Industrial Wastes from the Equipment Manufacturers' Viewpoint

Selection of proper equipment for waste treatment is as important as devising the correct process and flow sheet. Not less than a billion dollars of equipment may be required to eliminate stream pollution. Fortunately the equipment is already in general use in chemical, metallurgical, and sanitary engineering, and requires only intelligent adaptation to meet the requirements of waste treatment.

Each waste treatment problem must be regarded as separate and distinct, and usually will require extensive investigation in the field and in the laboratory. This means

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WHEN manufacturers consider waste treatment as a part of the initial cost of any process operation and its daily cost a part of their operating cost, there will be no difficulty in finding suitable equipment to treat these wastes. Most companies are taking a broad-minded attitude in the matter, and substantial progress has been made during the last decade; one survey shows 179 plants in the United States in 1928 and 565 plants in 1938.

It has been difficult for a manufacturing executive to justify substantial equipment when no financial returns are expected, and too many times makeshift or homemade units have been installed after only a cursory survey of the waste treatment problem. This has made for high operating costs, frequent replacements, and expensive upkeep. Accordingly this part of the plant was often a nightmare to everyone.

Although it is true that many companies, after thoroughly studying their waste problems, are able to increase their over-all recovery or yields by plugging leaks or minor changes in their processes, and although others may produce salable by-products from their wastes, it is perhaps wiser to consider waste treatment as man's duty to society and the cost as an overhead on the manufacturing operation. This situation may change over the years, but such an attitude will prevent many disappointments.

Estimates as to the probable expenditure required to eliminate stream pollution only from industrial plants can be but little better than guesses, because the solution of many of these problems is as yet unknown. Some figures indicate an expenditure of a billion dollars for the United States and any sum of this magnitude is obviously of interest to equipment manufacturers, a challenge to the engineers, and a temptation to all others.

Handling of waste problem inquiries by equipment manufacturers has been a difficult problem, quite different from the engineering and sales work normally encountered. Here, probably, no return on the investment can be shown; there is no incentive for the customer to order quickly, and accordingly this type of business has been costly to handle.

Although the necessary units of equipment are doubtless available on the market today, they are scattered throughout the sanitary, chemical, and metallurgical fields, and the necessary experience or ability to engineer each step in the treatment process is likewise widely scattered.

Plant wastes are usually a heterogeneous mixture, collected from various operations containing widely different materials in solution and suspension. Some accurate measurement of the hourly flows and some analysis of their make-up is necessary before any flow sheet or equipment can be recommended; and some such study is required before the problem can even be classified.

This study costs money and the equipment manufacturer should not be asked to do this work as a sales expense, particularly when many plants wish to delay any expenditure as long as possible, when they are tempted to use homemade units or the cheapest equipment possible, and when there is always a possibility that the waste and the problem may be eliminated by closing the circuit and re-using the water without the installation of new equipment.

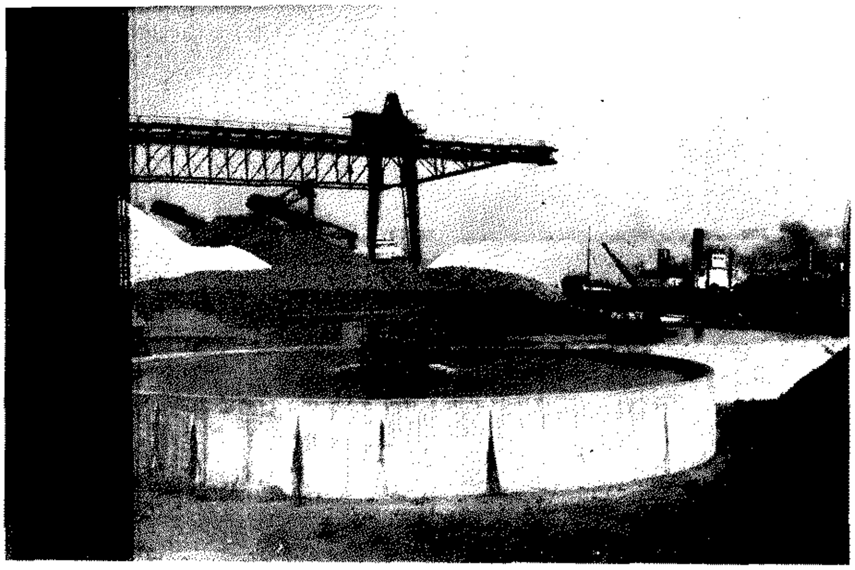
But few equipment manufacturers have the necessary staff with the varied experience required, and they obviously will quote higher prices than companies with no research and development expense. However, each waste treatment problem must be regarded as separate and distinct, and usually will require extensive investigation both in the field and in the laboratory. This means only that the problem must first be solved from an engineering standpoint by engineers competent to determine the treatment required before the question of suitable equipment can be considered.

The handling of wastes within the equipment manufacturer's own organization is also difficult. Often the sanitary engineers, from their experience with municipal sewage, can best solve the problem technically, but the industrial or chemical engineers know the men in charge of the plant polluting the stream and have more experience in working with this type of individual. It becomes then a problem of "men *vs.* machines"; perhaps the best compromise is to use the industrial engineer to make the contact and the sanitary or metallurgical engineer as a consultant or technical expert on the job. The sanitary man is all important if the city sewer system can take part of the industrial waste, or if some cooperative arrangement can be worked out.

To get any order out of these industrial waste problems, the problem must be solved by engineers competent to determine the treatment required before the question of suitable equipment can be considered.

Industrial waste problems are complex on account of the diversity of their composition, the restrictions placed on offenders by the regulatory authorities, and the possible failure economically of a technically successful process.

Waste treatment may be classified according to the nature of the offense, the type of regulatory body, or the aim of the treatment.



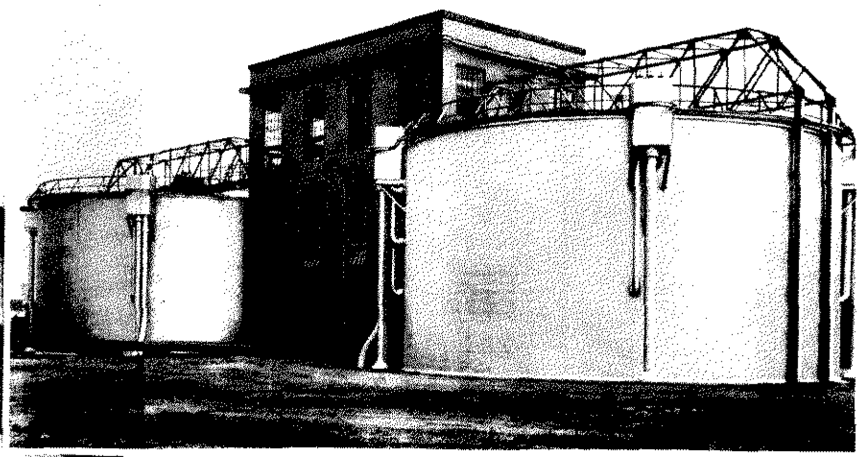
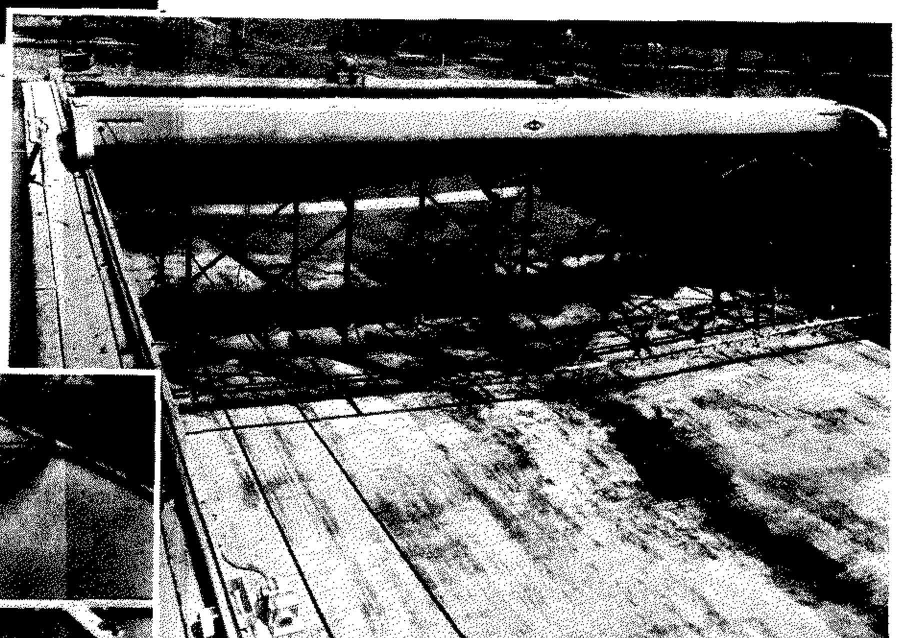
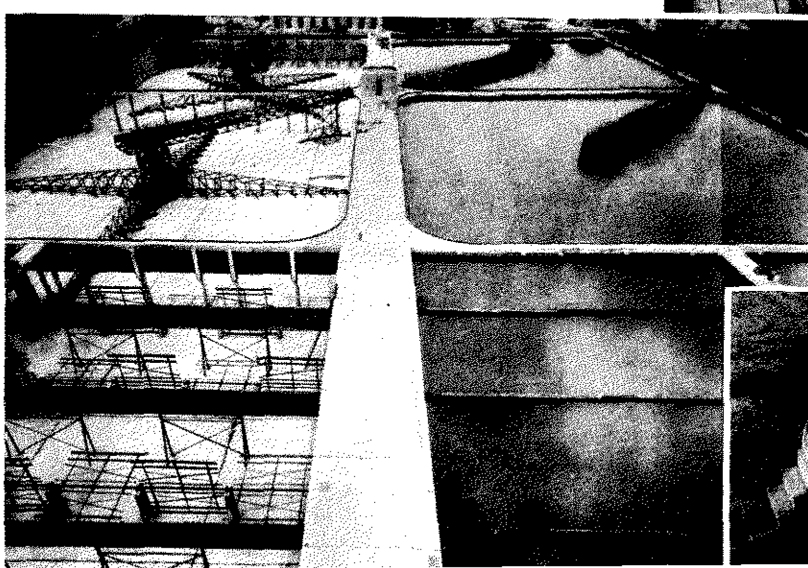


FIGURE 1 (*top*). THICKENER
FIGURE 2 (*above*). TWO TRAY THICKENERS
FIGURE 3 (*left*). ROUND, SANITARY CLARIFIER





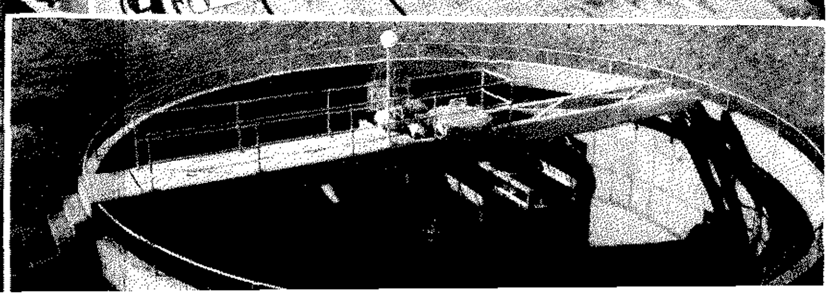
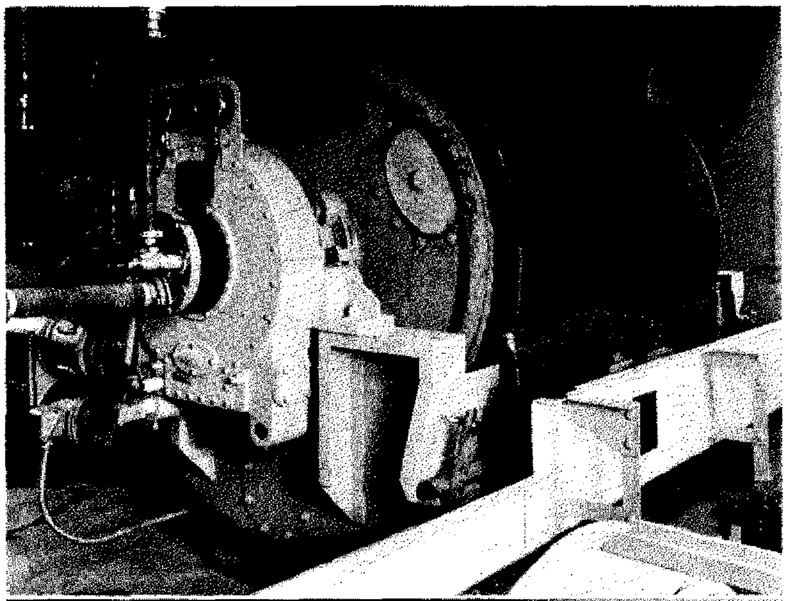


FIGURE 4 (*right*). MONORAKE FOR RECTANGULAR TANKS
FIGURE 5 (*below*). TWO FLOCCULATORS (ONE FULL AND ONE EMPTY) FEEDING SQUARE CLARIFIERS
FIGURE 6 (*lower right*). FLOCCULATOR-CLARIFIER IN A SINGLE CYLINDRICAL TANK



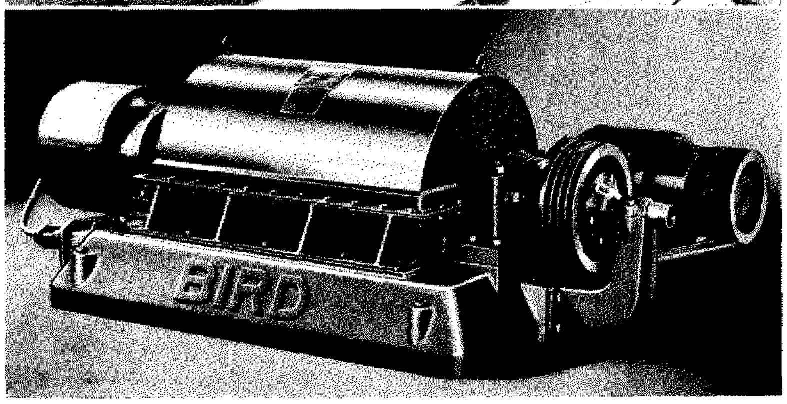


FIGURE 7 (*upper left*). CONTINUOUS ROTARY FILTER

FIGURE 8 (*lower left*). SOLID-BOWL CONTINUOUS CENTRIFUGE

some type of classification is necessary and obviously this may be done on several bases. Eldridge divided them into organic, toxic, and inert, but possibly the following discussion will further clarify the situation, at least from an equipment point of view.

We might classify as to purpose—that is, what is the source of the difficulty, and what department is concerned with the problem?

1. The War Department objects to the blocking of navigable streams. The offender would be a sand producer or a coal company and the wastes inert and granular and insoluble; perhaps only physical treatment is required.

2. The city or state wants color or turbidity removed. The company may be an oil refinery, a dyer or cleaner, a paper or pulp mill, and almost any sort of physical or chemical treatment may be necessary.

3. The Health Department of city or state requires B. O. D correction, elimination of bacteria, etc., from a distillery, brewery, milk plant, or pulp or paper company. This begins to be a sanitary problem requiring aeration, digestion, etc., possibly combined with physical or chemical preliminary units.

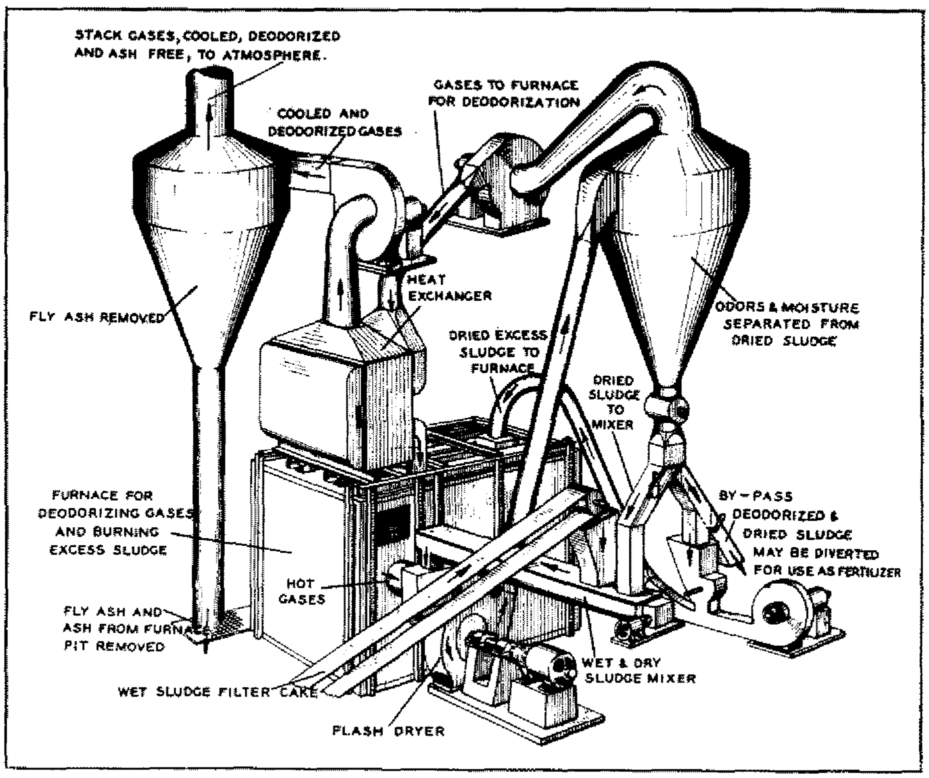
We might also classify as to type of treatment—(1) physical (metallurgical), (2) chemical, (3) biological, or any combination of the three, or we might classify as to what is required or expected: (1) by-product recovery or (2) cheapest and most efficient elimination of the pollution with no credit. A pickling liquor layout perhaps illustrates the latter classification; shall it neutralize the waste economically or try to recover the iron and acid for re-use?

Typical Flow Sheets

A few typical flow sheets will indicate how these units are used and how the experience in the process industries is helping solve waste problems.

CASE 1. An anthracite coal mining company must discontinue discharging fine coal to the river since the settled

FIGURE 9. C-E RAYMOND SLUDGE-DRYING AND INCINERATION SYSTEM



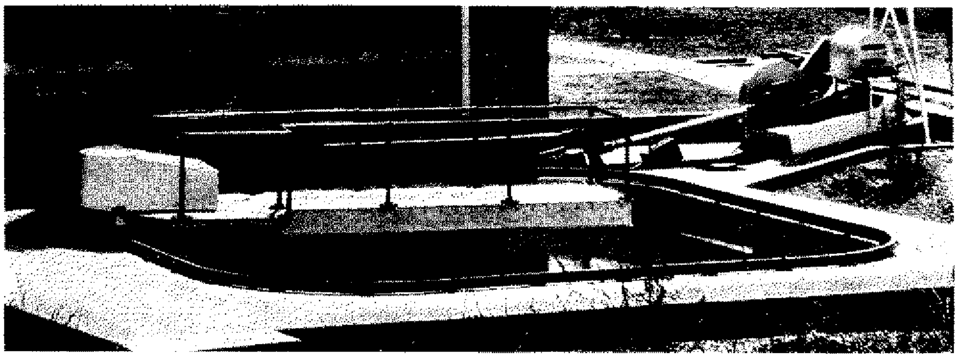


FIGURE 10. DETRITOR, DEVELOPED FROM THE BOWL CLASSIFIER

solids are building up behind a dam in the river. A preliminary study indicates that the fine coal is marketable if the ash content can be reduced sufficiently. By hydraulic classification tests, it is demonstrated that the +200-mesh material can be classified, tabled, or floated and burned as pulverized anthracite. The tails, ash, or float, together with the −200-mesh heads, must be dewatered even though no credit can be realized from them. The flow sheet finally evolved is then classification, tabling, flotation, thickening, and filtering, obviously a straight metallurgical problem; each step is equipped with machines manufactured by companies with long experience in handling metallurgical work of this type.

This, then, is a physical operation made necessary by regulations of the War Department because of obstructions to a navigable river below the dam and classifiers, sizers, tables, hydroseparators, flotation cells, thickeners, and filters are used—all metallurgical equipment.

CASE 2. A steel mill has been advised by the state authorities that it can no longer discharge its pickle liquor (sulfuric acid and ferrous sulfate) into the river adjoining the property.

The problem obviously is one for the chemical engineer, regardless of whether sulfuric acid and iron oxide are to be recovered and re-used or whether the acids are to be neutralized as cheaply as possible at a minimum initial expense and the resulting gypsum stacked as a valueless product. The mill is small, and only 2 tons of sulfuric acid are used per day. An acid recovery plant costs a quarter of a million dollars and is economical only if operated at ten or twenty times this tonnage. It is therefore decided to spend thirty thousand dollars and thirty dollars a day to treat the waste pickle with limestone.

Phosphoric acid experience indicates that the size of the gypsum crystals may be varied almost at will by recirculation. Chemical engineers know that ferric hydroxide will settle and filter but that ferrous hydroxide is slimy and difficult to handle. The flow sheet then becomes the following: Limestone, the cheapest alkali available, is ground in a closed circuit (this operation comes from the mining or metallurgical engineer); the slurry is oxidized with air during precipitation; and recirculation is used to increase the settling and filtration rates. The resulting water is neutral and inert, and the filter cake can be stacked, not lagooned. This practice obviously capitalizes on chemical engineering experience in many fields.

CASE 3. A pulp and paper mill is in difficulty because alkaline solutions discharge into a small river and because pulp in the white water decomposes and reduces the oxygen content of the stream. Here is a real problem. Possibly the paper mill circuit may be closed, and if so, putrescible solids are eliminated. Possibly an ADKA Save-all (a steal from the

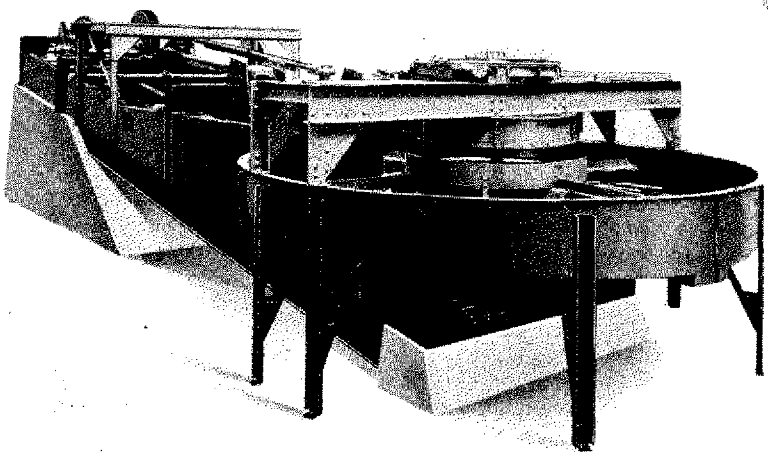
TABLE I. POSSIBLE TREATMENT REQUIRED FOR WASTES FROM VARIOUS PLANTS

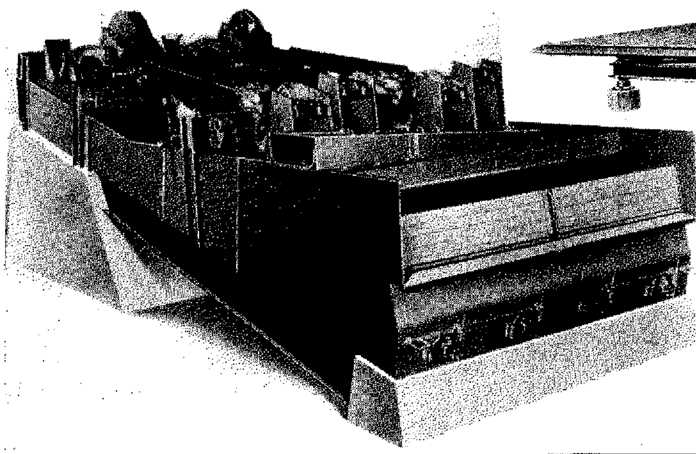
Kind of Plant	Cited by: United States (physical)	Cited by: City or state (chemical)	Cited by: Health officer (biological)	Cited for: Segregation	Cited for: Acidity, color, turbidity	Cited for: B. O. D.	Treatment: Sanitary	Treatment: Chemical	Treatment: Metallurgical	Equipment: Screens	Equipment: Agitator	Equipment: Flocculator	Equipment: Classifier or detritor	Equipment: Clarifier or thickener	Equipment: Filter or centrifuge	Equipment: Aerator	Equipment: Digestor or trickling filter	Equipment: Flotation cell or ADKA
Blast furnace	x[1]	..	..	x	..	..	..	..	x	..	..	..	x	x	x	..	..	..
Brewery	..	..	x	..	..	x	x	..	..	x	x	x	..	x	x	x	x	..
Cannery	..	..	x	..	..	x	x	..	..	x	..	x	..	x	..	x	x	..
Coal	x	..	..	x	..	..	..	..	x	x	x	..	x	x	x	..	..	x
Coal-tar	..	x	(x)	..	x	..	(x)	x	..	..	x	..	..	x	..	x	..	..
Dairy	..	..	x	..	..	x	x	..	..	..	(x)	(x)	..	x	..	x	x	..
Distillery	..	..	x	..	..	x	x	(x)	..	x	..	..	..	x	x	(x)	(x)	..
Dyehouse	..	x	..	..	x	..	(x)	x	..	..	x	x	..	x	x	(x)	(x)	..
Gashouse	..	x	(x)	..	x	(x)	(x)	x	..	..	x	x	..	x	x	..	..	..
Glue	..	..	x	..	..	x	x	..	..	x	x	x	..	x	..	x	..	..
Laundry	..	x	(x)	..	x	(x)	(x)	x	..	..	x	x	..	x	x	x	x	..
Packinghouse	..	..	x	..	..	x	x	..	..	x	..	x	x	x	x	x	x	..
Paint	..	x	..	..	x	..	..	x	..	..	x	..	..	x	x	(x)	..	..
Paper	..	x	(x)	..	x	(x)	(x)	..	x	x	x	x	..	x	x	..	..	(x)
Pickling-liquor	..	x	..	..	x	..	..	x	..	..	x	..	..	x	x	..	..	..
Pulp	..	(x)	x	..	x	(x)	x	(x)	..	..	x	x	..	x	x	..	x	..
Refinery	x	..	(x)	..	x	(x)	..	..	x	..	x	..	..	x	..	..	..	..
Rubber	x	..	..	x	..	..	..	..	x	x	..	..	x	x	..	..	..	x
Sand	x	..	..	x	..	..	..	..	x	x	..	..	x	x	x	..	..	..
Soap	..	x	..	..	x	..	..	x	..	..	x	x	..	x	x	..	..	..
Sugar	..	..	x	..	..	x	x	..	..	x	..	x	..	x	..	..	x	..
Tannery	..	..	x	(x)	..	x	x	..	..	x	..	x	x	x	x	x	..	..
Textile	..	x	..	..	x	..	..	x	..	x	..	x	..	x	x	..	..	..
Wool	..	..	x	..	x	..	..	x	..	x	..	..	..	x	x	..	..	..

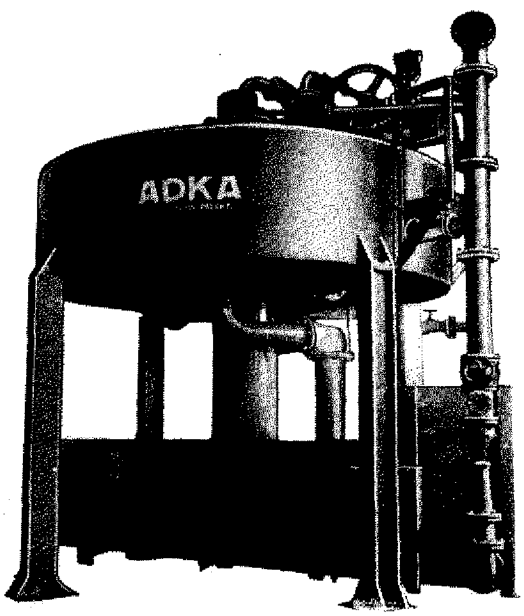
[1] x indicates equipment used; (x) indicates equipment which might be used on secondary or alternative basis.

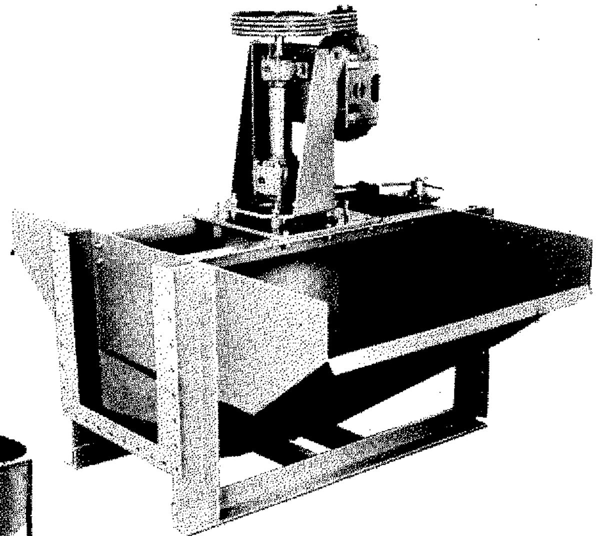
(Reading from top to bottom)

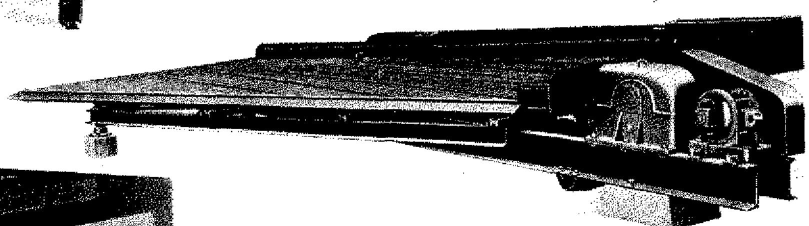
FIGURE 11. BOWL CLASSIFIER FOR FINER SOLIDS
FIGURE 12. TYPE-F STRAIGHT CLASSIFIER
FIGURE 13. ADKA SAVE-ALL FOR APPLYING FLOTATION TO PAPER PULP AND FILLER











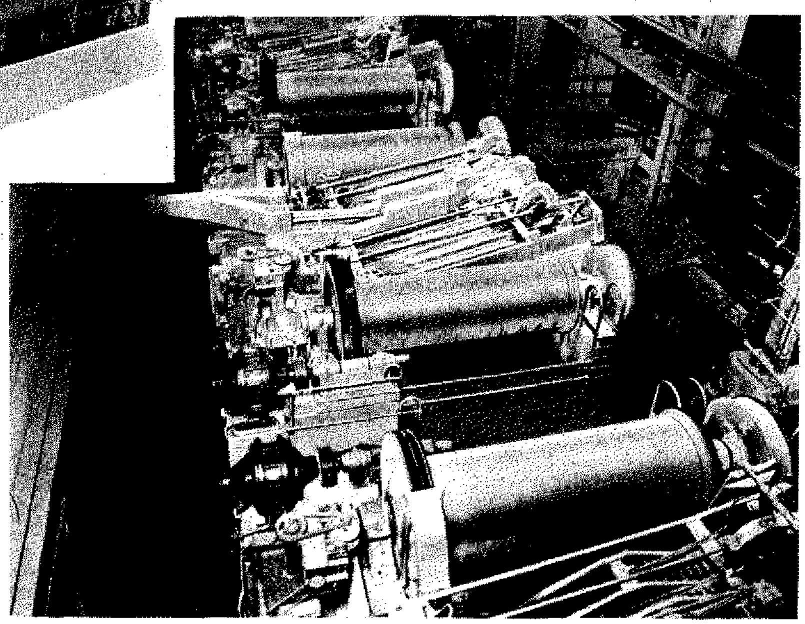


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FIGURE 14. METALLURGICAL FLOTATION CELL
FIGURE 15. METALLURGICAL TABLE
FIGURE 16. CLASSIFIERS IN CLOSED CIRCUIT WITH TUBE MILLS FOR GRINDING

metallurgical industry) will float the pulp from the white water down to 0.3 pound per thousand gallons of water; but what of the pulp mill waste? If the plant is producing kraft pulp, possibly continuous filters to replace diffusers will close the black liquor circuit or additional evaporator capacity will help. Mixing of the bleach and decker waters may neutralize them, and the mixture may be discharged without further treatment. A trickling filter will reduce the B. O. D. of any special liquors still carrying the sodium salts of lignins in solution. This is a combination of the best in the chemical and sanitary engineers' experience.

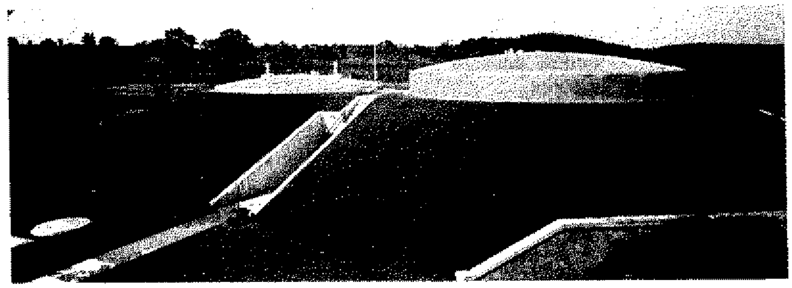
CASE 4. Many articles have been written on packinghouse wastes, and several plants are in successful operation. Often the municipal sewer assists in taking some partially treated effluents. The flow sheet includes a fine screen flash mixer for dosing, flocculator, and two primary clarifiers, the clarifier underflows going to two-stage digestion and finally filtration. Primary clarifier overflows are treated on trickling filters and the effluents are further clarified, the settled solids joining those from primary clarification ahead of digestion. Incidentally this plant now includes a detritor and a gas holder for digester gas. This is a sanitary engineering operation throughout.

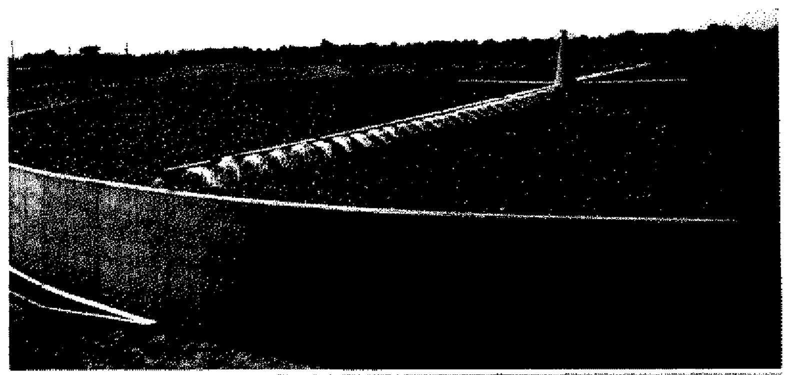
If we assume that segregating solids offend the War Department, that acidity, color, and turbidity are forbidden by city or state, and that B. O. D. and odors are obnoxious to the Health Department, we can prepare a table and at once make some sort of general estimate as to the possible type of treatment required and the equipment that might be used. This is inexact but at least gives an indication. It is surprising to note how much waste treatment is nonsanitary work.

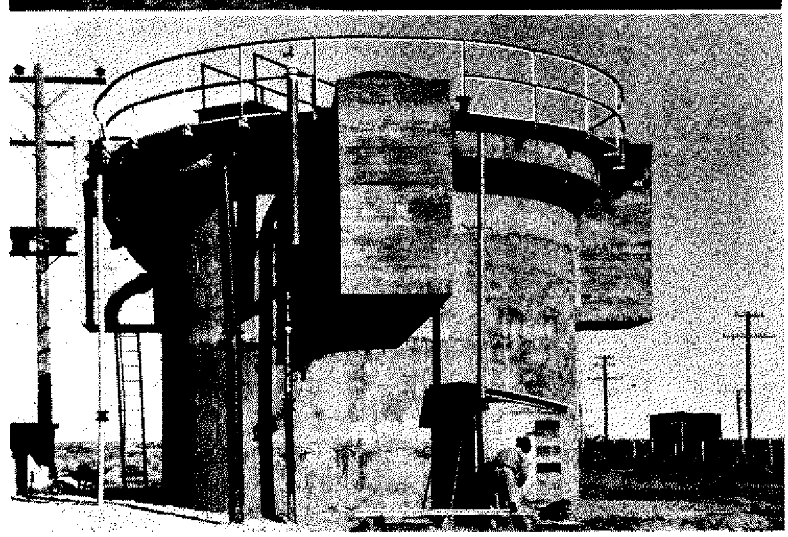
The following machines are representative:

Sanitary	Chemical	Metallurgical
Screen	Screen	Screen
Flash mixer	Agitator	Agitator
Flocculator	.....	....
Detritor	.....	Classifier
Clarifier	Thickener	Thickener
Filter	Filter	Filter
Centrifuge	Centrifuge	....
Aerator	.....	....
Digester	.....	....
Trickling filter	.....	....
.....	ADKA Save-all	Flotation cell

As an example let us consider the first entry of Table I. This is flue gas from a blast furnace operation. The solids are inert and the liquid is practically neutral. The coarser solids would be removed from the furnace gases by dry dust catchers, some finer solids perhaps with electrical precipitators, and the remainder by wet scrubbers. Thickeners would separate the wetted dust from the scrubber water, and filters might follow. This, then, is a metallurgical problem using equipment primarily from the metallurgical industry.







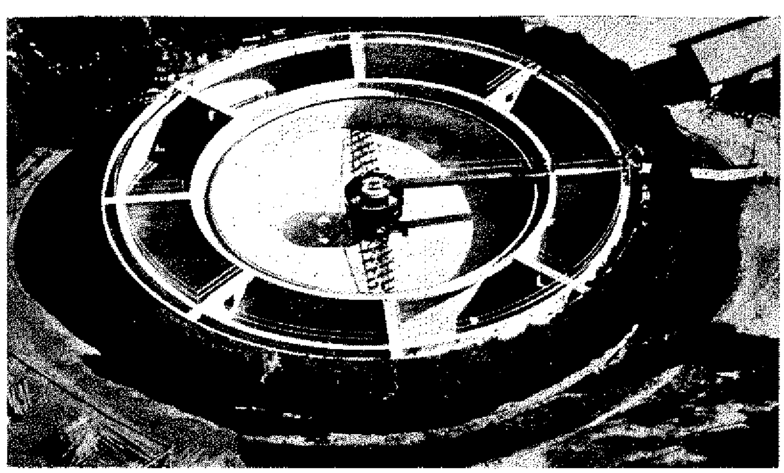
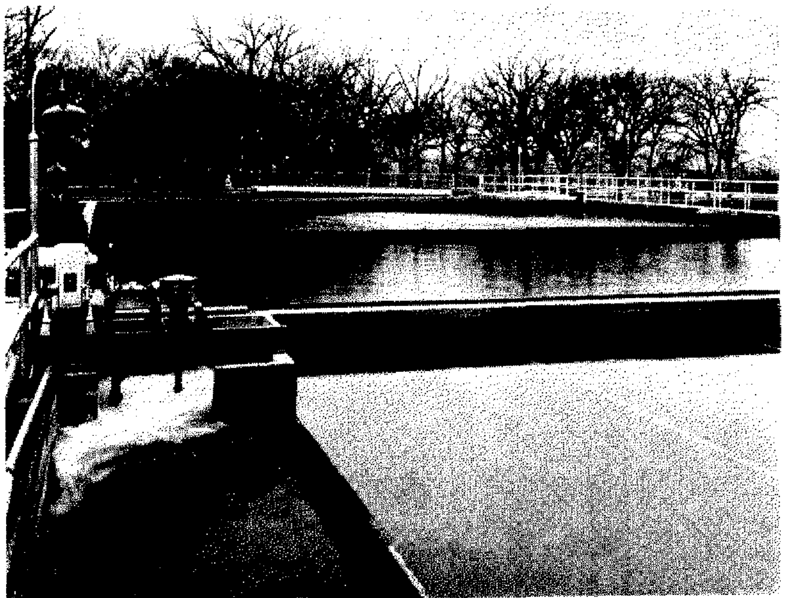
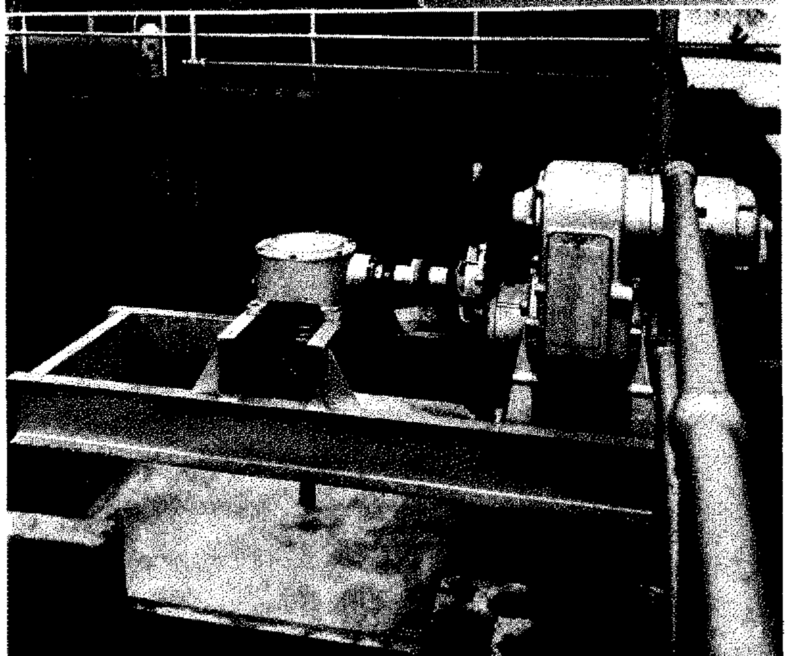


FIGURE 17. DIGESTER IN A SEWAGE PLANT
FIGURE 18. DISTRIBUTOR FEEDING A TRICKLING FILTER
FIGURE 19. CLARIGESTER (CLARIFIER AND DIGESTER IN A SINGLE TANK)
FIGURE 20. CLARAETOR (AERATORS SURROUNDING A ROUND CLARIFIER)





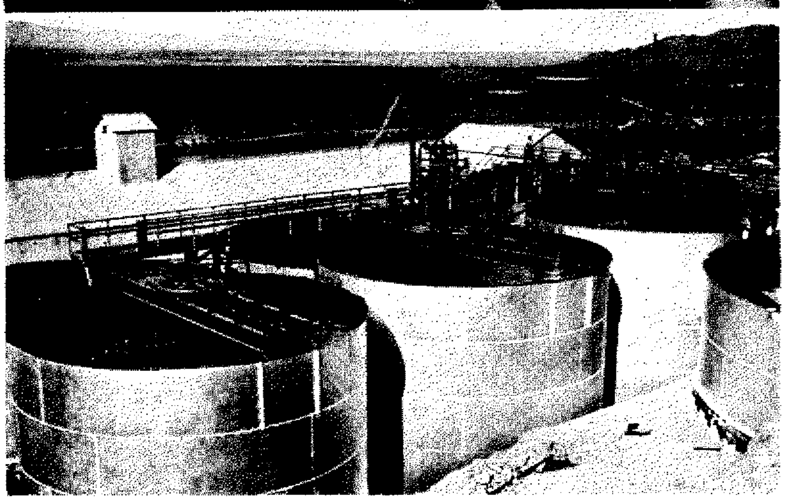


FIGURE 21. TURBO FLASH MIXER PRECEDING FLOCCULATOR AND CLARIFIER
FIGURE 22. TURBO OXIDIZER (SMALL ONES INDUCE THEIR OWN AIR)
FIGURE 23. AGITATORS, USUALLY FOR METALLURGICAL OPERATIONS

The next entry of Table I has to do with the removal of organic solids, both soluble and insoluble, from a brewery waste. These solids are putrescible and the health officer has objected. Correction of B. O. D. is required, and it is a sanitary problem probably making use of screens, aerators, digesters, trickling filters, and clarifiers.

The third, a cannery waste, is fundamentally like the second; the fourth, a coal waste, is metallurgical again, probably using flotation, closed-circuit grinding, and tabling in addition to the units described under blast furnace, and so on.

Equipment

Although it might not be fair to say that no new equipment has been or need be developed for waste treatment, in general existing machines or modification of them will suffice. The illustrations demonstrate that we have an abundance of equipment units for mechanical handling of waste and that the principal remaining problem is to classify and segregate wastes and then develop a flow sheet using the equipment and process best suited.

A discussion of equipment for waste disposal should include machines and flow sheets for air pollution elimination. This is a large subject; and since my experience has been almost entirely with liquid wastes, I do not feel competent to discuss air pollution except where it ties in closely with stream pollution. Blast furnace flue dust is actually air pollution, but with wet scrubbers the problem becomes a stream pollution problem. Other plants listed have air pollution problems and manufacturers have contributed much to abate odor and dust nuisances by chlorination, activated carbon, and similar means.

Monkhouse, of the Ministry of Health in Great Britain, made an address last March classifying air pollution problems into:

Solid particles—grit dust and fume; calls for dry precipitation or scrubbing, followed by a physical or metallurgical plant.

Liquid particles—mist; requires condensation, precipitation, or scrubbing.

Gases—toxic, injurious, and offensive; becomes a chlorination or activated carbon problem.

Liquid effluents emitting smell alone or when in contact with other liquids—uses chemical treatment, carbon, etc.

Let us now consider some of the machines used, which are actually a combination of many operations known to the chemical, metallurgical, or sanitary engineer. Numerous types of aerators, flocculators, clarifiers, filters, etc., are on the market, but the cuts shown were most readily available. Since tests indicate better clarity and more capacity for centrally fed clarifiers, this type is preferred. Rectangular clarifiers are illustrated because in some cases space limitations preclude the use of the more efficient arrangement.

Since a sedimentation step appears in most waste treatment flow sheets, let us consider first the thickener or clarifier. Many types are available. The unit-compartment central-drive machine with torque arms (Figure 1) is used for coal, blast furnace flue dust, and the metallurgical type of plant; where floor space is at a premium, the tray may be preferable (Figure 2).

In the treatment of organic wastes and where flocculent light precipitates are to be removed, the sanitary type usually called a clarifier (Figure 3) is standard equipment. This may be round or square. The mechanism may rotate at a slower speed, and the feed should enter at the center—thus the siphon-feed principle. For rectangular tanks the Monorake illustrates a type (Figure 4). With these light materials flocculation is often induced to aid settlement or clarification, either by mechanical flocculators or the building of a synthetic floc by chemical treatment or both. A conventional type of flocculator is shown in Figure 5.

Since flocs must be carefully handled to prevent breakage or dispersion, the combination flocculator-clarifier (Figure 6) has been developed and is in considerable demand.

Clarifiers in general give a satisfactory effluent or overflow, but the settled solids or underflow still carry considerable water. These underflows are still a problem in many cases, but usually they may be filtered on a continuous filter (Figure 7), and more recently the continuous centrifuge (Figure 8) seems to offer possibilities.

Some of these filter cakes or recovered solids may be burned; Figure 9 illustrates an incineration system which is being used with good results.

With organic wastes, bar and rotary screens often precede sedimentation for removal of the coarser suspended solids. Finer materials in suspension are classified ahead of sedimentation; the detritor (Figure 10) fills this gap in sanitary-type problems, and the bowl classifier (Figure 11) or straight classifier (Figure 12) is used in metallurgical-type operations. These units give a clean, well-washed sand and take care of this part of the problem.

Light particles in suspension, such as pulp in white water from paper mills, are now recovered by flotation in the ADKA Save-all (Figure 13), metallurgical flotation reagents being commonly used. The effluents are abnormally clear, and the recovered stock is in admirable shape for return to the paper machine. Figure 14 shows a metallurgical type of flotation cell, as used in recovering coal from fines recovered from a river. The metallurgical table (Figure 15) recovers the coarse coal and separates it from the slate; flotation cells do the same for the finer suspended particles. In this operation closed-circuit grinding (Figure 16) may well be used.

Clarifier effluents may be clean as far as suspended particles are concerned but unsatisfactory as to B. O. D., dissolved solids, etc. They may be aerated in many types of equipment. Underflows may be digested (Figure 17) or passed through trickling filters by means of distributors (Figure 18), and combinations of these units are available. Figure 19 shows a Clarigester, a clarifier and digester in one tank; Figure 20 is a Claraetor, clarifier and aerator together. Magnetite filters are used for further removal of turbidity or color from a clarifier effluent; this automatically washed sand filter may have a future of considerable interest.

Agitators of many types are available. The flash mixer of the turbo type (Figure 21) appears in most plants; it requires addition of chemicals for flocculation and gives a few seconds or minutes of violent agitation to the total flow. The aerator type of turbo (Figure 22) will oxidize ferrous precipitates to the ferric to facilitate handling. Figure 23 illustrates the metallurgical-type agitator for large tanks, and Figure 24 the slurry mixer for storing and blending suspensions to provide uniform flows. These may be used in tanks up to 40 feet in diameter and nearly as deep.

These examples, together with the flow sheets, will bear out the statements that adequate equipment is available to handle any waste mechanically, and technical knowledge is also available, although it is possibly somewhat scattered. If any given waste is studied and classified, a solution may almost certainly be found.

Feeders and Proportioners

If waste treatment is to be a new overhead, it is obvious that the manufacturer should do all possible to make the plants self-operating and the daily cost a minimum. Equipment is available to regulate the dosage with one or more chemicals and to vary it with the volume of feed and pH of the incoming waste. These units are dependable, accurate, and substantial, and are doing much toward solving waste problems.

It seems obvious that this is not just another operation or another unit process, but a subject far more complex. It calls for all the knowledge accumulated in the sanitary, chemical, and metallurgical fields, and each waste problem can doubtless be solved in a myriad of ways.

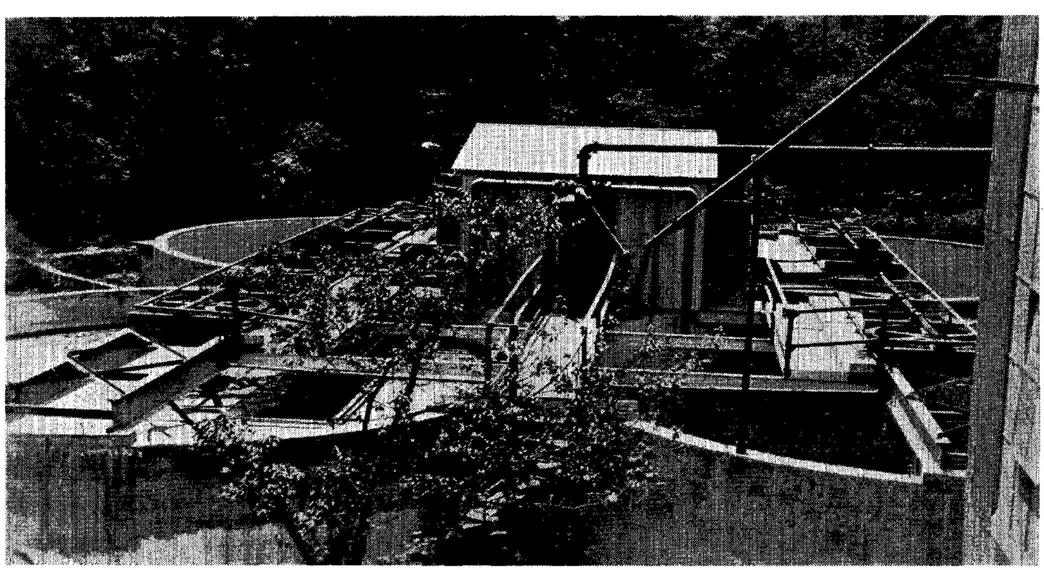


FIGURE 24. SLURRY MIXERS IN A CEMENT PLANT