Chapter

8

WASTEWATER TREATMENT TECHNOLOGIES

This section discusses a number of wastewater treatment technologies considered by EPA for the development of these guidelines and standards for the CWT Industry. Many of these technologies are being used currently at CWT facilities. This section also reviews other technologies with potential application in treating certain CWT pollutants of concern.

Facilities in the CWT industry use a wide variety of technologies for treating wastes received for treatment or recovery operations and wastewater generated on site. The technologies are grouped into the following five categories for this discussion:

- Best Management Practices, section 8.2.1;
- Physical/Chemical/Thermal Treatment, section 8.2.2;
- Biological Treatment, section 8.2.3;
- Sludge Treatment and Disposal, section 8.2.4; and
- Zero Discharge Options, section 8.2.5.

The processes reviewed here include both those that remove pollutant contaminants in wastewater and those that destroy them. Using a wastewater treatment technology that removes, rather than destroys, a pollutant will produce a treatment residual. In many instances, this residual is in the form of a sludge, that, typically, a CWT further treats on site in preparation for disposal. Section 8.2.4 discusses technologies for dewatering sludges to concentrate them prior to disposal. In the case of other types of treatment residuals, such as spent activated carbon and filter media, CWT facilities generally send those off site to a vendor facility for management.

TECHNOLOGIES CURRENTLY IN USE *8.1*

EPA obtained information on the treatment technologies in use in the CWT industry from responses to the Waste Treatment Industry (WTI) Questionnaire, site visits, public comments to the original proposal and the 1996 Notice of Data Availability. As described in Section 4, of the estimated 205 CWT facilities, EPA has obtained detailed facility–specific technology information for 116 of the direct and indirect discharging CWT facilities. Although EPA has facility-specific information for 145 facilities, only 116 of these facilities provided technology information. The detail provided regarding the technology information differs depending on the source. Information for the 65 facilities that completed the WTI Questionnaire was the most explicit because the questionnaire contained a detailed checklist of wastewater treatment technologies, many of which are discussed in this section. Technology information from other sources, however, is much less descriptive.

Table 8-1 presents treatment technology information by subcategory for the 116 indirect and direct discharging CWT facilities for which EPA has facility-specific treatment technology information. The information in Table 8-1 has not been scaled to represent the entire population of CWT facilities. Responses to the WTI Questionnaire provide the primary basis for the technology information for the metals and the organics subcategories. Comments to the 1996 Notice of Data Availability provide the primary source of the technology information for the oils subcategory. It should be noted that a number of facilities commingle different subcategory wastes for treatment. EPA has attributed these

treatment technologies to all appropriate subcategories.

Table 8-1. Percent Treatment In-place by Subcategory and by Method of Wastewater Disposal

	Metals Subcategory		Oils Subcategory		Organics Subcategory	
Disposal Type	Direct	Indirect	Direct	Indirect	Direct	Indirect
Number of Facilities with Treatment Technology Data	9[1]	41[1]	3[1,2]	80[1,3]	4[1]	14[1]
Equalization[4]	78	68	100	65	75	71
Neutralization[4]	89	73	100	61	100	57
Flocculation[4]	44	51	100	48	75	57
Emulsion Breaking	11	29	33	56	25	50
Gravity-Assisted Separation	89	61	100	85	100	64
Skimming[4]	22	27	100	58	25	57
Plate/Tube Separation[4]	0	10	0	19	0	21
Dissolved Air Flotation	22	5	33	23	50	0
Chromium Reduction[4]	33	76	0	48	0	57
Cyanide Destruction[4]	33	46	100	23	25	29
Chemical Precipitation	78	88	0	34	25	64
Filtration	44	32	33	19	25	21
Sand Filtration[4]	11	15	0	16	0	21
Mutimedia Filtration[4]	11	5	0	0	0	7
Ultrafiltration	0	0	0	8	0	0
Reverse Osmosis[4]	11	0	0	3	0	0
Carbon Adsorption	22	12	67	18	0	21
Ion Exchange[4]	0	2	0	0	0	0
Air Stripping	0	7	0	11	0	0
Biological Treatment	56	2	100	11	100	7
Activated Sludge	33	0	100	0	100	0
Sequencing Batch Reactors[4]	0	2	0	0	0	7
Vacuum Filtration[4]	11	17	100	6	25	7
Pressure Filtration[4]	67	61	100	39	75	36

[1]Sum does not add to 116 facilities. Some facilities treat wastes in multiple subcategories.
[2]Of the 3 direct discharging oils facilities for which EPA has facility-specific information, only one completed the WTI Questionnaire.
[3]Of the 80 indirect discharging oils facilities for which EPA has facility-specific information, only 31 completed the WTI Questionnaire.
[4]Information for these technologies for the oils subcategory is based on responses to the WTI Questionnaire only.

TECHNOLOGY DESCRIPTIONS 8.2

Best Management Practices 8.2.1

In addition to physical/chemical treatment technologies, CWT facilities employ a number of ancillary means to prevent or reduce the discharge of pollutants. These efforts are termed "best management practices. EPA believes that CWT facilities should design best management

practices in the CWT industry with the following objectives in mind:

- Maximize the amount of waste materials and residuals that are recycled rather than disposed as residuals, as wastewater, or as waste material.
- Maximize recycling and reuse of wastewaters generated on site.
- Minimize the introduction of uncontaminated wastewaters into the treatment waste stream.
- Encourage waste generators to minimize the mixing of different wastes.
- Segregate wastes for treatment particularly where waste segregation would improve treatment performance and maximize opportunities for recycling.

Waste segregation is one of the most important tools available for maximizing waste recycling and improving treatment performance. For example, separate treatment of wastes containing different types of metals allows the recovery of the individual metals from the resultant sludges. Similarly, separate treatment collection and treatment of waste oils will allow recycling. Many oils subcategory facilities currently practice waste oil recycling.

Physical/Chemical/Thermal Treatment 8.2.2

Equalization 8.2.2.1

GENERAL DESCRIPTION

The wastes received at many facilities in the CWT industry vary considerably in both strength and volume. Waste treatment facilities often need to equalize wastes by holding wastestreams in a tank for a certain period of time prior to treatment in order to obtain a stable waste stream which is easier to treat. CWT facilities frequently use holding tanks to consolidate small waste volumes and to minimize the variability of incoming wastes prior to certain treatment operations. The receiving or initial treatment tanks of a facility often serve as equalization tanks.

The equalization tank serves many functions. Facilities use equalization tanks to consolidate smaller volumes of wastes so that, for batch treatment systems, full batch volumes are available. For continuous treatment systems, facilities equalize the waste volumes so that they may introduce effluent to downstream processes at a uniform rate and strength. This dampens the effect of peak and minimum flows. Introducing a waste stream with a more uniform pollutant profile to the treatment system facilitates control of the operation of downstream treatment units, resulting in more predictable and uniform treatment results. Equalization tanks are usually equipped with agitators or aerators where mixing of the wastewater is desired and to prevent suspended solids from settling to the bottom of the unit. An example of effective equalization is the mixing of acid and alkaline wastes. Figure 8-1 illustrates an equalization system.

EPA does not consider the use of equalization tanks for dilution as a legitemate use. In this context, EPA defines dilution as the mixing of more concentrated wastes with greater volumes of less concentrated wastes in a manner that reduces the concentration of pollutant in the concentrated wastes to a level that enables the facility to avoid treatment of the pollutant.

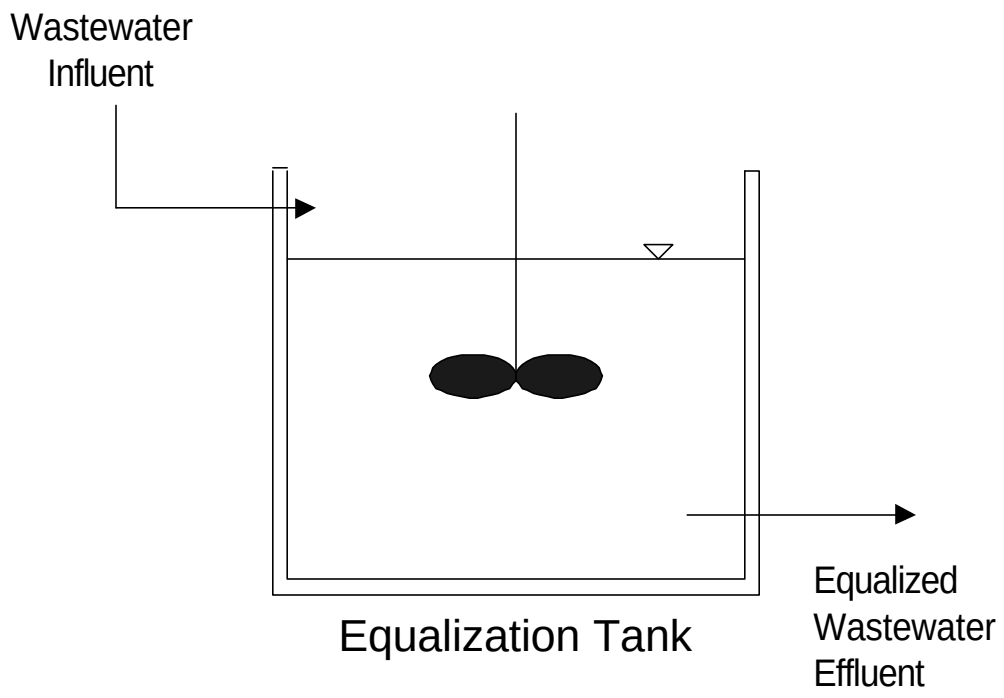

Figure 8-1. Equalization System Diagram

INDUSTRY PRACTICE

EPA found equalization being used at facilities in all of the CWT subcategories. Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning the use of equalization, 44 operate equalization systems. Of these, approximately 44 percent emply unstirred tanks and 56 percent use stirred or aerated tanks.

The combining of separate waste receipts in large receiving tanks provides for effective equalization even though it is not necessarily recognized as such. Nearly every facility visited by EPA performed equalization, either in tanks specifically designed for that purpose or in waste receiving tanks. Consequently, EPA has concluded that equalization is underreported in the data base.

Neutralization *8.2.2.2*

GENERAL DESCRIPTION

Wastewaters treated at CWT facilities have a wide range of pH values depending on the types of wastes accepted. Untreated wastewater may require neutralization to eliminate either high or low pH values prior to certain treatment systems, such as biological treatment. Facilities often use neutralization systems also in conjunction with certain chemical treatment processes, such as chemical precipitation, to adjust the pH of the wastewater to optimize treatment efficiencies. These facilities may add acids, such as sulfuric acid or hydrochloric acid, to reduce pH, and alkalies, such as sodium hydroxides, to raise pH values. Many metals subcategory facilities use waste acids and waste alkalies for pH adjustment. Neutralization may be performed in a holding tank, rapid mix tank, or an equalization tank. Typically, facilities use neutralization systems at the end of a treatment system to control the pH of the discharge to between 6 and 9 in order to meet NPDES and POTW pretreatment limitations.

Figure 8-2 presents a flow diagram for a typical neutralization system.

INDUSTRY PRACTICE

EPA found neutralization systems in-place at facilities identified in all of the CWT subcategories. Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning the use of neutralization, 45 operate neutralization systems.

Flocculation/Coagulation *8.2.2.3*

GENERAL DESCRIPTION

Flocculation is the stirring or agitation of chemically-treated water to induce coagulation. The terms coagulation and flocculation are often used interchangeably. More specifically, "coagulation" is the reduction of the net electrical repulsive forces at particle surfaces by addition of coagulating chemicals, whereas "flocculation" is the agglomeration of the destabilized particles by chemical joining and bridging. Flocculation enhances sedimentation or filtration treatment system performance by increasing particle size resulting in increased settling rates and filter capture rates.

Flocculation generally precedes sedimentation and filtration processes and usually consists of a rapid mix tank or in-line mixer, and a flocculation tank. The waste stream is initially mixed while a coagulant and/or a coagulant aid is added. A rapid mix tank is usually designed for a detention time of 15 seconds to several minutes. After mixing, the coagulated wastewater flows to a flocculation basin where slow mixing of the waste occurs. The slow mixing allows the particles to agglomerate into heavier, more settleable/filterable solids. Either mechanical paddle mixers or diffused air provides mixing. Flocculation basins are typically designed for a detention time of 15 to 60 minutes. Figure 8-3 presents a diagram of a clarification system incorporating coagulation and flocculation.

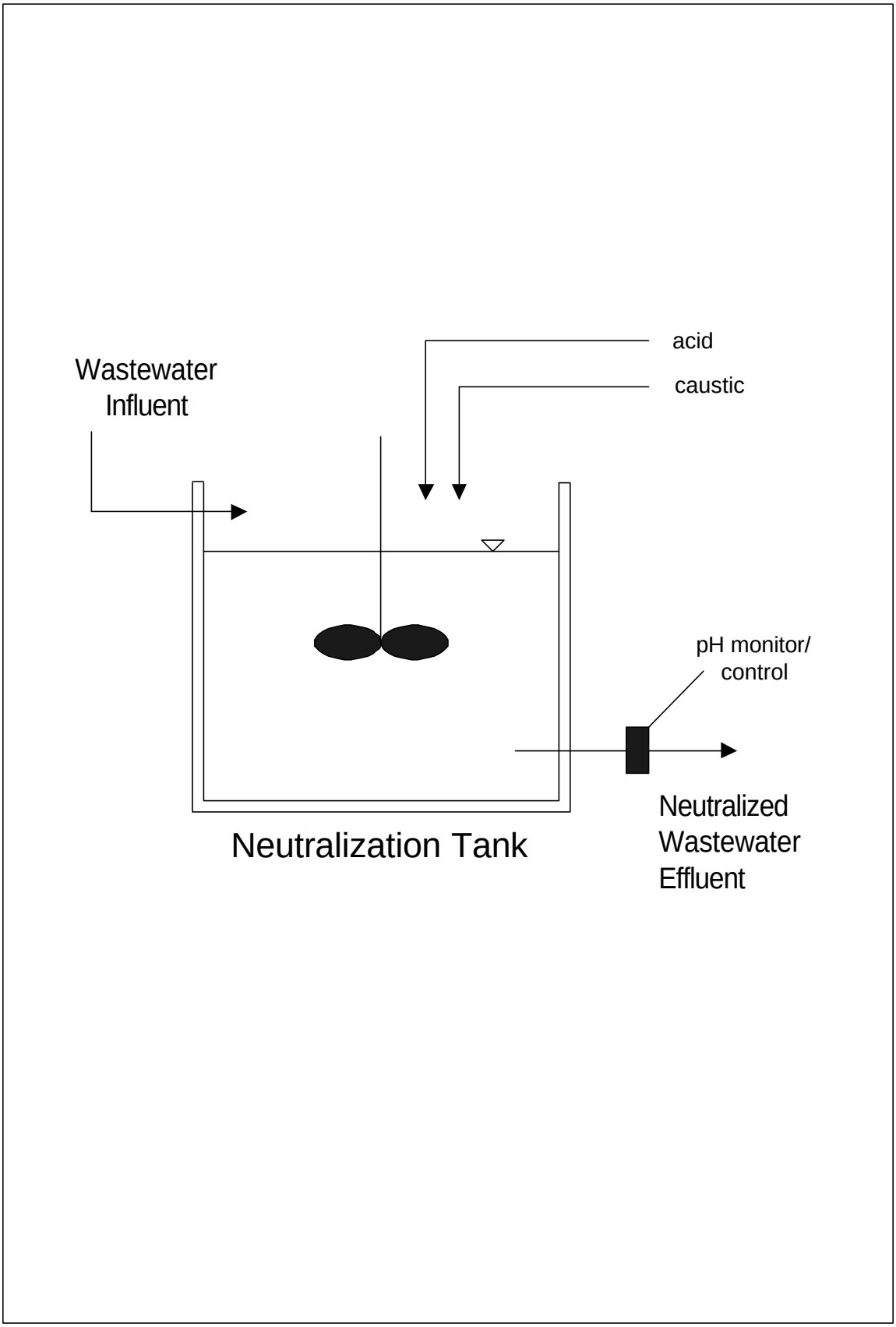

Figure 8-2. Neutralization System Diagram

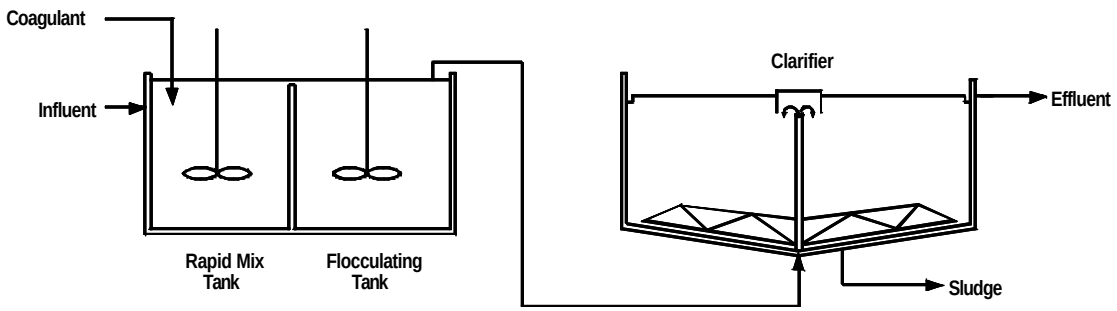

Figure 8-3. Clarification System Incorporating Coagulation and Flocculation

There are three different types of treatment chemicals commonly used in coagulation/flocculation processes: inorganic electrolytes, natural organic polymers, and synthetic polyelectrolytes. The selection of the specific treatment chemical is highly dependent upon the characteristics and chemical properties of the contaminants. Many CWT facilities use bench-scale jar tests to determine the appropriate type and optimal dosage of coagulant/flocculent for a given waste stream.

INDUSTRY PRACTICE

Chemical treatment methods to enhance the separation of pollutants from water as a solid residual may include both chemical precipitation and coagulation/flocculation. Chemical precipitation is the conversion of soluble pollutants such as metals into an insoluble precipitate and is described separately. Flocculation is often an integral step in chemical precipitation, gravity separation, and filtration. Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning the use of coagulation/flocculation, 31 operate coagulation/flocculation systems. However, due to the integral nature of flocculation in chemical precipitation and coagulation, and the interchangeable use of the terminology, the use of coagulation/flocculation at CWT facilities may have been underreported.

Emulsion Breaking *8.2.2.4*

GENERAL DESCRIPTION

One process used to treat emulsified oil/water mixtures is emulsion breaking. An emulsion, by definition, is either stable or unstable. A stable emulsion is one where small droplets of oil are dispersed within the water and are prevented from coalescing by repulsive electrical surface charges that are often a result of the presence of emulsifying agents and/or surfactants. In stable emulsions, coalescing and settling of the dispersed oil droplets would occur very slowly or not at all. Stable emulsions are often intentionally formed by chemical addition to stabilize the oil mixture for a specific application. Some examples of stable emulsified oils are metal-working coolants, lubricants, and antioxidants. An unstable emulsion, or dispersion, settles very rapidly and does not require treatment to break the emulsion.

Emulsion breaking is achieved through the addition of chemicals and/or heat to the emulsified oil/water mixture. The most commonly-used method of emulsion breaking is acid-cracking where sulfuric or hydrochloric acid is added to the oil/water mixture until the pH reaches 1 or 2. An alternative to acid-cracking is chemical treatment using emulsion–breaking chemicals such as surfactants and coagulants. After addition of the treatment chemical, the tank contents are mixed. After the emulsion bond is broken, the oil residue is allowed to float to the top of the tank. At this point, heat (100 to 150° F) may be applied to speed the separation process. The oil is then skimmed by mechanical means, or the water is decanted from the bottom of the tank. The oil residue is then further processed or disposed. A diagram of an emulsion breaking system is presented in Figure 8-4.

INDUSTRY PRACTICE

Emulsion breaking is a common process in the CWT industry. Of the 116 CWT facilities in EPA's WTI Questionnaire and NOA comment data base that provided information concerning the use of emulsion breaking, 49 operate emulsion breaking systems. Forty-six of the 83 oils subcategory facilities in EPA's data base use emulsion-breaking. As such, EPA has concluded that emulsion breaking is the baseline, current performance technology for oils subcategory facilities that treat emulsified oily wastes.

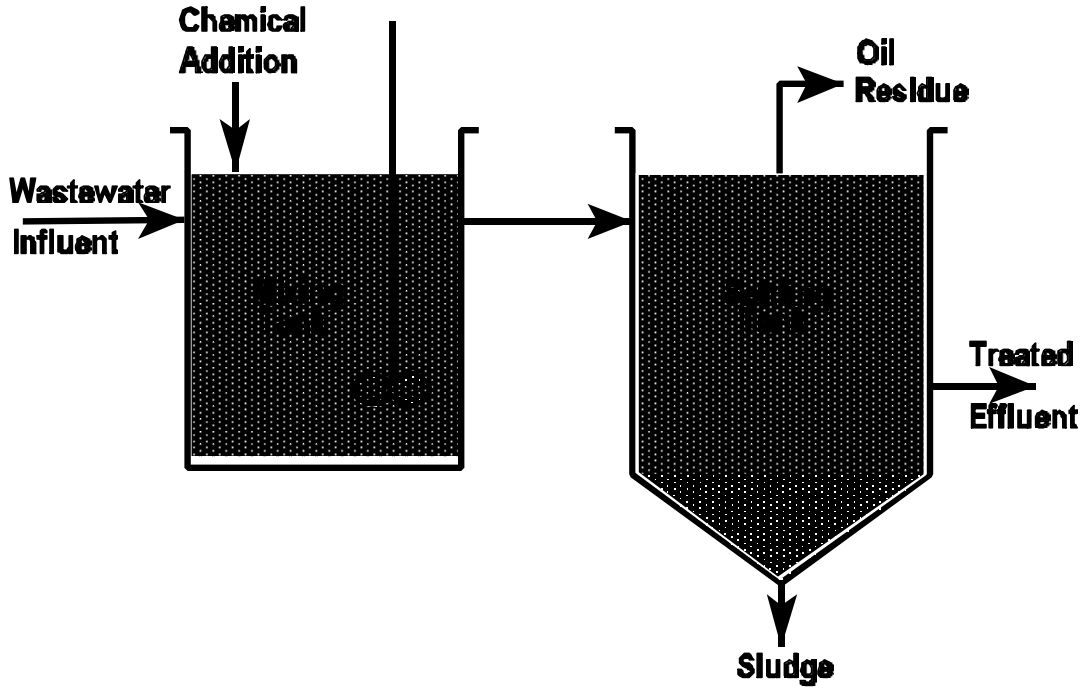

Figure 8-4. Emulsion Breaking System Diagram

Gravity Assisted Separation *8.2.2.5*

1. Gravity Oil/Water Separation

General Description

Like emulsion breaking, another in-place treatment process used to remove oil and grease and related pollutants from oil/water mixtures is gravity separation. Unlike emulsion breaking, gravity separation is only effective for the bulk removal of free oil and grease. It is not effective in the removal of emulsified or soluble oils. Gravity separation is often used in conjunction with emulsion breaking at CWT facilities.

Gravity separation may be performed using specially designed tanks or it may occur within storage tanks. During gravity oil/water separation, the wastewater is held under quiescent conditions long enough to allow the oil droplets, which have a lower specific gravity than water, to rise and form a layer on the surface. Large droplets rise more readily than smaller droplets. Once the oil has risen to the surface of the wastewater, it must be removed. This is done mechanically via skimmers, baffles, plates, slotted pipes, or dip tubes. When treatment or storage tanks serve as gravity separators, the oil may be decanted off the surface or, alternately, the separated water may be drawn off the bottom until the oil layer appears. The resulting oily residue from a gravity separator must then be further processed or disposed.

Because gravity separation is such a widely-used technology, there is an abundance of equipment configurations available. A very common unit is the API (American Petroleum Institute) separator, shown in Figure 8-5. This unit uses an overflow and an underflow baffle to skim the floating oil layer from the surface. Another oil/water gravity separation process utilizes parallel plates which shorten the necessary retention time by shortening the distance the oil droplets must travel before separation occurs.

Industry Practice

Of the 116 CWT facilities in EPA's WTI Questionnaire and NOA comment data base that provided information concerning the use of oil/water gravity separation, 16 operate skimming systems, seven operate coalescing plate or tube separation systems, and 42 operate oil/water gravity separation systems. Oil/water separation is such an integral step at oils subcategory facilities that every oils subcategory facility visited by EPA performed gravity oil/water separation, either in tanks specifically designed for that purpose or in waste receiving or storage tanks.

2. Clarification

General Description

Like oil/water separators, clarification systems utilize gravity to provide continuous, low-cost separation and removal of particulates, flocculated impurities, and precipitates from water. These systems typically follow wastewater treatment processes which generate suspended solids, such as chemical precipitation and biological treatment.

In a clarifier, wastewater is allowed to flow slowly and uniformly, permitting the solids more dense than water to settle to the bottom. The clarified wastewater is discharged by flowing from the top of the clarifier over a weir. Solids accumulate at the bottom of a clarifier and a sludge must be periodically removed, dewatered and disposed. Conventional clarifiers are typically circular or rectangular tanks. Some specialized types of clarifiers additionally incorporate tubes, plates, or lamellar networks to increase the settling area. A circular clarification system is illustrated in Figure 8-6.

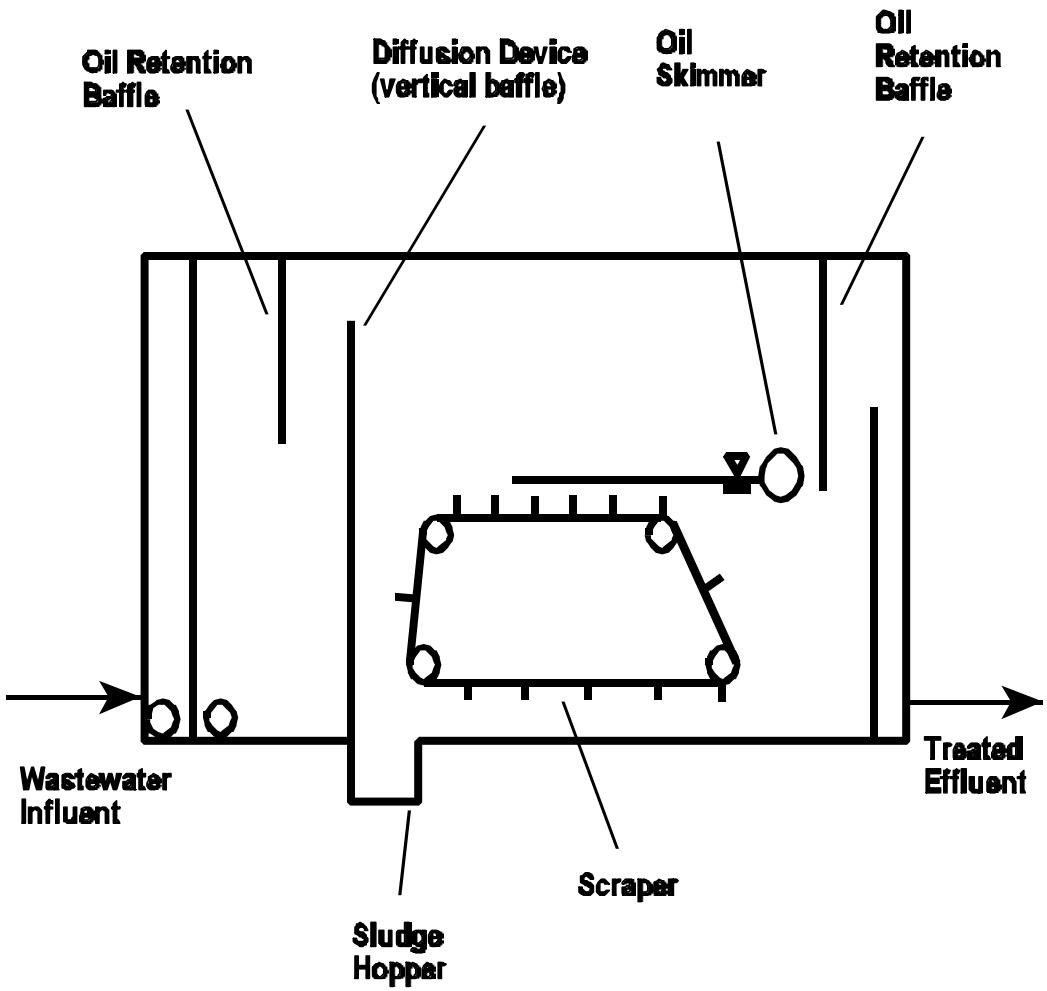

Figure 8-5. Gravity Separation System Diagram

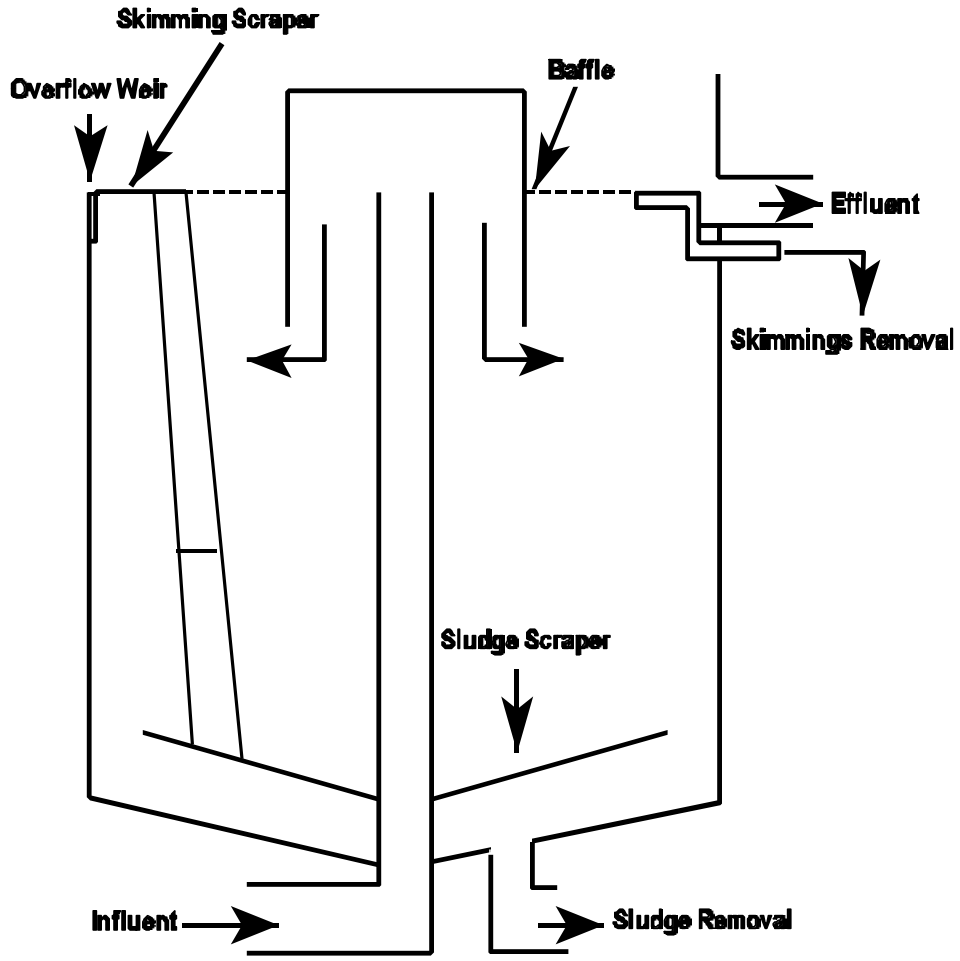

Figure 8-6. Clarification System Diagram

INDUSTRY PRACTICE

Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning the use of clarification systems, 39 operate settling systems and seven operate coalescing plate or tube separation systems. EPA did not obtain detailed enough treatment technology information from the Notice of Data Availability comments for the oils subcategory facilities to determine the presence or absence of clarification systems. In general, oils subcategory facilities are more likely to utilize gravity oil/water separation. However, oils facilities that also utilize solids generation processes such as chemical precipitation or biological treatment as part of their waste treatment train will likely utilize clarification systems.

3. *DISSOLVED AIR FLOTATION*

GENERAL DESCRIPTION

Flotation is the process of using fine bubbles to induce suspended particles to rise to the surface of a tank where they can be collected and removed. Gas bubbles are introduced into the wastewater and attach themselves to the particles, thereby reducing their specific gravity and causing them to float. Fine bubbles may be generated by dispersing air mechanically, by drawing them from the water using a vacuum, or by forcing air into solution under elevated pressure followed by pressure release. The latter, called dissolved air flotation (DAF), is the flotation process used most frequently by CWT facilities and is the focus of the remaining discussion.

DAF is commonly used to remove suspended solids and dispersed oil and grease from oily wastewater. It may effectively reduce the sedimentation times of suspended particles that have a specific gravity close to that of water. Such particles may include both solids with specific gravity slightly greater than water and oil/grease particles with specific gravity slightly less than water. Flotation processes are particularly useful for inducing the removal of oil-wet solids that may exhibit a combined specific gravity nearly the same as water. Oil-wet solids are difficult to remove from wastewater using gravity sedimentation alone, even when extended sedimentation times are utilized. Figure 8-7 is a flow diagram of a DAF system.

The major components of a conventional DAF unit include a centrifugal pump, a retention tank, an air compressor, and a flotation tank. For small volume systems, the entire influent wastewater stream is pressurized and contacted with air in a retention tank for several minutes to allow time for the air to dissolve. The pressurized water that is nearly saturated with air is then passed through a pressure reducing valve and introduced into the flotation tank near the bottom. In larger units, rather than pressurizing the entire wastewater stream, a portion of the flotation cell effluent is recycled through the pressurizing pump and the retention tank. The recycled flow is then mixed with the unpressurized main stream just prior to entering the flotation tank.

As soon as the pressure is released, the supersaturated air begins to come out of solution in the form of fine bubbles. The bubbles attach to suspended particles and become enmeshed in sludge flocs, floating them to the surface. The float is continuously swept from the tank surface and is discharged over the end wall of the tank. Sludge, if generated, may be collected from the bottom of the tank. The mechanics of the bubble-particle interaction include: (1) attachment of the bubbles on the particle surface, (2) collision between a bubble and a particle, (3) agglomeration of individual particles or a floc structure as the bubbles rise, and (4) absorption of the bubbles into a floc structure as it forms. As such, surface chemistry plays a critical role in the effective performance of air flotation.

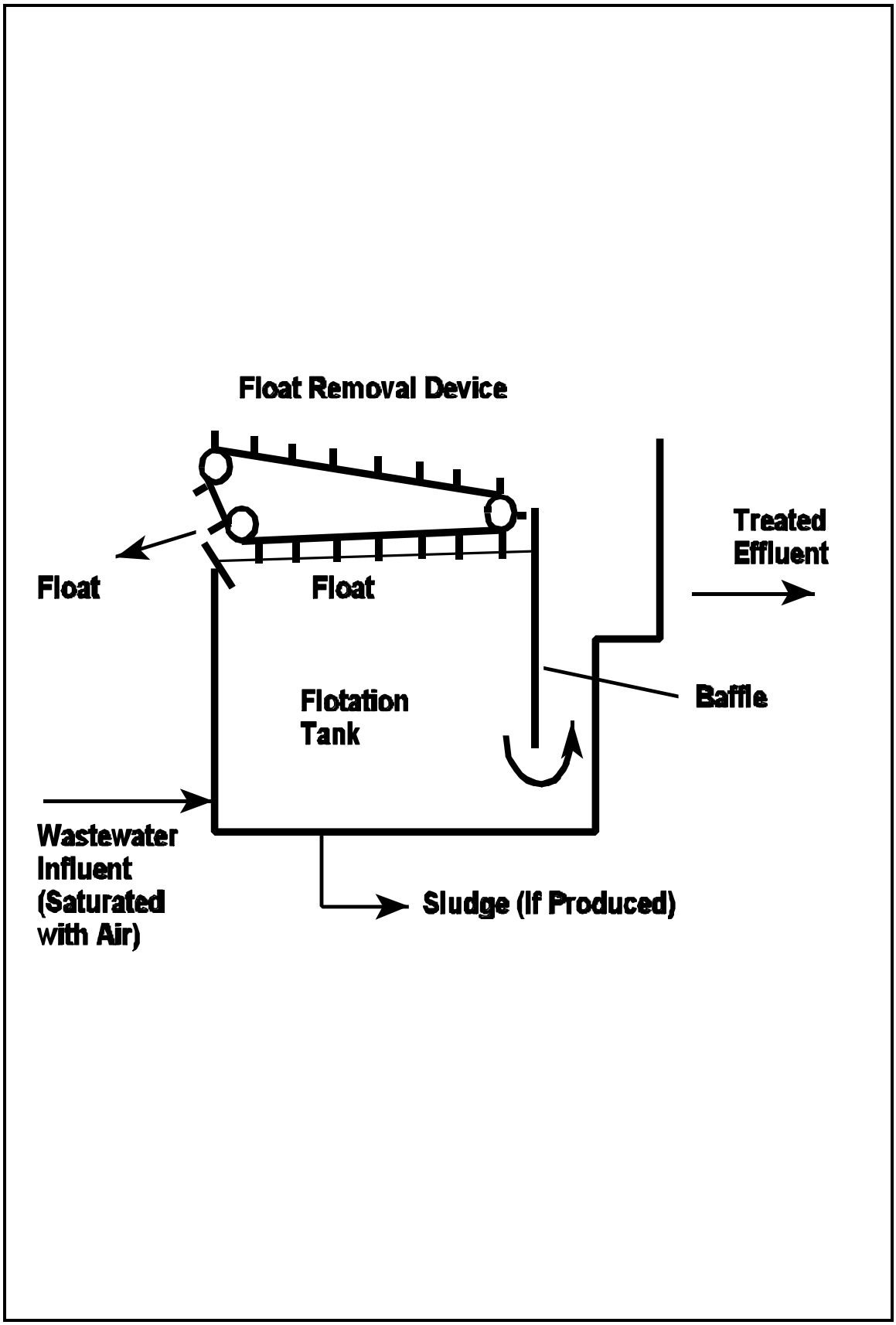

Figure 8-7. Dissolved Air Flotation System Diagram

Other operating variables which affect the performance of DAF include the operating pressure, recycle ratio, detention time, the air/solids ratio, solids and hydraulic loading rates, and the application of chemical aids.

The operating pressure of the retention tank influences the size of the bubbles released. If the bubbles are too large, they do not attach readily to the suspended particles. If the bubbles are too fine, they will disperse and break up fragile floc. Wastewater treatment textbooks generally recommend a bubble size of 100 micrometers. The most practical way to establish the proper rise rate is to conduct experiments at various air pressures.

The air-to-solids ratio in the DAF unit determines the effluent quality and solids concentration in the float. This is because adequate air bubbles are needed to float suspended solids to the surface of the tank. Partial flotation of solids will occur if inadequate or excessive amounts of air bubbles are present.

Researchers have demonstrated that the addition of chemicals to the water stream is an effective means of increasing the efficiencies of DAF treatment systems. The use of coagulants can drastically increase the oil removal efficiency of DAF units. Three types of chemicals are generally utilized to improve the efficiency of air flotation units used for treatment of produced water; these chemicals are surface active agents, coagulating agents, and polyelectrolytes. The use of treatment chemicals may also enhance the removal of metals in air flotation units. EPA's collection of data from the CWT industry has shown that many facilities use DAF systems to remove metals from their waste streams.

INDUSTRY PRACTICE

Of the 116 CWT facilities in EPA's WTI Questionnaire and NOA comment data base that provided information concerning use of DAF, 21 operate DAF systems.

Chromium Reduction *8.2.2.6*

GENERAL DESCRIPTION

Reduction is a chemical reaction in which electrons are transferred from one chemical to another. The main reduction application at CWT facilities is the reduction of hexavalent chromium to trivalent chromium, which is subsequently precipitated from the wastewater in conjunction with other metallic salts. A low pH of 2 to 3 will promote chromium reduction reactions. At pH levels above 5, the reduction rate is slow. Oxidizing agents such as dissolved oxygen and ferric iron interfere with the reduction process by consuming the reducing agent.

The use of strong reducing agents such as sulfur dioxide, sodium bisulfite, sodium metabisulfite, and ferrous sulfate also promotesshexavalent chromium reduction. The two most commonly used reducing agents in the CWT industry are sodium metabisulfite or sodium bisulfite and gaseous sulfur dioxide. The remaining discussion will focus on chromium reduction using these agents only. Figure 8-8 is a diagram of a chromium reduction system.

Chromium reduction using sodium metabisulfite ($Na_2S_2O_5$) and sodium bisulfite ($NaHSO_3$) are essentially similar. The mechanism for the reaction using sodium bisulfite as the reducing agent is:

$$3NaHSO_3 + 3H_2SO_4 + 2H_2CrO_4$$
$$6\ Cr_2(SO_4)_3 + 3NaHSO_4 + 5H_2O$$

The hexavalent chromium is reduced to trivalent chromium using sodium metabisulfite, with sulfuric acid used to lower the pH of the solution. The amount of sodium metabisulfite needed to reduce the hexavalent chromium is reported as 3 parts of sodium bisulfite per part of chromium, while the amount of sulfuric acid is 1 part per part of chromium. The theoretical retention time is about 30 to 60 minutes.

A second process uses sulfur dioxide (SO_2) as the reducing agent. The reaction mechanism is as follows:

$$3SO_2 + 3H_2O \rightarrow 3H_2SO_3$$

$$3H_2SO_3 + 2H_2CrO_4 \rightarrow Cr_2(SO_4)_3 + 5H_2O$$

The hexavalent chromium is reduced to trivalent chromium using sulfur dioxide, with sulfuric acid used to lower the pH of the solution. The amount of sulfur dioxide needed to reduce the hexavalent chromium is reported as 1.9 parts of sulfur dioxide per part of chromium, while the amount of sulfuric acid is 1 part per part of chromium. At a pH of 3, the theoretical retention time is approximately 30 to 45 minutes.

INDUSTRY PRACTICE

Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning the use of chromium reduction, 35 operate chromium reduction systems. All of the 35 facilities are in the metals subcategory. At these 35 facilities, there are four sulfur dioxide processes, 21 sodium bisulfite processes, and two sodium metabisulfite processes. The remaining systems use various other reducing agents.

Cyanide Destruction *8.2.2.7*

GENERAL DESCRIPTION

Electroplating and metal finishing operations produce the major portion of cyanide-bearing wastes accepted at CWT facilities. EPA observed three separate cyanide destruction techniques during site visits at CWT facilities. The first two methods are alkaline chlorination with gaseous chlorine and alkaline chlorination with sodium hypochlorite. The third method is a cyanide destruction process, details of which the generator has claimed are confidential business information (CBI). The two alkaline chlorination procedures are discussed here.

Alkaline chlorination can destroy free dissolved hydrogen cyanide and can oxidize all simple and some complex inorganic cyanides. It, however, cannot effectively oxidize stable iron, copper, and nickel cyanide complexes. The addition of heat to the alkaline chlorination process can facilitate the more complete destruction of total cyanides. The use of an extended retention time can also improve overall cyanide destruction. Figure 8-9 is a diagram of an alkaline chlorination system.

In alkaline chlorination using gaseous chlorine, the oxidation process is accomplished by direct addition of chlorine (Cl_2) as the oxidizer and sodium hydroxide (NaOH) to maintain pH levels. The reaction mechanism is as follows:

$$NaCN + Cl_2 + 2NaOH \rightarrow NaCNO + 2NaCl + H_2O$$

$$2NaCNO + 3Cl_2 + 6NaOH \rightarrow 2NaHCO_3 + N_2 + 6NaCl + 2H_2O$$

The destruction of the cyanide takes place in two stages. The primary reaction is the partial oxidation of the cyanide to cyanate at a pH above 9. In the second stage, the pH is lowered to a range of 8 to 8.5 for the oxidation of the cyanate to nitrogen and carbon dioxide (as sodium bicarbonate). Each part of cyanide requires 2.73 parts of chlorine to convert it to cyanate and an additional 4.1 parts of chlorine to oxidize the cyanate to nitrogen and carbon dioxide. At least 1.125 parts of sodium hydroxide are required to control the pH with each stage.

Alkaline chlorination can also be conducted with sodium hypochlorite (NaOCl) as the oxidizer. The oxidation of cyanide waste using sodium hypochlorite is similar to the gaseous chlorine process. The reaction mechanism is:

$$NaCN + NaOCl \rightarrow NaCNO + NaCl$$

$$2NaCNO + 3NaOCl + H_2O \rightarrow 2NaHCO_3 + N_2 + 3NaCl$$

In the first step, cyanide is oxidized to cyanate with the pH maintained in the range of 9 to 11. The second step oxidizes cyanate to carbon dioxide (as sodium bicarbonate) and nitrogen at a controlled pH of 8.5. The amount of sodium hypochlorite and sodium hydroxide needed to perform the oxidation is 7.5 parts and 8 parts per part of cyanide, respectively.

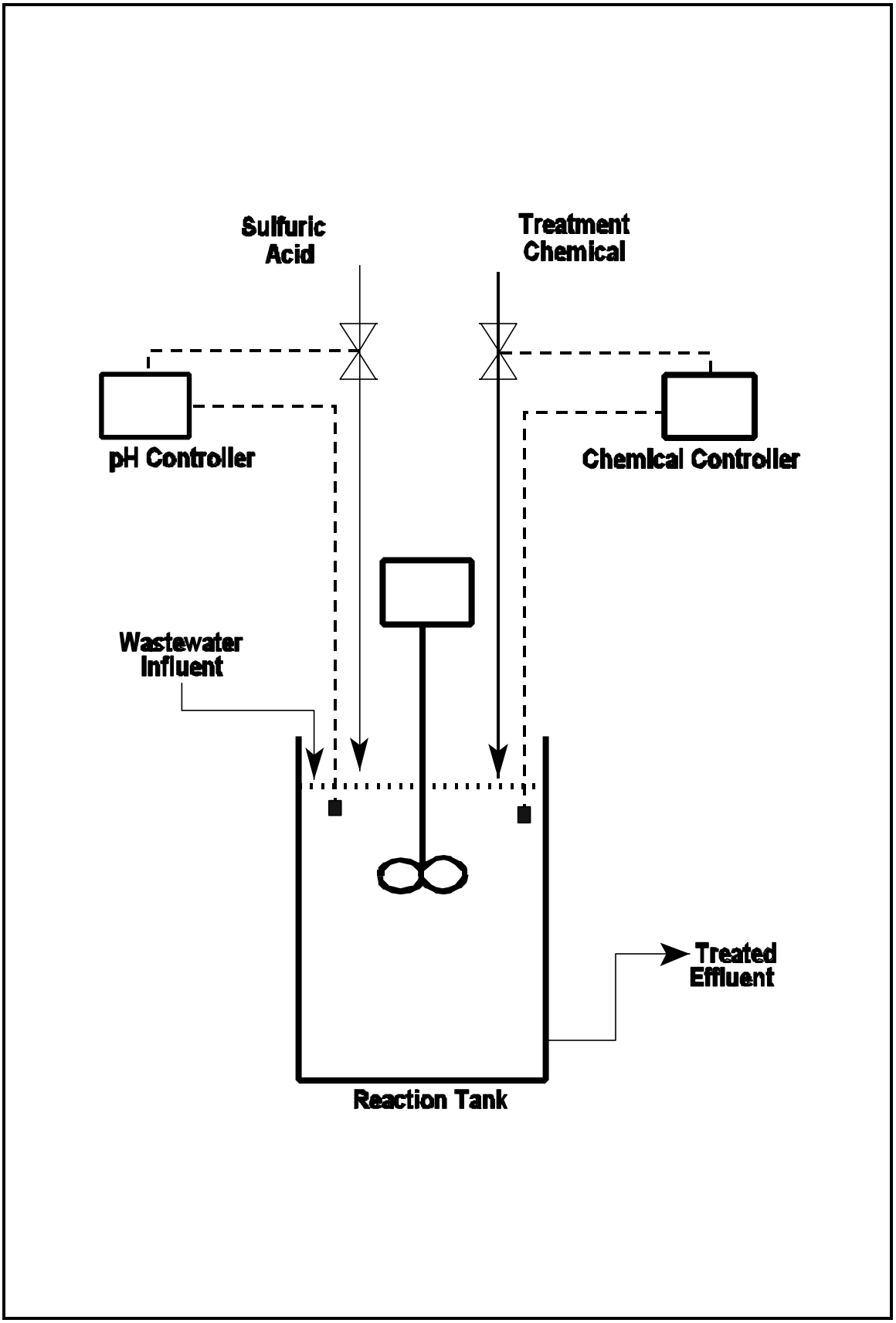

Figure 8-8. Chromium Reduction System Diagram

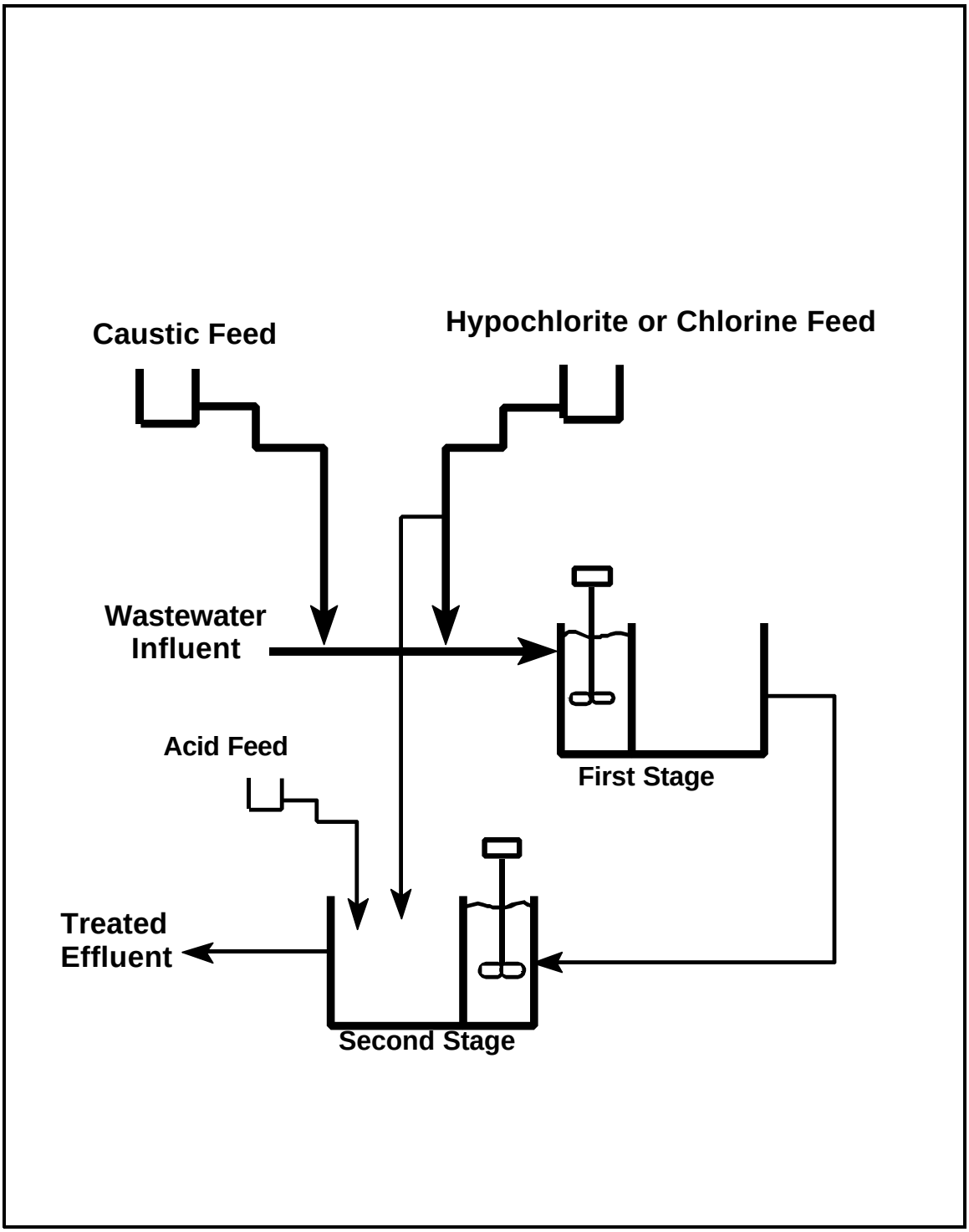

Figure 8.9 Cyanide Destruction by Alkaline Chlorination

INDUSTRY PRACTICE

Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning the use of cyanide destruction, 22 operate cyanide destruction systems. All of the 22 facilities are in the metals subcategory. Of these 22 facilities, one is a thermal unit, one is the CBI unit, and the rest are chemical reagent systems.

Chemical Precipitation *8.2.2.8*

GENERAL DESCRIPTION

Many CWT facilities use chemical precipitation to remove metal compounds from wastewater. Chemical precipitation converts soluble metallic ions and certain anions to insoluble forms, which precipitate from solution. Chemical precipitation is usually performed in conjunction with coagulation/flocculation processes which facilitate the agglomeration of suspended and colloidal material. Most metals are relatively insoluble as hydroxides, sulfides, or carbonates. Coagulation/flocculation processes are used in conjunction with precipitation to facilitate removal by agglomeration of suspended and colloidal materials. The precipitated metals are subsequently removed from the wastewater stream by liquid filtration or clarification (or some other form of gravity-assisted separation). Other treatment processes such as equalization, or chemical oxidation or reduction (e.g., hexavalent chromium reduction) usually precede the chemical precipitation process. Chemical interactions, temperature, pH, solubility of waste contaminants, and mixing effects all affect the performance of the chemical precipitation process.

Chemical precipitation is a two-step process. At CWT facilities, it is typically performed in batch operations. In the first step, precipitants are mixed with the wastewater, typically by mechanical means, such as mixers, allowing the formation of the insoluble metal precipitants. The detention time in this step of the process is specific to the wastewater being treated, the treatment chemicals used, and the desired effluent quality. In the second step, the precipitated metals are removed from the wastewater, typically through filtration or clarification. If clarification is used, a flocculent is sometimes added to aid the settling process. The resulting sludge from the clarifier or filter must be further treated, disposed, or recycled. A typical chemical precipitation system is shown in Figure 8-10.

Various chemicals may be used as precipitants. These include lime, sodium hydroxide (caustic), soda ash, sodium sulfide, and ferrous sulfate. Other chemicals used in the precipitation process for pH adjustment and/or coagulation include sulfuric and phosphoric acid, ferric chloride, and polyelectrolytes. Often, facilities use a combination of these chemicals. CWT facilities generally use hydroxide precipitation and/or sulfide precipitation. Hydroxide precipitation is effective in removing metals such as antimony, arsenic, chromium, copper, lead, mercury, nickel, and zinc. Sulfide precipitation is used instead of, or in addition to, hydroxide precipitation to remove specific metal ions including lead, copper, silver, cadmium, zinc, mercury, nickel, thallium, arsenic, antimony, and vanadium. Both hydroxide and sulfide precipitation are discussed in greater detail below.

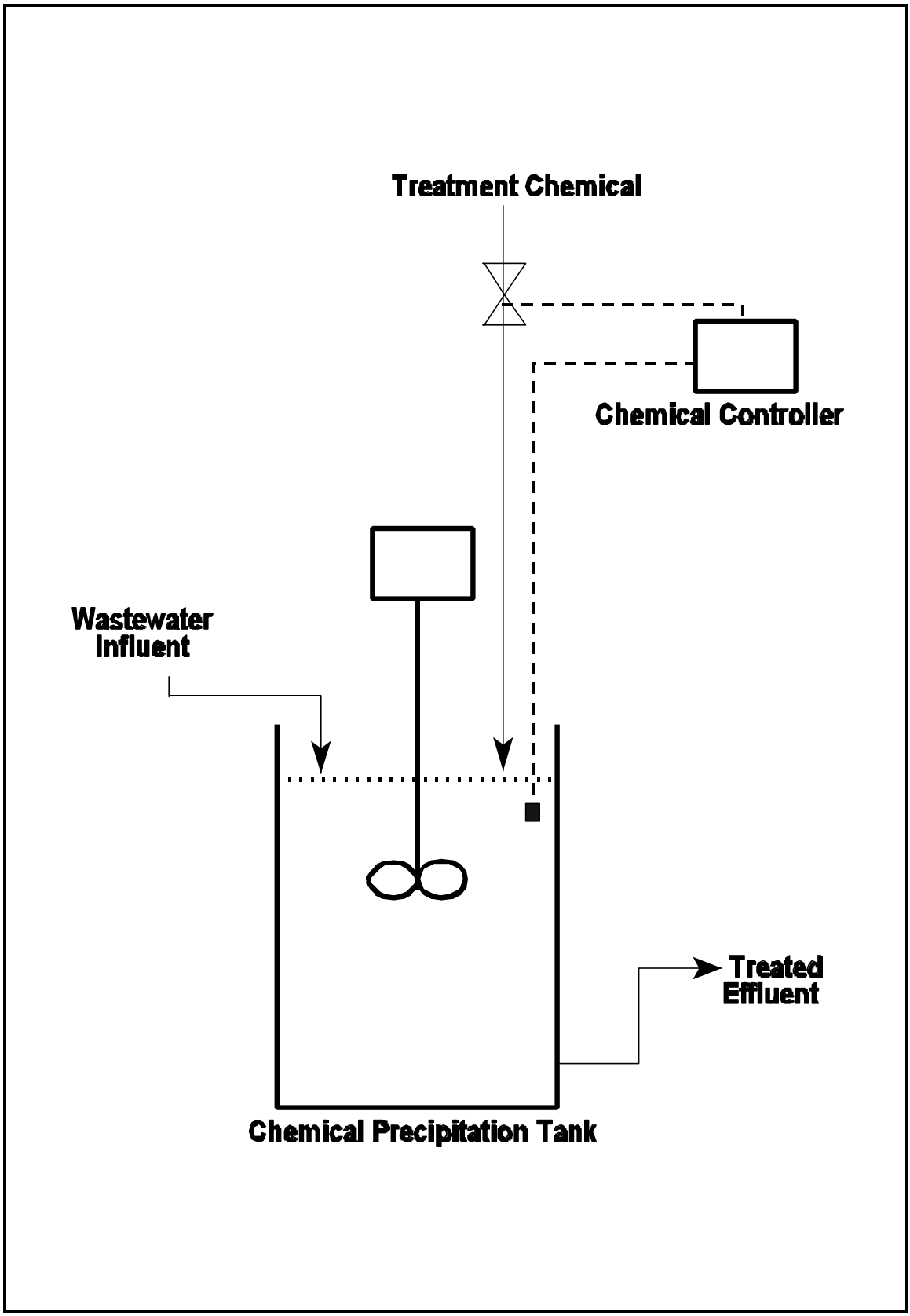

Figure 8-10. Chemical Precipitation System Diagram

Hydroxide precipitation using lime or caustic is the most commonly-used means of chemical precipitation at CWT facilities. Of these, lime is used more often than caustic. The reaction mechanism for each of these is as follows:

$$M^{++} + Ca(OH)_2 \rightarrow M(OH)_2\downarrow + Ca^{++}$$

$$M^{++} + 2NaOH \rightarrow M(OH)_2\downarrow + 2Na^{++}$$

The chief advantage of lime over caustic is its lower cost. However, lime is more difficult to handle and feed, as it must be slaked, slurried, and mixed, and can plug the feed system lines. Lime also produces a larger volume of sludge than caustic, and the sludge is generally not suitable for reclamation due to its homogeneous nature.

Sulfide precipitation is the next most commonly-used means of chemical precipitation at CWT facilities. It is used to remove lead, copper, silver, cadmium, zinc, mercury, nickel, thallium, arsenic, antimony, and vanadium from wastewaters. An advantage of the sulfide process over the hydroxide process is that it can reduce hexavalent chromium to the trivalent state under the same process conditions required for metals precipitation. The use of sulfides also allows for the precipitation of metals when chelating agents are present. The two most common sulfide precipitation processes are the soluble sulfide process and the insoluble sulfide (Sulfex) process.

In the soluble sulfide process, either sodium sulfide or sodium hydrosulfide, both highly soluble, is added in high concentration either as a liquid reagent or from rapid mix tanks using solid reagents. This high concentration of soluble sulfides results in rapid precipitation of metals which then results in the generation of fine precipitate particles and hydrated colloidal particles. These fine particles do not settle or filter well without the addition of coagulating and flocculating agents to aid in the formation of larger, fast-settling floc. The high concentration of soluble sulfides may also lead to the generation of highly toxic and odorous hydrogen sulfide gas. To control this problem, the treatment facility must carefully control the dosage and/or the process vessels must be enclosed and vacuum evacuated. The reaction mechanism for soluble sulfide precipitation is as follows:

$$M^{++} + S^{--} \rightarrow MS\downarrow$$

The basic principle governing the insoluble sulfide process is that ferrous sulfide (FeS) will disassociate into ferrous and sulfide ions, as predicted by its solubility, producing a sulfide concentration of approximately 2 mg/l under normal conditions. In the insoluble sulfide process, a slurry of freshly prepared FeS (prepared by reactive $FeSO_4$ and NaHS) is added to the wastewater. As the sulfide ions are consumed in precipitating the metal pollutants, additional FeS will disassociate. This will continue as long as other heavy metals with lower equilibrium constants are present in solution. Because most heavy metals have sulfides that are less soluble than ferrous sulfate, they will precipitate as metal sulfides. In addition, if given enough time, any metal hydroxides present will dissolve and precipitate out as sulfides. If the operation is performed under alkaline conditions, the released ferrous ion will precipitate out as a hydroxide. The following reactions occur when FeS is added to a solution that contains dissolved metal and metal hydroxide:

$$FeS \rightarrow Fe^{++} + S^{--}$$

$$M^{++} + S^{--} \rightarrow MS\downarrow$$

$$M(OH)_2 \rightarrow M^{++} + 2(OH)^-$$

$$Fe^{++} + 2(OH)^- \rightarrow Fe(OH)_2\downarrow$$

One advantage of the insoluble sulfide process over the soluble sulfide process is that

the insoluble sulfide process generates no detectable H_2S gas odor. This is because the dissolved sulfide concentration is maintained at a relatively low concentration. Disadvantages of the insoluble sulfide process include considerably higher than stoichiometric reagent consumption and significantly higher sludge generation than either the hydroxide or soluble sulfide process.

Wastewater treatment facilities often choose to combine hydroxide precipitation and sulfide precipitation for optimal metals removal. A common configuration is a two-stage process in which hydroxide precipitation is followed by sulfide precipitation with each stage followed by a separate solids removal step. This will produce the high quality effluent of the sulfide precipitation process while significantly reducing the volume of sludge generated and the consumption of sulfide reagent.

In addition to the type of treatment chemical chosen, another important operational variable in chemical precipitation is pH. Metal hydroxides are amphoteric, meaning they can react chemically as acids or bases. As such, their solubilities increase toward both lower and higher pH levels. Therefore, there is an optimum pH for hydroxide precipitation for each metal, which corresponds to its point of minimum solubility. Figure 8-11 presents calculated solubilities of metal hydroxides. For example, as demonstrated in this figure, the optimum pH range where zinc is the least soluble is between 8 and 10. The solubility of metal sulfides is not as sensitive to changes in pH as hydroxides and generally decreases as pH increases. The typical operating pH range for sulfide precipitation is between 7 and 9. Arsenic and antimony are exceptions to this rule and require a pH below 7 for optimum removal. As such, another advantage of sulfide precipitation over hydroxide precipitation is that most metals can be removed to extremely low concentrations at a single pH.

For wastewater contaminated with a single metal, selecting the optimum treatment chemical and treatment pH for precipitation simply requires the identification of the treatment chemical/pH combination that produces the lowest solubility of that metal. This is typically done using a series of bench-scale treatability tests. However, when wastewater is contaminated with more than one metal, as is often the case for wastewaters at CWT facilities, selecting the optimum treatment chemical and pH for a single-stage precipitation process becomes more difficult and often involves a tradeoff between optimal removal of two or more metals. In general, for wastewater contaminated with multiple metals, EPA has concluded that a single-stage precipitation process does not provide for adequate treatment. In such cases, a series of chemical treatment steps using different pH values and/or different treatment chemicals may be more appropriate. Each of these treatment steps needs to be followed by a solids separation step in order to prevent the resolubilization of metal precipitates during the subsequent treatment step.

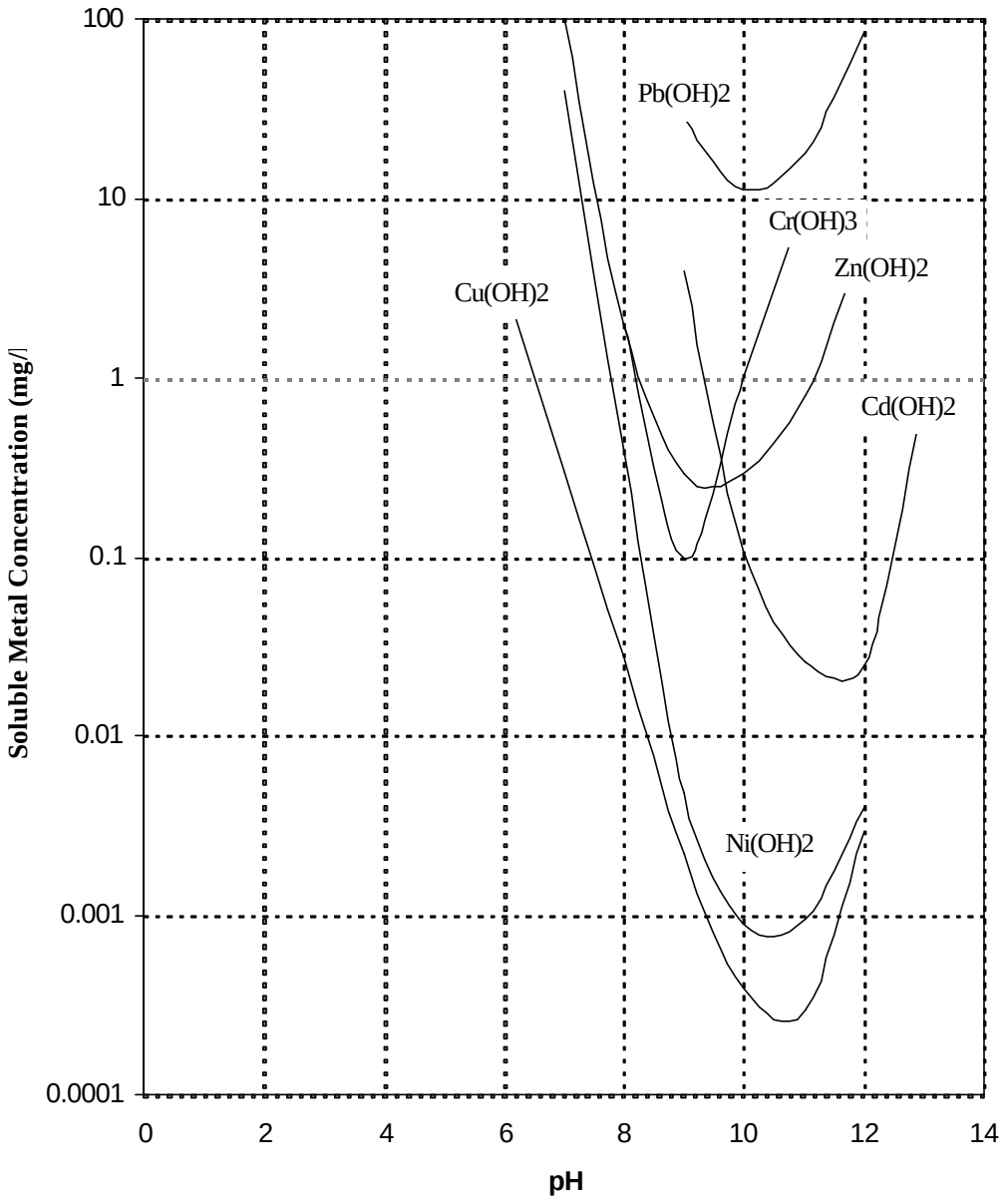

Figure 8-11. Calculated Solubilities of Metal Hydroxides

In order to take advantage of the effects of pH and treatment chemical selection on metals precipitation, a facility may hold its wastes and segregate them by pollutant content for treatment. This type of waste treatment management, called selective metals precipitation, may be adopted in order to optimize the recovery of specific metal pollutants. In instances where the segregated wastes contain several metals, the pH of the precipitation process may be adjusted so that the desired metal for recovery is precipitated in greater proportion than the other metals. Multiple precipitation steps are then performed in series on a single waste stream using different pH values, resulting in different metals being selectively precipitated into separate sludges. The production of specific sludges containing only the target metals makes the sludges more suitable for reclamation. If the sludge is to be sold to a smelter for re-use, then hydroxide precipitation using only caustic should be performed. The calcium compounds from lime would interfere with the smelting process.

Selective precipitation is advantageous because the metals may be reclaimed and re-used rather than disposed as a sludge in a landfill and because it allows for optimal removal of the metals of concern. However, selective metals precipitation does have additional costs such as those associated with the extra tanks and operating personnel required for waste segregation.

INDUSTRY PRACTICE

Of the 116 CWT facilities in EPA's WTI Questionnaire and NOA comment data base that provided information concerning the use of chemical precipitation, 57 operate chemical precipitation systems. Fifty-one of these facilities treat metals subcategory wastewaters. As discussed previously, a single facility may use several chemical precipitation steps, depending upon the type of waste being treated. Of the 51 chemical precipitation systems at metals subcategory facilities, 13 operate secondary precipitation processes, four operate tertiary precipitation processes, and one employs selective chemical precipitation processes.

Filtration *8.2.2.9*

Filtration is a method for separating solid particles from a fluid through the use of a porous medium. The driving force in filtration is a pressure gradient caused by gravity, centrifugal force, pressure, or a vacuum. CWT facilities use filtration treatment processes to remove solids from wastewaters after physical/chemical or biological treatment, or as the primary source of waste treatment. Filtration processes utilized in the CWT industry include a broad range of media and membrane separation technologies.

To aid in removal, the filter medium may be precoated with a filtration aid such as ground cellulose or diatomaceous earth. Polymers are sometimes injected into the filter feed piping downstream of feed pumps to enhance flocculation of smaller flocs to improve solids capture. The following sections discuss the various types of filtration in use at CWT facilities.

1. SAND FILTRATION

GENERAL DESCRIPTION

Sand filtration processes consist of either a fixed or moving bed of media that traps and removes suspended solids from water passing through the media. There are two types of fixed sand bed filters: pressure and gravity. Pressure filters contain media in an enclosed, watertight pressure vessel and require a feed pump to force the water through the media. A gravity filter operates on the basis of differential pressure of a static head of water above the media, which causes flow through the filter. Filter loading rates for sand filters are typically between 2 to 6 gpm/sq-ft.

Fixed media filters have influent and effluent distribution systems consisting of pipes and fittings. A stainless steel screen covered with gravel generally serves as the tank bottom and support for the sand. Dirty water enters the top of the filter and travels downward.

Moving bed filters use an air lift pump and draft tube to recirculate sand from the bottom to the top of the filter vessel, which is usually open at the top. Dirty water entering the filter at the bottom must travel upward, countercurrently, through the downward moving fluidized sand bed. Particles are strained from the rising water and carried downward with the sand. Due to the difference in specific gravity, the lighter particles are removed from the filter when the sand is recycled through a separation box often located at the top of the filter. The heavier sand falls back into the filter, while the lighter particles are washed over a weir to waste.

Both fixed media and moving bed filters build up head loss over time. Head loss is a measure of solids trapped in the filter. As the filter becomes filled with trapped solids, the efficiency of the filtration process falls off, and the filter must be backwashed. Reversing the flow will backwash filters so that the solids in the media are dislodged and may exit the filter. Sometimes air is dispersed into the sand bed to scour the media.

Fixed bed filters may be automatically backwashed when the differential pressure exceeds a preset limit or when a timer starts the backwash cycle. A supply of clean backwash water is required. Backwash water and trapped particles are commonly discharged to an equalization tank upstream of the wastewater treatment system's gravity separation system or screen for removal. Moving bed filters are continuously backwashed and have a constant rate of effluent flow.

INDUSTRY PRACTICE

Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning use of sand filtration, eight operate sand filtration systems.

2. *MULTIMEDIA FILTRATION*

GENERAL DESCRIPTION

CWT facilities may use multimedia, or granular bed, filtration to achieve supplemental removal of residual suspended solids from the effluent of chemical and biological treatment processes. In granular bed filtration, the wastewater stream is sent through a bed containing two or more layers of different granular materials. The solids are retained in the voids between the media particles while the wastewater passes through the bed. Typical media used in granular bed filters include anthracite coal, sand, and garnet.

A multimedia filter is designed so that the finer, denser media is at the bottom and the coarser, less dense media at the top. A common arrangement is garnet at the bottom of the bed, sand in the middle, and anthracite coal at the top. Some mixing of these layers occurs and is anticipated. During filtration, the removal of the suspended solids is accomplished by a complex process involving one or more mechanisms such as straining, sedimentation, interception, impaction, and adsorption. The medium size is the principal characteristic that affects the filtration operation. If the medium is too small, much of the driving force will be wasted in overcoming the frictional resistance of the filter bed. If the medium is too large, small particles will travel through the bed, preventing optimum filtration.

By designing the filter bed so that pore size decreases from the influent to the effluent side of the bed, different size particles are filtered out at different depths (larger particles first) of the filter bed. This helps prevent the build up of a single

layer of solids at the bed surface which can quickly increase the pressure drop over the bed resulting in shorter filter runs and more frequent backwash cycles. Thus, the advantage of multimedia filtration over sand filtration is longer filter runs and less frequent backwash cycles.

The flow pattern of multimedia filters is usually top-to-bottom. Upflow filters, horizontal filters, and biflow filters are also used. Figure 8-12 is a top-to-bottom multimedia filter. The classic multimedia filter operates by gravity. However, pressure filters are occasionally used.

The complete filtration process involves two phases: filtration and backwashing. As the filter becomes filled with trapped solids, the efficiency of the filtration process falls off. Head loss is a measure of solids trapped in the filter. As the head loss across the filter bed increases to a limiting value, the end of the filter run is reached and the filter must be backwashed to remove the suspended solids in the bed. During backwashing, the flow through the filter is reversed so that the solids trapped in the media are dislodged and can exit the filter. The bed may also be agitated with air to aid in solids removal. Backwash water and trapped particles are commonly discharged to an equalization tank upstream of the wastewater treatment system's gravity separation system or screen for removal.

An important feature in filtration and backwashing is the underdrain. The underdrain is the support structure for the filtration bed. The underdrain provides an area for the accumulation of the filtered water without it being clogged from the filtered solids or the media particles. During backwash, the underdrain provides even flow distribution over the bed. This is important because the backwash flowrate is set so that the filter bed expands but the media is not carried out with the backwashed solids. The media with different densities then settle back down in somewhat discrete layers at the end of the backwash step.

INDUSTRY PRACTICE

Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning use of multimedia filtration, four operate multimedia filtration systems.

3. PLATE AND FRAME PRESSURE FILTRATION

GENERAL DESCRIPTION

Another filtration system for the removal of solids from waste streams is a plate and frame pressure filtration systems. Although plate and frame filter presses are more commonly used for dewatering sludges, they are also used to remove solids directly from wastewater streams. The liquid stream plate and frame pressure filtration system is identical to the system used for the sludge stream (section 8.4.1) with the exception of a lower solids level in the influent stream. The same equipment is used for both applications, with the difference being the sizing of the sludge and liquid units. See section 8.4.1 for a detailed description of plate and frame pressure filtration. No CWT facilities in EPA's database use plate and frame filtration.

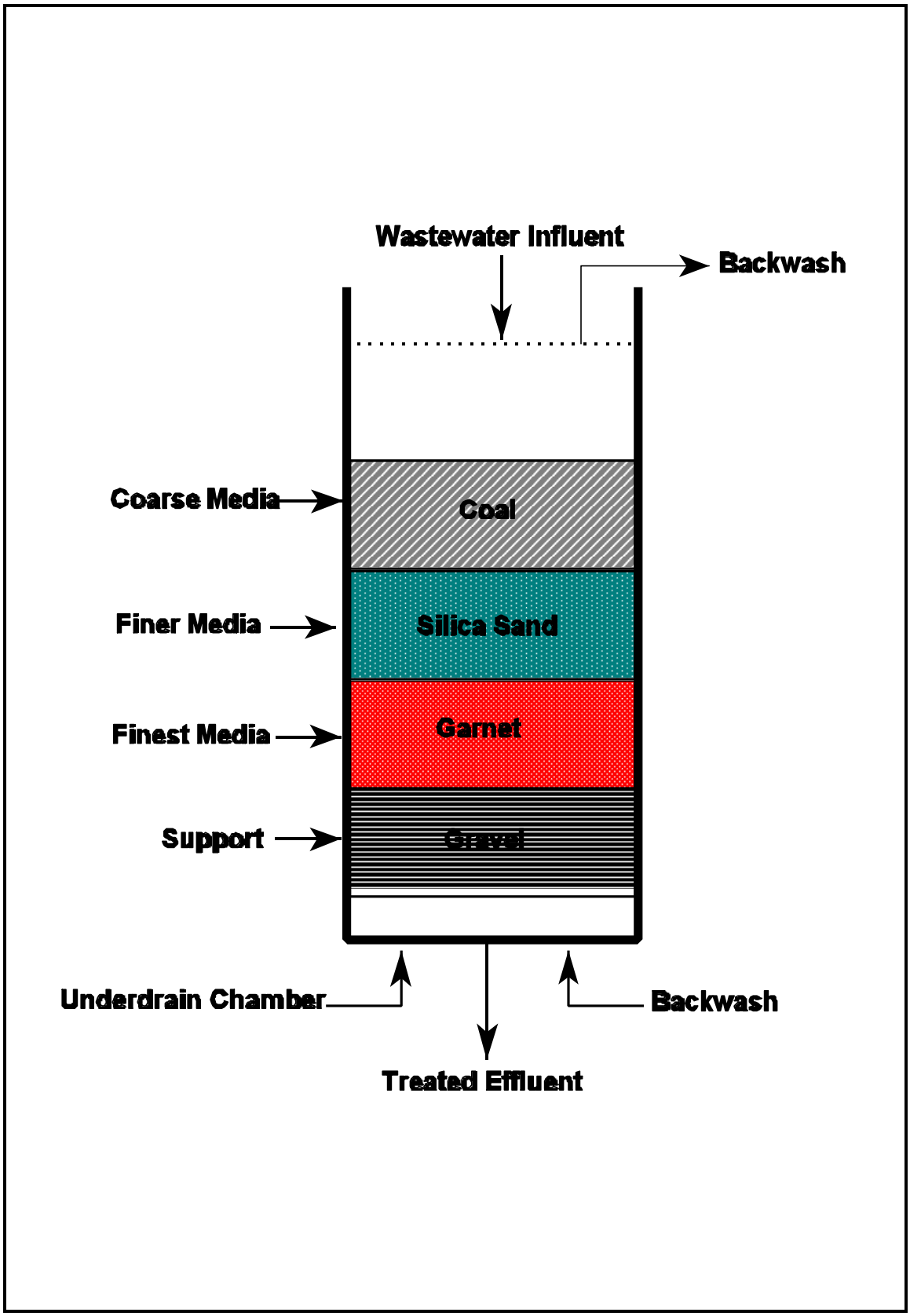

Figure 8-12. Multi-Media Filtration System Diagram

4. *MEMBRANE FILTRATION*

GENERAL DESCRIPTION

Membrane filtration systems are processes which employ semi-permeable membranes and a pressure differential to remove solids in wastestreams. Reverse osmosis and ultrafiltration are two commonly-used membrane filtration processes.

A. *ULTRAFILTRATION*

GENERAL DESCRIPTION

CWT facilities commonly use ultrafiltration (UF) for the treatment of metal-finishing wastewater and oily wastes. It can remove substances with molecular weights greater than 500, including suspended solids, oil and grease, large organic molecules, and complexed heavy metals. UF can be used when the solute molecules are greater than ten times the size of the solvent molecules, and are less than one-half micron. In the CWT industry, UF is applied in the treatment of oil/water emulsions. Oil/water emulsions contain both soluble and insoluble oil. Typically the insoluble oil is removed from the emulsion by gravity separation assisted by emulsion breaking. The soluble oil is then removed by UF. Oily wastewater containing 0.1 to 10 percent oil can be effectively treated by UF. Figure 8-13 shows a UF system.

In UF, a semi-permeable microporous membrane performs the separation. Wastewater is sent through membrane modules under pressure. Water and low–molecular –weight solutes (for example, salts and some surfactants) pass through the membrane and are removed as permeate. Emulsified oil and suspended solids are rejected by the membrane and are removed as concentrate. The concentrate is recirculated through the membrane unit until the flow of permeate drops. The permeate may either be discharged or passed along to another treatment unit. The concentrate is contained and held for further treatment or disposal. An important advantage of UF over reverse osmosis is that the concentrate may be treated to remove the concentrated solids and the separated water may then be retreated through the UF system.

The primary design consideration in UF is the membrane selection. A membrane pore size is chosen based on the size of the contaminant particles targeted for removal. Other design parameters to be considered are the solids concentration, viscosity, and temperature of the feed stream, pressure differential, and the membrane permeability and thickness. The rate at which a membrane fouls is also an important design consideration.

INDUSTRY PRACTICE

Of the 116 CWT facilities in EPA's WTI Questionnaire and NOA comment data base that provided information concerning use of ultrafiltration, six operate ultrafiltration systems.

B. *REVERSE OSMOSIS*

GENERAL DESCRIPTION

Reverse osmosis (RO) is a process for separating dissolved solids from water. CWT facilities commonly use RO in treating oily or metal-bearing wastewater. RO is applicable when the solute molecules are approximately the same size as the solvent molecules. A semi–permeable, microporous membrane and pressure are used to perform the separation. RO systems are typically used as polishing processes, prior to final discharge of the treated wastewater. Reverse osmosis systems have been demonstrated to be effective in removing dissolved metals.

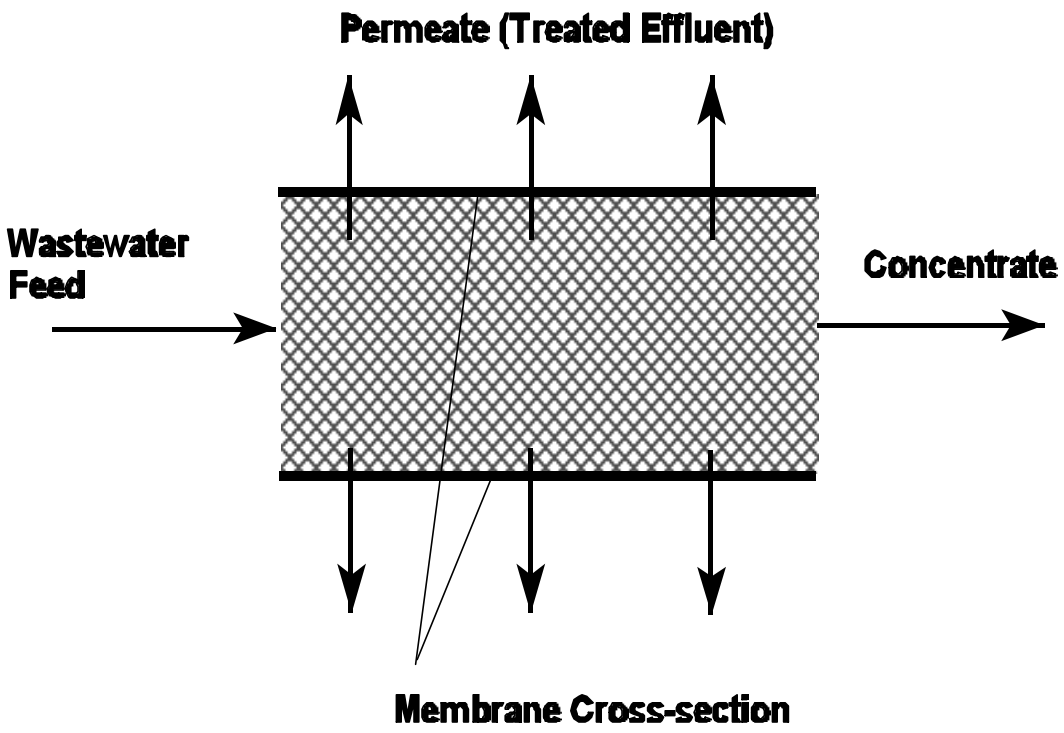

Figure 8-13. Ultrafiltration System Diagram

Osmosis is the diffusion of a solvent (such as water) across a semi-permeable membrane from a less concentrated solution into a more concentrated solution. In the reverse osmosis process, pressure greater than the normal osmotic pressure is applied to the more concentrated solution (the waste stream being treated), forcing the purified water through the membrane and into the less concentrated stream which is called the permeate. The low-molecular-weight solutes (for example, salts and some surfactants) do not pass through the membrane. They are referred to as concentrate. The concentrate is recirculated through the membrane unit until the flow of permeate drops. The permeate can either be discharged or passed along to another treatment unit. The concentrate is contained and held for further treatment or disposal. Figure 8–14 shows an RO system.

The performance of an RO system is dependent upon the dissolved solids concentration and temperature of the feed stream, the applied pressure, and the type of membrane selected. The key RO membrane properties to be considered are: selectivity for water over ions, permeation rate, and durability. RO modules are available in various membrane configurations, such as spiral-wound, tubular, hollow-fiber, and plate and frame. In addition to the membrane modules, other capital items needed for an RO installation include pumps, piping, instrumentation, and storage tanks. The major operating cost is attributed to membrane replacement. A major consideration for RO systems is the disposal of the concentrate due to its elevated concentrations of salts, metals, and other dissolved solids.

INDUSTRY PRACTICE

Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning use of reverse osmosis, two operate reverse osmosis systems.

5. *LANCY FILTRATION*

GENERAL DESCRIPTION

The Lancy Sorption Filter System is a patented method for the continuous recovery of heavy metals. The Lancy sorption filtration process may reduce metals not removed by conventional waste treatment technologies to low concentrations.

In the first stage of the Lancy filtration process, a soluble sulfide is added to the wastewater in a reaction tank, converting most of the heavy metals to sulfides. From the sulfide reaction tank, the solution is passed through the sorption filter media. Precipitated metal sulfides and other suspended solids are filtered out. Any remaining soluble metals are absorbed by the media. Excess soluble sulfides are also removed from the waste stream.

The Lancy filtration process reportedly reduces zinc, silver, copper, lead, and cadmium to less than 0.05 mg/l and mercury to less than 2 Fg/l. In addition to the effective removal of heavy metals, the system has a high solids filtration capacity and a fully automatic, continuous operation. The system continuously recycles and reuses the same filter media thereby saving on operating costs. The system may be installed with a choice of media discharge - slurry or solid cake. Figure 8-15 illustrates the Lancy Sorption Filtration System.

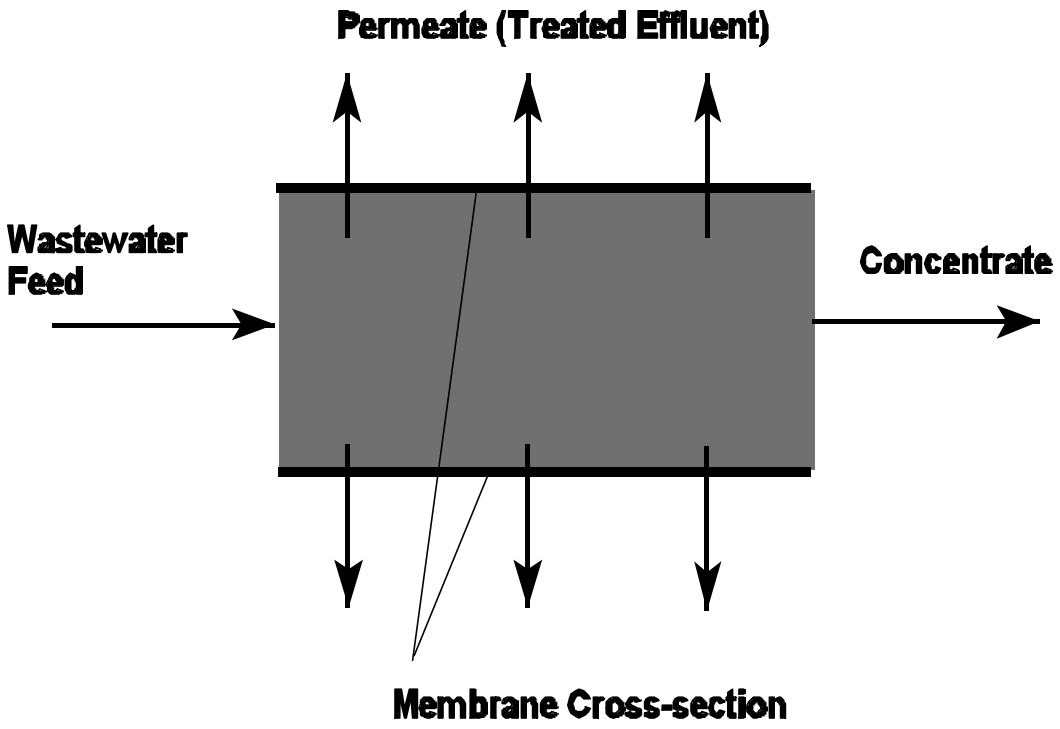

Figure 8-14. Reverse Osmosis System Diagram

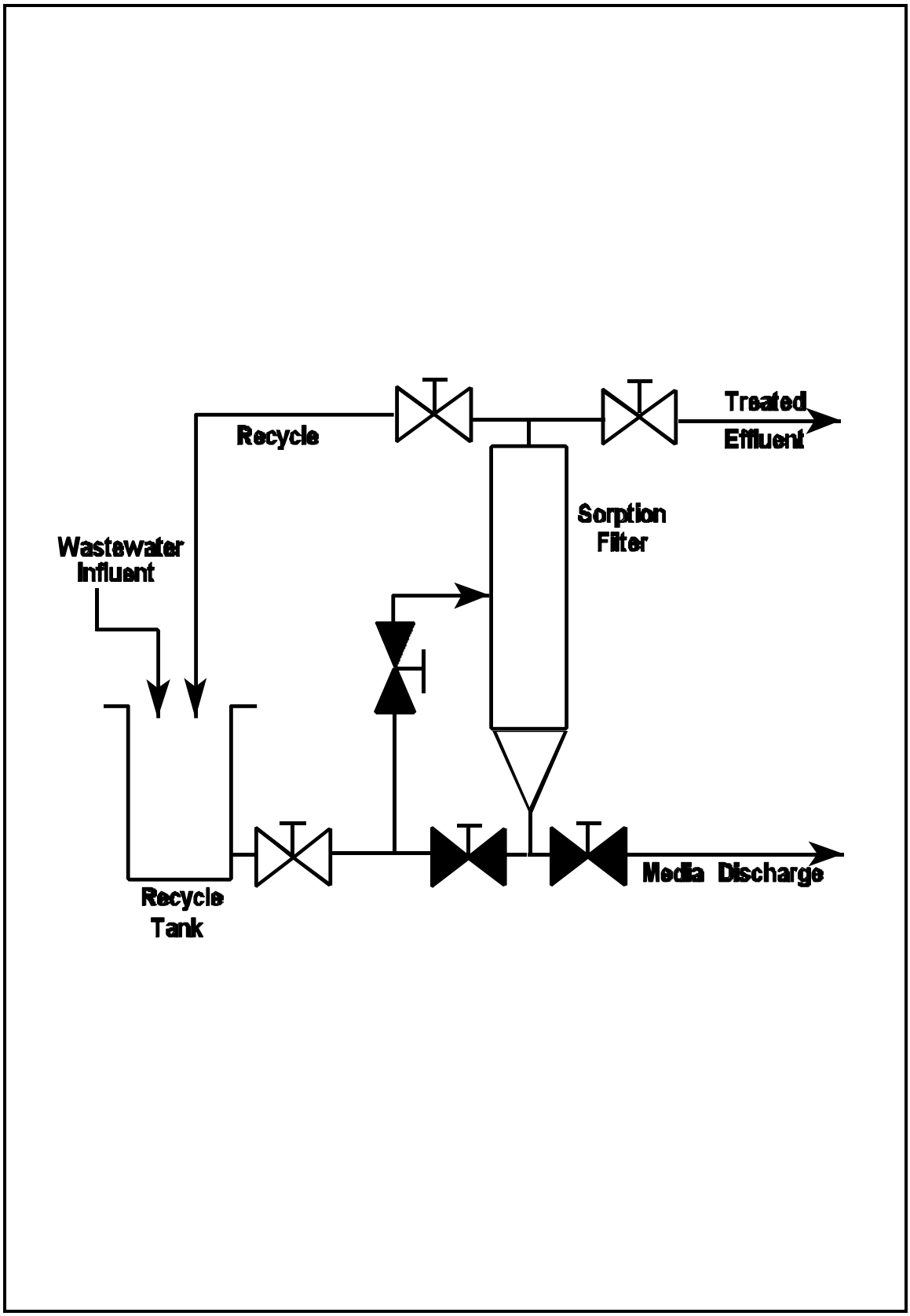

Figure 8-15. Lancy Filtration System Diagram

INDUSTRY PRACTICE

Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning use of filtration systems, only one operates the Lancy Sorption Filtration System. This unit is used for polishing effluent from a treatment sequence including chemical precipitation, clarification, and sand filtration. EPA obtained performance data for this system during a sampling episode at one of the metals subcategory facilities. The performance data showed that some metals were reduced to the target levels while the concentration of some pollutants increased. This may not represent optimal performance of the system, however, because the facility reported that they were experiencing operational problems throughout the sampling episode.

Carbon Adsorption *8.2.2.10*

GENERAL DESCRIPTION

Activated carbon adsorption is a demonstrated wastewater treatment technology that uses activated carbon to remove dissolved organic pollutants from wastewater. The activated carbon is made from many carbonaceous sources including coal, coke, peat, wood, and coconut shells. The carbon source material is "activated" by treating it with an oxidizing gas to form a highly porous structure with a large internal surface area. CWT facilities generally use granular forms of activated carbon (GAC) in fixed bed columns to treat wastewater. However, some use powdered activated carbon (PAC) alone or in conjunction with biological treatment. Figure 8-16 presents a diagram of a fixed-bed GAC collumn.

In a fixed bed system, the wastewater enters the top of the unit and is allowed to flow downward through a bed of granular activated carbon. As the wastewater comes into contact with the activated carbon, the dissolved organic compounds adsorb onto the surface of the activated carbon. In the upper area of the bed, the pollutants are rapidly adsorbed. As more wastewater passes through the bed, this rapid adsorption zone moves downward until it reaches the bottom of the bed. At this point, all of the available adsorption sites are filled and the carbon is said to be exhausted. This condition can be detected by an increase in the effluent pollutant concentration, and is called breakthrough.

GAC systems are usually comprised of several beds operated in series. This design allows the first bed to go to exhaustion, while the other beds still have the capacity to treat to an acceptable effluent quality. The carbon in the first bed is replaced, and the second bed then becomes the lead bed. The GAC system piping is designed to allow switching of bed order.

After the carbon is exhausted, it can be removed and regenerated. Usually heat or steam is used to reverse the adsorption process. The light organic compounds are volatilized and the heavy organic compounds are pyrolyzed. Spent carbon may also be regenerated by contacting it with a solvent which dissolves the adsorbed pollutants. Depending on system size and economics, some facilities may choose to dispose of the spent carbon instead of regenerating it. For very large applications, an on-site regeneration facility is more economical. For smaller applications, such as in the CWT industry, it is generally cost-effective to use a vendor service to deliver regenerated carbon and remove the spent carbon. These vendors transport the spent carbon to their centralized facilities for regeneration.

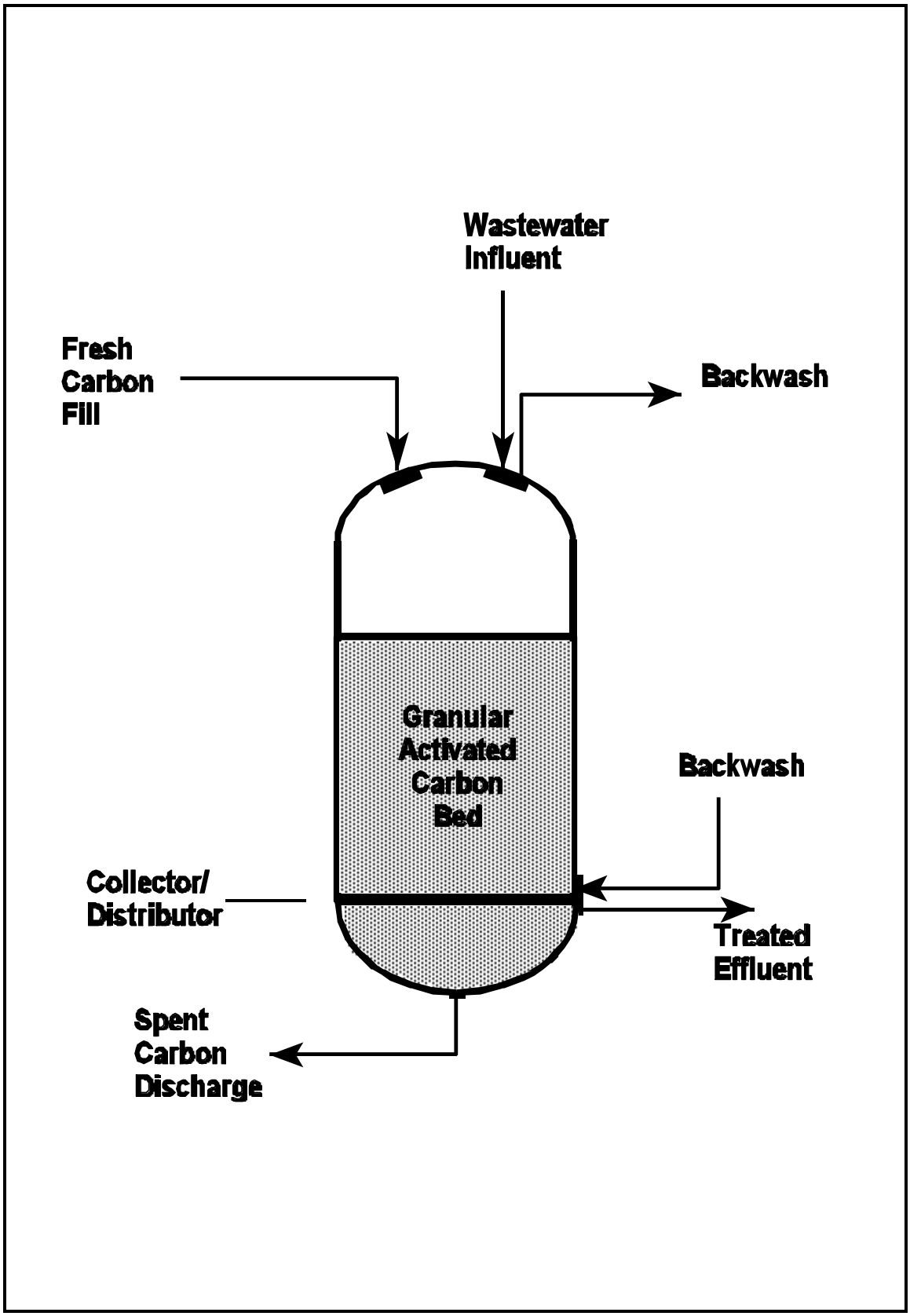

Figure 8-16. Carbon Adsorption System Diagram

The carbon adsorption mechanism is complicated and, although the attraction is primarily physical, is a combination of physical, chemical, and electrostatic interactions between the activated carbon and the organic compound. The key design parameter for activated carbon is the adsorption capacity of the carbon. The adsorption capacity is a measure of the mass of contaminant adsorbed per unit mass of activated carbon and is a function of the compound being adsorbed, the type of carbon used, and the process design and operating conditions. In general, the adsorption capacity is inversely proportional to the adsorbate solubility. Nonpolar, high molecular weight organics with low solubility are readily adsorbed. Polar, low molecular weight organics with high solubilities are more poorly adsorbed.

Competitive adsorption between compounds has an effect on adsorption. The carbon may preferentially adsorb one compound over another. This competition could result in an adsorbed compound being desorbed from the carbon. This is most pronounced when carbon adsorption is used to treat wastewater with highly variable pollutant character and concentration.

INDUSTRY PRACTICE

Of the 116 CWT facilities in EPA's WTI Questionnaire and NOA comment data base that provided information concerning use of carbon adsorption, 17 operate carbon adsorption systems.

Ion Exchange *8.2.2.11*

GENERAL DESCRIPTION

A common process employed to remove heavy metals from relatively low–concentration waste streams, such as electroplating wastewater, is ion exchange. A key advantage of the ion exchange process is that the metal contaminants can be recovered and reused. Another advantage is that ion exchange may be designed to remove certain metals only, providing effective removal of these metals from highly-contaminated wastewater. A disadvantage is that the resins may be fouled by some organic substances.

In an ion exchange system, the wastewater stream is passed through a bed of resin. The resin contains bound groups of ionic charge on its surface, which are exchanged for ions of the same charge in the wastewater. Resins are classified by type, either cationic or anionic. The selection is dependent upon the wastewater contaminant to be removed. A commonly-used resin is polystyrene copolymerized with divinylbenzene.

The ion exchange process involves four steps: treatment, backwash, regeneration, and rinse. During the treatment step, wastewater is passed through the resin bed and ions are exchanged until pollutant breakthrough occurs. The resin is then backwashed to reclassify the bed and to remove suspended solids. During the regeneration step, the resin is contacted with either an acidic or alkaline solution containing high concentrations of the ion originally present in the resin. This "reverses" the ion exchange process and removes the metal ions from the resin. The bed is then rinsed to remove residual regenerating solution. The resulting contaminated regenerating solution must be further processed for reuse or disposal. Depending upon system size and economics, some facilities choose to remove the spent resin and replace it with resin regenerated off-site instead of regenerating the resin in-place.

Ion exchange equipment ranges from simple, inexpensive systems such as domestic water softeners, to large, continuous industrial applications. The most commonly-encountered industrial setup is a fixed-bed resin in a vertical column, where the resin is regenerated in-place. Figure 8-17 is a diagram of this type of system. These systems may be designed so that the regenerant flow is concurrent or countercurrent

to the treatment flow. A countercurrent design, although more complex to operate, provides a higher treatment efficiency. The beds may contain a single type of resin for selective treatment, or the beds may be mixed to provide for more complete deionization of the waste stream. Often, individual beds containing different resins are arranged in series, which makes regeneration easier than in the mixed bed system.

INDUSTRY PRACTICE

EPA is aware of only one CWT facility using ion exchange.

Electrolytic Recovery *8.2.2.12*

GENERAL DESCRIPTION

Another process for reclaiming metals from wastewater is electrolytic recovery. It is a common technology in the electroplating, mining, and electronic industries. It is used for the recovery of copper, zinc, silver, cadmium, gold, and other heavy metals. Nickel is poorly recovered due to its low standard potential.

The electrolytic recovery process uses an oxidation and reduction reaction. Conductive electrodes (anodes and cathodes) are immersed in the metal-bearing wastewater, with an electric potential applied to them. At the cathode, a metal ion is reduced to its elemental form (electron-consuming reaction). At the same time, gases such as oxygen, hydrogen, or nitrogen form at the anode (electron-producing reaction). After the metal coating on the cathode reaches a desired thickness, it may be removed and recovered. The metal-stripped cathode can then be used as the anode.

The equipment consists of an electrochemical reactor with electrodes, a gas-venting system, recirculation pumps, and a power supply. Figure 8-18 ia a diagram of an electrolytic recovery system. Electrochemical reactors are typically designed to produce high flow rates to increase the process efficiency.

A conventional electrolytic recovery system is effective for the recovery of metals from relatively high-concentration wastewater. A specialized adaptation of electrolytic recovery, called extended surface electrolysis, or ESE, operates effectively at lower concentration levels. The ESE system uses a spiral cell containing a flow-through cathode which has a very open structure and therefore a lower resistance to fluid flow. This also provides a larger electrode surface. ESE systems are often used for the recovery of copper, lead, mercury, silver, and gold.

INDUSTRY PRACTICE

Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning use of electrolytic recovery, three operate electrolytic recovery systems.

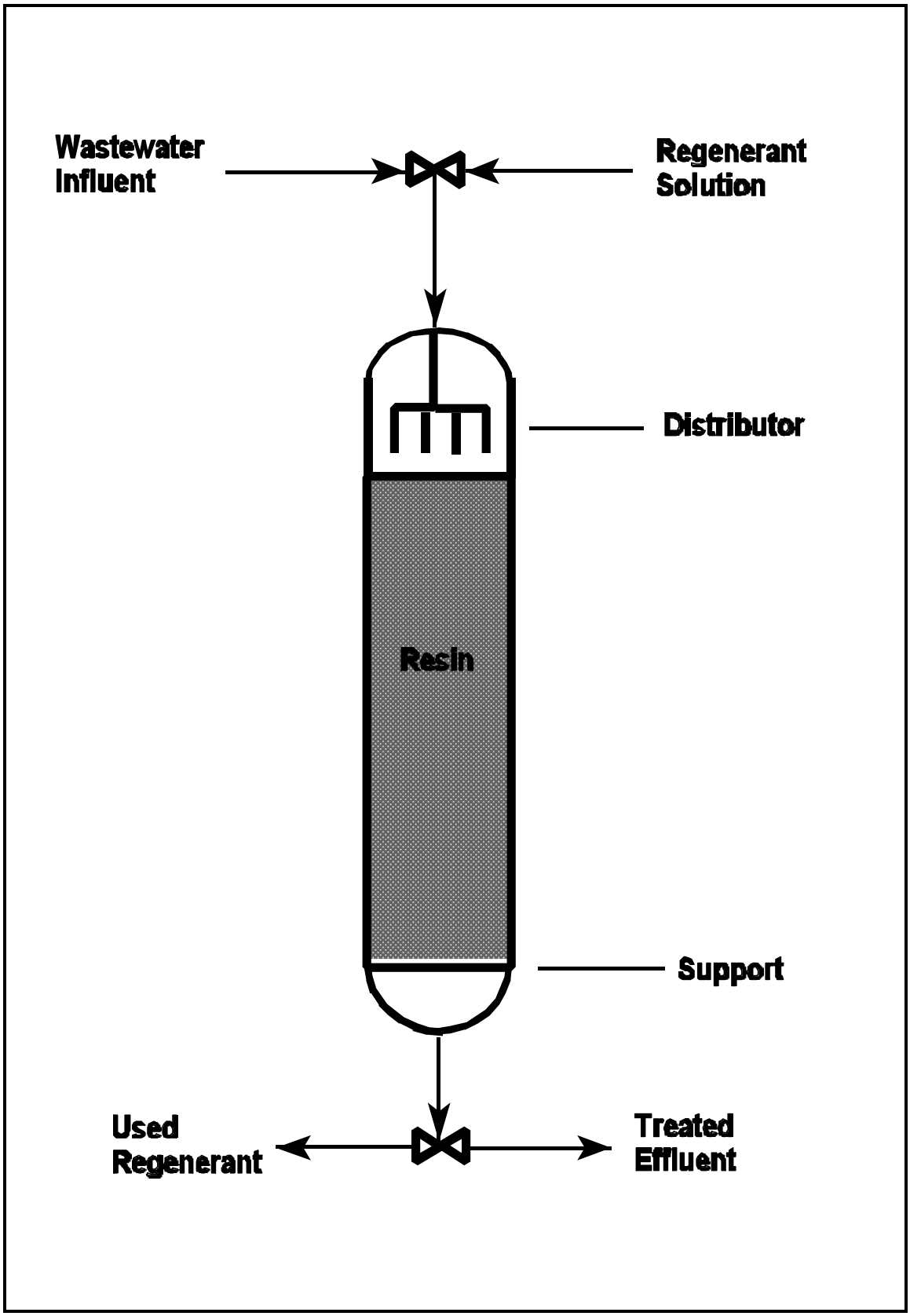

Figure 8-17. Ion Exchange System Diagram

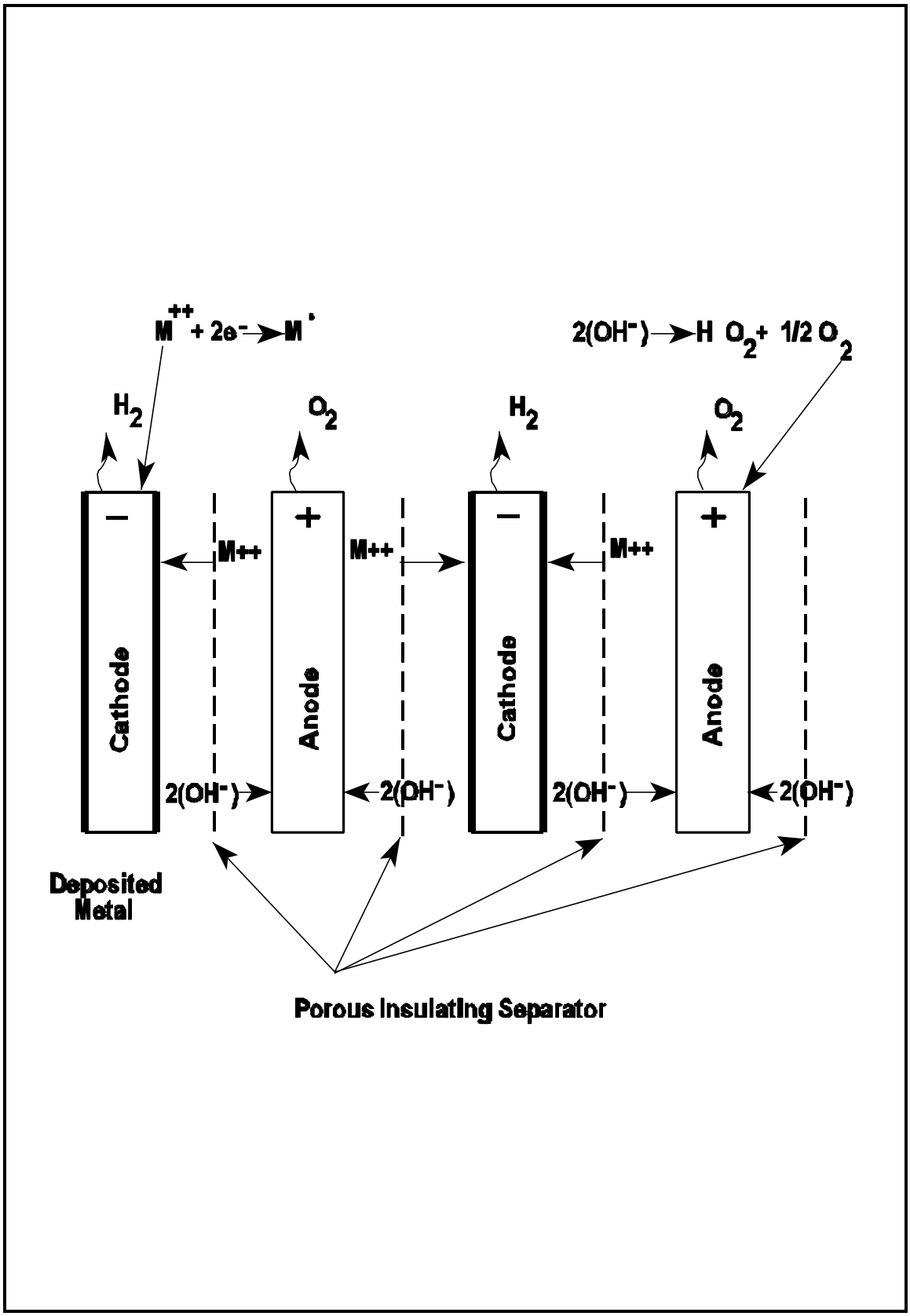

Figure 8-18. Electrolytic Recovery System Diagram

Stripping *8.2.2.13*

Stripping is a method for removing dissolved volatile organic compounds from wastewater. The removal is accomplished by passing air or steam through the agitated waste stream. The primary difference between air stripping and steam stripping is that steam stripping is operated at higher temperatures and the resultant off-gas stream is usually condensed and recovered or incinerated. The off-gas from air stripping contains non-condenseable air which must be either passed through an adsorption unit or incinerated in order to prevent transfer of the volatile pollutants to the environment. EPA is not aware of any applications of steam stripping technologies in the CWT industry.

1. AIR STRIPPING

GENERAL DESCRIPTION

Air stripping is effective in removing dissolved volatile organic compounds from wastewater. The removal is accomplished by passing high volumes of air through the agitated wastewater stream. The process results in a contaminated off-gas stream which, depending upon air emissions standards, usually requires air pollution control equipment. Stripping can be performed in tanks or in spray or packed towers. Treatment in packed towers is the most efficient application. The packing typically consists of plastic rings or saddles. The two types of towers that are commonly used, cross-flow and countercurrent, differ in design only in the location of the air inlets. In the cross-flow tower, the air is drawn through the sides for the total height of the packing. The countercurrent tower draws the entire air flow from the bottom. Cross-flow towers have been found to be more susceptible to scaling problems and are less efficient than countercurrent towers. Figure 8-19 is a countercurrent air stripper.

The driving force of the air stripping mass-transfer operation is the difference in concentrations between the air and water streams. Pollutants are transferred from the more concentrated wastewater stream to the less concentrated air stream until equilibrium is reached. This equilibrium relationship is known as Henry's Law. The strippability of a pollutant is expressed as its Henry's Law Constant, which is a function of both its volatility or vapor pressure and solubility.

Air strippers are designed according to the strippability of the pollutants to be removed. For evaluation purposes, organic pollutants can be divided into three general strippability ranges (low, medium, and high) according to their Henry's Law Constants. The low strippability group (Henry's Law Constants of 10^{-4} [mg/m^3 air]/[mg/m^3 water] and lower) are not effectively removed. Pollutants in the medium (10^{-1} to 10^{-4}) and high (10^{-1} and greater) groups are effectively stripped. Pollutants with lower Henry's law constants require greater column height, more trays or packing material, greater temperature, and more frequent cleaning than pollutants with a higher strippability.

The air stripping process is adversely affected by low temperatures. Air strippers experience lower efficiencies at lower temperatures, with the possibility of freezing within the tower. For this reason, depending on the location of the tower, it may be necessary to preheat the wastewater and the air feed streams. The column and packing materials must be cleaned regularly to ensure that low effluent levels are attained.

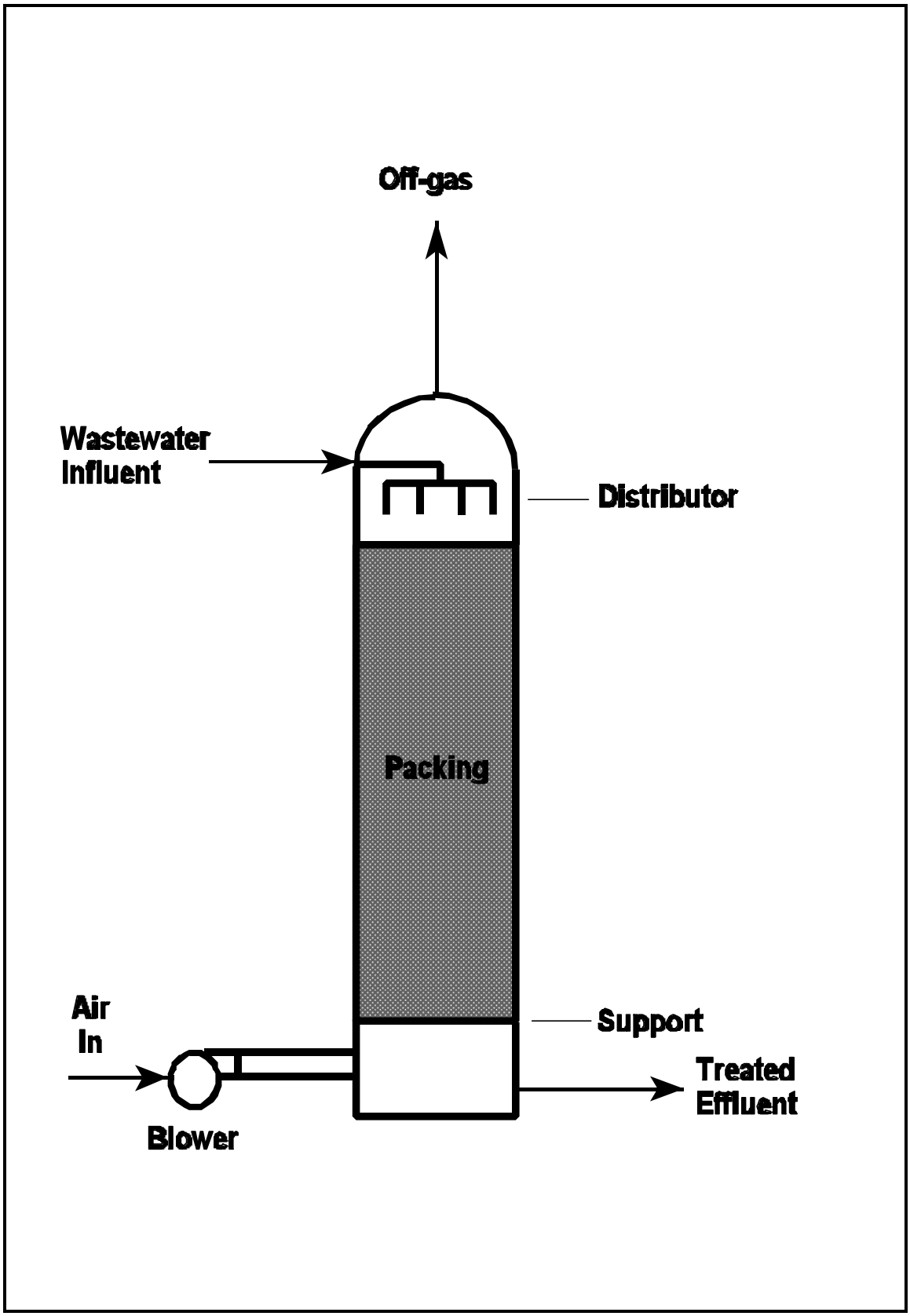

Figure 8-19. Air Stripping System Diagram

Air stripping has proved to be an effective process in the removal of volatile pollutants from wastewater. It is generally limited to influent concentrations of less than 100 mg/l organics. Well-designed and operated systems can achieve over 99 percent removals.

INDUSTRY PRACTICE

Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning use of air stripping, 11 operate air stripping systems.

Liquid Carbon Dioxide Extraction 8.2.2.14

GENERAL DESCRIPTION

Liquid carbon dioxide (CO_2) extraction is a process used to extract and recover organic contaminants from aqueous waste streams. A licensed, commercial application of this technology is utilized in the CWT industry under the name "Clean Extraction System" (CES). The process may be effective in the removal of organic substances such as hydrocarbons, aldehydes and ketones, nitriles, halogenated compounds, phenols, esters, and heterocyclics. It is not effective in the removal of some compounds which are very water-soluble, such as ethylene glycol, and low molecular weight alcohols. It may provide an alternative in the treatment of waste streams which historically have been incinerated.

In liquid carbon dioxide extraction, the waste stream is fed into the top of a pressurized extraction tower containing perforated plates, where it is contacted with a countercurrent stream of liquefied CO_2. The organic contaminants in the waste stream are dissolved in the CO_2; this extract is then sent to a separator, where the CO_2 is redistilled. The distilled CO_2 vapor is compressed and reused. The concentrated organics bottoms from the separator can then be disposed or recovered. The treated wastewater stream which exits the extractor (raffinate) is pressure-reduced and may be further treated for residual organics removal if necessary to meet discharge standards. Figure 8-20 is a diagram of the CES is presented in.

INDUSTRY PRACTICE

EPA is aware of only one facility using this technology in the CWT industry. Pilot–scale information submitted to EPA by the CWT facility showed effective removal for a variety of organic compounds. EPA sampled this commercial CWT CES unit during this rulemaking effort. Performance was not optimal, however, as the facility reported operational problems with the unit throughout the sampling episode.

Biological Treatment 8.2.3

A portion of the CWT industry accepts waste receipts that contain organic pollutants, which are often amenable to biological degradation. This subset of CWT facilities is referred to as the organics subcategory. In addition, a portion of the facilities in the oils subcategory also use biological treatment to treat wastewater separated from oily wastes.

Biological treatment systems use microbes which consume, and thereby destroy, organic compounds as a food source. The microbes use the organic compounds as both a source of carbon and as a source of energy. These microbes may also need supplemental nutrients for growth, such as nitrogen and phosphorus, if the waste stream is deficient in these nutrients. Aerobic microbes require oxygen to grow, whereas anaerobic microbes will grow only in the absence of oxygen. Facultative microbes are an adaptive type of microbe that can grow with or without oxygen.

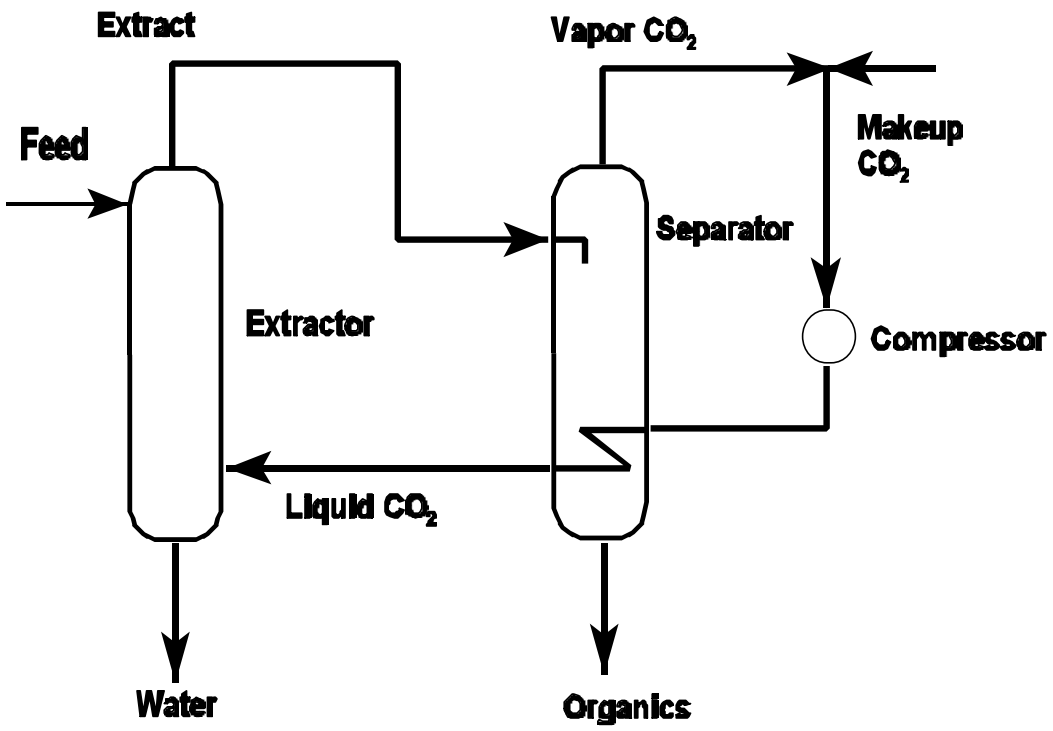

Figure 8-20. Liquid CO_2 Extraction System Diagram

The success of biological treatment is dependent on many factors, such as the pH and temperature of the wastewater, the nature of the pollutants, the nutrient requirements of the microbes, the presence of inhibiting pollutants, and variations in the feed stream loading. Certain compounds, such as heavy metals, may be toxic to the microorganisms and must be removed from the waste stream prior to biological treatment. Load variations are a major concern, especially in the CWT industry, where waste receipts vary over time in both concentration and volume.

There are several adaptations of biological treatment. These adaptations differ in three basic ways. First, a system may be aerobic, anaerobic, or facultative. Second, the microorganisms may either be attached to a surface (as in a trickling filter), or be unattached in a liquid suspension (as in an activated sludge system). Third, the operation may be either batch or continuous.

Of the 116 facilities in the WTI Questionnaire and NOA comment data base that responded to EPA's inquiry concerning the use of biological treatment, 17 operate biological treatment systems. There were no anaerobic systems reported. Theses systems include sequencing batch reactors, attached growth systems (biotowers and trickling filters) and activated sludge systems. With the exception of trickling filters, EPA sampled at least one application of each of the following biological treatment technologies during the development of these effluent guidelines.

Sequencing Batch Reactors *8.2.3.1*

General Description

A sequencing batch reactor (SBR) is a suspended growth system in which wastewater is mixed with existing biological floc in an aeration basin. SBRs are unique in that a single tank acts as an equalization tank, an aeration tank, and a clarifier. An SBR is operated on a batch basis where the wastewater is mixed and aerated with the biological floc for a specific period of time. The contents of the basin are allowed to settle and the supernatant is decanted. The batch operation of an SBR makes it a useful biological treatment option for the CWT industry, where the wastewater volumes and characteristics are often highly variable. Each batch can be treated differently depending on waste characteristics. Figure 8-21 shows an SBR.

The SBR has a four cycle process: fill, react, settle, and decant. The fill cycle has two phases. The first phase, called static fill, introduces the wastewater to the system under static conditions. This is an anaerobic period and may enhance biological phosphorus uptake. During the second phase of the fill cycle wastewater is mechanically mixed to eliminate the scum layer and prepare the microorganisms to receive oxygen. In the second cycle, the react cycle, aeration is performed. The react cycle is a time–dependent process where wastewater is continually mixed and aerated, allowing the biological degradation process to occur. The third cycle, called the settling cycle, provides quiescent conditions throughout the tank and may accommodate low settling rates by increasing the settling time. During the last or decant cycle, the treated wastewater is decanted by subsurface withdrawal from below the scum layer. This treated, clarified effluent may then be further treated or discharged.

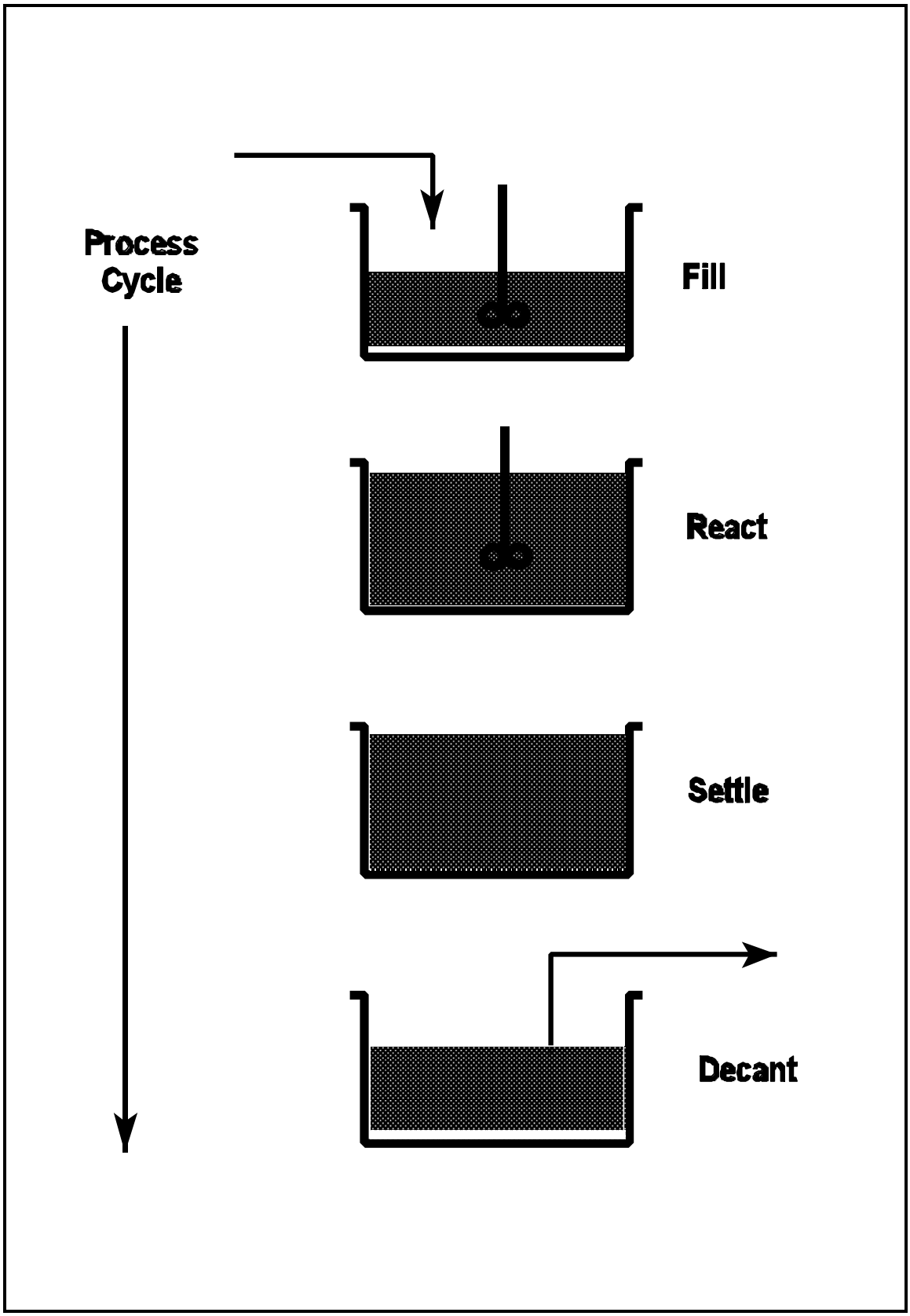

Figure 8-21. Sequencing Batch Reactor System Diagram

When the quantity of biomass in the SBR exceeds that needed for operation, the excess biomass is removed. The sludge that is removed from the SBR may be reduced in volume by thickening and dewatering using any of the sludge treatment processes discussed in section 8.2.4. The dewatered sludge may be disposed in a landfill or used as an agricultural fertilizer.

An SBR carries out all of the functions of a conventional continuous flow activated sludge process, such as equalization, biological treatment, and sedimentation, in a time sequence rather than a space sequence. Detention times and loadings vary with each batch and are highly dependent on the specific raw wastewater loadings. Typically, an SBR operates with a hydraulic detention time of 1 to 10 days and a sludge retention time of 10 to 30 days. The mixed liquor suspended solids (MLSS) concentration is maintained at 3,500 to 10,000 mg/l. The overall control of the system may be accomplished automatically by using level sensors or timing devices. By using a single tank to perform all of the required functions associated with biological treatment, an SBR reduces land requirements. It also provides for greater operation flexibility for treating wastes with viable characteristics by allowing the capability to vary detention time and mode of aeration in each stage. SBRs also may be used to achieve complete nitrification/denitrification and phosphorus removal.

INDUSTRY PRACTICE

EPA is aware of only one CWT facility that uses an SBR. This facility is in the organics subcategory, and its SBR unit was sampled during the development of these effluent guidelines.

Attached Growth Biological Treatment Systems *8.2.3.2*

Another system used to biodegrade the organic components of a wastewater is the attached growth biological treatment system. In these systems, the biomass adheres to the surfaces of rigid supporting media. As wastewater contacts the supporting medium, a thin-film biological slime develops and coats the surfaces. As this film (consisting primarily of bacteria, protozoa, and fungi) grows, the slime periodically breaks off the medium and is replaced by new growth. This phenomenon of losing the slime layer is called sloughing and is primarily a function of organic and hydraulic loadings on the system. The effluent from the system is usually discharged to a clarifier to settle and remove the agglomerated solids.

Attached growth biological systems are appropriate for treating industrial wastewaters amenable to aerobic biological treatment. When used in conjunction with suitable pre- and post-treatment processes, attached growth biological systems remove suspended and colloidal materials effectively. The two major types of attached growth systems used at CWT facilities are trickling filters and biotowers. This section describes these processes.

1. TRICKLING FILTERS

GENERAL DESCRIPTION

Trickling filtration is an aerobic fixed-film biological treatment process that consists of a structure, packed with inert medium such as rock, wood, or plastic. The wastewater is distributed over the upper surface of the medium by either a fixed spray nozzle system or a rotating distribution system. The inert medium develops a biological slime that absorbs and biodegrades organic pollutants. Air flows through the filter by convection, thereby providing the oxygen needed to maintain aerobic conditions. Figure 8-22 is a flow diagram of a trickling filter.

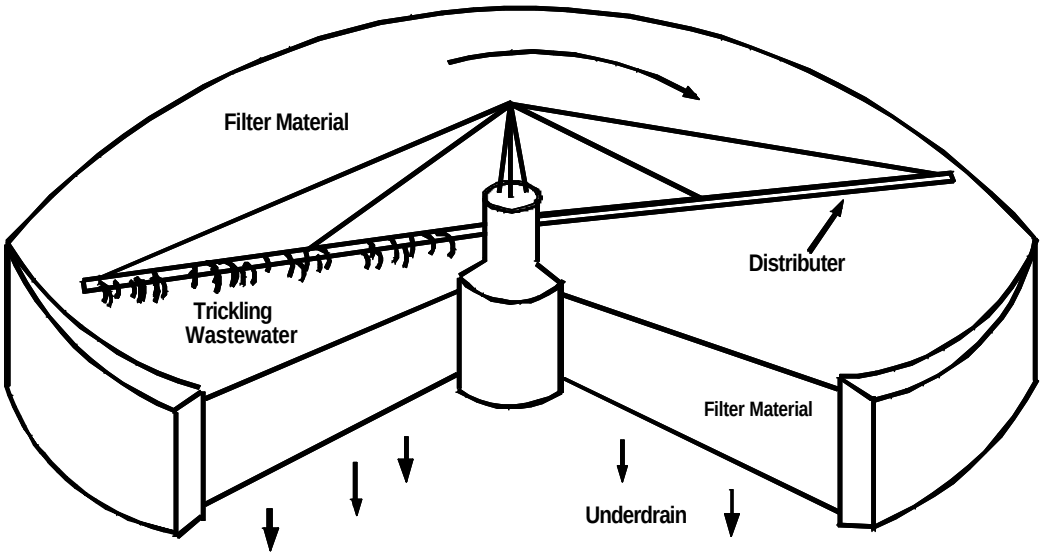

Figure 8-22. Trickling Filter System Diagram

Trickling filters are classified as low-rate or high-rate, depending on the organic loading. Typical design organic loading values range from 5 to 25 pounds and 25 to 45 pounds BOD_5 per 1,000 cubic feet per day for low-rate and high-rate, respectively. A low-rate filter generally has a media bed depth of 1.5 to 3 meters and does not use recirculation. A high-rate filter may have a bed depth from 1 to 9 meters and recirculates a portion of the effluent for further treatment.

INDUSTRY PRACTICE

EPA is aware of only one CWT facility that uses a trickling filter. This facility is in the oils subcategory.

2. BIOTOWERS

GENERAL DESCRIPTION

A variation of a trickling filtration process is the aerobic biotower. Biotowers may be operated in a continuous or semi-continuous manner and may be operated in an upflow or downflow manner. In the downflow mode, influent is pumped to the top of a tower, where it flows by gravity through the tower. The tower is packed with plastic or redwood media containing the attached microbial growth. Biological degradation occurs as the wastewater passes over the media. Treated wastewater collects in the bottom of the tower. If needed, additional oxygen is provided via air blowers countercurrent to the wastewater flow. In the upflow mode, the wastewater stream is fed into the bottom of the biotower and is passed up through the packing along with diffused air supplied by air blowers. The treated effluent exits from the top of the biotower.

Variations of this treatment process involve the inoculation of the raw influent with bacteria and the addition of nutrients. Wastewater collected in the biotowers is delivered to a clarifier to separate the biological solids from the treated effluent. A diagram of a biotower is presented in Figure 8-23.

INDUSTRY PRACTICE

EPA is aware of two biotowers in operation in the CWT Industry. One system treats a waste stream which is primarily composed of leachate from an on-site landfill operation. The other system treats high-TOC wastewater from a metals recovery operation. EPA conducted sampling at this facility during the development of these effluent guidelines.

Activated Sludge *8.2.3.3*

GENERAL DESCRIPTION

The activated sludge process is a continuous-flow, aerobic biological treatment process that employs suspended-growth aerobic microorganisms to biodegrade organic contaminants. In this process, a suspension of aerobic microorganisms is maintained by mechanical mixing or turbulence induced by diffused aerators in an aeration basin. This suspension of microorganisms is called the mixed liquor. Figure 8-24 is a diagram of a conventional activated sludge system.

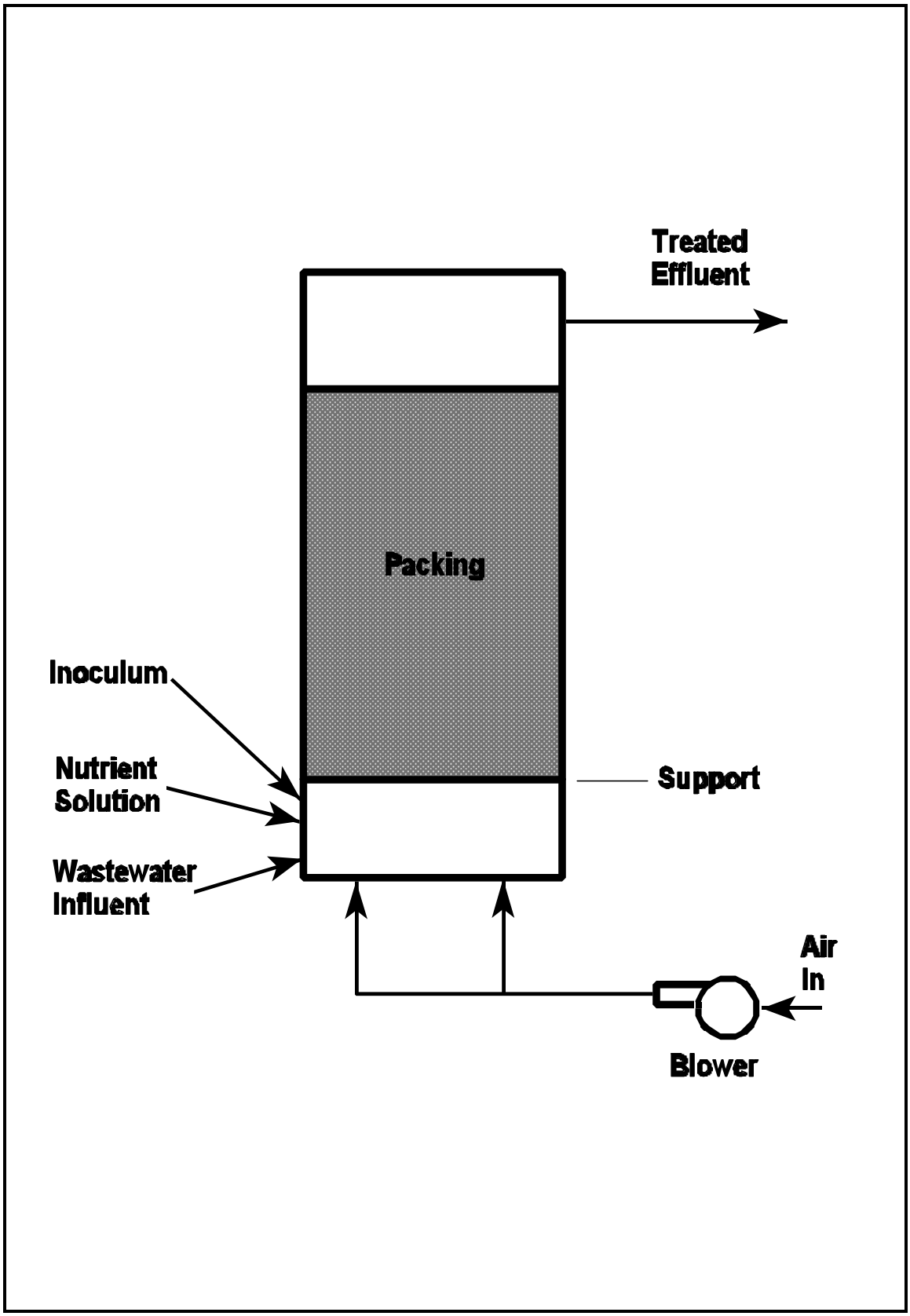

Figure 8-23. Biotower System Diagram

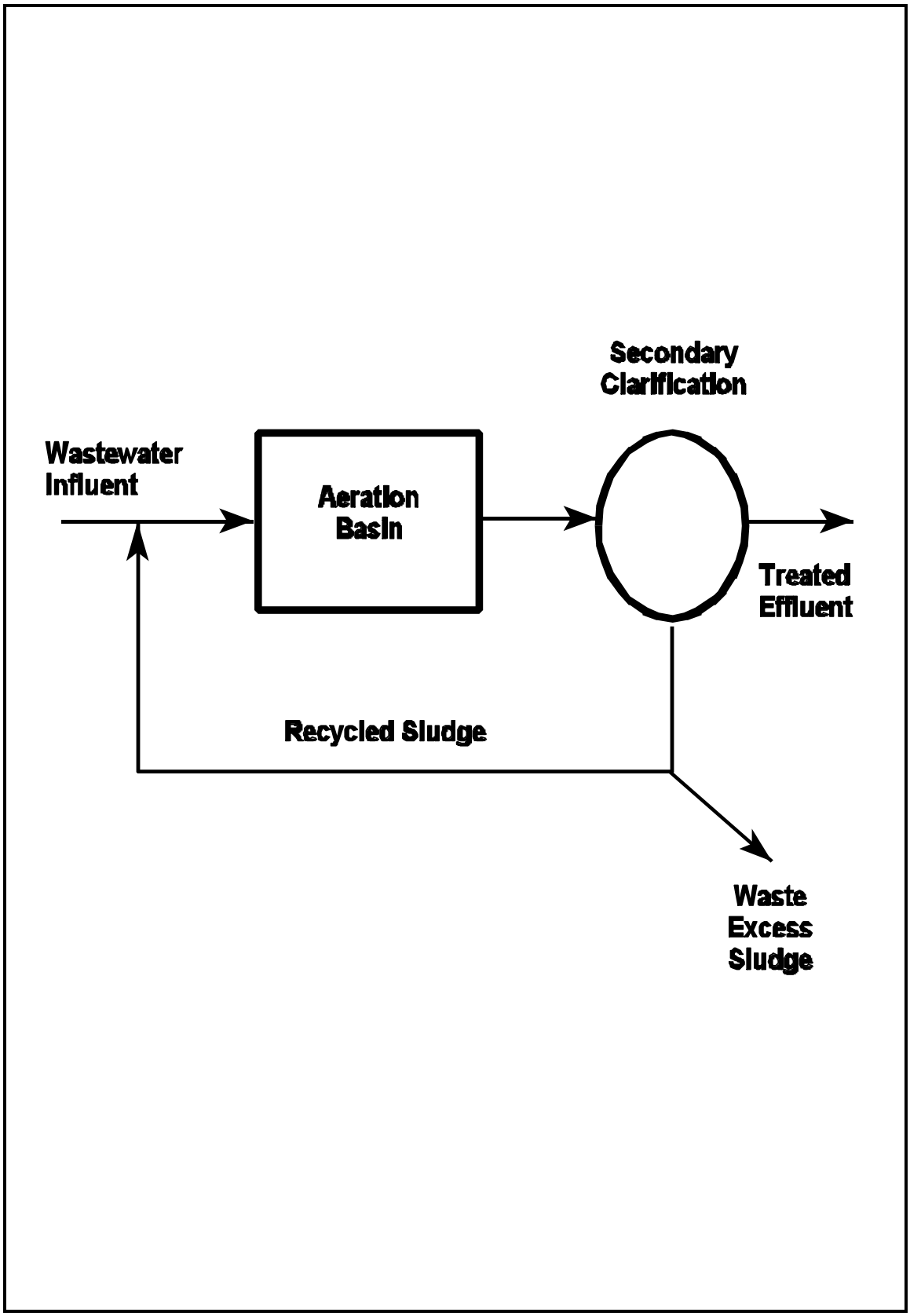

Figure 8-24. Activated Sludge System Diagram

Influent is introduced into the aeration basin and is allowed to mix with the contents. A series of biochemical reactions is performed in the aeration basin, degrading organics and generating new biomass. Microorganisms oxidize the soluble and suspended organic pollutants to carbon dioxide and water using the available supplied oxygen. These organisms also agglomerate colloidal and particulate solids. After a specific contact period in the aeration basin, the mixture is passed to a settling tank, or clarifier, where the microorganisms are separated from the treated water. A major portion of the settled solids in the clarifier is recycled back to the aeration system to maintain the desired concentration of microorganisms in the reactor. The remainder of the settled solids is wasted and sent to sludge handling facilities.

To ensure biological stabilization of organic compounds in activated sludge systems, adequate nutrient levels must be available to the biomass. The primary nutrients are nitrogen and phosphorus. Lack of these nutrients can impair biological activity and result in reduced removal efficiencies. Certain wastes may have low concentrations of nitrogen and phosphorus relative to the oxygen demand. As a result, nutrient supplements (e.g., phosphoric acid addition for additional phosphorus) have been used in activated sludge systems at CWT facilities.

The effectiveness of the activated sludge process is governed by several design and operation variables. The key variables are organic loading, sludge retention time, hydraulic or aeration detention time, and oxygen requirements. The organic loading is described as the food-to-microorganism (F/M) ratio, or kilograms of BOD_5 applied daily to the system per kilogram of mixed liquor suspended solids (MLSS). The MLSS in the aeration tank is determined by the rate and concentration of activated sludge returned to the tank. The organic loading (F/M ratio) affects the BOD_5 removal, oxygen requirements, biomass production, and the settleability of the biomass. The sludge retention time (SRT) or sludge age is a measure of the average retention time of solids in the activated sludge system. The SRT affects the degree of treatment and production of waste sludge. A high SRT results in a high quantity of solids in the system and therefore a higher degree of treatment while also resulting in the production of less waste sludge. The hydraulic detention time determines the size of the aeration tank and is calculated using the F/M ratio, SRT, and MLSS. Oxygen requirements are based on the amount required for biodegradation of organic matter and the amount required for endogenous respiration of the microorganisms. The design parameters will vary with the type of wastewater to be treated and are usually determined in a treatability study.

Modifications of the activated sludge process are common, as the process is extremely versatile and can be adapted for a wide variety of organically contaminated wastewaters. The typical modification may include a variation of one or more of the key design parameters, including the F/M loading, aeration location and type, sludge return, and contact basin configuration. The modifications in practice have been identified by the major characteristics that distinguish the particular configuration. The characteristic types and modifications are briefly described as follows:

- <u>Conventional</u> The aeration tanks are long and narrow, with plug flow (i.e., little forward or backwards mixing).

- <u>Complete Mix</u> The aeration tanks are shorter and wider, and the aerators, diffusers, and entry points of the influent and return sludge are arranged so that the wastewater mixes completely.

- Tapered Aeration A modification of the conventional process in which the diffusers are arranged to supply more air to the influent end of the tank, where the oxygen demand is highest.

- Step Aeration A modification of the conventional process in which the wastewater is introduced to the aeration tank at several points, lowering the peak oxygen demand.

- High Rate Activated Sludge A modification of conventional or tapered aeration in which the aeration times are shorter, the pollutants loadings are higher per unit mass of microorganisms in the tank. The rate of BOD_5 removal for this process is higher than that of conventional activated sludge processes, but the total removals are lower.

- Pure Oxygen An activated sludge variation in which pure oxygen instead of air is added to the aeration tanks, the tanks are covered, and the oxygen-containing off-gas is recycled. Compared to normal air aeration, pure oxygen aeration requires a smaller aeration tank volume and treats high-strength wastewaters and widely fluctuating organic loadings more efficiently.

- Extended Aeration A variation of complete mix in which low organic loadings and long aeration times permit more complete wastewater degradation and partial aerobic digestion of the microorganisms.

- Contact Stabilization An activated sludge modification using two aeration stages. In the first, wastewater is aerated with the return sludge in the contact tank for 30 to 90 minutes, allowing finely suspended colloidal and dissolved organics to absorb to the activated sludge. The solids are settled out in a clarifier and then aerated in the sludge aeration (stabilization) tank for 3 to 6 hours before flowing into the first aeration tank.

- Oxidation Ditch Activated Sludge An extended aeration process in which aeration and mixing are provided by brush rotors placed across a race-track-shaped basin. Waste enters the ditch at one end, is aerated by the rotors, and circulates.

INDUSTRY PRACTICE

Because activated sludge systems are sensitive to the loading and flow variations typically found at CWT facilities, equalization is often required prior to activated sludge treatment. Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning use of activated sludge, four operate activated sludge systems.

Sludge Treatment and Disposal *8.2.4*

Several of the waste treatment processes used in the CWT industry generate a sludge. These processes include chemical precipitation of metals, clarification, filtration, and biological treatment. Some oily waste treatment processes, such as dissolved air flotation and centrifugation, also produce sludges. These sludges typically contain between one and five percent solids. They require dewatering to concentrate them and prepare them for transport and/or disposal.

Sludges are dewatered using pressure, gravity, vacuum, or centrifugal force. There are several widely-used, commercially-available methods for sludge dewatering. Plate and frame pressure filtration, belt pressure filtration, and vacuum filtration are the primary methods used for sludge dewatering at CWT facilities. A plate and frame filter press can produce the driest filter cake of these three systems, followed by the belt press, and lastly, the vacuum filter. Each of

these sludge dewatering methods are discussed below.

In some instances, depending upon the nature of the sludge and the dewatering process used, the sludge may first be stabilized, conditioned, and/or thickened prior to dewatering. Certain sludges require stabilization (via chemical addition or biological digestion) because they have an objectionable odor or are a health threat. Sludges produced by the CWT industry usually do not fall into this category. Sludge conditioning is used to improve dewaterability; it can be accomplished via the addition of heat or chemicals. Sludge thickening, or concentration, reduces the volume of sludge to be dewatered and is accomplished by gravity settling, flotation, or centrifugation.

Plate and Frame Pressure Filtration 8.2.4.1

GENERAL DESCRIPTION

Plate and frame pressure filtration systems is a widely used method for the removal of solids from waste streams. In the CWT industry, plate and frame pressure filtration system are used for filtering solids out of treated wastewater streams and sludges. The same equipment is used for both applications, with the difference being the solids level in the influent stream and the sizing of the sludge and liquid units. Figure 8-25 is a plate and frame filter press.

A plate and frame filter press consists of a number of recessed filter plates or trays connected to a frame and pressed together between a fixed end and a moving end. Each plate is constructed with a drainage surface on the depressed portion of the face. Filter cloth is mounted on the face of each plate and then the plates are pressed together. The sludge is pumped under pressure into the chambers between the plates of the assembly while water passes through the media and drains to the filtrate outlets. The solids are retained in the cavities of the filter press between the cloth surfaces and form a cake that ultimately fills the chamber. At the end of the cycle when the filtrate flow stops, the pressure is released and the plates are separated. The filter cake drops into a hopper below the press. The filter cake may then be disposed in a landfill. The filter cloth is washed before the next cycle begins.

The key advantage of plate and frame pressure filtration is that it can produce a drier filter cake than is possible with the other methods of sludge dewatering. In a typical plate and frame pressure filtration unit, the filter cake may exhibit a dry solids content between 30 and 50 percent. It is well-suited for use in the CWT industry as it is a batch process. However, its batch operation results in greater operating labor requirements.

INDUSTRY PRACTICE

Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning the use of pressure filtration, 34 operate pressure filtration systems. Of these 34 facilities, 25 operate plate and frame pressure filtration systems, three operate belt pressure filtration systems, and six did not specify the type of presure filtration systems utilized.

Belt Pressure Filtration *8.2.4.2*

GENERAL DESCRIPTION

A belt pressure filtration system uses gravity followed by mechanical compression and shear force to produce a sludge filter cake. Belt filter presses are continuous systems which are commonly used to dewater biological treatment sludge. Most belt filter installations are preceded by a flocculation step, where polymer is added to create a sludge which has the strength to withstand being compressed between the belts without being squeezed out. Figure 8-26 shows a typical belt filter press.

During the press operation, the sludge stream is fed onto the first of two moving cloth filter belts. The sludge is gravity-thickened as the water drains through the belt. As the belt holding the sludge advances, it approaches a second moving belt. As the first and second belts move closer together, the sludge is compressed between them. The pressure is increased as the two belts travel together over and under a series of rollers. The turning of the belts around the rollers shear the cake which furthers the dewatering process. At the end of the roller pass, the belts move apart and the cake drops off. The feed belt is washed before the sludge feed point. The dropped filter cake may then be disposed.

The advantages of a belt filtration system are its lower labor requirements and lower power consumption. The disadvantages are that the belt filter presses produce a poorer quality filtrate, and require a relatively large volume of belt wash water.

Typical belt filtration applications may dewater an undigested activated sludge to a cake containing 15 to 25 percent solids. Heat-treated, digested sludges may be reduced to a cake of up to 50 percent solids.

INDUSTRY PRACTICE

Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning the use of pressure filtration, 36 operate pressure filtration systems. Of these 34 facilities, 25 operate plate and frame pressure filtration systems, three operate belt pressure filtration systems, and six did not specify the type of presure filtration systems utilized.

Vacuum Filtration *8.2.4.3*

GENERAL DESCRIPTION

A commonly-used process for dewatering sludge is rotary vacuum filtration. These filters come in drum, coil, and belt configurations. The filter medium may be made of cloth, coil springs, or wire-mesh fabric. A typical application is a rotary vacuum belt filter; a diagram of this equipment is shown in Figure 8-27.

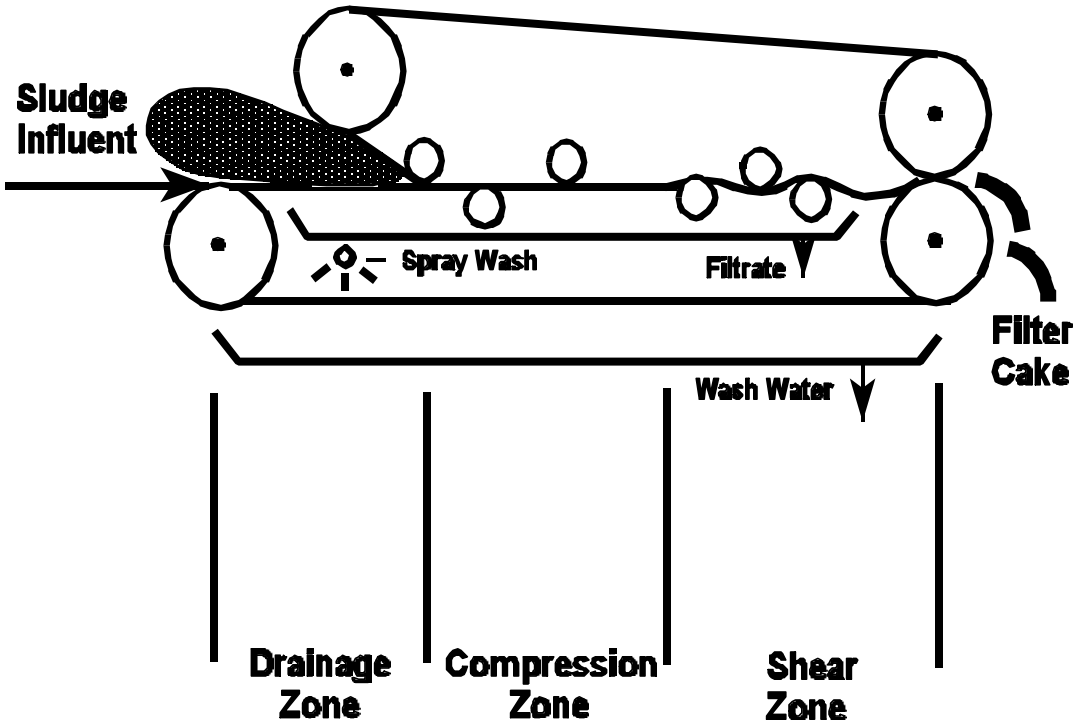

Figure 8-26. Belt Pressure Filtration System Diagram

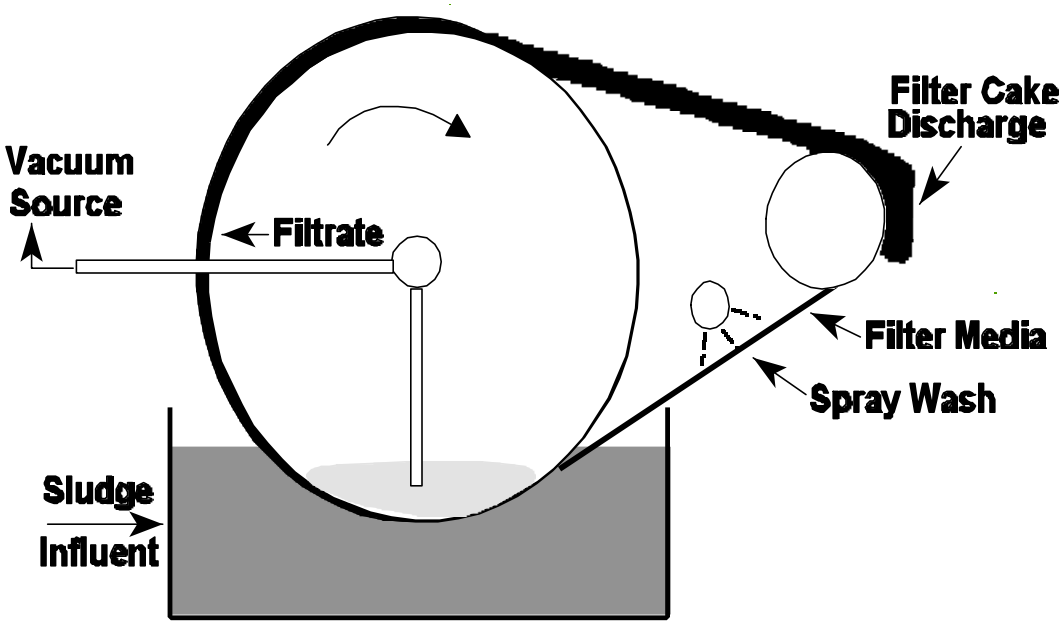

Figure 8-27. Vacuum Filtration System Diagram

In a rotary vacuum belt filter, a continuous belt of filter fabric is wound around a horizontal rotating drum and rollers. The drum is perforated and is connected to a vacuum. The drum is partially immersed in a shallow tank containing the sludge. As the drum rotates, the vacuum which is applied to the inside of the drum draws the sludge onto the filter fabric. The water from the sludge passes through the filter and into the drum, where it exits via a discharge port. As the fabric leaves the drum and passes over the roller, the vacuum is released. The filter cake drops off of the belt as it turns around the roller. The filter cake may then be disposed.

Vacuum filtration may reduce activated sludge to a cake containing 12 to 20 percent solids. Lime sludge may be reduced to a cake of 25 to 40 percent solids.

Because vacuum filtration systems are relatively expensive to operate, they are usually preceded by a thickening step which reduces the volume of sludge to be dewatered. An advantage of vacuum filtration is that it is a continuous process and therefore requires less operator attention.

INDUSTRY PRACTICE

Of the 65 CWT facilities in EPA's WTI Questionnaire data base that provided information concerning the use of vacuum filtration, eight operate vacuum filtration systems.

Filter Cake Disposal *8.2.4.4*

After a sludge is dewatered, the resultant filter cake must be disposed. The most common method of filter cake management used in the CWT industry is transport to an off–site landfill for disposal. Other disposal options are incineration or land application. Land application is usually restricted to biological treatment residuals.

Zero or Alternate Discharge Treatment Options ***8.2.5***

This section discusses zero discharge wastewater treatment and disposal methods. In this context, zero discharge refers to any wastewater disposal method other than indirect discharge to a POTW or direct discharge to a surface water. A common zero discharge method employed by CWT facilities that generate small volumes of wastewater is transportation of the wastewater to an off-site disposal facility such as another CWT facility. Other methods discussed below include deep well disposal, evaporation, and solidification.

Deep well disposal consists of pumping the wastewater into a disposal well, that discharges the liquid into a deep aquifer. Normally, these aquifers are thoroughly characterized to insure that they are not hydrogeologically-connected to a drinking water supply. The characterization requires the confirmation of the existence of impervious layers of rock above and below the aquifer. Pretreatment of the wastewater using filtration is often practiced to prevent the plugging of the face of the receiving aquifer.

Traditionally used as a method of sludge dewatering, evaporation (or solar evaporation) also can involve the discharge and ultimate storage of wastewater into a shallow, lined, on-site basin or ditch. Because the system is open to the atmosphere, the degree of evaporation is greatly dependent upon climatic conditions. This option is generally available only to those facilities located in arid regions.

Solidification is a process in which materials, such as fly ash, cement, and lime, are added to the waste to produce a solid. Depending on both the contaminant and binding material, the solidified waste may be disposed of in a landfill or incinerated.

INDUSTRY PRACTICE

EPA has information for 24 CWT facilities not discharging directly to surface waters or POTWs that employ zero and alternate discharge methods. Of those 24 facilities, seven dispose of wastewater by deep well injection, 13 transport wastewater to an off-site commercial or intra-company wastewater treatment facility, two dispose of wastewater by evaporation, one solidifies wastewater and landfills it on-site, and one discharges wastewater to a privately-owned treatment works.

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