharge were controlled through an equalization system so that the volume at any time would not exceed 10 per cent of the volume of sewage (6). This method of disposal, however, cannot always be used because some textile wastes contain toxic and other components which may interfere with sewage treatment.

Metallurgical Wastes

A detailed investigation of the wastes from the pickling operations at one of the large brass and copper plants revealed the startling fact that the dilute wash waters carry away 88 per cent of the acid used and 90 per cent of the lost metals. The remainder is lost in the form of spent pickle liquor (8). The composition and enormous variation of the wastes discharged from each of the three main departments was found to be:

Source of Waste	Concentration in P.P.M.			
	Sulphuric Acid	Copper	Zinc	Total Chromium
Rolling Mill				
Hourly Maximum	2,000	90	115	85
Hourly Minimum	105	10	20	5
Average	590	35	55	30
Tube Mill				
Hourly Maximum	245	145	70	80
Hourly Minimum	10	35	20	5
Average	85	75	40	25
Rod and Wire Mill				
Hourly Maximum	4,940	1,580	4,300	1,110
Hourly Minimum	190	385	350	345
Average	1,390	890	1,465	690

A great deal of research has been undertaken in an attempt to find a satisfactory method for treating this type of waste and in 1935 a pilot

plant was operated at a large brass manufacturing plant where the pickling wastes were mixed with cooling and other used water (9). The average composition of these combined wastes covering a period of about six months was found to be:

Sulfuric acid	105 p.p.m.
Copper	24 p.p.m.
Zinc	20 p.p.m.
Chromium (total)	20 p.p.m.
Chromium (as chromate)	9 p.p.m.

The purpose of this study was to recover the copper and zinc in a form that could be re-used in the furnaces and the chromium in a form satisfactory for re-use in pickling.

The results of this investigation indicated that a complete treatment plant to handle 3,000,000 gallons per day would cost approximately $200,000 to construct. The annual fixed and operating costs were estimated at $79,000 and the value of recovered products at $55,000.

The information obtained is valuable in indicating the difficulties and cost of treating the combined wastes and also in pointing the way to new lines of attack. After the war it is anticipated that research in the treatment of these wastes will proceed along the lines of concentrating the metals from the dilute wastes, and their recovery from the concentrated solution.

Treatment of wastes from iron and steel pickling operations has for some years been carried out at one plant by neutralization with lime, flocculation and precipitation, on a continuous flow basis. The effluent contains practically no iron, is nearly neutral and water clear. Sludge is disposed of in lagoons. Another plant has manufactured copperas from concentrated wastes for more than 20 years, with some of the more dilute wastes discharged to the sewerage system.

Paper Board Mill Wastes

The volume of these wastes in the different plants varies from 5,000 to 40,000 gallons per ton of product. They usually have a pH of from 5.0 to 7.0 and contain from 2 to 6 lbs. per 1,000 gallons of suspended solids with occasional surges of several times the high figure. The 5-day B.O.D. usually varies from 100 to 600 p.p.m.

Save-alls of various types are used primarily for reducing the fiber loss in the plant. However, from a pollution standpoint the revolving screen type in general use cannot ordinarily be expected to produce an effluent with a suspended solids content of much less than 2 lbs. per 1,000 gallons.

More effective treatment can be obtained either by sedimentation or flotation and the solids removed can generally be re-used. The following results may be obtained:

Treatment	Percentage of Fiber Removed
Sedimentation (approximately 2 hours)	75
Sedimentation plus flocculation without chemicals	85
Sedimentation plus flocculation with chemicals	95
Flotation with chemicals	95

Temperature is a factor affecting the sedimentation of these solids, not only in the difference between that of the wastes and the atmosphere but also between the wastes themselves.

In addition to the value of the recovered solids a substantial saving can accrue from the re-use of the clarified water, where the quantity is limited and particularly where the temperature must be raised.

Ordinary settling basins, without provision for sludge removal, are not practicable because of the large capacity necessary and the over-all inadequacy of sedimentation due to the constantly increasing sludge volume, together with the exposure of large surface areas to wind currents. The difficulty in eventually removing and disposing of the sludge which is not satisfactory for re-use, because of septic action, presents a serious problem. The sludge must be in a fresh condition for re-use.

Textile Wastes (10) (11)

The liquid wastes produced in dyeing and finishing operations on cotton, wool, rayon, silk and felt materials vary greatly in composition and volume, and do not lend themselves to the recovery of by-products. The exception to this is the recovery of caustic soda from mercerizing liquors by dialysis or by centrifuging and evaporation.

It is impossible to discuss, or even summarize in a few minutes, the whole problem of treating textile wastes because of the many different manufacturing processes involved, and the countless combinations of wastes which are produced and they usually are of a complex nature.

Chemical precipitation is the most widely used method of treatment which, naturally, has its limitations as far as the quality of effluent produced is concerned. In the smaller plants this is usually carried out in tanks on the fill and draw or batch method, because of the need for equalization and an opportunity for preliminary tests to determine the proper amount of chemicals necessary. Continuous flow tanks are generally more applicable for the large volumes produced in large plants.

The chemicals found to be most effective are lime and iron salts—either ferrous sulfate (copperas) or ferric sulfate. Combinations of lime and alum, ferric chloride, calcium chloride and soda ash are effective on certain wastes. Sulfuric acid, at times, is necessary for pH control, neutralization of strongly alkaline wastes, precipitation of certain dyes and to break up soap solutions.

The B.O.D. of composite wastes usually varies between 200 and 1,500 p.p.m. With the addition of proper amounts of chemicals and adequate mixing or flocculation preceding a sedimentation period of

about 2 hours, 80 to 90 per cent of the oxygen consuming material can be removed when the B.O.D. is over 800 p.p.m. and 60 per cent removal can be obtained when the B.O.D. is from 200 to 300 p.p.m. The amount of chemicals necessary is usually 1 to 2 lbs. per 1,000 gallons for the weaker wastes and greater quantities for the more concentrated.

The cost of chemical treatment is of course dependent upon many factors. However, for plants discharging less than 500,000 gallons per day, the fixed and operating costs may run from 10 to 20 cents per 1,000 gallons. For plants treating over 1,000,000 gallons per day the costs may be less than 10 cents per 1,000 gallons.

The causticity of kier liquors can be reduced by exposure to air, thus permitting the absorption of carbon dioxide. Complete neutralization of the caustic alkalinity was found after 7 days exposure with an 8-inch depth of liquid. The greatest reduction in the oxidizable organic matter as measured by oxygen consumed was found by partial neutralization through exposure and completion of neutralization by sulfuric acid followed by sedimentation. Another method for treating these wastes has been developed whereby flue gases and calcium chloride are used with the possible recovery of calcium carbonate.

The disposal of sludge from the treatment of textile wastes presents a problem unless there is sufficient land available for lagoons, in which it is dried, removed and finally disposed of elsewhere.

The effluents from chemical treatment plants are rarely clear. They may be colored, turbid and contain dissolved organic matter. Where higher degrees of treatment are necessary this can be accomplished on biological filters.

Oil and Grease

For many reasons oil and grease are among the most objectionable elements of pollution and metallurgical industries usually discharge appreciable quantities of them. Their recovery is neither difficult nor expensive. One metallurgical plant has, for several years, recovered, by means of a simple oil separator, approximately 2,000 gallons per week for re-use at a substantial profit.

The American Petroleum Institute has made a distinct contribution to abatement of pollution due to oil, through its studies and development of equipment for removing oil from industrial wastes (12). The following tabulation is interesting as an indication of the thickness of an oil film according to its appearance and the amount present when uniformly distributed:

Approximate Thickness of Film (inches)	Appearance	Approximate Quantity of Oil for Film 1 Sq. Mi. in Area (gallons)
0.0000015	Barely visible under most favorable light conditions	25
0.0000030	Visible as silvery sheen on surface of water	50
0.0000060	First trace of color may be observed	100
0.0000120	Bright bands of color are visible	200
0.0000400	Colors begin to turn dull	666
0.0000800	Colors are much darker	1,332