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Chemical Aids Manual For Wastewater Treatment Facilities

by

Nancy E. Heim
Bruce E. Burris
Culp/Wesner/Culp
Clean Water Consultants
Santa Ana, California 92707

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EPA Project Officer
Lehn Potter

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INTRODUCTION

PURPOSE OF THE MANUAL

The purpose of this manual is to assist wastewater treatment plant operators in the proper use of commonly used chemicals in wastewater treatment processes. Emphasis has been placed on providing practical guidance on the use of chemicals to overcome temporary operational problems or to upgrade performance without extensive design work or plant modifications. The manual specifically addresses:

- The use of chemicals as a temporary aid in solving operational problems.
- Selection of chemicals to be used in terms of treatment efficiency, cost and other considerations.
- Selecting points for injection of the chemicals.
- Determining proper chemical dosages.
- Sludge considerations associated with chemical additions.
- Identification of equipment for proper feeding and handling of chemicals.
- General information on each chemical including uses, available forms, commercial strength, cost, safety considerations, feeders, storage, handling materials and major manufacturers.

While chemical addition may be helpful in many wastewater treatment processes, it must be recognized that many situations presented in the manual are indications of problems associated with overloading or weaknesses in process control. Short term correction using chemicals may be necessary, but the condition causing the problem also must be corrected. CHEMICALS SHOULD NOT BE USED AS A SUBSTITUTE FOR GOOD PLANT OPERATING PROCEDURES.

Some problems in plant operation may be beyond the ability of the operator to control and are too detailed to be presented adequately in this manual. The operator should learn to identify and define these problems through experience and the use of references provided in this manual. Plant modifications and installation of chemical storage, handling, and feed equipment, as noted in this publication, generally should not be performed by the operator without the aid of a qualified consulting engineer. Most modifications require an engineering analysis of the problem and a detailed engineering design of the change.

MANUAL ORGANIZATION

In order to simplify the manual and maximize its potential use as a reference guide, the manual has been organized into five sections plus an Appendix. The sections may be used independently or in combination depending on the operator's background and need. Each section is preceded by a quick reference index to help the operator locate specific information quickly and easily. Each section is followed by a separate list of references which provide more detailed information relative to that section.

Section 1 — INTRODUCTION

The purpose and organization of the manual, along with an example of the use of the manual are described in this section.

Section 2 — PLANNING AND EVALUATING PLANT EFFECTS

The optimum use and efficiency of many chemicals are interrelated with such factors as wastewater pH and temperature, the point at which the chemical is added in the treatment train, chemical dosage, and the physical operation of the treatment facilities. This section of the manual discusses these factors and provides guidance on planning and evaluating plant effects when chemicals are added to various treatment processes.

Section 3 — SELECTING CHEMICALS FOR USE

This section describes general factors to consider in selecting chemicals including effectiveness, cost, reliability of supply, sludge considerations, compatibility with other treatment processes, and environmental effects.

Section 4 — FEEDING AND HANDLING SYSTEMS

During the decision-making process of which chemical to use, the operator may need information on chemical feeding and handling systems. This section contains basic information on dry, solution and gaseous feed systems as well as special requirements for certain chemicals. Various types of control systems for chemical feeders also are described.

Section 5 — PROBLEMS WHICH CAN BE SOLVED BY CHEMICAL ADDITION

This section of the manual serves primarily as a troubleshooting guide to help identify problems which can be solved by the addition of chemcials. Problems are identified by the treatment process where the problem would occur. A solution is provided for each problem, along with a list of possible chemicals for solving the problem, advantages and disadvantages of each chemical, and potential application points. The section is preceded by an INDEX OF PROBLEMS which serves as quick reference to locating problems with various treatment processes.

Appendix INFORMATION ON CHEMICALS

General information on each chemical is provided in this section, including uses of the chemical, trade names, available forms, commercial strength, feeders, storage, safety considerations, approximate cost, acceptable handling materials, and major chemical manufacturers. For easy reference, the chemicals are arranged in alphabetical order. Because it is not possible or practical to identify all manufacturers of each chemical, the operator is encouraged to add his own local supplier to the list wherever possible.

USE OF THE MANUAL

To give the operator a good basic understanding of the manual and its format, the following provides a simplified, step-by-step example on how the manual might be used.

Example Situation

A 5-mgd trickling filter plant normally uses sodium hypochlorite for disinfection of its effluent. The plant is equipped with a ROTODIP Feeder for application of the sodium hypochlorite. Because the plant is isolated from any large cities, the operator normally stores large quantities (several months' supply) of the disinfectant on-site at the plant to minimize shipping problems and chemical costs. However, the effluent lacks sufficient chlorine residual, even with relatively high chlorine dosages. The operator suspects that the sodium hypochlorite supply may be losing its disinfection power because of long-term storage. As a result, the operator is considering the use of other chemicals for disinfection.

Steps to Problem Solution

1. Using the index to Section 5 (page 104), the operator locates the DISINFECTION process on page 124.

2. The operator turns to page 124 and identifies several possible chemicals which may solve the problem. Examining the advantages and disadvantages of each chemical, the operator notes the following:

- CHLORINE GAS may be feasible but expensive for a plant of this size.

- SODIUM HYPOCHLORITE (as currently being used) is economical for small plants but deteriorates more rapidly than some other chlorine forms.

- CALCIUM HYPOCHLORITE is more stable and has more available chlorine than sodium hypochlorite, and it is economical for small plants.

- CHLORINE DIOXIDE is expensive and must be generated on-site.

- OZONE also is expensive, leaves no residual and must be generated on-site.

3. Upon assessing these advantages and disadvantages, the operator is able to see that it may be possible to use CHLORINE GAS, CALCIUM HYPOCHLORITE, or continue to use SODIUM HYPOCHLORITE with some adjustments in plant operations.

4. Faced with the uncertainty of which chemical to use, the operator checks Section 3 to find out other factors which may influence the choice of chemical. He notes that EFFICIENCY, COST, and RELIABILITY OF SUPPLY will be important considerations.

5. If the operator is unfamiliar with the EFFECTIVENESS aspects of chlorine and chlorine compounds he would refer to Section 2 for more information.

6. To evaluate chemical COSTS, the operator would determine the pounds per day of each chemical required. Referring to the APPENDIX index (Page A-2) the operator checks for more information on each chemical:

CHLORINE	Page A-13
CALCIUM HYPOCHLORITE	Page A-9
SODIUM HYPOCHLORITE	Page A-36

Assuming a 10 mg/l chlorine dosage and a plant flow of 5 mgd, the operator makes the following cost comparison:

CHLORINE

- 10 mg/l x 8.33 x 5 mgd = 417 lb/day

- From page A-13, cost = $195 - $230/ton

- 417 lb/day x ton/2000 lb x $230/ton = $48/day

CALCIUM HYPOCHLORITE (65%)

- $\frac{10 \text{ mg/l} \times 8.33 \times 5 \text{ mgd}}{0.65} = 642 \text{ lb/day}$
- From page A-9, cost = \$0.70/lb
- 642 lb/day x \$0.70/lb = \$449/day

SODIUM HYPOCHLORITE (12%)

- $\frac{10 \text{ mg/l} \times 8.33 \times 5 \text{ mgd}}{0.12 \times 10 \text{ lb/gal}} = 348 \text{ gal/day}$
- From page A-36, cost = \$0.40-\$0.90/gal
- 348 gal/day x \$0.90/gal = \$313/day

NOTE - This is NOT a complete cost comparison and only involves the cost of chemicals. It does not include feeding and handling costs which could make a considerable difference in overall plant costs. For example, chlorine gas itself may be very inexpensive but feeding, handling and storage facilities may make it more expensive than other chlorine forms.

7. Referring to the APPENDIX, the operator identifies and contacts major manufacturers to verify chemical COSTS and the RELIABILITY OF SUPPLY in the local area.

8. Again studying the APPENDIX, the operator notes relevant information on the storage, feeding, handling and safety aspects for each of the chemicals under consideration. In particular, the operator notes the following:

   - CHLORINE -- requires a gas feeder (which the plant does not have) and special safety precautions that will require additional equipment expenditures. He makes a more detailed assessment of chlorine feeders after referring to the text in Section 4.

   - CALCIUM HYPOCHLORITE -- is corrosive and must be stored carefully, but can be fed with a ROTODIP Feeder -- the same feeder already being used for sodium hypochlorite. To make sure there is not other important information on feeding calcium hypochlorite, the operator checks Section 4.

9. Based on the information gathered by the operator, a reasonable comparison between the alternative chemicals has been made taking into account:

   - Cost
   - Effectiveness

- Safety
- Storage
- Feeders
- Reliability of Supply

Since not all of these factors will be equally important, the operator must consider circumstances specific to the treatment plant before making a final choice on the chemical to use.

SECTION 2

PLANNING AND EVALUATING PLANT EFFECTS

SECTION 2

PLANNING AND EVALUATING PLANT EFFECTS

QUICK REFERENCE INDEX OF SUBJECTS

SECTION 2

PLANNING AND EVALUATING PLANT EFFECTS

Most often, the use of chemicals in wastewater treatment is related to one or more of the following major applications:

- Disinfection
- Coagulation and flocculation
- Precipitation of dissolved substances
- pH adjustment
- Sludge conditioning

Because there are large variations in wastewater composition from plant to plant, it is impossible to present precise predictions on how a particular plant or process will be affected by the addition of chemicals to the treatment scheme. The optimum use and efficiency of many chemicals is interrelated with such factors as wastewater pH and temperature, the point at which the chemical is added in the treatment train, chemical dosage, and the physical operation of the treatment facilities.

This section of the manual will address these factors and provide guidance on planning and evaluating plant effects when chemicals are added to various treatment processes. THE OPERATOR IS REMINDED THAT CONSIDERATION MUST BE GIVEN TO THE EFFECTS OF CHEMICAL ADDITION ON SUBSEQUENT TREATMENT PROCESSES AND OVERALL PLANT OPERATIONS. IF THE OPERATOR IS NOT COMPLETELY FAMILIAR WITH TECHNIQUES DESCRIBED IN THIS SECTION, THE SERVICES OF A CONSULTANT ARE HIGHLY RECOMMENDED.

TREATMENT EFFICIENCIES

Disinfection

Although there are other chemicals which can be used for disinfection, only the most commonly used chemicals will be discussed, including liquid-gas chlorine, hypochlorites, chlorine dioxide and ozone.

When chlorine is added to water, several reactions occur which result in the formation of hypochlorous acid (HOCl) and hypochlorite ions (OCl^-). Table 1 shows the distribution of these two species at various pH values. As illustrated in the table, low pH values favor the formation of HOCl which is a much more effective germicide than OCl^-. Because liquid-gas chlorine tends to lower the pH, and hypochlorites such as sodium hypochlorite and calcium hypochlorite tend to raise pH, the residual formed by liquid-gas chlorine would be a more effective germicide in poorly buffered waters. There are four major factors which may have an adverse effect on the germicidal efficiency of chlorine:

- The presence of ammonia and organic nitrogen
- High pH (above 7.5)
- Low wastewater temperature
- Insufficient chlorine dosage or contact time.

In practice, the germicidal efficiency of chlorine dioxide in the neutral pH range is about the same as that of chlorine. However, the efficiency of chlorine dioxide is increased when the pH is raised above 8.5.

Ozone is a rapid and highly effective disinfectant capable of destroying bacteria as well as viruses. Unlike chlorine, the effectiveness of ozone is relatively independent of pH and temperature.

TABLE 1

Distribution of HOCl and OCl^- with pH

pH	Percentage of Total Free Chlorine as: HOCl	OCl^-
6.0	96.8	3.2
7.0	75.2	24.8
7.5	49.1	50.9
8.0	23.2	76.8
9.0	2.9	97.1

Coagulation

The chemicals most commonly used as coagulants in wastewater treatment are lime {$Ca(OH)_2$}, alum {$Al_2(SO_4)_3 \cdot 14H_2O$}, ferric chloride {$FeCl_3$}, ferrous sulfate {$FeSO_4$}, ferric sulfate {$Fe_2(SO_4)_3$}, and sodium aluminate {$Na_2Al_2O_4 \cdot 3H_2O$}. Coagulant aids most often used include polymers and bentonite clay. These coagulants and coagulant aids are added to wastewaters primarily to enhance removal of suspended solids and phosphorus, but also to reduce heavy metal concentrations and improve disinfection. The choice of specific coagulants and coagulant aids depends on the nature of the solid-liquid system to be separated, and particularly on the pH of the wastewater.

Proper choice of chemical coagulants can be best determined by laboratory testing. This testing should be extensive enough to permit evaluation of different chemicals and combinations of chemicals and to determine an approximate dosage. Laboratory test results usually cannot be applied directly to the actual plant situation, since plant hydraulics are not simulated in the laboratory. The chemical or combination of chemicals which appears most favorable in the laboratory should be further evaluated in a pilot-scale test.

For enhanced suspended solids and BOD removal, coagulants can be added to primary or secondary clarifiers. Table 2 shows clarifier performance before and after chemical addition, and illustrates considerable variation in BOD and SS removals. However, the greatest improvement resulting from polymer addition occurs where the existing clarifier performance is poor. The variations shown make it difficult to project the expected improvement due to chemical addition at a specific treatment plant. Pilot plant tests or full scale plant trials generally are necessary for such predictions to be made accurately. As guidance, however, Table 3 provides a summary of typical removal efficiencies for both activated sludge and trickling filter plants when polymer is added to the primary clarifier.

Lime addition to primary clarifiers for phosphorus removal has been used in many locations. In all cases, significant improvements in both SS and BOD removal also were noted, as shown in Table 4.

In many cases where chemicals are added to secondary processes, the principal goal has been phosphorus removal. Very often the addition of iron and aluminum salts used for phosphorus removal can also improve greatly the performance of the secondary clarifier depending on the dosage applied, point of chemical addition and the flocculating characteristics of the system. Several examples of typical clarifier performance before and after chemical addition are shown in Table 5.

When the biological and chemical processes are combined, the coagulant may be added either ahead of the primary clarifier or directly to the aeration tank of an activated sludge system. When added ahead of the primary clarifier, alum, iron or lime may be used; when added directly to the aeration tank, iron or alum salts are used. In the approach which separates the physical-chemical processes from biological treatment, any of the above coagulants may be added to the secondary effluent with subsequent settling downstream.

Systems in which chemical coagulation is combined with the biological process are capable of phosphorus removal rates of 75-85 percent. This would be equivalent to effluent phosphorus concentration of 1-2 mg/l. Subsequent filtration of this effluent may reduce the phosphorus concentrations to 0.5 mg/l if the coagulant dose is proper. In systems using chemical coagulation of secondary effluent as a separate process, lower phosphorus concentrations on the order of 0.05 mg/l can be achieved. More detailed information on the use of chemicals solely for phosphorus removal is described in the Process

TABLE 2

Effect of Chemical Treatment on Primary Clarifier Performance

Type and Amount of Chemical Added	Performance Preceding Chemical Treatment				Weight Ratio of WAS/PS[1]	Performance After Chemical Treatment				Weight Ratio of WAS/PS[1]
	SS Removed		BOD Removed			SS Removed		BOD Removed		
	mg/l	percent	mg/l	percent		mg/l	percent	mg/l	percent	
Purifloc A21 (0.95 mg/l)	13	12	28	26	0.61	75	65	46	48	0.31
DOW SA1193 (0.2 mg/l)	13	12	28	26	0.61	72	55	36	37	0.41
Purifloc A21 (1 mg/l)	157	43	82	23	--	281	76	127	33	--
DOW - SA1193 (0.25 mg/l)	120	47	--	--	0.8	151	61	--	--	0.46
$FeCl_3$ + NaOH + Purifloc A23(0.3 mg/l)	230	82	111	31	--	379	79	74	39	--
$FeCl_3$ + NaOH + Purifloc A23(0.3 mg/l)	104	49.7	83	43.8	--	173	76.8	105	57.8	--
Purifloc A23 (0.25 mg/l)	52	31	47	31	1.44	80	51	58	46.4	0.67
$FeCl_3$ + Purifloc A23	93	33	53	34	--	196	74	102	61	--
Purifloc A21 (0.74 mg/l)	--	50	--	36	--	--	63	--	45	--
Purifloc A21M (1.14 mg/l)	--	43	--	--	--	--	63	--	--	--
$FeCl_3$ (20 mg/l) + Purifloc A23 (0.3 mg/l)	1	1.3	--	--	--	38	24.4	--	--	--
$FeCl_3$(15-18 mg/l Fe^{3+}) + Purifloc A23 (0.5 mg/l)	--	35.3	--	19.1	--	--	63.6	--	54.5	--
$FeCl_3$(20-25 mg/l Fe^{3+}) + Purifloc A23 (0.4 mg/l)	--	--	--	--	--	41	74.0	115	57.4	--
$FeCl_3$(22 mg/l Fe^{3+}) + Purifloc A23 (0.5 mg/l)	--	--	--	--	--	61.7	84	226	38	--

TABLE 2 (Continued)

Type and Amount of Chemical Added	Performance Preceding Chemical Treatment				Ration of WAS/PS[1]	Performance After Chemical Treatment				Ratio of WAS/PS[1]
	SS Removed		BOD Removed			SS Removed		BOD Removed		
	mg/1	percent	mg/1	percent		mg/1	percent	mg/1	percent	
Alum (15-20 mg/1 Al^{3+}) + Purifloc A23 (0.5 mg/1)	--	--	--	--	--	134.8	70	423.9	32	--
Alum (90 mg/1) + Polyelectrolyte (0.4 mg/1)	--	--	--	--	--	157	84	66	61.1	--
Alum (110 mg/1) + Polyelectrolyte (0.35 mg/1)	--	--	--	--	--	204	74	126	71	--

[1]WAS -- Waste activated sludge

PS -- Primary sludge

TABLE 3

Polymer Addition to Primary Clarifier

Treatment Process	Coagulant	Dose	Primary Clarifier: Percent Removal Before Polymer Addition		Primary Clarifier: Percent Removal After Polymer Addition		Total Plant: Percent Removal Before Polymer Addition		Total Plant: Percent Removal After Polymer Addition	
		mg/l	BOD	SS	BOD	SS	BOD	SS	BOD	SS
Activated Sludge	Purifloc A-21	1	26	--	48	--	83	--	90	--
Trickling Filter	Purifloc A-21	1	23	43	33	76	79	72	85	84
Activated Sludge	Purifloc A-23	0.21	31	31	46	51	79	85	83	89

TABLE 4

Lime Addition to Primary Clarifier

Location	Lime Added	Percent Removal in Primary Before Lime Addition		Percent Removal in Primary After Lime Addition		Remarks
	mg/l CaO	BOD	SS	BOD	SS	
Duluth,	75	50	70	60	75	--
Minnesota	125	55	70	75	90	--
Rochester, New York	100	--	--	50	80-90	Jar tests
Lebanon, Ohio	145	--	--	66	74	Pilot plant
Richard Hill, Ontario	175	21	37	71	77	Full-scale
Central Contra	378	46	71	74	79	Full-scale
Costa, Calif.	303	37	71	69	76	Full-scale

TABLE 5

Effect of Chemical Treatment on Secondary Clarifier Performance

Location	Type of Plant	Location of Chemical Addition	Chemical and Dosage	Effluent BOD_5 (or COD) Before Chemical Addition mg/l	Effluent SS Before Chemical Addition mg/l	Effluent BOD_5 (or COD) After Chemical Addition mg/l	Effluent SS After Chemical Addition mg/l	Total Phos. Removal percent
Richardson, Texas	Trickling filter std. rate	Before final settling	Al/P Mole Dosage 1.6/1	20	15	<5	<7	95
Chapel Hill, North Carolina	Trickling filter high rate	Before final settling	Al/P Mole Dosage 1.6/1	44	64	15	34	82
Pennsylvania State	Conventional activated sludge	Aerator effluent	Al/P wt. Ratio 3/1	13	26	9	22	86
Cincinnati, Ohio	Activated sludge (100 gpd pilot)	Aerator	10 mg/l Al^{3+}	(89%)[1]	(95%)[1]	(92%)[1]	(96%)[1]	94
Lebanon, Ohio	Activated sludge (0.11 mgd pilot)	Final clarifier	Add lime to raise pH=9.4-10.9	—	43.5	—	16.5	—
Minneapolis, Minnesota	Trickling filter low rate	Before final settling	720 mg/l $Ca(OH)_2$	83	—	27	—	86
Madison, Wisconsin	—	Before final settling	200 mg/l Alum	8–29	—	1.8–2.9	—	98.7
University Park, Pennsylvania	Trickling filter	Before final settling	160 mg/l Alum	18	31	6	19	96.4
			46 mg/l $Na_2Al_2O_4$	61	95	23	8	93.4
Bloomington, Illinois	Activated sludge	Aerator	33.9 mg/l Fe^{3+} +0.7 mg/l Purifloc – A23	8.8	12.7	5.0	8.6	—
	Trickling filter	Before final settling	25-30 mg/l Fe^{3+} +0.5 mg/l Purifloc – A23	13.0	49.6	3.3	16.0	—
Blue Plains,[2] Washington, D.C.	Modified Activated sludge	Before final settling	26 mg/l Alum	47	48	40	43	—
			50 mg/l Alum	38	39	27	36	—
			60 mg/l Alum	68	53	25	36	—
			80 mg/l Alum	46	41	41	31	—
			89 mg/l Alum	50	57	30	31	—
Sandusky, Ohio	Conventional activated sludge	Aerator	50 mg/l Alum	9	24	2	15	80
Michigan City, Indiana	Conventional activated sludge	Aerator	60 mg/l Alum	13	19	9	7	92.2
Guelph, Ontario	Conventional activated sludge	Aerator	100 mg/l Alum	26	38	14	22	87
Palmetto, Florida	Trickling filter	Before final settling	45 mg/l Alum	—	30-40	—	10	—

[1]Percent removal.

[2]Data are monthly average.

Design Manual for Phosphorus Removal (Reference 4). The manual provides a comprehensive discussion of phosphorus removal methods involving chemical precipitation, design information, and operating procedures aimed at removal of phosphorus to comply with water quality standards.

Precipitation of Heavy Metals

Because many heavy metals form insoluble hydroxides at pH 11, lime coagulation results in a significant reduction in metal concentrations. Except for mercury, cadmium, and selenium, lime coagulation at pH 11 can remove at least 90 percent of most heavy metals. Higher removal efficiencies occur when lime coagulation is followed by filtration.

Sludge Conditioning

In most cases, it is not practical to dewater sludge, especially secondary sludge, without conditioning. The conditioning step can take the form of either a chemical or a physical process. Chemical methods include the use of organic and inorganic flocculating chemicals as well as chlorine oxidation. The physical processes include the use of heat and freezing to change the characteristics of the sludge. Only the use of chemicals for conditioning will be addressed in this section, since the physical processes are outside the scope of this manual.

The most common chemical conditioning method is the use of ferric chloride alone or in combination with lime. Lime alone is a fairly popular conditioner for raw primary sludge and ferric chloride alone has been used for conditioning activated sludges. Lime treatment to a pH of 10.4 or above has the added advantage of providing a significant degree of disinfection of the sludge. Other inorganic chemicals used include ferrous salts and aluminum salts.

Organic polymer coagulants and coagulant aids have been developed in the past 20 years and are rapidly gaining acceptance for sludge conditioning since they accelerate the removal of liquid from sludge particles during dewatering. There are three basic types of these polymers:

1. Anionic (negative charge) - serve as coagulant aids to inorganic Al^{+++} and Fe^{+++} coagulants by increasing the rate of flocculation, size, and toughness of particles. Because of improved flocculation with anionic polymers, smaller dosages of alum or other primary coagulants usually are required.

2. Cationic (positive charge) - serve as primary coagulants alone or in combination with inorganic coagulants such as alum, or even with other anionic and nonionic polymers. When used alone, strongly cationic polymers react much more slowly than inorganic coagulants, and therefore require longer mixing times.

3. Nonionic (equal amounts of positively and negatively charged groups in monomers) - serve as coagulant aids in a manner similar to that of both anionic and cationic polymers. Nonionic polymers are generally

reliable coagulant aids since treatment is usually less sensitive to minor overdoses.

Usually, cationic polymers have the greatest application to waste sludge dewatering. In some cases, cationic polymers and ferric salts together have been used effectively. For tertiary waste treatment sludges containing aluminum, ferric, or lime sludges, anionic polymers are often effective.

With proper chemical conditioning, the sludge moisture can be reduced from 90 - 96 percent to 64 - 80 percent, depending on the nature of the solids to be dewatered. The conditioning step greatly increases the rate of dewatering by changing the chemical and physical nature of the sludge. However, because of the differences in sludges and their conditioning properties, it is common practice to run either a Buchner funnel or a filter leaf test to determine the best flocculating chemical. These tests help to estimate the rate at which the solids can be filtered and the final moisture content the cake will attain. Various chemicals and combinations of chemicals can be tried in the laboratory to establish the full-scale chemical dosage. Laboratory tests generally will define the chemical dosage and operating characteristics of a dewatering unit within 15 percent of the range established for the full-sized facility.

The use of polymers and other conditioning chemicals has allowed more sludge types to be dewatered more efficiently by centrifuges, vacuum filters and pressure filters. Table 6 shows typical solid bowl centrifuge sludge cake characteristics and the effect of various polymer dosages on percent solids recovery. The degree of solids recovery can be controlled over wide ranges depending on the amount of coagulating chemical applied. When polymers are used, however, a wetter sludge cake usually is produced because of the additional fines capture. Table 7 summarizes design and performance data for vacuum filtration of different types of sludges using different chemical conditioners. Table 8 summarizes similar data for pressure filtration using various conditioners.

SELECTING POINTS FOR CHEMICAL ADDITION

In many applications, proper points for chemical addition are well defined and easily recognized by the operator. For example, wastewater disinfection is the last step in a secondary plant, and disinfectants are added directly to the secondary effluent prior to discharge from the plant. On the other extreme, it is generally more difficult for an operator to determine the best point for adding coagulants to enhance suspended solids, BOD, or phosphorus removal. The remainder of this section will describe some of the more important factors to consider in selecting points for coagulant addition. Section 5 of this manual provides more general guidance on application points for other chemicals and processes used in wastewater treatment.

TABLE 6

Typical Solid Bowl Centrifuge Performance

Sludge Type	Design Assumption	Percent Solids to Centrifuge	Percent Solids Recovery
Raw or digested primary	no conditioning	28-35	70-90
Raw or digested primary, plus trickling filter humus	5-15 lbs polymer/ton	20-30	80-95
	no conditioning		60-75
Raw or digested primary, plus activated sludge	5-20 lbs polymer/ton	15-30	80-95
	no conditioning		50-65
Activated sludge	5-10 lbs polymer/ton	8-9	80-85
Oxygen activated sludge	3-5 lbs polymer/ton	8-10	80-85
High-lime sludges	no conditioning	50-55	90
Lime classification	no conditioning	40	70

TABLE 7

Typical Design and Performance Data for Vacuum Filters

Sludge Type	Design Assumptions	Typical Loading Rates, (psf/hr)	Percent Solids to VF	Percent Solids VF Cake
Primary	Thickened to 10% solids Polymer conditioned	8-10	10	25-38
Primary + $FeCl_3$	85 mg/l $FeCl_3$ dose Lime conditioning Thickening to 2.5% solids	1.0-2.0	2.5	15-20
Primary + low lime	300 mg/l lime dose Polymer conditioned Thickened to 15% solids	6	15	32-35
Primary + high lime	600 mg/l lime dose Polymer conditioned Thickened to 15% solids	10	15	28-32
Primary + WAS	Thickened to 8% solids Polymer conditioned	4-5	8	16-25
Primary + (WAS + $FeCl_3$)	Thickened to 8% solids $FeCl_3$ and lime conditioned	3	8	20
(Primary + $FeCl_3$) + WAS	Thickened primary sludge to 2.5% Flotation thickened WAS to 5% Dewater blended sludges	1.5	3.5	15-20
Waste activated sludge (WAS)	Thickened to 5% solids Polymer conditioned	2.5-3.5	5	15
WAS + $FeCl_3$	Thickened to 5% solids Lime + $FeCl_3$ conditioned	1.5-2.0	5	15
Digested primary	Thickened to 8-10% solids Polymer conditioned	7-8	8-10	25-38
Digested primary + WAS	Thickened to 6-8% solids Polymer conditioned	3.5-6	6-8	14-22
Digested primary + (WAS + $FeCl_3$)	Thickened to 6-8% solids $FeCl_3$ + lime conditioned	2.5-3	6-8	16-18
Tertiary alum	Diatomaceous earth precoat	0.4	0.6-0.8	15-20

TABLE 8

Typical Performance Data for Pressure Filters

Sludge Type	Sludge Conditioning	Typical Cycle Length (hrs)	Percent Solids to Pressure Filter	Percent Solids Filter Cake
Primary	5% $FeCl_3$, 10% Lime	2	5	45
	100% Ash	1.5		50
Primary + $FeCl_3$	10% Lime (200 lb/ton)	4	4*	40
Primary + 2 stage high lime	None	1.5	7.5	50
Primary + WAS	5% $FeCl_3$, 10% Lime	2.5	8*	45
	150% Ash	2.0		50
Primary + (WAS + $FeCl_3$)	5% $FeCl_3$, 10% Lime	3	8*	45
(Primary + $FeCl_3$) + WAS	10% Lime	4	3.5*	40
WAS	7.5% $FeCl_3$, 15% Lime	2.5	5*	45
	250% Ash	2.0		50
WAS + $FeCl_3$	5% $FeCl_3$, 10% Lime	3.5	5*	45
Digested primary	6% $FeCl_3$, 30% Lime	2	8	40
Digested primary + WAS	5% $FeCl_3$, 10% Lime	2	6-8*	45
	100% Ash	1.5		50
Digested primary + (WAS + $FeCl_3$)	5% $FeCl_3$, 10% Lime	3	6-8*	40
Tertiary alum	10% Lime	6	4*	35
Tertiary low lime	None	1.5	8*	55

* Thickening used to achieve this solids concentration.

Chemical Addition for Increased SS and BOD Removal

The most favorable point for addition of chemical coagulants and flocculants may be influenced by the form in which phosphorus is present. Raw sewage in primary tanks, for example, usually contains polyphosphates which are later broken down to orthophosphate by biological treatment. Polyphosphates in relatively high concentrations (more than 1 mg/l of P_2O_5) are capable of interfering with coagulation and sedimentation. Orthophosphate compounds produce no interference with normal coagulation and sedimentation. If the amount of polyphosphate interference in the primary state is great, then chemical addition should follow conversion of this material to orthophosphate.

Adding chemicals to the primary clarifier is an effective upgrading procedure for a secondary plant when:

1. Wastewater flow is intermittent or varies greatly.
2. Space available for additional clarification facilities is limited.
3. Industrial wastes that would interfere with biological treatment are present.
4. Plant is hydraulically and/or organically overloaded.
5. Improvements in existing treatment performance are required as an interim measure before the addition of new facilities.

When considering the addition of chemicals to primary clarifiers, IT IS IMPORTANT TO BE AWARE OF THE EFFECT ON SUBSEQUENT TREATMENT UNITS. The increased removal of SS and BOD from raw wastewater can affect the downstream biological process in a number of ways. If the BOD load to the aeration basin falls below 0.25 to 0.35 lb BOD/lb MLVSS/day for long periods of time, nitrification can develop in the aeration basin. This can reduce the total oxygen demand of the effluent, but will cause an added oxygen demand on the aeration facility because the oxidation of one pound of ammonia nitrogen requires about 4.6 pounds of oxygen.

A lower aeration basin loading will usually require more careful sludge management to ensure stable operation of the aeration basin. However, the quantity of excess activated sludge generated under these reduced loading conditions will be much less than that generated under normal loading conditions. This may be considered an added advantage of adding chemicals to the primary clarifier, if the additional fines captured chemically do not seriously degrade the quality of the primary sludge.

Whenever possible, some flexibility should be built into the plant design to allow for different points of chemical addition, since this aspect may severely affect costs and process efficiencies. There may be some question as to where coagulants such as alum or iron salts should be added to the treatment scheme when improved BOD, suspended solids and phosphorus removal is the primary goal. As a general rule, where no flash mix tanks are provided, alum should be added at a point where turbulence is present to insure rapid mixing. Addition of alum directly to an aeration tank will not adversely affect the biological process, but some build-up of aluminum compounds in the recirculated sludge may occur.

Some studies have indicated that the turbidity of the final plant effluent may be increased when alum is added to the aeration system. This may occur when the alum dosage is high enough that it reduces the pH below the optimum pH for good alum flocculation, resulting in an increase in pinfloc in the final effluent.

LIME ADDITION MAY NOT BE FEASIBLE FOR UPGRADING ACTIVATED SLUDGE SECONDARY CLARIFIERS BECAUSE OF THE POTENTIAL ADVERSE EFFECT OF RECIRCULATED LIME SLUDGE ON MIXED LIQUOR MICROBIAL CHARACTERISTICS. Lime addition to either trickling filter or activated sludge secondary clarifiers will require pH adjustment of the effluent before discharge to the receiving waters. Lime addition to primary clarifiers may be used, if consideration is given to controlling the pH within acceptable limits for the subsequent processes, and to changes in sludge characteristics and handling requirements.

The chemical addition of lime or metallic salts at various points in a wastewater treatment plant usually results in increased solids weight and/or sludge volume. Therefore, sludge piping, pumping and process units should be large enough to handle the increased sludge quantities. Sludge considerations associated with the use of chemicals at various points in the treatment process are covered in a later section of this chapter.

Chemical Addition for Phosphorus Removal

As illustrated in Figure 1, there are several points where lime can be added to the treatment scheme for phosphorus removal. Lime may be added before the primary sedimentation tank in a biological treatment plant. Because an excessively high pH would interfere with the biological process, lime addition to the primary sedimentation tank ahead of an activated sludge system is limited to a pH of about 9.0. However, it is not unusual for 2-3 mg/l of phosphorus to remain soluble at this limited pH. Additional phosphorus removal may be achieved by using aluminum or iron addition in the aeration tanks or final sedimentation tank. Another advantage to the use of lime in primary treatment is the increase in organic and suspended solids removal in the primary sedimentation tank. This, in turn, decreases the load on the aeration system.

A second alternative is lime treatment following biological treatment. Phosphorus removal from the secondary effluent assures that there will be adequate phosphorus to meet the needs of the biological floc under aeration. In addition, the biological system breaks down many of the complex phosphates to a form which is more easily removed by chemical treatment. However, pH of the returned sludge could affect biological treatment and should be considered.

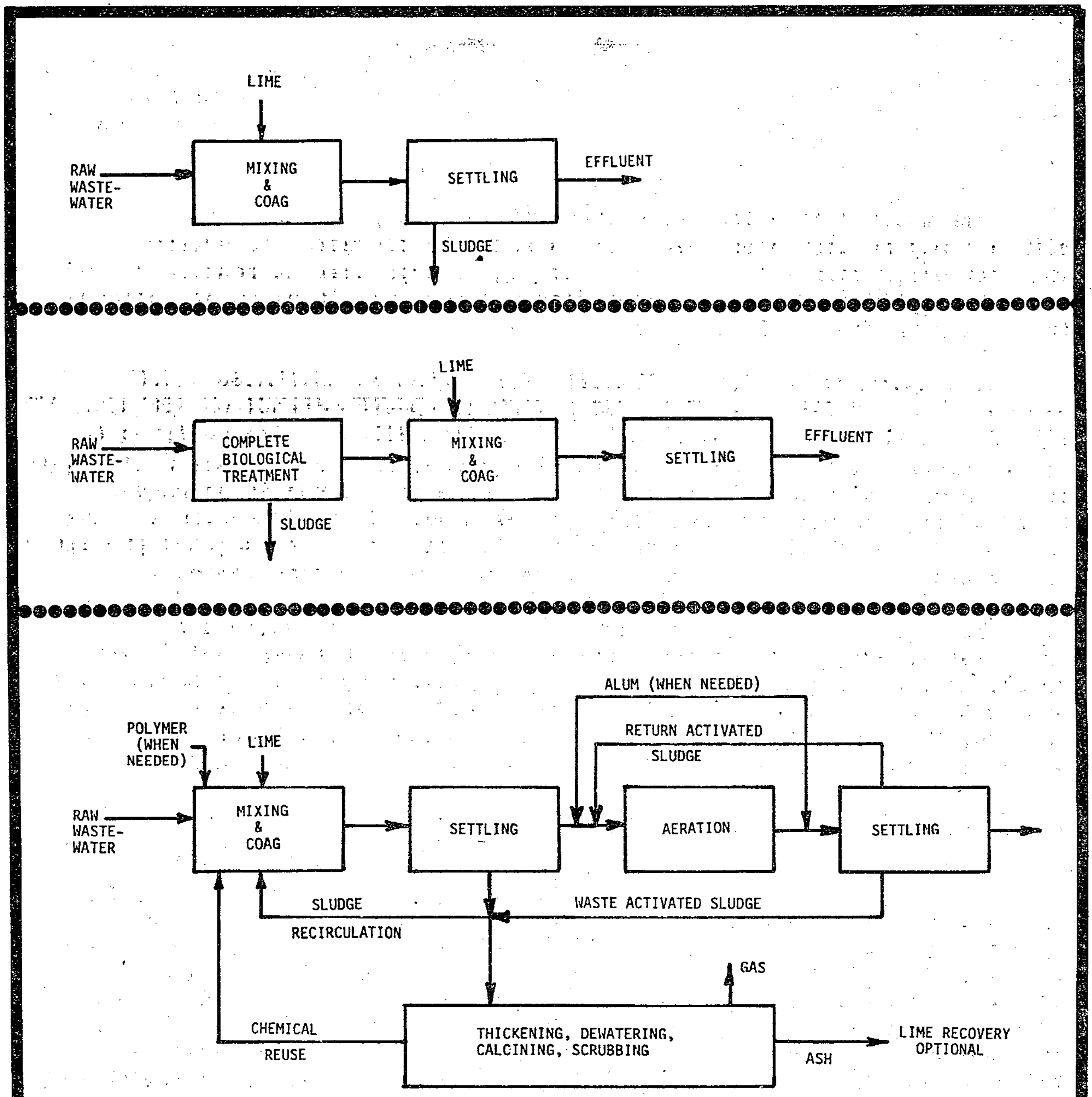


Figure 1. Potential lime application points for phosphorus removal.

Like lime, there are several points where alum may be added to the treatment scheme for phosphorus removal. Alum may be added before the primary settling tank, in the aeration tank, or following aeration before final sedimentation. Alum addition before the primary settling tank removes not only phosphorus, but also removes suspended solids and organics. These removals, however, require an increased alum dosage to make up for the added demand.

Providing alum addition in the activated sludge aeration tank allows the usage of the mixing already provided for that system. The best point of addition for alum in an activated sludge plant may be in the effluent channel of the aeration basin which carries mixed liquor to the final settling basin. The turbulence in this channel provides adequate mixing for the chemical. By adding alum after the biological system, the wastewater is stabilized and the complex phosphates are put into a form more easily removed by the chemical.

GUIDANCE ON CHEMICAL DOSAGES

In order to plan adequately for the addition of chemicals to any treatment process, design considerations should include an estimate of the chemical dosages required. It is not always possible to determine through theoretical calculations and laboratory tests precise dosages for optimum operating conditions at the plant. However, Table 9 provides a summary of testing techniques commonly used for evaluating chemical dosages for various applications. The table identifies the test name, purpose of the test, and a reference describing the test procedure. These tests along with the guidance provided in this section of the manual will help the operator to determine the general ranges for dosages of chemicals commonly used in wastewater treatment.

Disinfectants

The chlorine dosage required for disinfection depends primarily on the quality of the effluent to be treated. Table 10 provides typical dosages of chlorine for various levels of treated wastewater. Each plant's precise requirements, however, also depend on the effluent, the degree of mixing provided, the detention time available in the contact tank or outfall, and the most probable number (MPN) requirements of the regulatory agency.

Chlorine dosage normally is controlled by maintaining a chlorine residual. Regular analyses of bacterial quality should be made and the target residual adjusted depending on the trend of the results.

For ozone disinfection of secondary effluent, typical dosages range from 5 to 15 mg/l for an MPN of 100/100 ml. The amount and characteristics of suspended solids present in the secondary effluent can affect the required ozone dosage.

TABLE 9

Techniques for Evaluation of Chemical Dosages

Test Name	Purpose of Test	Reference for Test Procedures
Jar test	Proper choice of coagulant and optimum coagulant dosage	Ref. 7-Page 256
Buchner Funnel Test	Optimum chemical dosage for sludge dewatering	Ref. 7-Page 258
Filter Leaf Test	Measure effects of chemical dosages, fabrics, and drying time on vacuum filter yield	Ref. 8-Page 109
pH	Measure acidity or basicity of wastewater for proper neutralization and control of chemical additions	Ref. 6-Page 460 Ref. 5-Page 512
Chlorine Residual	Proper control of chlorine dosage	Ref. 6-Page 318 Ref. 5-Page 520
BOD	Control of methanol dosage in denitrification	Ref. 6-Page 543 Ref. 5-Page 518
Turbidity	Control of filter aid dosage	Ref. 6-Page 132
MPN Coliform	Control of chemical addition for disinfection	Ref. 6-Page 875 Ref. 5-Page 524

TABLE 10

Chlorine Dosage Ranges

Wastewater To Be Disinfected	Chlorine Dosage mg/l
Raw sewage	6 to 12
Raw sewage (septic)	12 to 25
Settled sewage	5 to 10
Settled sewage (septic)	12 to 40
Chemical precipitation effluent	3 to 10
Trickling filter effluent	3 to 10
Activated sludge effluent	2 to 8
Sand filter effluent	1 to 5

Coagulants

The quantity of chemical coagulant needed to obtain good coagulation varies with time and from wastewater to wastewater. Aluminum and iron salt requirements for good phosphorus removal are generally proportional to the phosphorus concentration, while lime requirements are determined largely by the alkalinity of the wastewater. Typical coagulant dosages are:

Aluminum sulfate	75 - 250 mg/1
Ferric chloride	45 - 90 mg/1
Lime	200 - 400 mg/1
Sodium Aluminate	75 - 150 mg/1

The lime dosage required to achieve a given pH and turbidity and/or phosphate removal is primarily a function of the wastewater alkalinity and is relatively independent of the influent phosphorus concentration. In general, phosphate removal increases with increasing pH. Essentially all orthophosphate is converted to the insoluble form at pH greater than 9.5. The actual pH that will be required to precipitate a given amount of phosphate, and the amount of lime addition that will be required to raise the pH to the desired level will vary with the specific wastewater composition. These parameters should be determined by laboratory jar tests (See Ref. 7, page 256). Figure 2 illustrates the relationship between alkalinity and the lime dosage required to achieve a pH of 11. With high alkalinity wastewater, a pH of 9.5 to 10 can result in excellent phosphorus removal. Unless a high pH is used, waters with low alkalinity (150 mg/1 or less) form a poorly settleable floc.

It should be noted, however, that lime precipitation of phosphorus may require filtration to insure continuous compliance with effluent requirements. Even at a process pH as high as 11.4, high residual phosphorus may appear in the effluent. Although high pH values insure that virtually all phosphorus is insolubilized, effluent total phosphorus is determined by suspended solids removal efficiency. Where the floc is difficult to settle, filtration can be used to provide the necessary SS and phosphorus removal.

The starting point for the determination of chemical dosages for alum and other mineral precipitants can be based on phosphorus removal efficiencies and side reactions. Figure 3 illustrates typical phosphorus reductions with varying dosages of alum. Since the optimum dosages cannot be calculated readily because of the complexity of the reactions involved, the laboratory jar test should be used to determine actual chemical requirements.

Dosage requirements for sodium aluminate are similar to alum. In general, dosages in the range of 75 to 150 mg/1 will be required. In wastewater treatment sodium aluminate dosage more often is determined by phosphorus removal requirements than by suspended solids considerations.

Because iron salts react with the natural alkalinity of the wastewater, the dosage requirements for optimum coagulation using ferric chloride or

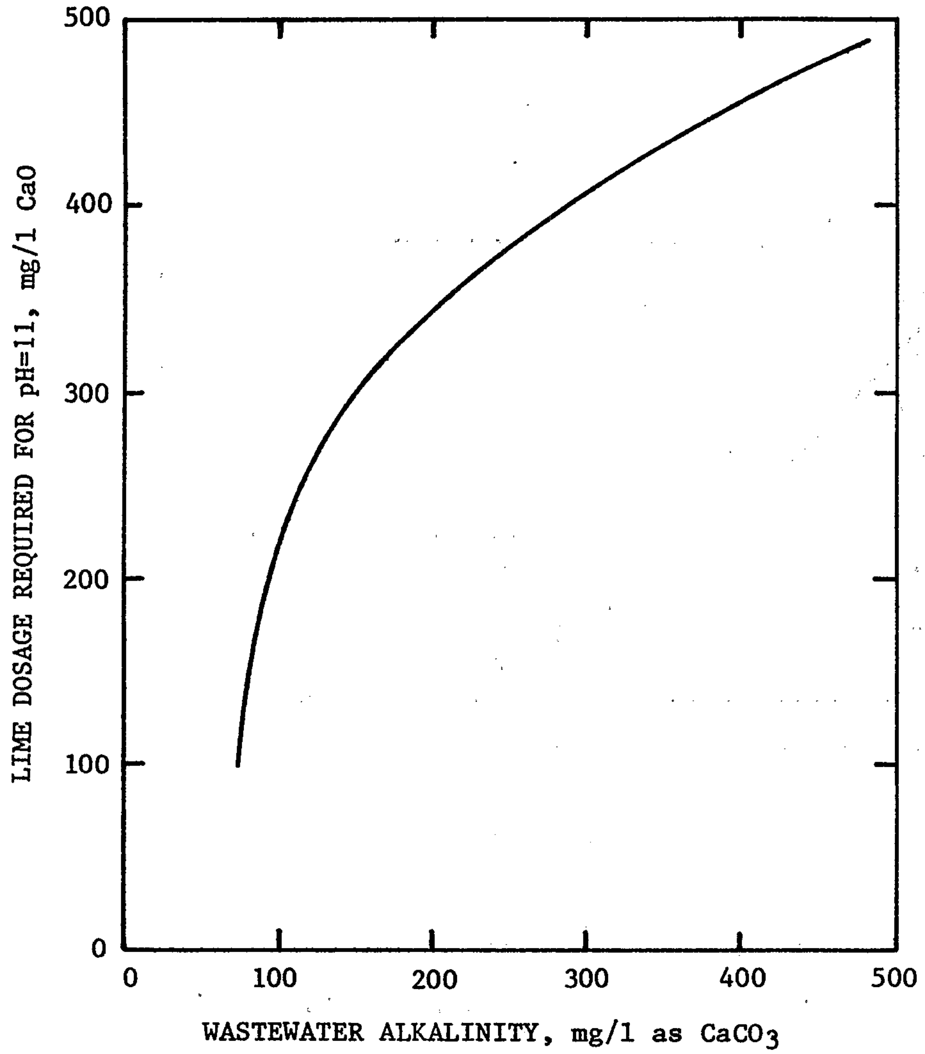


Figure 2. Lime dosage as related to wastewater alkalinity.

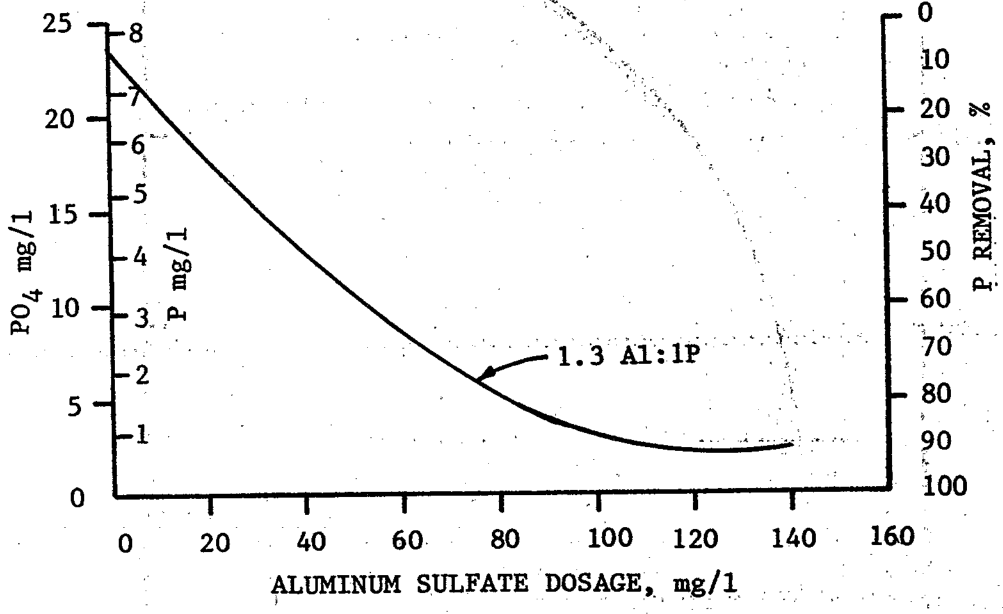


Figure 3. Typical phosphorus reduction with alum.

ferric sulfate may be in excess of theoretical levels. If natural alkalinity is not sufficient it may be necessary to add alkalinity in forms such as lime or soda ash to the wastewater. In addition, the use of iron salts will result in some pH depression in the wastewater. This effect will vary with coagulant dosage and wastewater characteristics. As with the other coagulants discussed in this section, optimum dosages are best determined by laboratory jar tests.

Coagulant Aids

Coagulant aids or flocculants are often used to enhance the efficiency of coagulants. Typical dosage ranges for various coagulant aids are shown below; however, jar testing is recommended to determine optimum dosage.

Bentonite	3 - 20 mg/1
Activated silica	5 - 25 mg/1 (as (SiO_2)
Polymer	0.1 - 0.25 mg/1

Caution should be exercised in using coagulant aids, particularly polymer, since overdosing can restabilize solids and make them very difficult to settle out.

Filter Aids

A major element in optimizing filter performance is the use of an appropriate amount of filter aid (polymer and/or alum).

The amount of filter aid needed increases with lower water temperature, high flow rates through the filters, and higher applied water turbidities. The optimum dosage of filter aid is that which causes the maximum desired filter headloss to be reached just as turbidity breakthrough is about to occur. Too much filter aid shortens the length of filter runs, and too little will allow turbidity breakthrough before the maximum allowable headloss is reached.

When lime is the primary coagulant, it is usually desirable to use some alum (5 to 20 mg/1) as a filter aid even when a polymer is used. When used as a filter aid, typical polymer dosages may range from 0.01 to 0.1 mg/1 depending on turbidity tests of the effluent.

pH Adjustment

One of the most common types of chemical treatment used in wastewater treatment plants is pH adjustment. Wastewaters that are highly acidic or highly alkaline are objectionable in collection systems, treatment plants, and natural streams. pH adjustment is simply the raising or lowering of a pH to a more desirable value by the addition of chemicals.

Alkaline reagents used to treat acidic wastes vary in the quantity of acid they are capable of neutralizing. For comparison each alkali can be assigned a "basicity factor." This factor is the weight of a specific alkali equivalent in acid neutralizing power to a unit weight of calcium oxide (CaO). Basicity factors for the more common alkaline reagents are shown in Table 11. To use Table 11, the neutralizing capacity as well as solubility of the chemical must be considered when comparing alkaline reagents. Also, there is no direct relation between pH and acidity. In order to adjust the pH of an acidic wastewater, a titration curve must be constructed.(See Ref. 6) The acidities, as mg/1 $CaCO_3$, are determined from the titration curve for any desired pH level. Finally, to determine the amount of base required to neutralize the wastewater to a pH of 7.0, the acidity, as mg/1 $CaCO_3$, at the pH 7.0 endpoint must be known. The concentration factors for the various alkaline reagents shown in Table 11 can then be used to design the chemical feed system.

In some cases, it may become necessary to adjust the pH of a wastewater stream downward. Discharge of effluents with pH greater than 8.5 is generally undesirable and in many cases not allowed. To lower the pH, carbon dioxide or acid may be added to the wastewater. As in the case of acid neutralization, a titration curve is necessary to determine the acid requirements for neutralizing alkalinity. To neutralize 1.0 mg/1 of alkalinity the dosages of 100 percent acid required would be:

Sulfuric Acid (H_2SO_4)	0.98 mg/1
Hydrochloric Acid (HCl)	0.72 mg/1
Nitric Acid (HNO_3)	0.63 mg/1

Because these acids are available in different strengths, these figures would need to be adjusted by a dilution factor depending on acid strength. (Table 11).

Sludge Conditioning

The most common chemical conditioning method for sludge is the use of inorganic chemicals such as ferric chloride, ferrous salts, lime, or aluminum salts. More recently, organic polymers have been used. Feed rates for chemical conditioning of sludges are extremely variable depending on the process used, nature of the sludge, and type of chemical. Typical ranges for dosages are shown in Table 12.

Because of large variations in sludges and their properties, it is recommended that either a Buchner Funnel or filter leaf test be conducted to determine the best chemical and optimum dosage. These tests are described in Reference 7, page 258 and Reference 8, page 109, respectively. Through the use of these tests, various chemicals and combinations of chemicals can be tried in the laboratory to establish the full-scale chemical dosages. Laboratory tests generally will define the chemical dosage and operating characteristics of a dewatering unit within 15 percent of the range established for the full-sized facility.

TABLE 11

Neutralization Factors for Common Alkaline and Acid Reagents

Chemical	Formula	To Neutralize one mg/1 Acidity or Alkalinity (Expressed as $CaCO_3$) Requires: (mg/1)	Neutralization Factor, Assuming 100% Purity of All Compounds
			Basicity
Calcium carbonate	$CaCO_3$	1.0	1.0/0.56 = 1.786
Calcium oxide	CaO	0.560	0.56/0.56 = 1.000
Calcium hydroxide	$Ca(OH)_2$	0.740	0.74/0.56 = 1.321
Magnesium oxide	MgO	0.403	0.403/0.56 = 0.720
Magnesium hydroxide	$Mg(OH)_2$	0.583	0.583/0.56 = 1.041
Dolomitic quicklime	$[(CaO)_{0.6}(MgO)_{0.4}]$	0.497	0.497/0.56 = 0.888
Dolomitic hydrated lime	$\{[Ca(OH)_2]_{0.6}[Mg(OH)_2]_{0.4}\}$	0.677	0.677/0.56 = 1.209
Sodium hydroxide	$NaOH$	0.799	0.799/0.56 = 1.427
Sodium carbonate	Na_2CO_3	1.059	1.059/0.56 = 1.891
			Acidity
Sulfuric acid	H_2SO_4	0.98	0.98/0.56 = 1.750
Hydrochloric acid	HCl	0.72	0.72/0.56 = 1.285
Nitric acid	HNO_3	0.63	0.63/0.56 = 1.125

TABLE 12

Typical Chemical Dosages for Sludge Conditioning

Sludge Type	$FeCl_3$, lb/ton dry Solids	Lime, lb CaO/ton dry Solids	Polymer, lb/ton dry Solids
Raw primary + waste activated sludge	40-50	110-300	15-20
Digested primary + waste activated sludge	80-100	160-370	30-40

Chemicals for Other Uses

There are many other chemicals and uses for chemicals in addition to those already presented in this section of the manual. Table 13 provides a summary of uses and average dosages of several chemicals which are commonly used by operators to solve plant problems. As with other chemical uses, the operator must consider the effect of these chemicals on subsequent treatment units.

SLUDGE CONSIDERATIONS

Chemical addition can result in a noticeable difference in overall sludge characteristics. For example, when lime or metallic salts are added to processes in a wastewater treatment plant, a new source of sludge is produced. Depending on where the chemicals are added, increased quantities of primary or secondary sludges may occur. Also, the ratio of primary to secondary sludge will be affected by the use of chemicals. For example, if lime or a mineral salt is added to the primary settling tank, floc production and solids capture will be increased. Because of this increase in primary sludge, the ratio of primary to secondary will be increased. This can result in a noticeable difference in overall sludge characteristics at the treatment plant. As will be explained in the following paragraphs, it is not only the quantity, but also the dewatering characteristics of the sludge that are important.

Sludge Quantities

In chemical precipitation, the pounds of sludge produced per million gallons of wastewater treated can vary considerably. Data on production of sludges for chemical treatment at various points in a secondary plant are summarized in Tables 14 through 16. It is difficult to obtain a true measurement of sludge quantities in laboratory tests because of solids loss during decanting and other procedures. It is possible, however, to estimate the weight of sludge solids by calculating the sum of the expected solids removal and the precipitation products expected from the chemical dosage applied. Jar tests generally can be used to obtain the necessary information for this calculation.

TABLE 13

Chemical Dosage Guide

Chemical	Use	Average Dosage
Activated Carbon	Organics Removal	250-1,800 lb/mil gal
Chlorine	TF flies and ponding	0.5-1.0 mg/l residual
	Bulking sludge	5-60 mg/l
	Breakpoint chlorination (N-removal)	10 mg/l
	Odor control	1 mg/l residual
	Prechlorination	2-5 mg/l
Copper Sulfate	Lagoon algacide	5-10 lb/mil gal
Hydrogen Peroxide	Bulking sludge	50-200 mg/l
	Odor control	1-1.5 mg/l per 1 mg/l H_2S
Methanol	Denitrification	3 methanol: 1 nitrate-N
Ozone	Odor control	1-2 mg/l (by volume of air treated)
Polymer	Scale prevention (in stripping tower)	0.5-5.0 mg/l
	Improve sand drying bed	5-30 lb/dry ton
Sulfur dioxide	Dechlorination	1 mg/l SO_2 per 1 mg/l Cl_2 residual

TABLE 14

Additional Sludges to be Handled with Chemical Treatment Systems:

Primary Treatment for Removal of Phosphorus

Sludge Production Parameter	Conventional Primary	Lime Addition to Primary Influent	Lime Addition to Primary Influent	Alum Addition to Primary Influent*	Fe^{+3} Addition to Primary Influent
Level of chemical addition (mg/1)	0	350-500	800-1600	143-250	25.80
Percent sludge solids					
Mean	5.25	11.1	4.4	1.2	2.25
Range	5.0-5.5	3.0-19.5	2.1-5.5	0.4-2.0	1.0-4.5
1b/mil gal					
Mean	788	5,630	9,567	1,323	2775
Range	600-950	2500-8000	4700-15,000	1200-1545	1400-4500
gal/mil gal					
Mean	4,465	8,924	28,254	23,000	21,922
Range	3,600-5,000	4663-18,000	16,787-38,000	10,000-36,000	9000-38,000

* MW of Alum: $Al_2(SO_4)_3 \cdot 14H_2O = 594$

TABLE 15

Additional Sludge to be Handled with Chemical Treatment Systems:
Mineral Addition to Aeration Basin for Removal of Phosphorus

	Alum Addition to Aeration Basin*		Fe^{3+} Addition to Aeration Basin	
Sludge Production Parameter	Conventional Secondary	With Alum Addition	Conventional Secondary	With Fe^{3+} Addition
Level of chemical addition (mg/l)	0	103-253	0	10-30
Percent sludge solids				
Mean	0.91	1.12	1.2	1.3
Range	0.58-1.4	0.75-2.0	1.0-1.4	1.0-2.2
lb/mil gal				
Mean	672	1,180	1,059	1,705
Range	384-820	744-1,462	218-1,200	1,100-2,035
gal/mil gal				
Mean	9,100	13,477	10,650	18,650
Range	7,250-12,300	7,360-20,000	10,300-11,000	6,000-24,000

* MW of Alum: $Al_2(SO_4)_3 \cdot 14H_2O = 594$

TABLE 16

Additional Sludge to be Handled with Chemical Treatment Systems: Mineral Addition to Secondary Effluent for Removal of Phosphorus

Sludge Production Parameters	Lime Addition	Alum Addition	Fe^{+3} Addition
Level of chemical addition (mg/l)	268-450	200	10-30
Percent sludge solids			
Mean	1.1	1.0	1.0
Range	0.6-1.72	-	-
lb/mil gal			
Mean	4,650	568	507
Range	3,100-6,800	-	175-781
gal/mil gal			
Mean	53,400	6,810	6,080
Range	50,000-63,000	-	2,100-9,400

There are several computation methods available to estimate sludge quantities produced by chemical addition. EPA Technology Transfer Process Design Manual for Phosphorus Removal (Ref. 4) describes several methods and provides detailed procedures for estimating chemical sludge quantities. Other procedures are outlined in EPA Technology Transfer Manual, Physical-Chemical Wastewater Treatment Plant Design (Ref. 10) and are reproduced in Tables 17 through 19 in this manual for easy reference. The basic equations needed to perform the calculations shown in Tables 17 through 19 are as follows:

$$3PO_4^{3-} + 5Ca^{2+} + OH^- \rightarrow Ca_5OH(PO_4)_3\downarrow \quad (1)$$

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

$$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3\downarrow \quad (3)$$

$$CaCO_3 \xrightarrow[\Delta]{1800^\circ F} CaO + CO_2\uparrow \text{ (incineration)} \quad (4)$$

$$CaO + H_2O \rightarrow Ca(OH)_2 \quad (5)$$

$$Al^{3+} + PO_4^{3-} \rightarrow AlPO_4\downarrow \quad (6)$$

$$Al^{3+} + 3OH^- \rightarrow Al(OH)_3\downarrow \quad (7)$$

$$2Al(OH)_3 \xrightarrow[\Delta]{1400^\circ F} Al_2O_3 + 3H_2O \text{ (incineration)} \quad (8)$$

$$Fe^{3+} + PO_4^{3-} \rightarrow FePO_4\downarrow \quad (9)$$

$$Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3\downarrow \quad (10)$$

$$2Fe(OH)_3 \xrightarrow[\Delta]{1400^\circ F} Fe_2O_3 + 3H_2O \text{ (incineration)} \quad (11)$$

$$\Sigma \text{ coagulant in} = \Sigma \text{ coagulant out} \quad (12)$$

Sludge Processability

In every case where chemical treatment is used, there are waste chemical sludges or mixtures of biological and chemical sludges requiring disposal. Many methods of disposal however, involve dewatering the sludge prior to final disposal. The ease with which sludge may be dewatered should be a consideration in chemical selection.

There may be some benefits in the dewatering and drying of biological sludges containing alum. In tertiary treatment, alum and iron coagulants generally produce gelatinous floc which is difficult and expensive to dewater. On the other hand, lime coagulation produces a sludge which is much easier to thicken and dewater. The quantity and nature of organics present in the chemical sludge may alter significantly its dewatering characteristics. For example, the presence of large quantities of activated sludge solids may make the dewatering of lime sludges much more difficult than lime sludge alone.

Methods and equipment ordinarily used in handling and processing biological sludges are generally applicable to chemical sludges or chemical-biological sludge mixtures. Gravity or flotation thickening may be used, and dewatering may be achieved by use of drying beds, lagoons, centrifuges, vacuum filters, filter presses, or horizontal belt filters. The important points to be considered, however, are:

TABLE 17

Estimate of Lime Sludge Quantities

Raw sewage suspended solids	250 mg/l
Raw sewage volatile suspended solids	150 mg/l
Raw sewage PO_4^{3-}	11.5 mg/l as P
Raw sewage total hardness	170.5 mg/l as $CaCO_3$
Raw sewage Ca^{2+}	60 mg/l
Raw sewage Mg^{2+}	5 mg/l
Effluent PO_4	0.3 mg/l as P
Effluent Ca^{2+}	80 mg/l
Effluent Mg^{2+}	0
Lime dosage	400 mg/l as $Ca(OH)_2$ or 216 mg/l as Ca^{2+}
From equation 1	$Ca_5OH(PO_4)_3$ formed is 1 mole per 3 moles P $\frac{11.2}{30.97}$ = 0.365 mole P removed Therefore $\frac{0.365}{3}$ or 0.122 mole $Ca_5OH(PO_4)_3$ are formed; fw is 502 Therefore weight is 0.122 X 502 = 61 mg/l as $Ca_5OH(PO_4)_3$
From equation 2	$Mg(OH)_2$ formed is 1 mole per mole Mg^{2+} $\frac{5}{24.31}$ = 0.206 Therefore 0.206 X 58.31 = 12 mg/l as $Mg(OH)_2$
From equation 12	Ca^{2+} in = Ca^{2+} out; Ca^{2+} in = 60 + 216 = 276 Ca^{2+} content of $Ca_5OH(PO_4)_3$ formed = 5 X 40 X 0.122 = 24 mg/l Ca^{2+} lost in effluent = 80 mg/l Therefore Ca^{2+} not accounted for = 276 − (80 + 24) = 172 mg/l
From equation 3	$CaCO_3$ formed is 1 mole per mole Ca^{2+} Therefore $\frac{172}{40}$ = 4.3 moles $CaCO_3$; fw = 100 So weight of $CaCO_3$ = 430 mg/l

Sludge composition

Sludge species	Total weight	Ash
		Pounds per million gallons
Raw sewage solids	250 mg/l = 2,080 pounds per million gallons	832
$Ca_5OH(PO_4)_3$	61 mg/l = 510 pounds per million gallons	510
$Mg(OH)_2$	12 mg/l = 100 pounds per million gallons	100
$CaCO_3$	430 mg/l = 3,600 pounds per million gallons	2,020
Total	6,290 pounds per million gallons	3,462

TABLE 18

Estimate of Alum Sludge Quantities

Raw sewage suspended solids	250 mg/l
Raw sewage volatile suspended solids	150 mg/l
Raw sewage PO_4^{3-}	11.5 mg/l as P
Raw sewage total hardness	170.5 mg/l as $CaCO_3$
Raw sewage Ca^{2+}	60 mg/l
Raw sewage Mg^{2+}	5 mg/l
Effluent PO_4	0.3 mg/l as P
Effluent Ca^{2+}	60 mg/l
Effluent Mg^{2+}	5
Effluent Al^{3+}	0

Alum dosage	200 mg/l as $Al_2(SO_4)_3 \cdot 14H_2O$ – fw = 594
From equation 6	$AlPO_4$ formed is 1 mole per mole of P
	$\frac{11.2}{30.97}$ = 0.365 mole P removed
	Therefore 0.365 mole of $AlPO_4$ are formed; fw is 122
	Therefore weight is 0.365 X 122 = 44 mg/l
From equation 12	Al^{3+} in = Al^{3+} out; Al^{3+} in = 18.1 mg/l
	Al^{3+} content of $AlPO_4$ = 0.365 X 27 = 9.9 mg/l
	Al^{3+} not accounted for = 18.1 – 9.9 = 8.2 mg/l
From equation 7	$Al(OH)_3$ formed is 1 mole per mole Al^{3+}
	Therefore $\frac{8.2}{27}$ = 0.31 mole $Al(OH)_3$; fw = 78
	So weight of $Al(OH)_3$ is 0.31 X 78 = 24 mg/l

Sludge composition

Sludge species	Total weight	Ash
		Pounds per million gallons
Raw sewage solids	250 mg/l = 2,080 pounds per million gallons	832
$AlPO_4$	44 mg/l = 368 pounds per million gallons	368
$Al(OH)_3$	24 mg/l = 200 pounds per million gallons	133
Total	2,648 pounds per million gallons	1,333

TABLE 19

Estimate of Iron Sludge Quantities

Raw sewage suspended solids	250 mg/l
Raw sewage volatile suspended solids	150 mg/l
Raw sewage PO_4^{3-}	11.5 mg/l as P
Raw sewage total hardness	170.5 mg/l as $CaCO_3$
Raw sewage Ca^{2+}	60 mg/l
Raw sewage Mg^{2+}	5 mg/l
Effluent PO_4	0.3 mg/l as P
Effluent Ca^{2+}	60 mg/l
Effluent Mg^{2+}	5
Effluent Fe^{3+}	0
$FeCl_3$ dosage	80 mg/l
From equation 9	$FePO_4$ formed is 1 mole per mole P
	$\frac{11.2}{30.97}$ = 0.365 mole P removed
	Therefore 0.365 mole of $FePO_4$ are formed; fw = 151
	Therefore weight is 0.365 X 151 = 55 mg/l
From equation 12	Fe^{3+} in = Fe^{3+} out; Fe^{3+} in = 28 mg/l
	Fe^{3+} content of $FePO_4$ = 0.365 X 55.8 = 20.4 mg/l
	Fe^{3+} not accounted for = 28 – 20.4 = 7.6 mg/l
From equation 10	$Fe(OH)_3$ formed is 1 mole per mole Fe^{3+}
	Therefore $\frac{7.6}{55.8}$ = 0.136 mole $Fe(OH)_3$; fw = 107
	So weight of $Fe(OH)_3$ = 0.136 X 107 = 15 mg/l

Sludge composition

Sludge species	Total weight	Ash
		Pounds per million gallons
Raw sewage solids	250 mg/l = 2,080 pounds per million gallons	832
$FePO_4$	55 mg/l = 460 pounds per million gallons	460
$Fe(OH)_3$	15 mg/l = 122 pounds per million gallons	105
Total	2,662 pounds per million gallons	1,397

- Greater solids production results from chemical usage.
- Greater solids production will have an impact on sludge handling and conditioning unit processes.
- Operation and maintenance difficulties may be significantly different with sludges containing large quantities of chemicals.

Finally, it is recommended that appropriate laboratory and pilot tests be used in determining the most effective and economical methods of sludge processing.

Another consideration in chemical sludge handling is the possibility of chemical recovery and reuse. For example, lime sludges can be recalcined and reused, but there is no method currently available for recovery and reuse of iron salts. In cases where sodium aluminate is a good coagulant, the alkaline method for alum recovery may be used. If laboratory testing shows sodium aluminate to be an unacceptable coagulant for the wastewater under consideration, then the acid method for alum recovery may be used when the treatment goal is suspended solids removal. On the other hand, the acid recovery method is not applicable if one of the treatment goals is phosphorus removal.

In many cases, sludge handling techniques may be too complex for the operator alone to evaluate effectively. The services of a consulting engineer would be most valuable in assessing the situation, recommending a solution, and designing the necessary components of the system.

Sludge Disposal

Sludge disposal is perhaps the most important factor governing the choice of chemicals. In locations where there are available large, remote areas of land, almost any kind of sludge, wet or dry, stable or decomposing, can be, and is, disposed of by hauling or pumping to these land disposal sites. In many places, however, this method for sludge disposal probably will not be allowed indefinitely and other alternatives will have to be developed.

Alum and iron sludges usually can be added to anaerobic digesters. The higher digester loadings resulting from additional sludge production usually will not upset the operation unless an organic overloading condition exists. Release of soluble phosphorus from the sludge during digestion is minimal. Final disposal of the digested sludge can be on land, in a landfill, or by dewatering and incineration.

Alum, iron, and lime sludges can be disposed of directly onto land, but at warm temperatures, alum and iron sludges may need lime treatment to prevent odors.

In large systems, sludge thickening or dewatering prior to lagooning or incineration should be considered. Sludge incineration, particularly for large cities, has the advantage of converting organic solids to ash, thus reducing the weight and volume of solids. Alum, iron and lime sludges can be effectively incinerated.

The operator may find it useful to refer to EPA Technology Transfer Manual, Process Design Manual for Sludge Treatment and Disposal, (Reference 9). The manual presents a review of sludge processing techniques and procedures for selecting optimum designs.

SECTION 3

SELECTING CHEMICALS FOR USE

SECTION 3

SELECTING CHEMICALS FOR USE

There are many different chemicals which can be used in practically every phase of wastewater treatment. As water quality and wastewater treatment requirements continue to become more stringent, the role of chemicals in improving or maximizing wastewater treatment plant performance becomes increasingly important. Often there is more than one chemical that can be used for a particular problem. In every case, there are advantages and disadvantages associated with each chemical as well as other factors which will influence the operator's choice of chemicals. General factors to consider in selecting chemicals include:

- Effectiveness
- Cost
- Reliability of supply
- Sludge considerations
- Compatibility with other treatment processes
- Environmental effects

There are a number of references available to the operator which provide detailed information on chemical use in relation to the above factors. Principal references include the following:

1. Operation of Wastewater Treatment Plants, Manual of Practice No. 11, Water Pollution Control Federation, 1976.

   The manual describes techniques of unit process operations, as well as corrective measures regarding process problems. Improved performance and physical-chemical treatment techniques are also covered in the text.

2. Wastewater Treatment Plant Design, Manual of Practice No. 8, Water Pollution Control Federation, 1977.

   The manual contains a chapter specifically on chemical treatment, including use in coagulation, phosphorus removal, and pH control. Mixing and chemical feed systems also are discussed.

3. Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, EPA-430/9-78-001, January 1978.

This manual describes procedures for evaluating and troubleshooting various unit processes commonly used at wastewater facilities. One chapter is devoted to chemical feeding and conditioning, and other chapters contain information on the use of chemicals in improving process operations. Procedures for evaluating process efficiencies also are included.

4. Process Design Manual for Phosphorus Removal, EPA 625/1-76-001a, April 1976.

   Phosphorus removal methods that have been found effective and practical are discussed in this manual. The methods include chemical precipitation using aluminum and iron salts, and lime. Practical points for chemical addition also are described and documented by case histories.

5. Process Design Manual for Suspended Solids Removal, EPA 625/1-75-003a, January 1975.

   This manual describes specific processes and design considerations for removal of suspended solids in municipal wastewater. Detailed information also is provided concerning the handling and application of coagulant chemicals.

6. Process Design Manual for Upgrading Existing Wastewater Treatment Plants, EPA 625/1-71-004a, October 1974.

   The capabilities, limitations and interrelationships of various unit processes are examined in this manual with considerable emphasis on the use of chemicals in upgrading treatment facilities.

7. Process Design Manual for Sludge Treatment and Disposal, EPA 625/1-79 -011, September 1979.

   Emphasis is placed on operational considerations and interrelationships of various sludge treatment processes including chemical conditioning of sludges.

EFFECTIVENESS

One of the first considerations in the selection of chemicals is the degree of effectiveness which can be expected from the chemical addition. As an aid in predicting effectiveness, it is very helpful to obtain information on experience and operating results from full-scale plants at other locations. However, caution should be exercised in using such data from other plants; the operator should not assume that a certain chemical used at one plant will produce identical results at a different plant. The operation of many treatment plants often is unique and chemicals chosen for use must be able to handle these variations in performance and still produce an effluent of uniform quality. The effectiveness of a particular chemical varies in different applications and often depends on operating conditions.

In order to have a better idea of the expected results of chemical addition, laboratory and/or pilot tests using the proposed chemical should be performed. The objectives of laboratory studies usually are: (1) to determine whether or not the wastewater or sludge may be successfully treated by the proposed chemical, and (2) to obtain data for the design and operation of pilot and full-scale facilities. After eliminating alternative chemicals which do not produce satisfactory results on the basis of laboratory studies, a cost comparison should be performed to select from the remaining chemicals. It should be recognized, however, that laboratory and pilot tests do not always adequately evaluate sludge problems or problems associated with recycled process streams or return solids. It is only at plant-scale that many of the real operational problems become completely evident.

More detailed information on chemical effectiveness is provided in Section 2 of this manual.

COST

Another factor in chemical selection is cost - both capital and operating. Capital costs for handling and feeding various chemicals can vary considerably depending on the characteristics of the chemical to be fed, the form (liquid, powder, gas) in which the chemical is purchased, and the form in which the chemical ultimately is used in the treatment process. Costs will be higher for chemicals which require special handling materials for storage, feeding, piping and accessories, and sophisticated pacing and control equipment. The appendix of this manual provides a ready reference for information on each chemical, its available forms, cost, storage, feeders, and acceptable handling materials. The costs quoted in the appendix were obtained from the November 5, 1979 issue of the Chemical Marketing Reporter. These costs are presented only for guidance and are subject to significant variations due to local market conditions. Transportation is a significant cost for some locations. Cost quotations for the chemicals being considered should be obtained from the manufacturer or supplier prior to final chemical selection.

The cost at point of origin usually is quoted by the manufacturer in cents or dollars per pound, per 100 pounds, or per ton, and varies according to the size of the order. It may be a price "f.o.b. cars" at the point of manufacture or at a regional stock point. When small lots are purchased, the f.o.b. point is important since the manufacturer ships to the regional stock point in bulk at lower rates in order to give the customer the benefit of this savings. The point of shipment origin should always be clearly stated since transportation costs on low-priced materials may actually be in excess of the cost of the material, especially if long hauls are involved. The manufacturer should supply this information, if it is requested by the customer.

Many manufacturers quote prices "f.o.b." from a distribution point but also will give the customer information on the expected cost of transportation by rail or truck to the point of usage. Sometimes, manufacturers will also quote "freight allowed," which means that they will assume the freight charge on the shipment. In small shipments, it is important to compare the cost of shipment by truck to the cost of shipment by rail. While the truck rate may be higher than the rail rate, the material will be taken from the manufacturer's plant and delivered to the door of the plant at no extra cost. On the other hand, by rail, even though the price given is as "f.o.b. your nearest freight station," there will be extra costs for handling and hauling of the material from the freight station to the plant. Therefore, the overall delivered cost may be less by truck. These factors should be considered in determining chemical costs.

In comparing the economics of various chemicals, one must not only consider the relative quantities of chemicals needed, but also the relative cost of handling the resulting sludges. For example, the cost per pound of lime is typically lower than that of alum, but larger dosages of lime generally are needed to achieve the same results as alum for wastewater coagulation. Clearly, a complete cost analysis including all of the system variables is necessary to determine which of the two chemicals is most economical.

Table 20 shows an example of a typical cost evaluation for two different chemical disinfection systems for a 5-mgd plant. The cost comparison shows both capital and annual costs for disinfection using chlorine and ozone. In this analysis the predominant factors responsible for the higher cost of ozonation are the capital cost and energy usage. Unit costs assumed in this analysis include labor at $9.00/hr, and energy at $0.03/kwh. In other situations the cost analysis may show nearly equal capital costs for several alternative chemicals. For example, in comparing various coagulants, the capital costs may be very close, but operation and maintenance costs may vary significantly depending on chemical dosages, unit chemical costs, sludge effects, and chemical handling costs.

Cost considerations also should include the possibility of using a single chemical for more than one purpose. For example, it may be more economical to use a single chemical such as chlorine for odor control, control of bulking sludge, and disinfection, rather than to use a different chemical for each of the three operations. The possible cost savings for such multiple usage can only be determined through a detailed cost analysis of the various alternatives.

RELIABILITY OF SUPPLY

Reliability of supply is perhaps as important as effectiveness in selecting chemicals. There is little advantage in selecting a chemical which satisfies all the requirements in a treatment process if the chemical is not readily available.

Regardless of the chemical used, there must be a sufficient supply on hand at all times to cover the treatment plant needs for daily operation

TABLE 20

Example Cost Comparison of

Disinfection Alternatives

for a 5-mgd Plant

	Chlorination	Ozonation
Capital Costs	$235,000	$510,000
Annual Costs		
Labor	12,000	8,200
Energy	2,000	56,000
Maint. & Material	27,000	7,800
Amortized Capital	21,970	47,680
TOTAL ANNUAL	$ 62,970	$119,680

ASSUMPTIONS: Chlorine dosage, 5 mg/l
Chlorine contact time, 30 minutes
Liquid chlorine cost, $250/ton
Ozone generation from air
Ozone dosage, 10 mg/l
Ozone contact time, 15 minutes
Amortization rate, 20 yrs @ 6-7/8%

plus enough to cover the time between order placement and receipt of the material. It is best to allow a reasonable factor of safety to overcome delays in shipment or transportation, especially if the chemical is to be transported long distances.

Another important consideration is the length of time a chemical will retain its full potency. This factor has a definite effect on the amount of chemical to be purchased and delivered at any one time. If the manufacturer states that the raw material will retain its full potency six months, then it would not be economical to purchase it in quantities which would last much longer. If potency will last for a year, it may be more economical to purchase the chemical in quantities sufficient to last for that period. In most cases there is a differential in price for purchases in large lots, particularly for higher priced items. But when large quantities are ordered to last over long periods, adequate provision must be made for proper storage facilities. Depending on the characteristics of the selected chemical, the cost of such storage facilities may add considerably to the overall cost of the item.

To avoid or minimize potential problems in obtaining chemicals, suppliers of the specific chemical should be contacted for details on chemical availability before the chemical is selected for use in the treatment plant. The Appendix can be used to identify major manufacturers and suppliers of various chemicals, and to provide information on typical shipping containers and quantities.

It is also advisable to consider market trends for wastewater treatment chemicals to anticipate possible chemical shortages or large cost increases. The market for wastewater treatment chemicals has expanded during the last decade and will probably continue to grow in future years. Both municipalities and industries will continue to improve and expand their treatment facilities to meet the more stringent effluent standards now in existence. This will result in increasing demands for wastewater treatment chemicals.

SLUDGE CONSIDERATIONS

Selection of a treatment chemical and point of application should take into account the relative sludge mass, and the ability to process and dispose of the additional solids.

The increase in sludge production depends primarily on the chemical used and the point at which it is applied in the treatment process. The resulting sludge can be handled by several conventional methods, but sludge characteristics such as dewatering and digestion characteristics may change. Section 2 of this manual contains more detailed information on sludge quantities, processability and disposal.

COMPATIBILITY WITH OTHER TREATMENT PROCESSES

Another consideration in chemical selection is compatibility with other processes used in the overall treatment scheme. The possible effects on waste streams or recycled solids also are very important.

Due to variations in wastewater characteristics and treatment plant design and operation, the choice of chemical and point of chemical addition will have varying effects on other plant processes. These effects are best determined in two steps: a laboratory feasibility study followed by pilot tests or by full-scale plant tests, if possible. The laboratory study should provide a preliminary evaluation of various chemicals to determine their general effectiveness and estimated dosage. Pilot or full-scale plant tests then should provide more detailed information on overall compatibility with other plant processes. Additional guidance on chemical dosages is provided in Section 2 of this manual.

ENVIRONMENTAL EFFECTS

As more stringent discharge requirements are initiated and enforced, additional consideration should be given to choosing chemicals which will be environmentally safe upon final disposal. For example, the most economical and widely accepted disinfectant for wastewaters is chlorine. However, because chlorine has been implicated in the formation of cancer-causing substances, there may be situations where ozone becomes a preferred disinfectant. But because of costs, high energy requirements, and the fact that ozone provides no residual protection, the use of ozone normally is not recommended unless unusual environmental concerns exist.

There are a number of other groups of chemicals in which selection may be influenced by environmental effects. Table 21 provides examples of such chemicals and the reasons why they may be considered environmentally undesirable.

In order to minimize problems of this nature it is best to consult with the appropriate local regulatory agency before making firm plans to use a chemical which may have undesirable impacts on the environment.

LABOR REQUIREMENTS

In selecting chemicals and chemical feeders, consideration should be given to labor requirements with respect to feeding and handling of chemicals and equipment operation and maintenance. It is important to recognize that labor associated with various chemicals depends not only on the particular chemical, but also on the characteristics of the chemical and the form in which it is purchased, stored, and fed. For example, less labor generally will be required to use a chemical which is both purchased and fed in the same form than a chemical which is purchased in dry form, dissolved for

TABLE 21

Environmental Effects of Chemical Discharges

Chemical	Potential Use	Environmental Effect
Ammonia	Control of pH or alkalinity	Upon discharge, high ammonia concentrations can be toxic to fish, deplete oxygen in receiving waters and encourage algae growth.
Alum or Iron salts	Coagulation	Increases effluent TDS. Increases sludge.
Chlorine	Disinfection	Increases effluent TDS, high residuals can be toxic to fish.
Chlorine	Breakpoint chlorination for NH_4 removal	May produce acidic effect on effluent, requiring addition of another chemical for neutralization. Increases chlorides in effluent.
Methanol	Carbon or food source for bacteria	If overdosed, methanol could be discharged in plant effluent, resulting in higher BOD.

storage and later diluted for feeding. Table 22 illustrates the wide variation in operation and maintenance labor for several commonly used chemicals for sludge conditioning. These figures show typical labor requirements for unloading, storing and feeding operations. The primary components which cause high labor requirements for unslaked lime are operation and maintenance related to the slaking and feeding equipment. As Table 22 illustrates, there can be considerable difference in staffing requirements for various chemicals, and these differences should be considered in selecting chemicals.

TABLE 22

Chemical Treatment Labor Requirements

Chemical	Capacity, lb/hr	Operation & Maintenance * Labor, hr/yr
Ferric chloride	10	150
	50	210
	100	300
	500	800
Lime (slaked)	100	1,800
	500	1,850
	1,000	2,100
Lime (unslaked)	100	2,400
	500	2,400
	1,000	2,900
Polymer (dry)	.5	500
	1.0	580
	5.0	750
	10.0	850
Polymer (liquid)	.5	390
	1.0	400
	5.0	420
	10.0	440

* Labor for operation and maintenance of unloading, storing and feeding facilities.

SECTION 4

FEEDING AND HANDLING SYSTEMS

SECTION 4

FEEDING AND HANDLING SYSTEMS

Feeding systems are necessary for the controlled addition of chemicals to wastewater, whether the chemicals are solid, liquid or gas. The design of a chemical feed system must consider the form of each chemical desired for feeding, the physical and chemical characteristics of the chemical, maximum and minimum waste flows, and the reliability of the feeding devices.

The facilities for chemical feeding are relatively simple and consist of equipment to store the chemical(s), feed the chemical(s) at controlled dosages, place the chemical(s) in solution or slurry, and feed the solution to the process as shown in Figure 4.

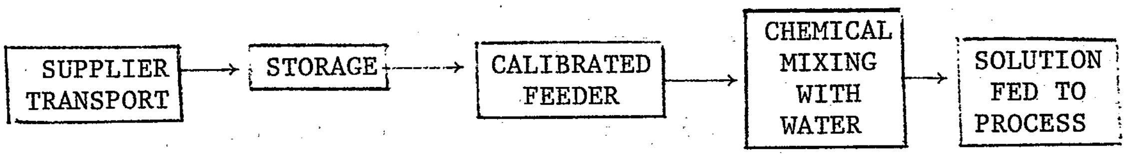


Figure 4. Chemical feeding system schematic.

In suspended and colloidal solids removal from wastewaters the chemicals used are generally in liquid or solid form. Those in solid form are usually converted to solution or slurry form prior to introduction to the wastewater stream; however, some chemicals are fed in a dry form. In either case, some type of solids feeder is usually required. This type of feeder has numerous different forms due to wide ranges in chemical characteristics, feed rates, and degree of accuracy required. Liquid feeding is somewhat more restrictive, depending mainly on liquid volume and viscosity.

The capacity of a chemical feed system is important to consider in both storage and feeding. Storage capacity design must take into account the advantage of quantity purchase versus the disadvantages of construction cost and chemical deterioration with time. Potential delivery delays and chemical use rates are important factors which must be considered. Storage tanks or bins for solid chemicals must be designed with proper consideration of the angle of repose of the chemical and its necessary environmental requirements, such as temperature and humidity. Size and slope of feeding lines are important along with their materials of construction, since some chemicals are corrosive to certain materials.

Chemical feeders must accommodate the minimum and maximum feeding rates required. Manually controlled feeders have a common range of 10:1, but this range can be increased to about 20:1 or 30:1 with dual control systems. Chemical feeder control can be manual, automatically proportioned to flow, dependent on some form of process feedback, or a combination of any two of these. More sophisticated control systems are feasible if proper sensors are available. If manual control systems are specified with the possibility of future automation, the feeders selected should be able to be converted with a minimum of expense. An example would be a feeder with an external motor which could easily be replaced with a variable speed motor or drive when automation is installed. Standby or backup units should be included for each type of feeder used. Points of chemical addition and piping to them should be capable of handling all possible changes in dosing patterns in order to have proper flexibility of operation. Designed flexibility in hoppers, tanks, chemical feeders and solution lines is the key to maximum benefits at least cost.

Solids characteristics vary considerably and the selection of a feeder must be made carefully, particularly in a smaller-sized facility where a single feeder may be used for more than one chemical. In general, provisions should be made to keep all dry chemicals cool and dry. Dryness is very important, as hygroscopic (water-absorbing) chemicals may become lumpy, viscous or even rock hard; other chemicals which absorb water less readily may become sticky from moisture on the particulate surfaces, causing increased arching in hoppers. In either case, moisture will affect the density of the chemical which may result in under-feed. Also, the effectiveness of dry chemicals, particularly polymers, may be reduced. Dust removal equipment should be used at shoveling locations, bucket elevators, hoppers, and feeders for neatness, corrosion prevention and safety reasons. Collected chemical dust may often be used along with stored chemicals. In general, only limited quantities of chemical solutions should be made from dry chemicals, since the shelf life of mixed chemicals (especially polymers) may be short.

DRY CHEMICAL FEEDERS

The simplest method of feeding dry or solid chemicals is by hand. Solid chemicals may be preweighed and added or poured by the bagful into a dissolving tank. This method is generally limited to very small operations, however, and dry chemical feed equipment is usually required.

A dry feed installation (Figure 5) consists basically of a storage bin and/or hopper, a feeder, and a dissolver tank. Dry feeders are either of the volumetric or gravimetric type. Volumetric feeders usually are used only where low initial cost and low feed rates are required. These feeders deliver a constant, preset amount of chemical and do not recognize changes in material density. This type of feeder must be calibrated by trial and error at the outset, and then readjusted periodically if the material changes in density.

Most types of volumetric feeders generally fall into the positive displacement category. All designs of this type use some form of moving

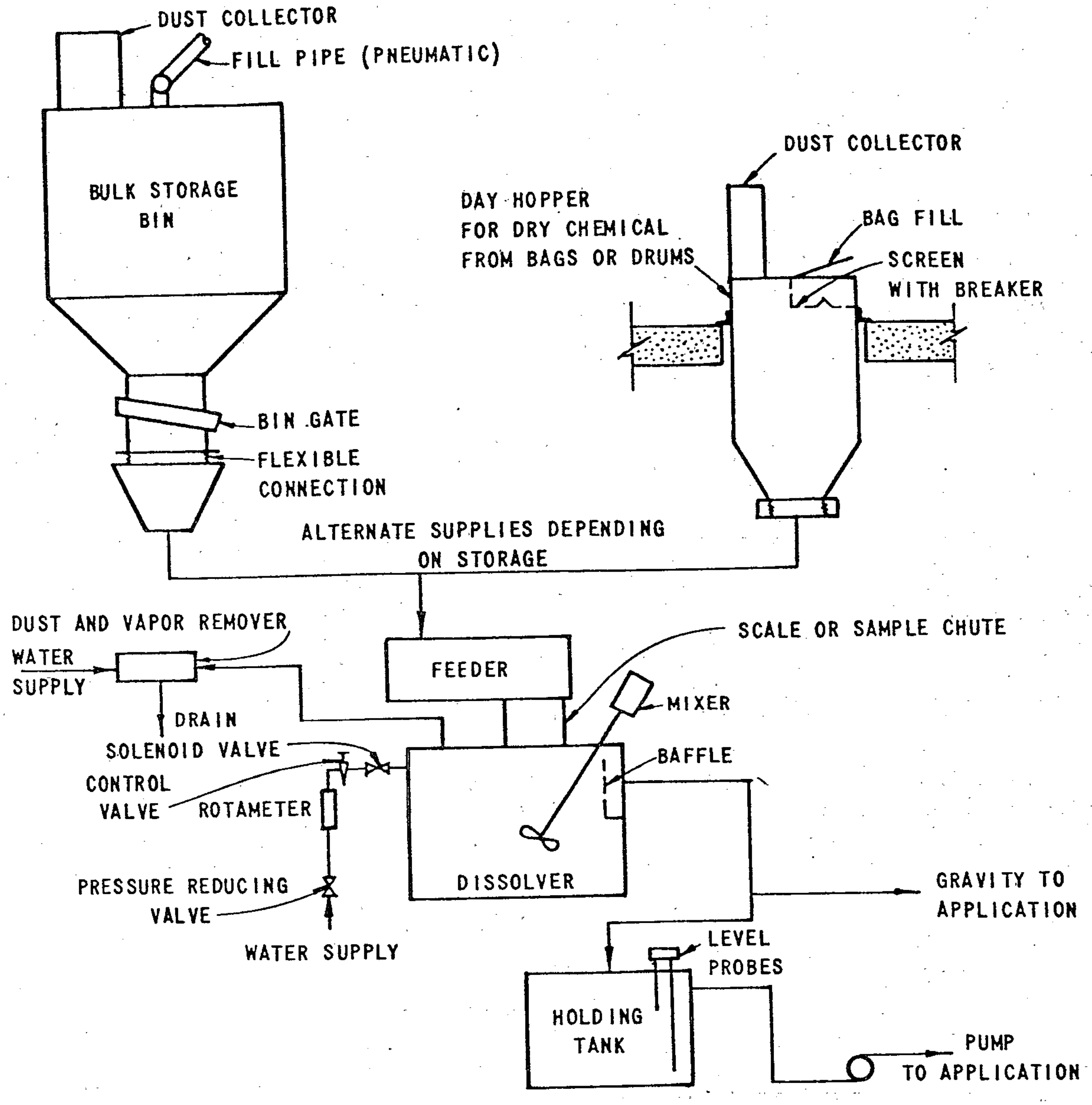


Figure 5. Typical dry feed system.

cavity of a specific or variable size. In operation, the chemical falls by gravity into the cavity and is almost fully enclosed and separated from the hopper's feed. The rate at which the cavity moves and is discharged, together with the cavity size, govern the amount of chemical fed. Positive displacement feeders often use air injection to enhance flowability of the material.

Rotary Paddle Feeder

An example of a positive displacement rotary feeder is illustrated in Figure 6. This rotary paddle feeder is especially effective for fine materials that tend to flood. The paddle or vane is located beneath the hopper discharge, with the feed being varied by means of a sliding gate and/or variable speed drive. The feed rate can be varied easily by adjusting the variable speed drive on the vane shaft. A variant of the rotary paddle feeder is the pocket feeder, also called the star or revolving door feeder, in which the paddle is tightly housed to permit delivery against vacuum or pressure.

Oscillating Hopper Feeder

Another type of volumetric feeder is the oscillating hopper, or oscillating throat feeder. This feeder (Figure 7) consists of a main hopper and an oscillating hopper which swivels on the end of the main hopper. The material completely fills both hoppers and rests on the tray beneath. As the oscillating hopper moves back and forth, the scraper, which rests on the fixed tray below, is moved first to the left and then to the right. As it moves, it pushes a ribbon-like layer of dry chemical off the tray. The capacity is fixed by the length of the stroke, which may be varied by means of a micrometer screw. Further adjustment is possible by changing the clearance between the hopper and the fixed tray, which may be raised or lowered. This type of feeder is one of the most widely used in small water and wastewater plants.

Oscillating Plate Feeder

In the oscillating plate feeder a plate is mounted below the bottom spout in the storage hopper so that the chemical spills out onto the plate as it comes out of the storage hopper. A leveling bar is mounted above the plate on each of the two ends. The plate is mechanically linked to the drive motor so that the plate slowly oscillates from side to side as the feeder operates. The magnitude of oscillation can be adjusted with the mechanical linkage. This provides a dosage adjustment. Each time the plate oscillates from one side to the other a measured amount of chemical drops off the plate into the solution tank. The rake bar above each end of the plate helps to regulate the repeatability of the feed rate.

Grooved Disc Feeder

This feeder consists of a grooved horizontal disc which meters the chemical addition. The disc rotates and the grooves are filled as they pass under the storage hopper, are struck off level, and then a stationary plow removes the material from the groove for metering. The feed rate is varied by changing the speed of disc rotation or by changing the groove size. Typically, these feeders are used for applications requiring small feed rates of dry materials.

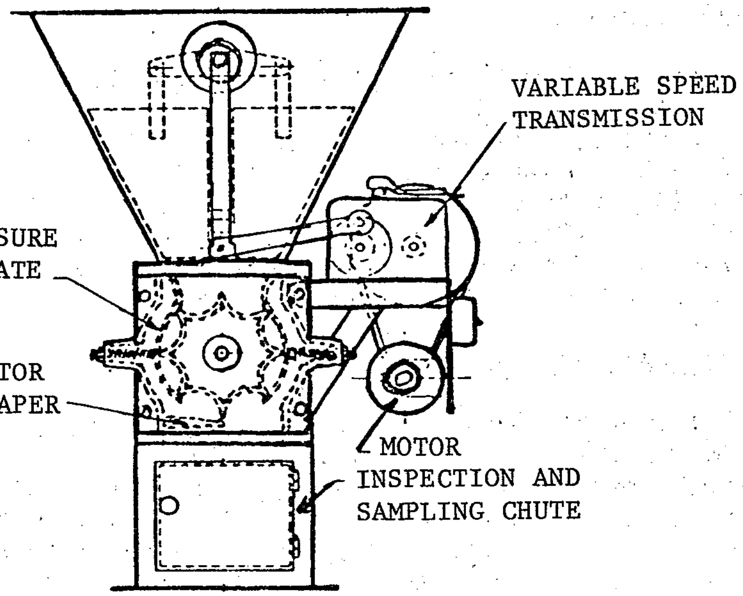


Figure 6. Positive displacement rotary feeder.

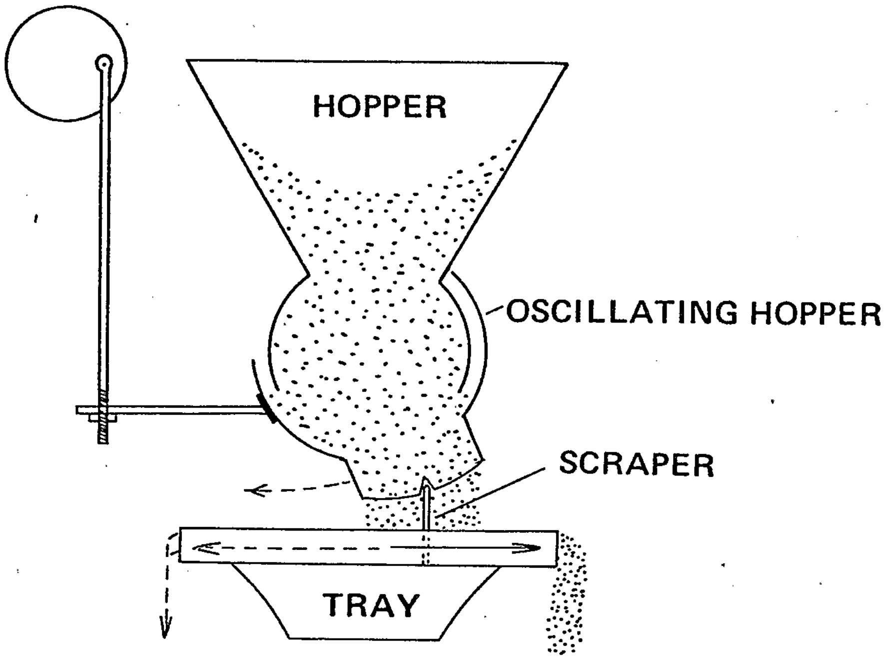


Figure 7. Oscillating hopper or universal volumetric feeder.

Vibrating Feeder

The vibrating feeder is another volumetric feeder. With this feeder, motion is obtained by means of an electromagnet anchored to the feeding trough, which in turn is mounted on flexible leaf springs. The magnet, energized by pulsating current, pulls the trough sharply down and back - then the leaf springs return it up and forward to its original position. This action is repeated 3600 times per minute (when operating on 60-cycle, a.c.), producing a smooth, steady flow of material.

Volumetric Belt Feeder

The volumetric belt feeder uses a continuous belt of specific width moving from under the hopper to the dissolving tank. The material falls on the feed belt from the hopper and passes beneath a vertical gate. For a given belt speed, the position of the gate determines the volume of material passing through the feeder. An example of a volumetric belt-type feeder is shown in Figure 8.

Screw-Type Feeder

The volumetric screw-type feeder employs a screw or helix at the bottom of the hopper to transfer dry chemical to the solution chamber. A typical screw-type volumetric feeder is shown in Figure 9.

The basic drawback of the volumetric feeder is that it cannot compensate for changes in the density of materials and is therefore not as accurate as two other types of dry feeders: the gravimetric and loss-in-weight feeders. For these feeders, the volumetric design is modified to include a gravimetric or loss-in-weight controller, which allows for weighing of the material as it is fed. Both gravimetric and volumetric feeders can be used to feed in proportion to the flow of wastewater.

Belt-Type Gravimetric Feeder

Belt-type gravimetric feeders have a wide capacity range and usually can be sized for any use in a wastewater treatment plant. Belt-type gravimetric feeders use a basic belt feeder with a weighing and control system. Feed rates can be changed by adjusting the weight per foot of belt, the belt speed, or both. There are two types of gravimetric belt-type feeders, the pivoted belt type and the rigid belt type.

The pivoted belt feeder consists of a feed hopper, an endless traveling belt mounted on a pivoted frame, an adjustable weight which counterbalances the load on the belt, and a means of continuously and automatically adjusting the feed of material to the belt. Dry chemical flow to the feeder can be controlled by a gate placed between the feed hopper and the belt (as shown in Figure 10) or by controlling the amplitude of vibration in a vibrating deck placed between the feed hopper and the belt.

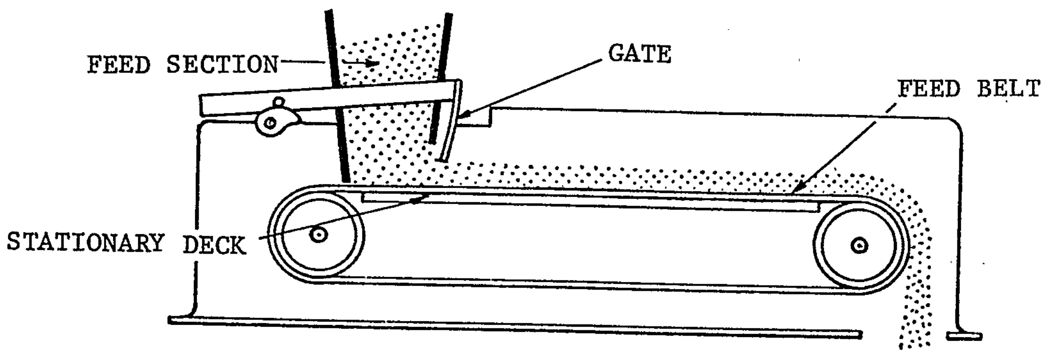


Figure 8. Volumetric belt type feeder.

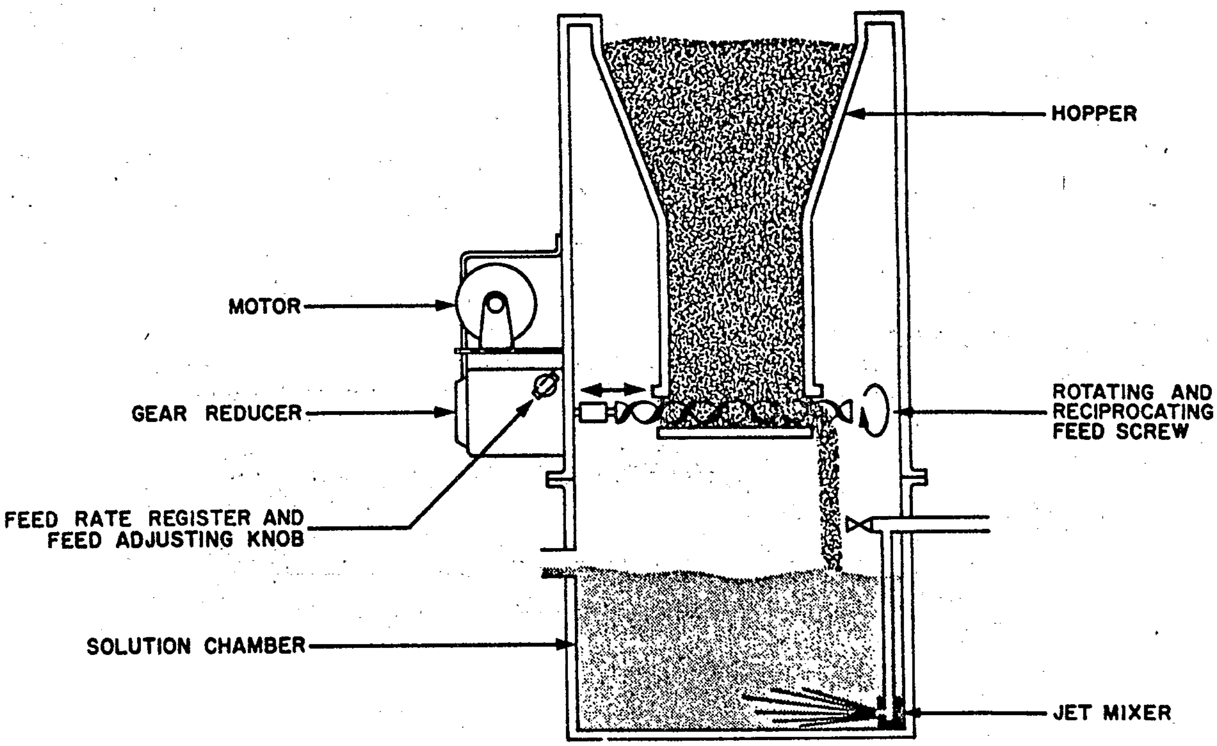


Figure 9. Typical helix or screw-type volumetric feeder (courtesy of Wallace & Tiernan, division of Pennwalt Corporation).

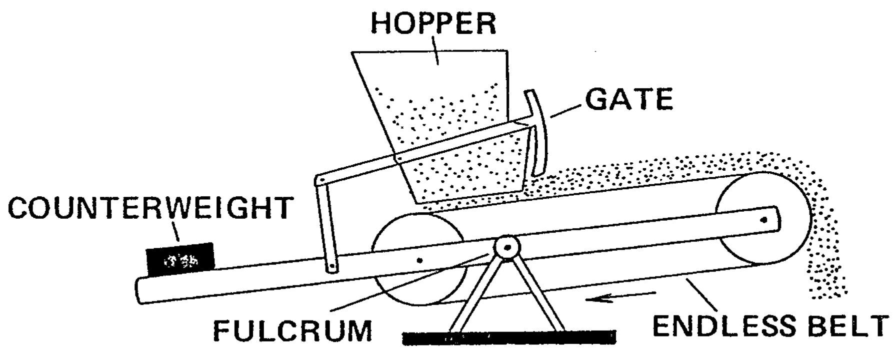


Figure 10. Pivoted belt gravimetric feeder.

The rigid belt feeder is similar to the pivoted belt feeder except for one main difference. With the pivoted belt filter, adjustment is accomplished through action of the belt tilting up and down, while with the rigid belt, adjusting occurs through action of the scale beam dependent only on the weight of the belt. An example of a rigid belt gravimetric feeder is given in Figure 11.

Good housekeeping and the need for accurate feed rates dictate that the gravimetric feeder be shut down and thoroughly cleaned on a regular basis. Chemical build-up can affect accuracy and can even jam the equipment in some cases.

Loss-In-Weight Feeder

The loss-in-weight feeder should be used where the greatest accuracy or more economical use of chemical is important. This feeder only works for feed rates up to a rate of 4,000 lb/hour. The loss-in-weight feeder has a material hopper and feeder set on enclosed scales. The feed rate controller is used to deliver the dry chemical at the desired rate.

Dissolvers

Dissolvers are also important to dry feed systems since any metered chemical must be wetted and mixed with water to provide a chemical solution free of lumps and undissolved particles. Most feeders, regardless of type, discharge their material to a small dissolving tank which is equipped with a nozzle system and/or mechanical agitator depending on the solubility of the chemical being fed. It is important that the surface of each particle become completely wetted before entering the feed tank to ensure accurate dispersal and to avoid clumping, settling or floating.

A dissolver for a dry chemical feeder is unlike a chemical feeder, which by simple adjustment and change of speed can vary its output tenfold. The dissolver must be designed for the job to be done. A dissolver suitable for a rate of 10 lb/hour may not be suitable for dissolving at a rate of 100 lb/hour.

The capacity of a dissolver is based on detention time, which is directly related to the wettability or rate of solution of the chemical. Therefore, the dissolver must be large enough to provide the necessary detention for both the chemical and the water at the maximum rate of feed.

SOLUTION FEEDERS

A typical solution feed system (Figure 12) consists of a storage tank, transfer pump, day tank (for dilution), and liquid feeder. Some liquid chemicals can be fed directly without dilution and the day tank would not be needed. Dilution water is usually still added to the solution feed pump discharge line after the chemical is metered to prevent plugging, reduce delivery time, and to help mix the chemical with the water being treated.

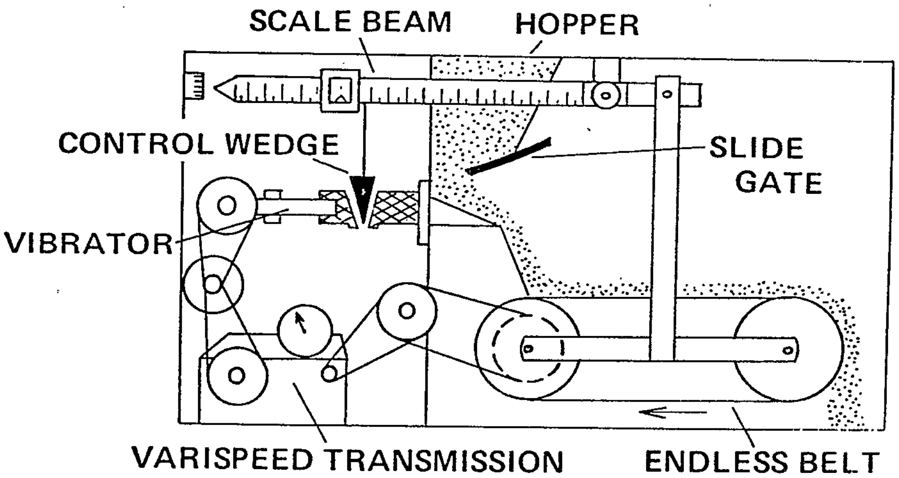


Figure 11. Rigid belt gravimetric feeder.

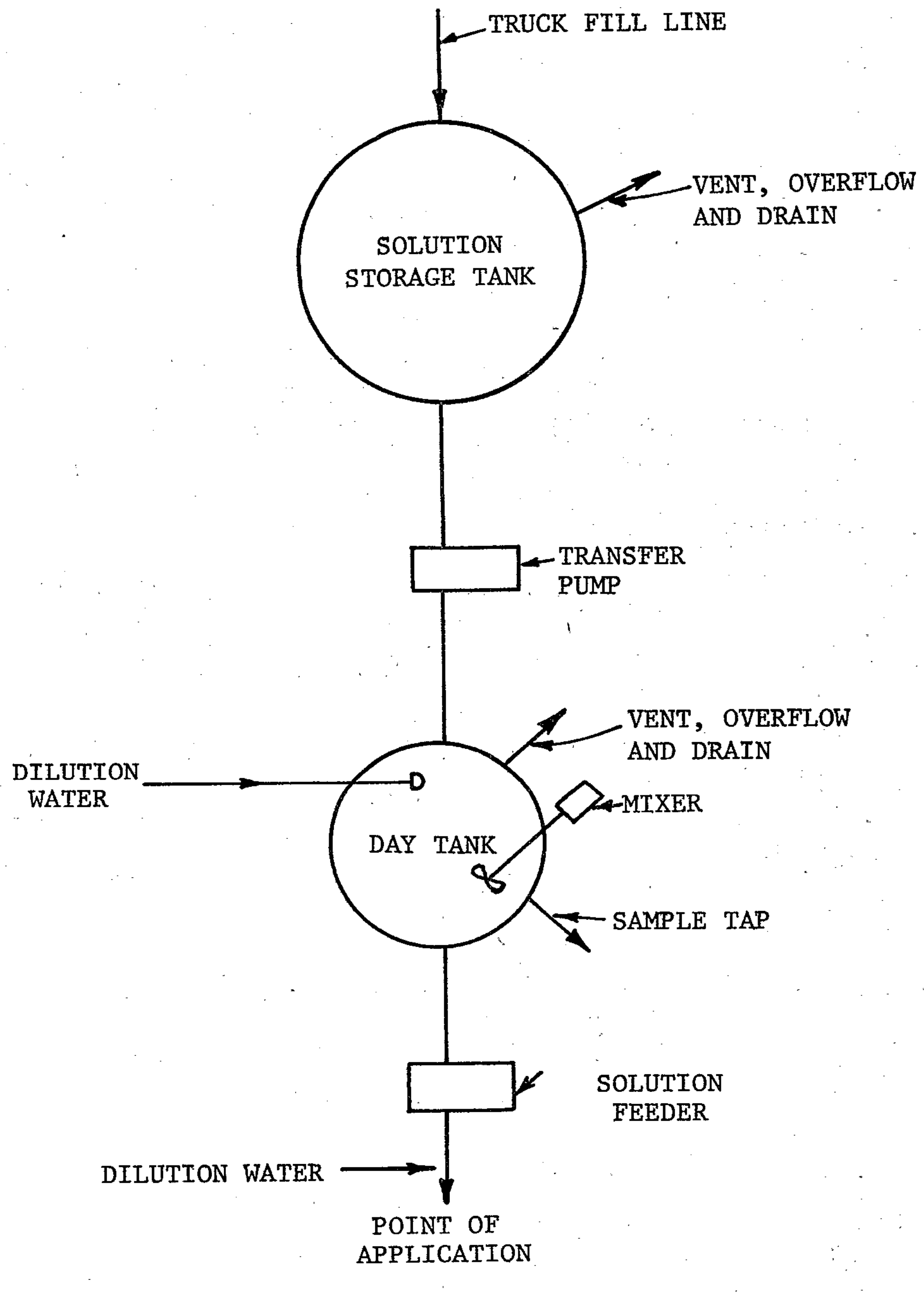


Figure 12. Typical solution feed system.

Liquid feed systems are generally recommended for use:

- When low chemical quantities are required.
- With less stable chemicals.
- With chemicals which are fed more easily as a liquid.
- Where handling of dusty chemicals or dangerous chemicals is undesirable.
- With materials only available as liquids.

Liquid feeders usually are metering pumps or orifices. These metering pumps usually are of the positive displacement variety, plunger or diaphragm type. Examples of plunger and diaphragm pumps are given in Figure 13. Positive displacement pumps can be set to feed over a wide range by adjusting the pump stroke length. In some cases, control valves and rotameters may be all that is needed, while in other cases the rotating dipper type feeder may be satisfactory. For uses like lime slurry feeding, however, centrifugal pumps with open impellers are used. The type of liquid feeder used depends on the viscosity, corrosivity, solubility, suction and discharge heads, and internal pressure relief requirements.

GAS FEEDERS

Gas feeders can be classifed as solution feed or direct feed. Solution feed vacuum type feeders are most commonly used in chlorination and in dechlorination with sulfur dioxide. In chlorination, chlorine gas is metered under vacuum and is mixed with water or plant effluent in an injector to produce a chlorine solution. The flow of chlorine gas is automatically shut off on loss of vacuum, stoppage of the solution discharge line, or loss of operating water pressure.

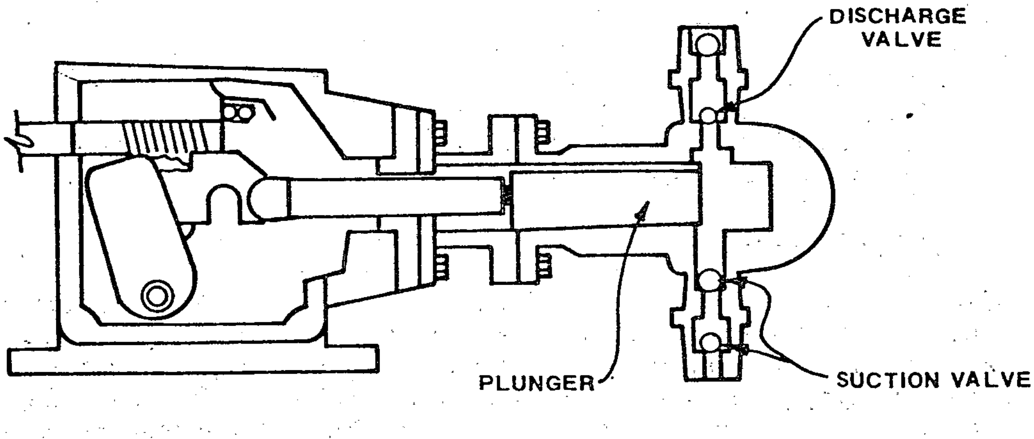
Direct feed or "dry feed" equipment is infrequently used, only when either water or electricity or both is unavailable at a site. This type of equipment is nearly the same as the solution feed type except that there is no device for making and injecting an aqueous solution. The gas itself is piped directly into the water to be treated.

More information about the uses and limitations of the general type of chemical feeders is given in Table 23.

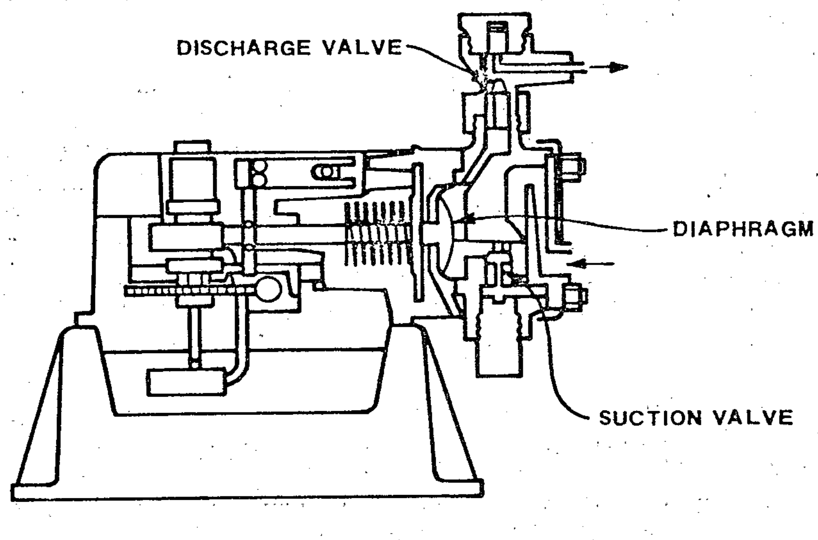
FEED SYSTEM REQUIREMENTS FOR SPECIFIC CHEMICALS

Alum

To prepare dry alum for feeding, dissolving tanks should be made of a non-corrosive material. Dissolvers should be the right size to get the desired solution strength. Most solution strengths are 0.5 lb of alum to 1 gallon of water, or a 6% solution. The dissolving tank should be designed



PLUNGER PUMP



DIAPHRAGM PUMP

Figure 13. Positive displacement pumps.

TABLE 23

Types of Chemical Feeders

Type of Feeder	Use	Limitations: General	Limitations: Capacity cu ft/hr	Limitations: Range
Dry feeder:				
Volumetric:				
Oscillating plate	Any material, granules or powder.	....	0.01 to 35	40 to 1
Oscillating throat (universal)	Any material, any particle size.	....	0.02 to 100	40 to 1
Rotating disc	Most materials including NaF, granules or powder.	Use disc unloader for arching.	0.01 to 1.0	20 to 1
Rotating cylinder (star)	Any material, granules or powder.	....	8 to 2,000 or 7.2 to 300	10 to 1 or 100 to 1
Screw	Dry, free flowing material, powder or granular.	....	0.05 to 18	20 to 1
Ribbon	Dry, free flowing material, powder, granular, or lumps.	....	0.002 to 0.16	10 to 1
Belt	Dry, free flowing material up to 1½-inch size, powder or granular.	....	0.1 to 3,000	10 to 1 or 100 to 1
Gravimetric:				
Continuous–belt and scale	Dry, free flowing, granular material, or floodable material.	Use hopper agitator to maintain constant density.	0.02 to 2	100 to 1
Loss in weight	Most materials, powder, granular or lumps.	....	0.02 to 80	100 to 1
Solution feeder:				
Nonpositive displacement:				
Decanter (lowering pipe)	Most solutions or light slurries	....	0.01 to 10	100 to 1
Orifice	Most solutions	No slurries	0.16 to 5	10 to 1
Rotameter (calibrated valve)	Clear solutions	No slurries	0.005 to 0.16 or 0.01 to 20	10 to 1
Loss in weight (tank with control valve).	Most solutions	No slurries	0.002 to 0.20	30 to 1
Positive displacement:				
Rotating dipper	Most solutions or slurries	....	0.1 to 30	100 to 1
Proportioning pump:				
Diaphragm	Most solutions. Special unit for 5% slurries.[1]	....	0.004 to 0.15	10 to 1
Piston	Most solutions, light slurries.	....	0.01 to 170	10 to 1
Gas feeders:				
Solution feed	Chlorine	....	8000 lb/day max	20 to 1
	Ammonia	....	2000 lb/day max	20 to 1
	Sulfur dioxide	....	7600 lb/day max	20 to 1
	Carbon dioxide	....	6000 lb/day max	20 to 1
Direct feed	Chlorine	....	300 lb/day max	10 to 1
	Ammonia	....	120 lb/day max	7 to 1
	Carbon dioxide	....	10,000 lb/day max	20 to 1

[1] Use special heads and valves for slurries.

for a minimum detention time of 5 minutes at the maximum feed rate. Dissolvers should have water meters and mixers so that the water/alum mixture can be controlled. Most liquid alum is fed as it is delivered, in a standard 50 percent solution.

Alum is usually fed by positive displacement metering pumps. Dilution water usually is added to an alum feed pump discharge line to prevent line plugging, to reduce delivery time to the point of application, and to help mix the alum with the water being treated. The output of the pumps can be controlled automatically in proportion to plant flow. This is done by setting the alum dosage for the maximum flow rate. The controls are then set to automatically adjust the off-on cycle and the amount of alum pumped to the actual flow.

Carbon Dioxide

Feeding systems for the stack gas source of carbon dioxide consist of simple valving arrangements, for admitting varying quantities of make-up air to the suction side of the constant volume compressors, or for venting excess gas on the compressor discharge.

Pressure generators and submerged burners are regulated by valving arrangements on the fuel and air supply. Generation of carbon dioxide by combustion is usually difficult to control, requires frequent operator attention and demands considerable maintenance over the life of the equipment, when compared to liquid CO_2 systems.

Commercial liquid carbon dioxide is more generally used because of its high purity, the simplicity and range of feeding equipment, ease of control, and smaller, less expensive piping systems. After vaporization, carbon dioxide with suitable metering and pressure reduction may be fed directly to the point of application as a gas. Metering of directly fed pressurized gas is difficult due to the high adiabatic expansion characteristics of the gas. Also, direct feed requires extremely fine bubbles to insure that the gas goes into solution; this, in turn, can lead to scaling problems. Because of this, vacuum operated, solution type gas feeders are preferred. Such feeders generally include safety devices and operating controls in a compact panel housing, with materials of construction suitable for carbon dioxide service. Absorption of carbon dioxide in the injector water supply approaches 100% when a ratio of 1.0 lb of gas to 60 gallons of water is maintained.

Chlorine

Elemental chlorine is a poisonous yellow-green gas at ordinary temperature and pressure. The gas is stored as a moisture-free liquid under pressure in specially constructed steel containers from which it is vaporized either directly or with heated vaporizers. Chlorine gas feeders may be classified into two types, direct feed or solution feed.

Direct feed or dry feed gas feeders deliver chlorine gas under pressure directly to the point of application. Direct feed gas chlorinators are less safe than solution feed chlorinators and are used when there is no adequate water supply available for ejector operation. In solution feed vacuum type feeders, chlorine gas is maintained under a vacuum throughout the apparatus. Vacuum is created by water flow through an injector to move the chlorine from the supply system through the chlorine gas metering devices to the injector. Chlorine gas is mixed with water in the injector and the chlorine solution is moved to the point of application. In this feeder, the vacuum controls the operation of the chlorine inlet valve such that the chlorine will not feed unless sufficient vacuum is induced through the apparatus. This type of feeder is most common because safe operation is assured. It employs a direct indicating meter, and the flow of chlorine is automatically shut off on loss of vacuum, stoppage of discharge line, or loss of operating water pressure.

In some cases it may be necessary to provide more than one point of injection from a single injector, and this requires manifolding. Valves for manifolding generally are either the ball type or diaphragm type.

There are two basic types of chlorine diffusers: one for discharging chlorine solution into a pipe flowing full; and the other for discharging into an open channel or open body of water.

A full discussion of chlorination is beyond the scope of this manual. More information concerning chlorination systems is available in References 3, 9 and 10.

Chlorine Dioxide

Chlorine dioxide is an intense greenish-yellow gas that is quite unstable, and, under certain conditions, is explosive. It cannot be shipped in containers as is chlorine gas because of its explosive nature, and it must be generated at the point of use and applied immediately.

Although readily soluble in water, it does not react with water as does chlorine. Chlorine dioxide is easily expelled from solution in water by blowing a small amount of air through the solution. Aqueous solutions of ClO_2 are also subject to some photodecomposition.

Chlorine dioxide is generated by oxidizing sodium chlorite with chlorine (either chlorine gas or hypochlorite) at a pH of 4 or less. This means that the injector system of the chlorination assembly must be such that the chlorine solution strength is never less than about 500 mg/l. Since the upper limit of this solution strength should not exceed 3,500 mg/l to prevent break-out of molecular chlorine at the point of application, the effective range of chlorine dioxide production is about 7:1. Chemical feed devices can handle ranges up to 20:1 on a flow proportional basis and 200:1 on a compound loop control system.

Ferric Chloride

Since ferric chloride is always fed as a liquid, it is normally obtained in liquid form containing 20 to 45 percent $FeCl_3$. When iron salts such as ferric chloride are used for wastewater coagulation in soft waters, a small amount of base (such as sodium hydroxide or lime) is needed to neutralize the acidity of these strong acid salts.

Because of hydrolysis, it may not be a good idea to dilute ferric chloride solution from its shipping concentration to a weaker feed solution. Ferric chloride solutions may be transferred from underground storage to day tanks with rubber-lined self-priming centrifugal pumps having teflon rotary and stationary seals. Because liquid ferric chloride can stain or deposit, glass-tube rotameters are not used for metering. Instead, rotodip feeders and diaphragm metering pumps made of rubber-lined steel and plastic often are used for feeding ferric chloride.

Ferric Sulfate

Feed solutions are usually made up at a water-to-chemical ratio of 2:1 to 8:1 (on a weight basis) with the usual ratio being 4:1 with a 20-minute detention time. Care must be taken not to dilute ferric sulfate solutions to less than 1 percent in order to prevent hydrolysis and deposition of ferric hydroxide.

Dry feeding requirements are similar to those for dry alum except that belt type feeders are rarely used because of their open type of construction. Closed construction, as found in the volumetric and loss-in-weight type feeders, generally exposes a minimum of operating components to the vapor, and thereby minimizes maintenance. A water jet vapor remover should be provided at the dissolver to protect both the machinery and operator.

Ferrous Sulfate

The granular form of ferrous sulfate has the best feeding characteristics and gravimetric or volumetric feeding equipment may be used. The optimum chemical-to-water ratio for continuous dissolving is 0.5 lb/gallon or 6 percent with a detention time of 5 minutes in the dissolvers. Mechanical agitation should be provided in the dissolver to assure complete solution.

Lime

Although lime comes in many forms, quicklime and hydrated lime are used most often for wastewater coagulation. Quicklime is almost all calcium oxide (70 to 96 percent CaO). High-calcium quicklime contains more than 88 percent CaO and less than 5 percent magnesium oxide (MgO) and is generally preferred for wastewater treatment. Dolomitic lime may contain up to 40 percent MgO, which is not desirable for wastewater coagulation and which adversely affects sludge thickening and dewatering.

Quicklime (unslaked lime) is almost all CaO and first must be converted to the hydrated form ($Ca(OH)_2$). Hydrated or slaked lime is a powder obtained by adding enough water to quicklime to satisfy its affinity for water. Hydrated lime needs only enough water to form milk of lime. Wetting or dissolving tanks usually are designed for 5 minutes detention with 0.5 lb/gallon of water or 6 percent slurry at the highest feed rate. Hydrated lime often is used where maximum feed rates are less than 250 lb/hour.

Dilution is not too important in lime feeding; therefore, it is not necessary to control the amount of water used in feeding. Hydraulic jets may be used for mixing in the wetting chamber of the feeder, but the jets should be the right size for the water supply pressure.

Lime is never fed as a solution because of its low solubility in water. Also, quicklime and hydrated lime usually are not applied dry directly to the wastewater for the following reasons:

- they are transported more easily as a slurry;
- a lime slurry mixes better with the wastewater than dry lime;
- pre-wetting the lime in the feeder with rapid mixing helps to make sure that all particles are wet and that none settles out in the treatment basin.

Major components of a lime feed system (illustrated in Figure 14) include a storage bin, dry lime feeder, lime slaker, slurry holding tank, and lime slurry feeder. The slurry holding tank is usually needed only when the point of application is at a remote location. Quicklime feeders usually must be the belt or loss-in-weight gravimetric types because bulk density changes so much. Feed equipment usually has an adjustable feed range of at least 20:1 to match the operating range of the slaker. The main parts of a lime slaker for wastewater treatment usually include one or more slaking bins, a dilution bin, a grit separation bin, and a continuous grit remover.

There are two basic types of lime slakers, the "paste" or "pug mill" type slaker and the "detention" type slaker. The paste-type slaker (Figure 15) admits water as required to maintain a desired mixing viscosity. The viscosity therefore sets the operating retention time of the slaker. The detention-type slaker (Figure 16) admits water to maintain a desired ratio with the lime, and therefore the retention time is set by the lime feed rate. The detention slaker produces a lime slurry of about 10 percent $Ca(OH)_2$ while the paste type produces a paste of about 36 percent. Other differences between the two slakers are that the detention type slaker operates with a higher water to lime ratio, a lower temperature, and a longer retention time. For either slaker type, vapor removers are required for feeder protection, since lime slaking produces heat in hydrating the CaO to $Ca(OH)_2$.

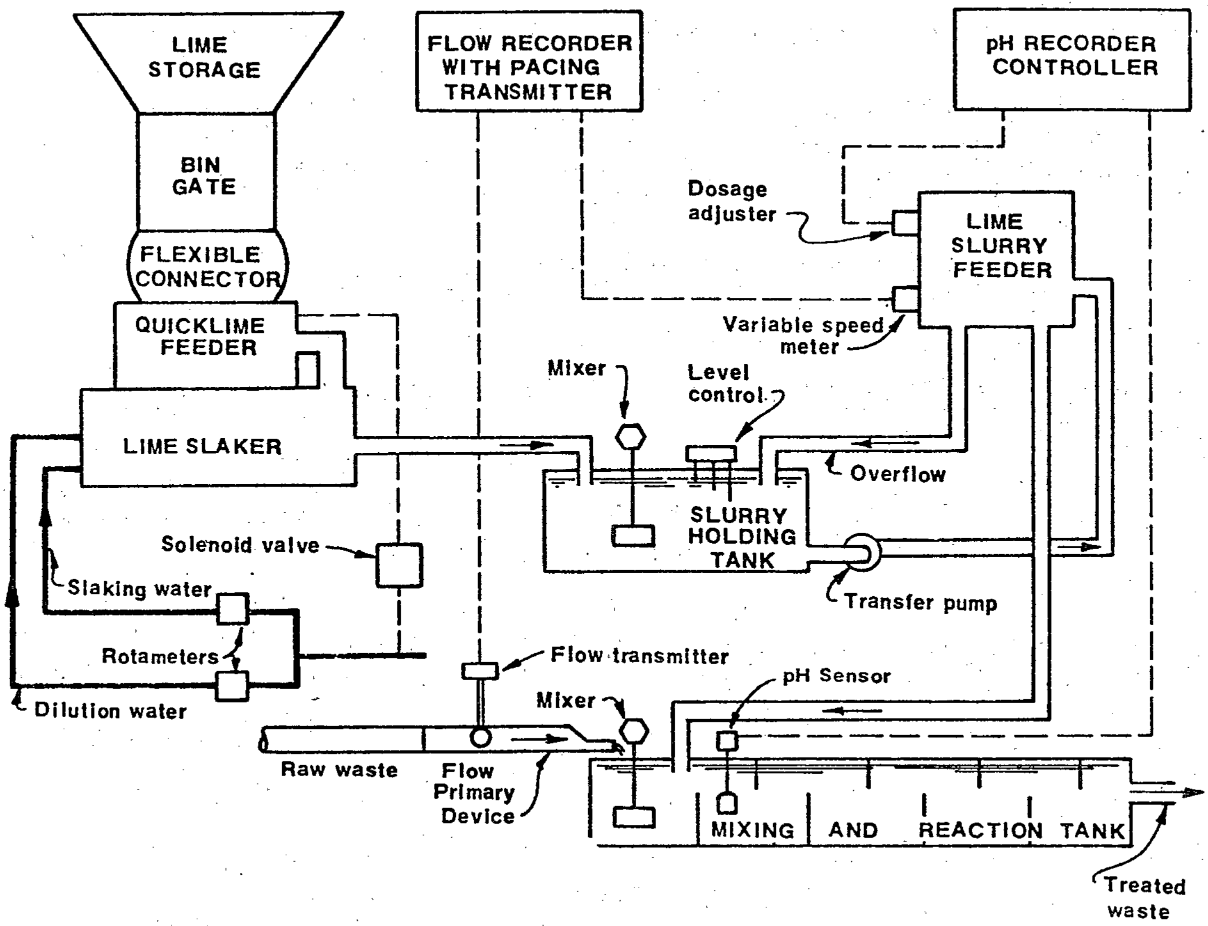


Figure 14. Illustrative lime feed system for wastewater coagulation.

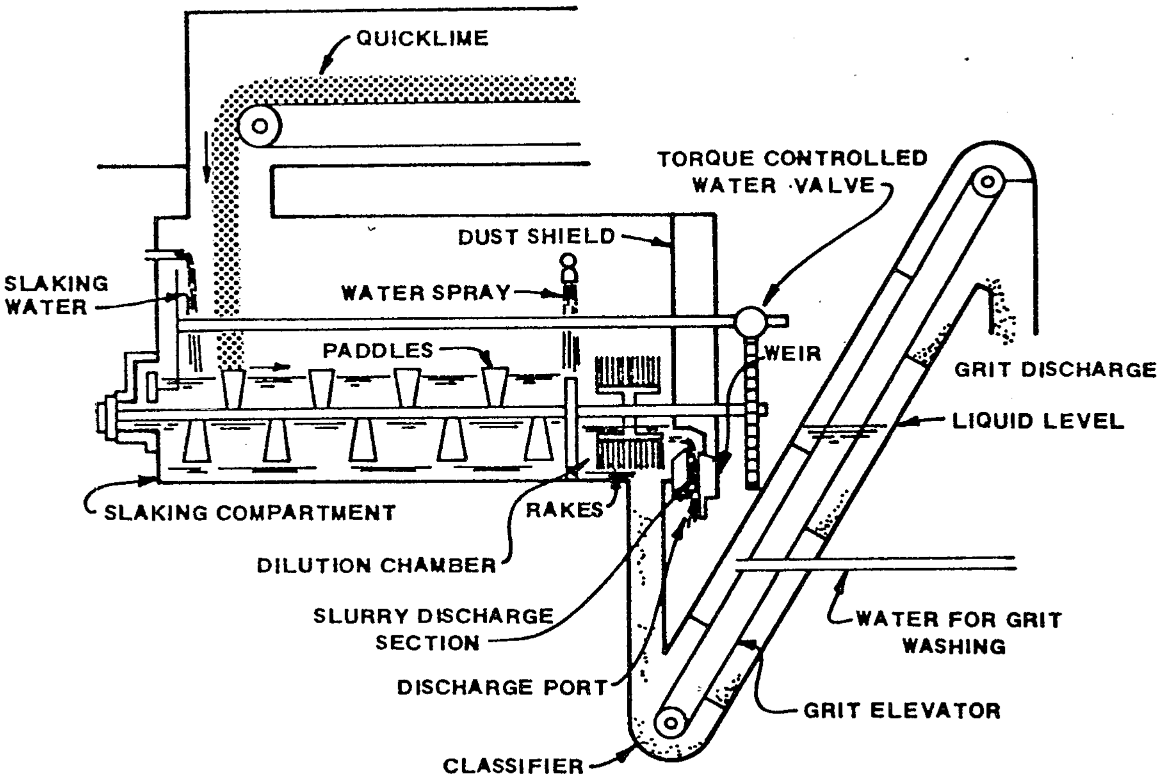


Figure 15. Typical paste-type slaker.

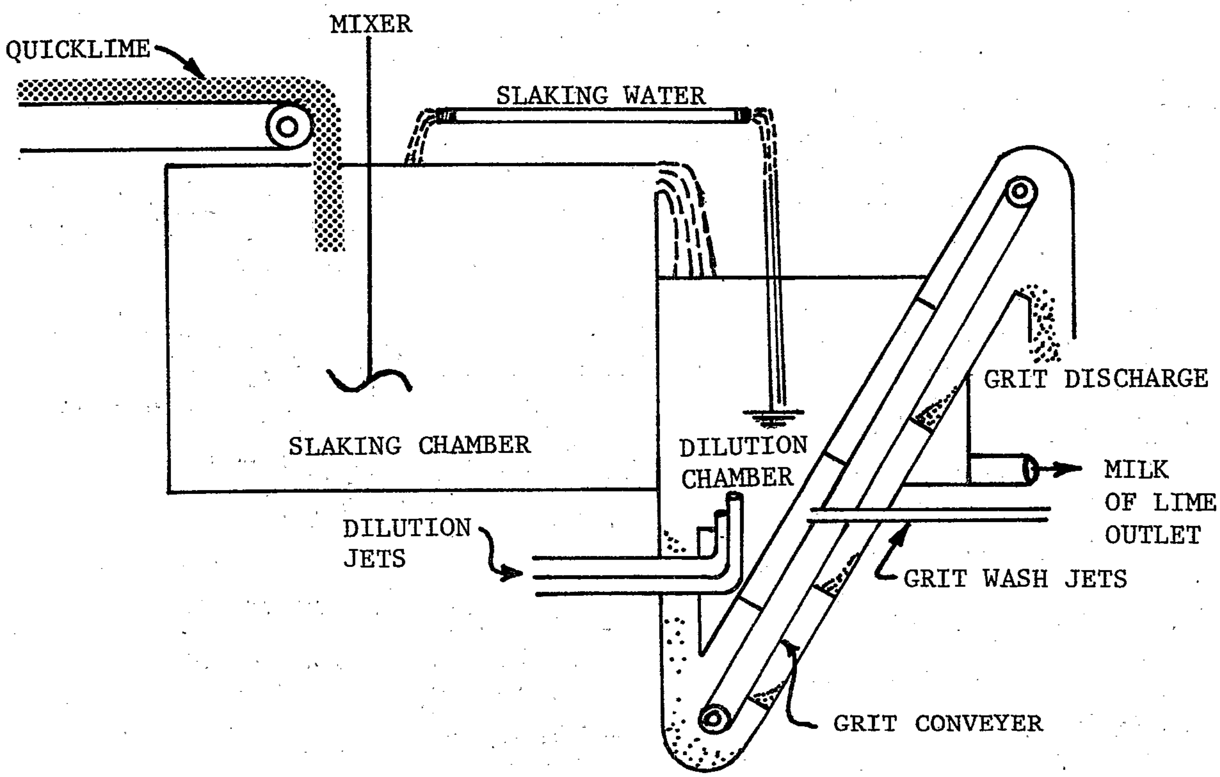


Figure 16. Typical detention-type slaker.

The required slaking time varies with the source of lime. Fast slaking limes will complete the reaction in 3 to 5 minutes, but poor quality limes may require up to 60 minutes and an external source of heat, such as hot water or steam. Before selecting a slaker, it is advisable to determine the slaking time, best initial water temperature, and optimum water:lime ratio for the lime to be used, according to procedures for slaking tests recommended by the American Water Works Association. More information about lime storage, handling, and use can be found in Reference 8.

Methanol

Methanol is a colorless liquid, and non-corrosive (except to aluminum and lead) at normal atmospheric temperature. Transfer pumps should always have positive suction pressure and should be protected by a strainer. There are three basic pumping arrangements which can be used: (1) diaphragm chemical feed pumps using an adjustable stroke for volume control; (2) positive displacement pumps with variable speed drives controlled by either a flow meter or by counting revolutions; (3) centrifugal or regenerative turbine pumps with variable speed drives controlled by a flow meter.

Ozone

Ozone is produced commercially by the reaction of an oxygen-containing feed gas in an electrical discharge. The feed gas, which may be air, pure oxygen, or oxygen enriched air, is passed between electrodes separated by an insulating material. A high voltage of up to 20,000 V is applied to the high tension electrode. The ozone molecule, made up of three oxygen atoms, is highly unstable, and is one of the most powerful oxidizing agents known.

Ozone is a pale blue gas having a distinct pungent odor. In concentrations usually employed, the odor is detectable but the color is not visible. It is both toxic and corrosive. Because of its unstable nature, it must be generated at the point of use. Consequently, safety aspects of transportation and storage are eliminated.

There are three basic ways to generate and use ozone in wastewater treatment: (1) generation from air, (2) generation from oxygen and recycle oxygen to the ozone generation system, and (3) generation from oxygen used for oxygen activated sludge system and recycle oxygen to the activated sludge system. Figure 17 shows these different methods.

The once-through air approach uses conventional air drying techniques such as compression and refrigeration, followed by desiccant drying. Ozone generated from air is usually 0.5 to 2.0 percent by weight, but is usually produced at 1.0 weight percent. Ozone is typically mixed with wastewater in a contact basin as shown in Figure 18. Fine bubble diffusers are used to feed the ozone into the basin. Packed beds have also been used as contactors. Following treatment in the covered ozone contactor, the gas is decomposed to prevent high concentrations of ozone from being released to the atmosphere.

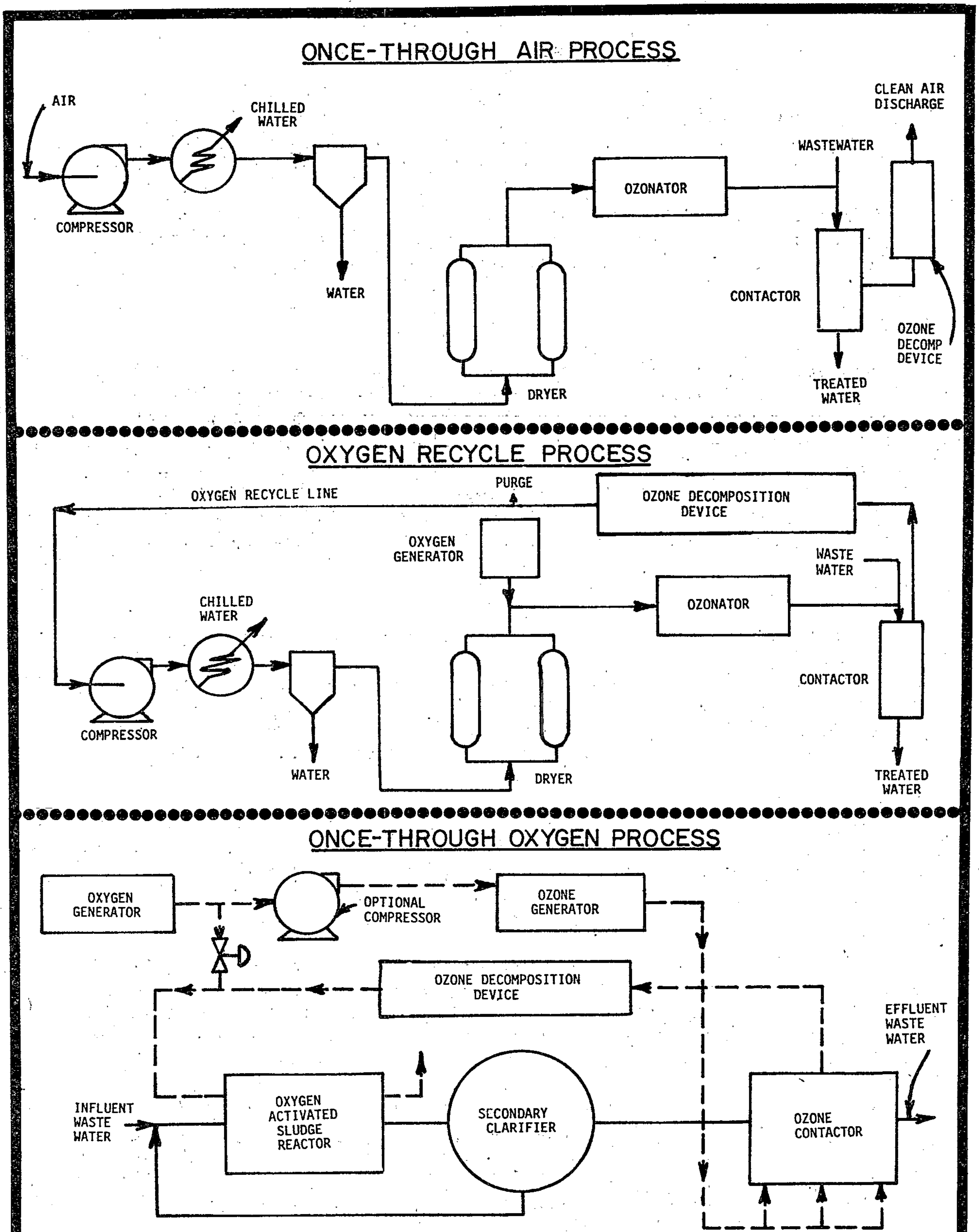


Figure 17. Alternative ozonation systems.

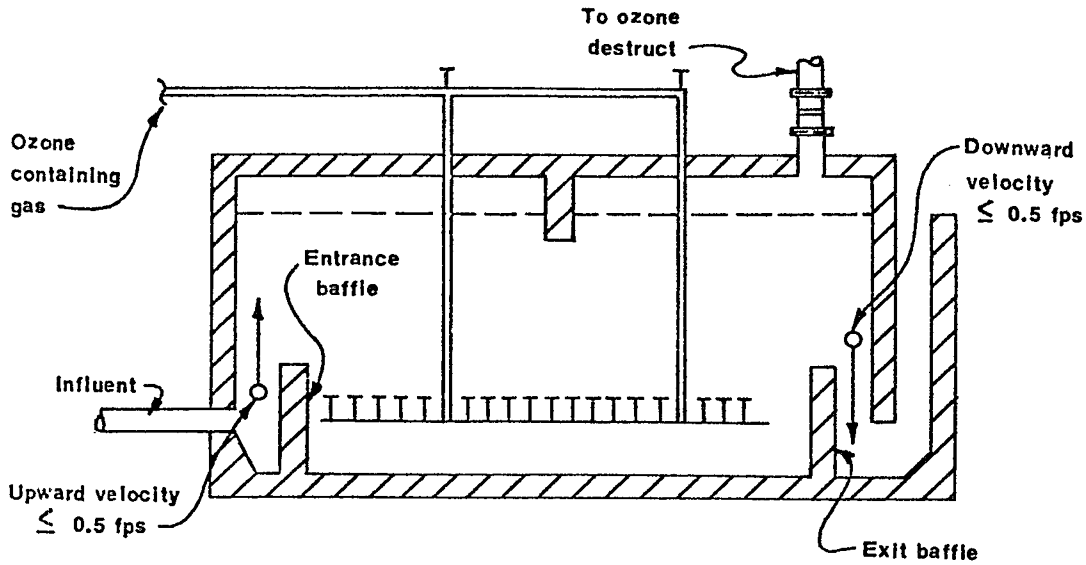


Figure 18. Typical ozone contact basin using porous diffusers.

The oxygen recycle approach may be used to recover valuable oxygen-rich off-gas from the contactor when very pure oxygen is fed to the ozone generator. High-purity oxygen gas sometimes is used since it enables the generator to produce two to three times as much ozone per unit time, and uses only about half as much generator power per pound compared to ozone produced from air.

Once-through oxygen is the simplest method of ozone wastewater disinfection. Dry oxygen is produced on-site by a cryogenic air separation process or by pressure-swing adsorption and then fed to the ozone generator. Wastewater is next treated by ozonation in the contactor and, after destruction of the unreacted ozone, the off-gas is used elsewhere in the plant. It may, for example, be used in a biological reactor or fed into incinerators for sludge disposal.

There are three basic types of commercially available ozone generators: the Otto plate, the tube and the Lowther plate. More information about the types of ozone generators available can be found in References 1 and 11.

Polymers

When dry polymers are used, the polymer and water must be blended and mixed to obtain the desired solution. Initially, complete wetting of the polymer is necessary using a funnel-type aspirator. After wetting, warm water must be added and gently mixed for about 1 hour. Polymer feed solution strengths are usually in the range of 0.1 to 0.75 percent. Stronger solutions are often too viscous to feed. Metered solution is usually diluted just prior to injection to the process to obtain better dispersion at the point of application.

The solution preparation system can include either a manual or an automatic blending system with the polymer dispensed by hand or by a dry feeder to a wetting jet and then to a mixing-aging tank at a controlled rate. The aged polymer solution is transported to a holding tank where metering pumps or rotodip feeders feed the polymer to the process. A schematic of a manual dry polymer feed system is shown in Figure 19.

The solution preparation system may be an automatic batching system, as shown in Figure 20, that fills the holding tank with aged polymer as required by level probes. Such a system is usually provided only at large plants.

Polymer solutions above 1 percent in strength should normally not be used because they are very viscous and difficult to handle. Most powdered polymers are very stable when dry, but even in cool, dry conditions, they should not be stored as powders in unopened bags for more than 1 year. Once polymers are dissolved, they may become unstable within 2 or 3 days.

Liquid polymers need no aging and simple dilution is the only requirement for feeding. The dosage of liquid polymers may be accurately controlled by metering pumps or rotodip feeders.

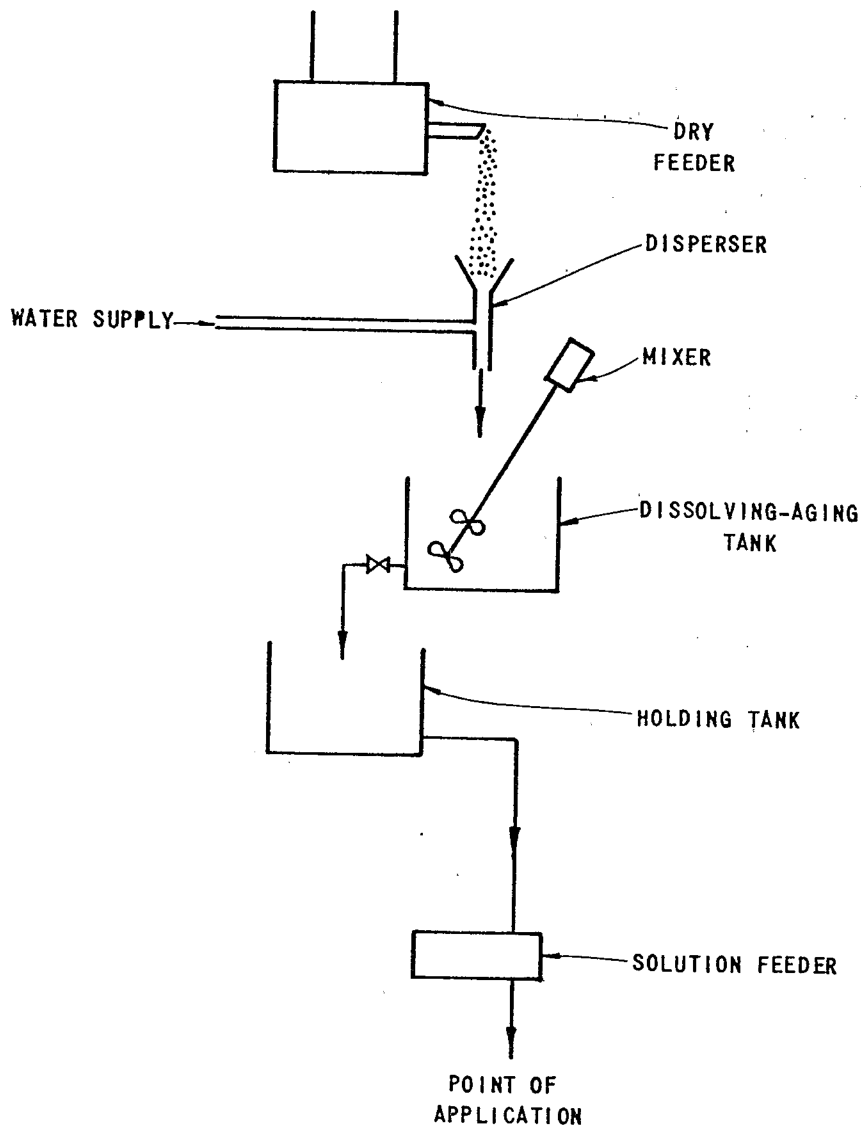


Figure 19. Manual dry polymer feed system.

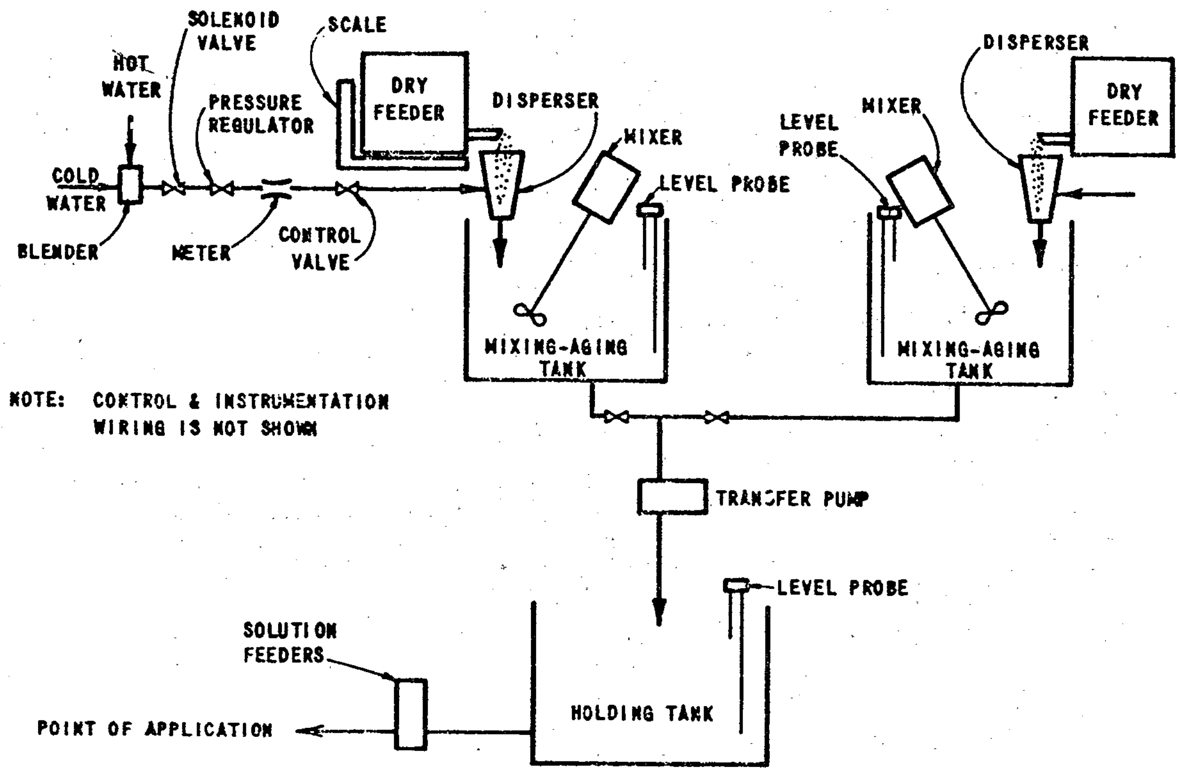


Figure 20. Automatic dry polymer feed system.

Because polymers can cause very slippery conditions in a treatment plant, spills should be cleaned up immediately. Other safety precautions as specified by the manufacturer should also be observed.

Powdered Carbon

When powdered activated carbon is used, it is mixed directly with the wastewater, fed as slurry, and removed by coagulation and settling. The carbon slurry is transported by pumping the mixture at a high velocity to keep the particles from settling and collecting along the bottom of the pipe. The velocity of the slurry should be kept between 3 and 5 ft/second. At velocities less than 3 ft/second, carbon will settle out in the pipeline; and at velocities greater than 10 ft/second, excessive carbon abrasion and pipe erosion will occur. At most plants, carbon slurries are fed at a concentration around 10.7 percent or 1 lb carbon/gallon water; typically, at this concentration, either centrifugal pumps or a combination of centrifugal pumps and eductors are used to transport the carbon slurry. Diaphragm slurry pumps or double-acting positive displacement pumps are used for transporting higher concentrations. Another transport method used is a pressure pot system in which carbon is loaded into a pressure tank and forced out by pressurizing the vessel. The carbon slurry may be fed using a rotodip feeder.

Activated carbon is a dusty respiratory irritant which smolders if ignited. Activated carbon should be isolated from flammable materials such as rags, chlorine compounds and all oxidizing agents.

Soda Ash

Dense soda ash is generally used in municipal applications because of superior handling characteristics. It has little dust, good flow characteristics, and will not arch in the bin or flood the feeder. It is relatively hard to dissolve and ample dissolver capacity must be provided. Normal practice calls for 0.5 lb of dense soda ash per gallon of water or a 6 percent solution retained for 20 minutes in the dissolver. Dissolving of soda ash may be hastened by the use of warm dissolving water. Mechanical or hydraulic jet mixing should be provided in the dissolver.

Sodium Aluminate

Dry sodium aluminate is not available in bulk quantities; therefore, small day-type hoppers with manual filling arrangements are used. Dissolvers for the free-flowing grade of sodium aluminate are normally sized for 0.5 lb per gallon or 6 percent solution strength with a dissolver detention time of 5 minutes at the maximum feed rate. After dissolving, agitation should be minimized or eliminated to prevent deterioration of the solution. Solution tanks should be covered to prevent carbonation of the solution.

Liquid sodium aluminate may be fed at shipping strength or diluted to a stable 5 to 10 percent solution. Stable solutions are prepared by direct addition of low-hardness water and mild agitation. Air agitation is not recommended.

Sodium Chlorite

Sodium chlorite ($NaClO_2$) for the generation of chlorine dioxide is available as an orange powder or as a solution.

The sodium chlorite pump is sized so as not to exceed a solution strength of 20 percent by weight (0.20 kg/l (1.66 lb/gal)). Diaphragm pumps rather than piston pumps normally are used for handling the solutions. The solution container for sodium chlorite is sized for at least one day's operation.

Sodium chlorite will withstand considerable rough handling if it is free from organic matter. However, in contact with organic materials (clothing, sawdust, brooms), it may ignite. It is sensitive to heat, friction, and impact. These problems are minimized with sodium chlorite solutions.

Sodium Hydroxide

Liquid sodium hydroxide, or caustic soda, is usually delivered in bulk shipments and must then be transferred to storage. The caustic soda is often heated and fed by metering pumps as a concentrated solution. Dilution water is usually added after feeding to the pump discharge line. Feeding systems for caustic soda are about the same as for liquid alum except for materials of construction.

Caustic soda is poisonous and dangerous if handled improperly. To avoid accidental spills, all pumps, valves and lines should be checked regularly for leaks. Operators should be properly instructed in the precautions related to the safe handling of this chemical.

STORAGE

The equipment used for storing and handling chemicals varies with the type of chemical used, liquid or dry form of the chemical, quantity of chemical used, and plant size. Storage requirements vary, but typically may be 15 to 30 days of use or 150 percent of the bulk transport capacity, whichever is greater.

It is also important to recognize that there may be special precautions necessary for the safe unloading and storage of certain chemicals. Because it is not practical to provide a complete discussion of these precautions in this manual, it is recommended that the operator obtain such information directly from the chemical manufacturer before implementing a chemical storage and handling system.

Unloading

Chemicals can be delivered to a wastewater treatment plant in dry, liquid or gaseous form. Dry chemicals are generally available in either bagged or bulk form. Where daily requirements are small, bagged chemicals are preferred and the handling and storage operations are relatively simple, usually involving either manual labor or mechanical aids. Bagged chemicals are delivered in loose bags or palletized in trucks or box cars and are generally transferred by hand truck or fork lift to storage. Unloading conveyors may be preferred for loose bags, especially if there is a long distance between the unloading point and storage area. Palletized bag shipments, with fork lift trucks moving the loaded pallets to storage and then to the point of use, eliminate much manual labor.

Bulk quantities of dry or liquid chemicals are delivered in trucks or by rail in box cars and hopper cars. Bulk unloading facilities usually must be provided at the treatment plant. Rail cars are constructed for top unloading and therefore require an air supply system and flexible connectors to pneumatically displace the chemical from the car. The United States Department of Transportation regulations concerning chemical tank car unloading should be observed. A typical pneumatic conveying system for dry chemicals is shown in Figure 21. Unloading of liquid chemicals from a tank truck is usually accomplished by gravity or by a truck-mounted pump.

Chlorine (as well as ammonia and sulfur dioxide), classified by the U.S. Department of Transportation and the U.S. Coast Guard as a nonflammable compressed gas, must be packaged in containers that comply with DOT and/or Coast Guard regulations regarding loading, handling, and labeling when shipped in the United States by rail, water or highway. Chlorine gas is commonly available in 100 lb and 150 lb steel cylinders, in ton containers, and also in large quantities in tank cars (rail), tank trucks, and barges.

Various mechanical devices, such as skids, troughs, and up-ending cradles facilitate handling of chlorine cylinders. When unloading from trucks or platforms, cylinders must not be dropped to ground level. If cylinders must be lifted and an elevator is not available, specially designed cradles or carrying platforms in combination with a crane or derrick are recommended; chains, lifting magnets, and rope slings that encircle the cylinders are unsafe and should not be used. For lateral movements a properly balanced handtruck is useful. Cylinders being moved should always have valve protection hoods in place; these hoods are not designed to hold the weight of cylinders and their contents, and cylinders should never be lifted by this means.

Ton containers may be moved by various methods, such as by specially fitted trucks and dollies, a monorail system, or rolling. Where it is necessary to lift them, as from a TMU car or truck, a suitable lift clamp in combination with a hoist or crane of at least 2-ton capacity should be used. Valve protection hoods should always be in place when ton containers are being moved.

Receiving and unloading areas and safety precautions applicable to handling single-unit railroad tank cars, tank trucks, and other shipping containers are subject to strict regulations.

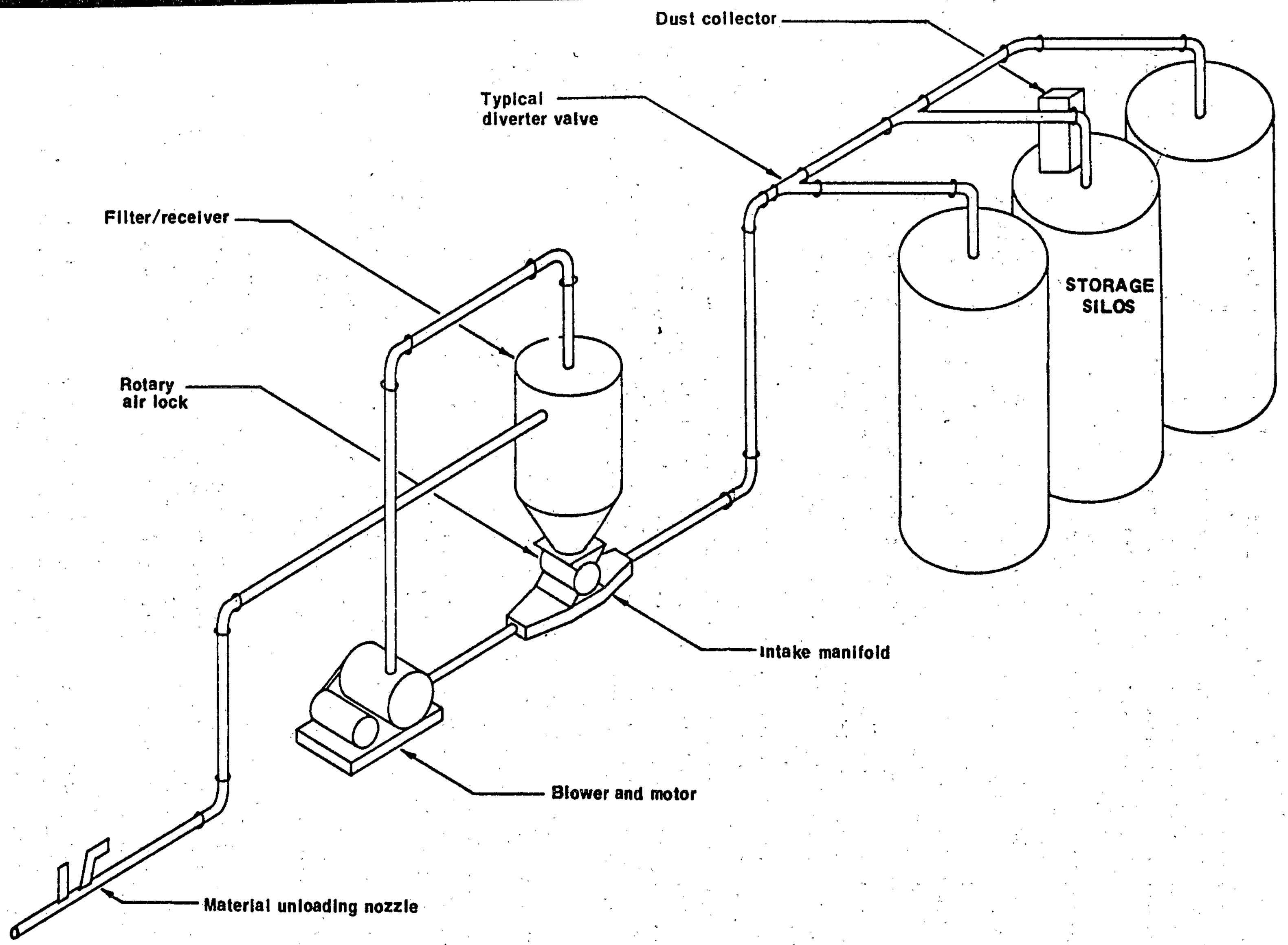


Figure 21. Typical positive-negative pneumatic conveying system.

Bulk Storage

A typical bulk storage tank or bin for dry chemicals is shown in Figure 22. Dust collectors should be provided on manually and pneumatically filled bins. The material of construction and the required slope on the bin outlet vary with the type of chemical stored; in addition, some dry chemicals such as lime must be stored in air-tight bins to keep moisture out.

Bulk storage bins should have a discharge bin gate so feeding equipment can be isolated for servicing. The bin gate should be followed by a flexible connection and a transition chute or hopper which acts as a conditioning chamber over the feeder (shown previously in Figure 5).

Liquid storage tanks should be sized according to maximum feed rate, shipping time required, and quantity of shipment. The total storage capacity should be 1½ times the largest anticipated shipment, and should provide at least a 10-day to 2-week supply of the chemical at the design average dose. Storage tanks for most liquid chemicals may be located inside or outside; however, outdoor tanks must usually be insulated and/or heated to prevent crystallization. Storage tanks for some liquids, such as liquid caustic soda, should be provided with an air vent for gravity flow.

Liquid storage tanks can be located either at ground level or above ground level, depending upon whether gravity feed or pressure feed is desired at the point of application. Figures 23 and 24 show two common liquid feed systems, one with overhead storage and one with ground storage. The rotodip-type feeder or rotameter often is used for gravity feed and the metering pump for pressure feed systems. Overhead storage can be used to gravity feed the rotodip as shown in Figure 23. A centrifugal transfer pump may also be used, but needs an excess flow recirculation line to the storage tank, as shown in Figure 24.

Bag and Drum Storage

In general, bags or drums should be stored in a dry, cool, low humidity area and used in proper rotation, i.e., first in, first out. Bag or drum loaded hoppers should have storage capacity for eight hours at the nominal maximum feed rate so personnel are not required to fill or charge the hopper more than once per shift.

Cylinder and Ton Container Storage

Whether in storage or in use, cylinders should not be permitted to stand unsupported. They should be chained to a fixed wall or support, and in such a manner as to permit ready access and removal. Ton containers should be stored horizontally, slightly elevated from ground or floor level, and blocked to prevent rolling; a convenient storage rack is obtained by supporting both ends of containers on rails of I-beams. Ton containers should not be stacked or racked more than one high unless special provision is made for easy access and removal. Chlorine cylinders and containers should be protected from impact, and handling should be kept to a minimum. Full and empty cylinders and ton containers should be stored separately.

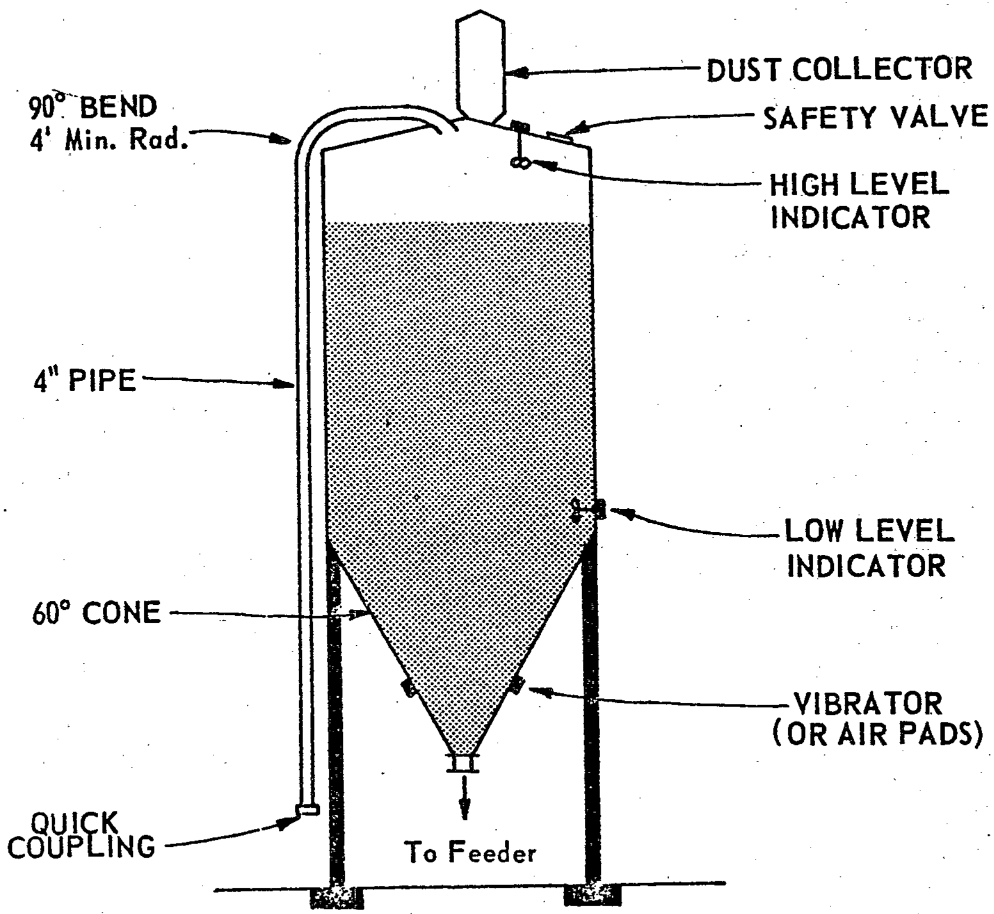


Figure 22. Typical bulk storage tank.

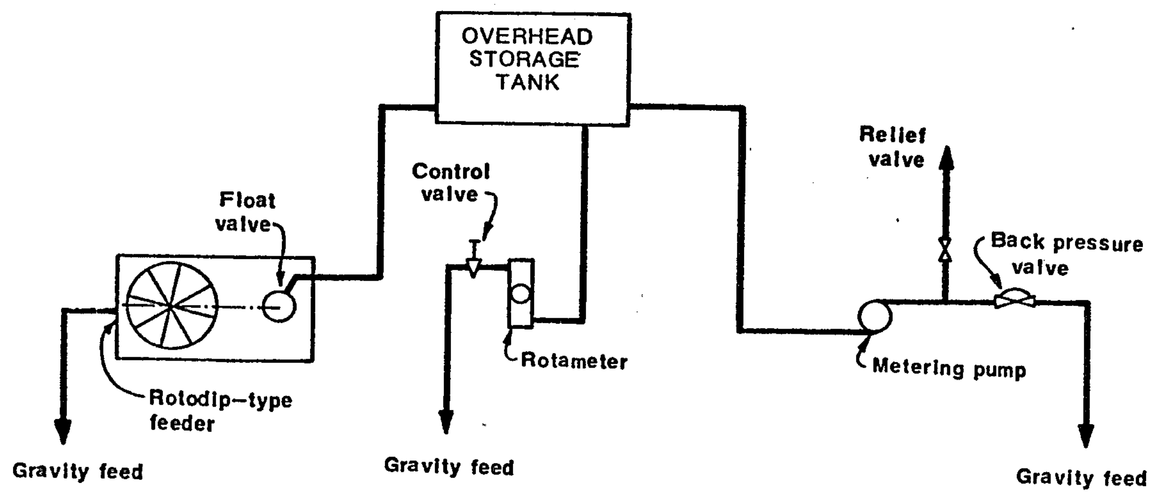


Figure 23. Alternative liquid feed systems for overhead storage.

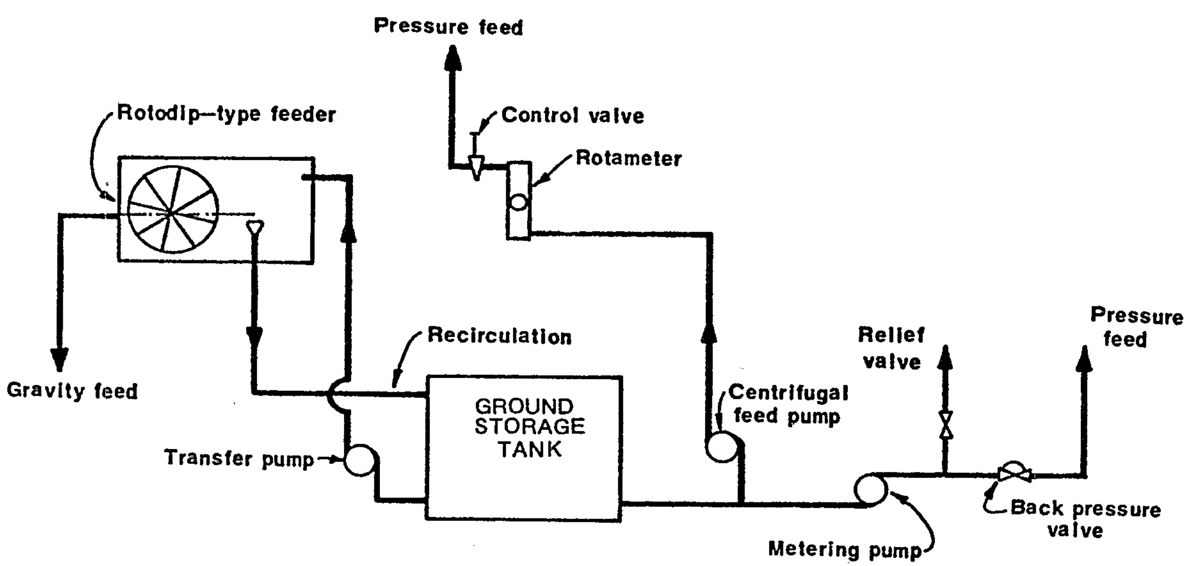


Figure 24. Alternative liquid feed systems for ground storage.

Storage areas should be clean, cool, well ventilated, and protected from corrosive vapors and continuous dampness. Cylinders and ton containers stored indoors should be in a fire-resistant building, away from heat sources (such as radiators, steam pipes, etc.), flammable substances, and other compressed gases. Subsurface storage areas should be avoided, especially for chlorine and sulfur dioxide. If natural ventilation is inadequate, as would be the case for chlorine, storage and use areas should be equipped with suitable mechanical ventilators. Cylinders and ton containers stored outdoors should be shielded from direct sunlight and protected from accumulations of rain, ice and snow.

All storage, handling, and use areas should be of such design that personnel can quickly escape in emergencies. It is generally desirable to provide at least two ways to exit. Doors should open out and lead to outside galleries or platforms, fire escapes, or other unobstructed areas.

PIPING AND HANDLING MATERIALS

Piping and accessories for transporting and feeding various chemicals should be provided only after specific chemicals have been selected for use in the treatment plant. Care must be taken to use only materials which are compatible with each chemical. For example, many chemical handling systems require special materials of construction and special types of:

- Piping and Transport Channels
- Pumps
- Valves
- Gaskets

Table 24 shows a summary of acceptable materials for piping and accessories for several commonly used chemicals. This table is not all-inclusive, but will provide the operator with a quick reference on material compatibility for most common chemicals. Because sodium hydroxide (caustic soda) is particularly dangerous to handle and requires special consideration, more detailed information on feeding and handling equipment for this chemical is listed in Table 25. The operator also is referred to the Appendix of this manual for a more general listing of acceptable handling materials for each chemical.

MANUAL AND FLOW PACING CONTROL FOR CHEMICAL FEED SYSTEMS

There are three frequently encountered chemical feed systems: (1) dry feeders, (2) solution feeders, and (3) gas feeders. Each type of feeder should have one or more means to adjust the chemical feed rate (dosage) easily. The adjustment(s) may be manual or flow pacing and must be accurate, repeatable, and easy to change. They should also provide the broadest possible adjustment span from minimum to maximum feed rate. Typical ranges are 10:1 to 20:1 but greater ranges are possible, as shown previously in Table 23.

TABLE 24

Compatible Materials for Piping and Accessories of Commonly Used Chemicals

CHEMICAL	*FRP	PLASTICS	316SS	304SS	STEEL	RUBBER-LINED STEEL	RUBBER-LINED IRON	IRON	LEAD	COPPER	RUBBER	CONCRETE	RESIN	TEFLON	SARAN	GLASS	BRONZE
ALUM																	
PIPES	●	●	●						●								
VALVES		●	●			●	●										
SODIUM ALUMINATE PIPES		●		●	●			●				●					
FERRIC CHLORIDE PIPES	●	●				●					●				●		
VALVES		●									●		●	●	●		
FERRIC SULFATE PIPES	●	●	●								●					●	
LIME																	
PIPES & CHANNELS		●			●			●			●	●					
PUMP IMPELLER LINING											●						●
SODIUM CARBONITE PIPING		●			●			●			●						
SODIUM HYDROXIDE PIPING					●						●	(ALSO SEE TABLE 25)					
CARBON DIOXIDE (COOL & DRY)					●												
CARBON DIOXIDE (HOT & MOIST GAS)		●	●														
CARBON DIOXIDE (SOLUTION)	●	●															
POLYMER (DRY) PIPING		●	●														

* FRP-Fiber reinforced plastic

TABLE 25

Materials Suitable for Caustic Soda Systems

Components	Recommended Materials for Use With 50% NaOH Up to 140°F
Rigid Pipe	Standard weight black iron
Flexible Connections	Rigid pipe with ells or swing joints, stainless steel or rubber hose
Diluting Tees	Type 304 stainless steel
Fittings	Steel
Permanent Joints	Welded or screwed fittings
Unions	Screwed steel
Valves - Non-leaking (Plug)	
Body	Steel
Plug	Type 304 stainless steel
Pumps (Centrifugal)	
Body	Steel
Impeller	Ni-Resist
Packing	Blue asbestos
Storage Tanks	Steel

Dry Feeders

Most dry feeders are of the belt, grooved disc, screw, or oscillating plate type. The feeding device (belt, screw, disc, etc.) is usually driven by an electric motor. Many belt feeders, particularly gravimetric type feeders, also contain a material flow control device such as a movable gate or rotary inlet device for metering or controlling the flow of chemical to the feed belt.

Volumetric Dry Feeders--

Most volumetric dry feeders are of the rotating screw or disc type, but the belt and rotary star valve types are also used. Generally, the screw or disc type is driven by an electric motor through a gear reducer drive. In some cases the drive assembly (excluding the motor) contains a variable speed or a linkage adjustment which allows feed rate changes. Otherwise, the feed rate adjustment must be made directly to the motor drive.

Manual Feed--Manual dosage adjustment of volumetric dry feeders is accomplished by one or more of the following means:

1. Drive motor for feed screw, belt, disc, or rotary valve.
   a. Manual variable speed.
   b. Percentage timer control motor which operates on a run-stop repeat cycle with run time set by percentage timer and adjustable from zero to 100 percent of the total cycle. Typical total run-stop cycle times are 15, 30, 60 seconds. For a system set up on a 60-second basis the following is typical operation:

Percentage timer setting	Run time, seconds	Off time, seconds
100	60	0
75	45	15
50	30	30
25	15	45
0	0	60

   c. Manually adjustable speed reducer or adjustable linkage on drive assembly.

2. Control gate for belt feeder.
   a. Manual setting of gate position to allow more or less material on belt.

Flow Pacing--Automatic proportioning of volumetric dry feeders to flow (commonly called flow pacing) is readily accomplished for a variety of flow signals. The more common flow and control signals are:

a. Pulse duration (on-off), with frequently used cycle times of 15, 30, and 60 cycles.

b. 3 - 15 psi pneumatic

c. 4 - 20 or 10 - 50 milliampere

d. 1 - 5 volt d.c.

Most modern feeders can accept one or more of the flow and control signals. If the feeder will not accept the particular signal available, signal converters are readily available to convert the signal to one that the feeder will accept. For example, a 3 - 15 psi pneumatic signal can be converted to a 4 - 20 mA signal. Signal converters are relatively inexpensive and are reliable.

If a volumetric feeder is automatically flow-proportioned, a means still must be available for setting the feed dosage. Typically, this is accomplished in one of two ways.

1. A "manual feed rate control" built into the feeder which modifies the automatic proportioning signal within the feeder control system.

2. A separate manual adjustment such as a mechanical linkage or feed gate adjustment, or a manual speed adjustment on the gear reducer drive system.

Gravimetric Dry Feeders--

Manual Feed-- A gravimetric dry feeder has a built-in control system to maintain a constant feed weight rather than volume for any given dosage setting. For manual feed systems, an operator dosage adjustment is provided as part of this gravimetric control system. The feed belt is weighed continuously, establishing automatic internal control of gate position (or rotary inlet valve speed) to maintain a constant belt weight for a given dosage setting.

Flow Pacing--The simplest method to obtain automatic proportioning control is to provide a variable speed drive for the belt. The automatic proportioning control can be used to vary the belt-drive motor speed.

If the feeders are to be shut down automatically, for instance when incoming wastewater flows are low and not all feeders are required, provisions should be made for shut-down and start-up of system components such as:

a. The feeder

b. Storage bin vibrators

c. Water supply to dissolvers

d. Mixers

e. Solution transfer pumps

Dissolver water supply and mixer should operate for an adjustable time delay after the feeder is stopped to prevent chemicals from settling in the dissolver.

Solution Feeders

The most common solution feeders are motor-driven diaphragm and plunger type feed pumps. Generally, these pumps have a built-in stroke adjustment mechanism which permits variation of the output feed rate.

Manual Feed--

For manual dosage control, the motor would operate at a constant speed and the operator could adjust the dosage with the stroke adjustment.

Flow Pacing--

Automatic proportioning control can be accomplished readily in one of the following ways:

1. Modification of drive motor to provide variable speed or on-off proportioning.

2. Installation of an automatic stroke adjuster.

The drive motor can be set up to operate at variable speeds proportional to pneumatic or electric signals. On-off pulse duration signals can be applied directly to the motor starter so that the motor operates on and off in proportion to the signal. This involves many start-stop cycles for the motor and it is recommended that only three phase motors be used for this type of duty. When the automatic proportioning is accomplished with the drive motor, the manual stroke adjustment is still available for operator-adjusted manual dosage changes.

Automatic stroke adjusters can be installed in place of the manual adjuster on most feeders. The automatic adjusters will accept various analog control signals, including pneumatic and electric. Obviously, these automatic stroke adjusters can be used for automatic proportioning, but in most cases there are not manual settings available for manual dosage adjustments. In some cases, a manual dosage adjustment can be incorporated into the automatic stroke adjustment mechanism or a manual variable speed motor drive can be provided for operator manual dosage adjustment. Probably the most satisfactory arrangement is to proportion automatically with a variable speed or pulse-duration motor drive, and to leave the manual stroke adjuster for operator dosage adjustments.

If the solution feed system is to be started and stopped with plant operation or on some other basis, consideration must be given to starting and stopping auxiliary systems such as the solution feeder, dilution water, transfer pumps, mixers, and similar equipment.

There are a number of solution batching and feed systems now on the market, particularly for polymers. These systems automatically produce a feedable polymer solution from dry polymer. Typical systems include a dry polymer storage hopper, dry feed, wetting, a dissolver tank with mixing, a feed tank, and solution feeders. Most of these systems are sold as a pre-engineered package and can be supplied for manual control, automatic proportioning and for automatic start and stop operation. Generally, these systems use solution feed pumps for metering and the previous comments concerning solution feeders are applicable.

Gas Feeders

Most modern gas feeders are vacuum operated. The gas is accurately metered through an orifice with a fixed pressure drop across the orifice. For adjustment of gas feed rate the orifice size can be changed manually or automatically.

Manual Feed--

Most small, inexpensive gas feeders have provisions for manual adjustment of the orifice size to change the gas-flow rate (dosage). This adjustment is made with a knob on the front of the feeder. Normally the gas flow rate is indicated by a visual flow indicator calibrated in pounds per day.

Flow Pacing--

Gas feeders may be automatically proportioned in a number of ways. Two common methods are variable vacuum control and automatic positioning of the orifice control.

Variable Vacuum Control--Variable vacuum control systems are an economical method of automatically proportioning gas feeders. The vacuum control system consists basically of a vacuum-producing device, such as the gas injector, a restricting orifice and an intermediate vacuum transmitter. The primary flow signal is converted to a proportional vacuum signal which is applied to the vacuum-regulating valve on the downstream side of the gas feeder orifice. The pressure ahead of the orifice is maintained at a constant value by the inlet gas pressure regulating valve. The gas feed rate is varied automatically as this proportioning vacuum signal changes with the flow.

Changes in the control vacuum signal cause comparable changes in the pressure downstream of the orifice and, therefore, in the differential across the orifice. Since the gas flow squared is proportional to the differential pressure across the orifice, the gas-feed rate will vary in accordance with the control-vacuum signal.

Automatic Positioning--Automatic positioning of the gas-flow control orifice is accomplished with a power positioner which can be selected to operate from a number of input signals such as:

a. 3 - 15 psi pneumatic

b. 4 - 20 or 1 - 50 milliampere electric

c. 1 - 5 volt d.c. electric

d. Potentiometer position

e. Pulse duration

f. Pulse frequency

g. Others by special application

When an automatic proportioning positioner is used, a manual dosage control knob is provided on the chlorinator so the operator can make manual adjustments of dosage. This adjustment modifies the automatic proportioning over a wide range.

Almost all gas-feeder control schemes are based on the use of variable vacuum or the use of an orifice-proportioning positioner. In most cases, the manual dosage adjustment is retained for operator use.

Gas feeders can be started and stopped simply by starting or stopping water flow through the injector. Usually this is all that is necessary to start or stop a typical gas-feed system such as a chlorinator or sulforator.

AUTOMATIC CONTROL FOR CHEMICAL FEED SYSTEMS

Various automatic control schemes are possible for chemical feed systems beyond the automatic flow proportioning discussed for each type of feeder. For example, automatic pH control is possible using a pH sensor, controller, and pH adjustment chemical feeder for sodium hydroxide with an automatic stroke positioner. Automatic chlorine residual control is possible using a chlorine residual analyzer, controller, and chlorinator with an automatic orifice positioner. These are "feed back" systems where the final control parameter, such as pH, is controlled by a previous feed of chemical. "Feed forward" systems are also possible where a parameter concentration prior to chemical feed is determined and related to the chemical feed for automatic control. An example is ammonia removal by breakpoint chlorination. Approximately 8 to 10 parts of chlorine are required to remove one part of ammonia. Therefore, if the ammonia concentration prior to chlorine feed is measured, the chlorine feed can be proportioned to 8 or 10 times the ammonia concentration.

Various types of "feed forward" or "feed back" systems or combinations can be devised in theory. The problem is that there are substantial delay times in such systems which most analog controllers are not designed to handle. The delays are mostly hydraulic in the time to change a chemical feeder setting, get the change to the injection point, process delays to the sample point, delay in the sample lines and delay in the analyzer. The total delay from the time a feed rate is changed until it is read out by an analyzer can be 5 minutes or longer. The control results can be unstable and can lead to wide cycles of the controlled variable. There are ways of overcoming these problems with proper design and equipment selection, but design of such systems is a very specialized art.

Automatically controlled systems must be arranged so that auxiliary systems such as mixers, dilution water, and slakers are started and stopped as needed. The point to be emphasized, therefore, is that such systems can be designed and applied where needed and that chemical feeders are available for use in such systems. These systems are complex enough and the analyzers require maintenance to the point that such systems should not be used except where they provide a benefit sufficient to overcome the operational disadvantages.

SECTION 4

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SECTION 5

PROBLEMS WHICH CAN BE AIDED BY CHEMICAL ADDITION

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PROBLEMS WHICH CAN BE AIDED BY CHEMICAL ADDITION

This section of the manual serves primarily as a troubleshooting guide to help identify problems which can be aided by the addition of chemicals. Problems are identified by the treatment process where the problem would most likely occur. A possible solution is provided for each problem, along with a list of possible chemicals for aiding the problem, advantages and disadvantages of each chemical, and potential application points.

While chemical addition may be helpful in many wastewater treatment processes, it must be recognized that there may be operational alternatives which are less expensive and more desirable. OPERATIONAL ALTERNATIVES SHOULD BE INVESTIGATED THOROUGHLY BEFORE CHOOSING A CHEMICAL ALTERNATIVE DESCRIBED IN THIS SECTION. In some cases, short-term correction using chemicals may be necessary, but the condition causing the problem also must be identified and corrected. This is particularly true when the problem is associated with an industrial discharge, lack of enforcement of pretreatment requirements, or an overloaded plant. CHEMICALS SHOULD NOT BE USED AS A SUBSTITUTE FOR GOOD PLANT OPERATING PROCEDURES.

For more information on troubleshooting and process control, the operator should refer to "Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities," EPA-430/9-78-001, January 1978. This manual describes procedures for evaluating and troubleshooting various unit processes commonly used at wastewater facilities. One chapter is devoted to chemical feeding and conditioning, and other chapters contain information on the use of chemicals in improving process operations. Procedures for evaluating process efficiencies also are included.

INDEX

TO

PROBLEMS WHICH CAN BE SOLVED BY CHEMICAL ADDITION

COLLECTION SYSTEMS

PROCESS: PUMP STATIONS AND PIPELINES

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Concrete corrosion	Sulfide control*	Pump stations, force mains, manholes upstream of problem	a. Chlorine	a. Reduces odor, economic for large plants	a. Costly to purchase and handle at small plants; overdoses could form odorous chlorinated phenols
			b. Calcium hypochlorite	b. Reduces odor, more economical than chlorine gas for small systems	b. Costly in large plants; overdoses could form odorous chlorinated phenols
			c. Ferric chloride Ferrous chloride	c. Relatively effective for very high sulfide industrial wastes	c. Ferric and ferrous salts must be used together, may require air addition
			d. Copper sulfate	d. Very effective	d. Expensive; excess dosage affects aerobic processes
			e. Hydrogen peroxide	e. Reduces odors, easy to handle; effective	e. May not completely remove H_2S; requires at least 15 min. detention time
2. Algae and slime accumulation in pipeline	Algae and slime removal	Pump station or manhole ahead of problem area	a. Chlorine	a. Effective and aids in odor control; economic for large systems	a. Costly to purchase for small plants
			b. Calcium hypochlorite	b. More economical than chlorine gas for small systems	b. Costly in large plants
			c. Sodium hypochlorite	c. More economical than chlorine gas for small systems	c. Costly in large plants
			d. Copper sulfate	d. Very effective	d. Relatively expensive
3. Roots in sewers	Root prevention	Pump station, manhole upstream of problem	Copper sulfate	Very effective	Relatively expensive

* Before using chemicals, check process control procedures (Reference 1).

PROCESS: PUMP STATIONS AND PIPELINES

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
4. Septic, odorous wastewater	Sulfide control*	Head of plant, pump station, manholes upstream of plant, force mains	a. Chlorine	a. Most commonly used; also acts as a disinfectant	a. Overdosing could damage biological systems
			b. Hydrogen peroxide	b. Economical; acts as a source of dissolved oxygen, inhibits regeneration of sulfide, forms nontoxic byproducts	b. Must have sufficient detention time to be effective
			c. Lime	c. Effectively raises pH to increase the solubility of H_2S	c. Increases sludge production
			d. Activated carbon	d. Adsorbs odor causing material	d. Relatively expensive
			e. Oxygen (preaeration)	e. Prevents septic conditions if sulfide is not already present	e. Once sulfide develops, oxygen would strip the sulfide and increase the odor problem

* Before using chemicals, check process control procedures (Reference 1)

CONVENTIONAL WASTEWATER TREATMENT

PROCESS: PREAERATION

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Odors or other problems associated with lack of dissolved oxygen	Enhancement of preaeration, odor control, use preaeration basin as a rapid mix bath for other chemical treatment	Preaeration tank, aerated grit basin, pump station, force main, or manholes upstream of problem	a. Lime	a. May not add salts to water	a. Produces large quantities of sludge
			b. Alum	b. Easy to handle, very soluble	b. Adds dissolved solids to the water, usually requires addition of strong base
			c. Ferric chloride	c. Less expensive per pound than alum	c. Adds dissolved solids to the water, usually requires addition of strong base
			d. Ozone	d. Very effective; no problem with overdosing; no increase in dissolved solids	d. Must be generated on site; relatively expensive
			e. Chlorine	e. Effective	e. High residual could damage biological units; increases dissolved solids in effluent.
			f. Hydrogen peroxide	f. Effectively oxidizes H_2S odors; does not enhance corrosion	f. Must have at least 15 min. residence time to be effective

PROCESS: GRIT REMOVAL

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Rotten egg odor in grit chamber	Control sulfide	Collection system, grit tank	Same as sulfide control for concrete corrosion control in collection system (see page 106)		
2. Influent pH too high	Reduce pH*	Headworks, grit chamber	a. Carbon dioxide	a. Economical for large plants	a. Generally too expensive for small plants
			b. Hydrochloric acid	b. Generally available, relatively inexpensive	b. Corrosive
			c. Nitric acid	c. Effective	c. May be restricted by effluent nutrient considerations
			d. Sulfuric acid	d. Most commonly used; economic for small plants	d. Not economical for large plants; difficult to handle
3. Influent pH too low	Raise pH*	Headworks, grit basin	a. Lime	a. Relatively inexpensive; improves coagulation; stronger per pound than sodium hydroxide	a. Not readily soluble
			b. Sodium hydroxide (Caustic soda)	b. Effective; easy to handle and feed; inexpensive	b. Dangerous to handle
			c. Sodium bicarbonate	c. Easy and safe to handle; very effective	c. More expensive than lime or sodium hydroxide
			d. Sodium carbonate (Soda ash)	d. Very soluble; easy to apply	d. More expensive than lime

* Before using chemicals, check process control procedures (Reference 1).
Problem may be caused by industrial waste.

PROCESS: MICROSCREENING

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Slime growth on microscreen	Prevent slime buildup, remove slime	Headworks, at microscreen	a. Chlorine	a. Very effective and economical for large plants, reduces odor	a. Overdose could damage biological treatment; can cause steel screen to corrode
			b. Sodium hypochlorite	b. Easy to handle; economical for small plants; reduces odors	b. Overdose could damage biological treatment; solution unstable and deteriorates faster than calcium hypochlorite
			c. Calcium hypochlorite	c. Relatively stable, less dangerous than chlorine gas; most economical for small plants; reduces odors	c. Overdose could damage biological treatment

PROCESS: PRIMARY CLARIFICATION

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Low grease removal due to inadequate particle agglomeration	Provide chlorine contact tanks with grease removal equipment	Ahead of primary clarifier, or in grit basin	a. Lime	a. Veryeffective, does not increase TDS	a. Increases sludge production
			b. Chlorine	b. Economical for large plants, very effective	b. Overdosing could upset biological system; costly for small systems
			c. Sodium hypochlorite	c. Safer and easier to handle than chlorine, economical for small systems	c. Overdosing could upset biological system; increases TDS
			d. Calcium hypochlorite	d. Safer and easier to handle than chlorine; economical for small systems	d. Overdosing could damage biological system; increases TDS
2. Heavy metals in the effluent	Precipitate heavy metals	Ahead of primary clarifier as in physical-chemical treatment, grit basin, preaeration basin	a. Lime	a. Removes many types of metals	a. Effective only above pH 11; produces large quantities of sludge
			b. Ferrous sulfate	b. Reduces chrome	b. Removal limited to chromium
			c. Sodium bisulfite	c. Reduces chrome	c. Removal limited to chromium
			d. Sulfur dioxide	d. Removes Cr^{+6}	d. Removal limited to chromium
			e. Alum	e. Easy to handle	e. Adds dissolved solids to effluent
3. High calcium, magnesium, silica or fluoride in plant effluent	Precipitation of Ca, Mg, Si, F	Grit basin, ahead of primary clarifier, preaeration basin	Lime	High removals of calcium and magnesium possible with wastewater of high carbonate hardness	Increased sludge production, sludge difficult to dewater
4. Odors at the primary clarifier (uncovered)	Pretreat wastewater, sulfide control	Grit chamber, preaeration basin collection system	See sulfide control in collection systems (page 106)		

PROCESS: PRIMARY CLARIFICATION (Continued)

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
5. Excessive iron and manganese in effluent	Precipitate or sequester iron and manganese	Ahead of primary clarifier, grit basin	a. Potassium permanganate	a. Highly soluble and easy to apply; rate of reaction much faster than Cl_2, not as pH-dependent as chlorine	a. Fire hazard in storing large quantities; expensive; potentially toxic
			b. Chlorine dioxide	b. Effective	b. Relatively expensive for small plants
			c. Chlorine	c. Readily available	c. Requires longer contact time than potassium permanganate; high residual can upset biological units
			d. Sodium hypochlorite	d. Easy to handle; economical for small plants	d. Requires longer contact time than potassium permanganate; high residual can upset biological units. Also solution unstable and deteriorates faster than calcium hypochlorite
			e. Calcium hypochlorite	e. Relatively stable, less dangerous than liquid chlorine; economical for small plants	e. Requires longer contact time than potassium permanganate; high residual can upset biological units

PROCESS: PRIMARY CLARIFICATION (Continued)

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
6. Excessive phosphorus in the final effluent	Precipitation of phosphate	Ahead of the primary clarifier, grit basin, preaeration basin	a. Lime	a. Very effective; may not increase TDS	a. Requires high dosages and produces large quantities of sludge; tendency towards scale buildup
			b. Alum	b. Easy to handle; requires about half as much dosage as lime for equal phosphorus removal	b. Costs more than twice as much per pound as lime; usually requires strong base addition
			c. Ferric chloride	c. Not as pH-sensitive as lime, effective over larger pH range	c. May require addition of strong base such as sodium hydroxide for pH control; adds TDS to effluent
			d. Anionic polymer	d. Requires relatively small dosage; easy to handle; does not increase solids	d. Improper dose results in poor floc formation; not effective in many cases when used alone; may be expensive
			e. Ferric sulfate	e. Not as pH-sensitive as lime	e. Solution very corrosive; usually need to add alkalinity; adds TDS to effluent
			f. Ferrous sulfate	f. Not as pH-sensitive as lime, less expensive than ferrous chloride	f. Usually requires addition of alkalinity
			g. Ferrous chloride	g. Less corrosive than ferric chloride	g. Adds TDS to effluent
			h. Sodium aluminate	h. Effective in high pH waters; alkaline; small dosage required	h. Often used with other chemicals; high cost; not effective in soft waters

PROCESS: PRIMARY CLARIFICATION (Continued)

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
7. Odors at the primary clarifier (covered)	Oxidize odors at the wet air scrubber	Wet air scrubber	a. Sodium hydroxide	a. Prevents low dissolved oxygen levels	a. Overdosing could adversely affect biological treatment
			b. Potassium permanganate	b. Reaction rate faster than chlorine; prevents anaerobic conditions	b. Explosive in presence of organics; produces solids to be disposed of
			c. Activated carbon	c. Very effective and reliable	c. Relatively expensive
			d. Hypochlorite (sodium or calcium)	d. Economic for small systems; easy to feed and handle	d. Overdosing could adversely affect biological system
			e. Chlorine	e. Very effective; most plants already have handling facilities; economical for large plants	e. Overdosing can adversely affect biological treatment
			f. Chlorine dioxide	f. Very effective	f. Must be generated on-site; expensive
			g. Ozone	g. Very strong oxidant and prevents anaerobic conditions	g. Must be generated on-site; too expensive for small plants

PROCESS: TRICKLING FILTER (BIOLOGICAL SECONDARY WASTEWATER TREATMENT)

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Filter flies	Control filter fly life cycle*	Ahead of trickling filter	a. Chlorine	a. Very effective and economical for large plants; reduces odor	a. Overdose could damage biological treatment
			b. Sodium hydroxide	b. Easy to handle; economical for small plants; reduces odors	b. Overdose could damage biological treatment; solution unstable and deteriorates faster than calcium hypochlorite
			c. Calcium hypochlorite	c. Relatively stable; economical for small plants; reduces odors	c. Overdose could damage biological system
2. Filter ponding due to snails, moss, roaches, or excessive slime growth	Kill excessive slime growth, control fungus growth*	Ahead of trickling filter	a. Chlorine	a. Very effective and economical for large plants; reduces odor	a. Overdose could damage biological treatment
			b. Sodium hydroxide	b. Easy to handle, economical for small plants; reduces odor	b. Overdose could damage biological treatment; solution unstable and deteriorates faster than calcium hypochlorite
			c. Calcium hypochlorite	c. Relatively stable; less dangerous than chlorine gas; most economical for small plants; reduces odors	c. Overdose could damage biological treatment
3. Odors in trickling filter (uncovered)	Sulfide control	Ahead of trickling filter during low flow, at headworks grit chamber, preaeration basin	Same as concrete corrosion control in collection system (see page 106)		
4. Odors in trickling filter (covered)	Oxidize odors at the wet air scrubber	Wet air scrubber	Same as odor control at covered primary clarifier (see page 115)		

* Before using chemicals, check process control procedures (Reference 1).

PROCESS: TRICKLING FILTERS (Continued)

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
5. Excessive phosphorus in the final effluent	Precipitate phosphorus	Ahead of trickling filter in primary clarifier or after trickling filter before final clarifier	a. Alum	a. Easy to handle, very effective	a. May cause filter to slough more; requires subsequent precipitation to be more effective
			b. Ferric chloride	b. Effective over a large pH range	b. May cause filter to slough more; requires subsequent precipitation to be more effective
			c. Sodium aluminate	c. Effective in high pH waters; relatively small dosage required	c. Often used with other chemicals; relatively high cost
			d. Polymer	d. Improves settling in many wastewaters	d. Usually not effective unless used with other coagulants
6. Trickling filter effluent high in suspended solids--sloughing due to seasonal changes	Improve settling in clarifier	Influent to clarifier	Polymer	Very effective; easy to handle; small dosages required	None known

PROCESS: ACTIVATED SLUDGE

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Filamentous growth/sludge bulking	Destroy filamentous organism*	In the aeration basin	a. Chlorine	a. Inexpensive; usually available at most plants	a. Ineffective when bulking is due to light diffuse flocs; only a temporary solution
			b. Hydrogen peroxide	b. Very effective, immediate improvement	b. Relatively expensive; only temporary solution
			c. Lime	c. Raises pH; may not increase TDS	c. Recirculated sludge may have adverse effects on mixed liquor characteristics
			d. Sodium hydroxide	d. Raises pH, easy to feed; relatively inexpensive	d. Dangerous to handle
			e. Polymer	e. Cationic polymer very effective; easy to handle	e. Improper choice of polymer results in no improvement
2. Mixed liquor low alkalinity or pH	Add alkalinity	In the aeration basin	a. Lime	a. No increase in TDS; very effective; stronger per pound than sodium hydroxide	a. Increased sludge production; not readily soluble
			b. Sodium hydroxide	b. Very effective, relatively inexpensive	b. Dangerous to handle
			c. Sodium bicarbonate	c. Easy and safe to handle, very effective	c. Relatively expensive
			d. Sodium carbonate	d. Highly soluble, easy to apply	d. More expensive than lime

* Before using chemicals, check process control procedures (Reference 1). This problem requires careful analysis.

PROCESS: ACTIVATED SLUDGE (Continued)

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
3. Excessive phosphorus in final effluent	Phosphorus precipitation	In the aeration basin or aeration basin effluent	a. Alum	a. Easy to handle	a. May consume alkalinity resulting in lower pH
			b. Ferric chloride	b. Effective over large pH range	b. May consume alkalinity resulting in lower pH
			c. Ferrous sulfate (pickle liquor)	c. Less expensive than ferric chloride and alum	c. May consume alkalinity resulting in lower pH
			d. Polymer	d. Improves settling in many wastewaters	d. Usually effective only if other coagulants are added

PROCESS: ROTATING BIOLOGICAL CONTACTORS

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. White biomas covering RBC due to H_2S or septic influent	Oxidize H_2S, add oxygen to system*	Before primary clarifier or influent to RBC	a. Hydrogen peroxide b. Sodium nitrate	a. Oxides H_2S and reduces odors b. Adds oxygen to system to prevent septic conditions	a. Relatively expensive b. Adds sodium to effluent

* Before using chemicals, check process control procedures (Reference 1). System may be overloaded.

PROCESS: LAGOONS

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Organic overload in lagoon	Add oxygen to the system*	Influent to lagoon	Sodium nitrate	Adds oxygen to system to prevent anaerobic conditions	Adds sodium to effluent; only a temporary solution
2. Excessive algae in lagoon	Control algae growth	Lagoon influent, lagoon surface using a boat	Copper sulfate	Very effective	Relatively expensive
3. Odors released during lagoon cleaning operations	Control odors by chemical addition	Lagoon	Lime	Effective and relatively inexpensive	None known

* Before using chemicals, check process control procedures (Reference 1).

PROCESS: SECONDARY CLARIFICATION (SEDIMENTATION)

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Excessive suspended solids or turbidity	Chemical precipitation of suspended solids*	Ahead of secondary clarifier, in aeration basin, in trickling filter	a. Lime	a. Commonly used, very effective; may not increase TDS; sludge dewaters easily	a. Very pH dependent; produces large quantities of sludge; overdose can result in poor effluent quality
			b. Alum	b. Easy to handle and apply; most commonly used; produces less sludge than lime; most effective between pH 6.8 - 7.5	b. Adds dissolved solids (salts) to water; effective over a limited pH range
			c. Ferric chloride	c. Effective between pH 4 - 11; also makes sludge dewatering easier	c. Adds dissolved solids (salts) to water
			d. Ferric sulfate	d. Effective between pH 4-6 and 8.8 - 9.2	d. Adds dissolved solids (salts) to water; usually need to add alkalinity
			e. Ferrous sulfate	e. Not as pH sensitive as lime	e. Adds dissolved solids (salts) to water; usually need to add alkalinity
			f. Polymer	f. Small dosage usually needed; easy to handle and feed	f. Improper dose results in poor floc formation
2. Rising sludge	Control of nocardia actinomyces*	MLSS, return sludge	a. Chlorine	a. Reduces oxygen demand of return sludge; very effective	a. Overdosing may upset biological system; increases TDS
			b. Lime	b. Enhances coagulation with higher pH; no increase in TDS	b. Increased sludge production; not readily soluble; recirculated sludge may adversely affect mixed liquor

* Before using chemicals, check process control procedures (Reference 1).
Problems with rising and bulking sludge are complex.
Chemical solutions only provide temporary relief.

PROCESS: SECONDARY CLARIFICATION (Continued)

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
3. Bulking sludge	Control growth of filamentous organism*	MLSS, return sludge	a. Chlorine	a. Inexpensive; usually available at most plants	a. Ineffective when bulking is due to light diffuse flocs; only a temporary solution
			b. Hydrogen peroxide	b. Very effective, immediate improvement	b. Relatively expensive; only a temporary solution
			c. Lime	c. Raises pH; no increase in TDS	c. Recirculated sludge may have adverse effect on mixed liquor
			d. Sodium hydroxide	d. Easy to handle and feed; relatively inexpensive	d. Overdosing could damage biological system
			e. Polymer	e. Cationic polymer very effective, easy to handle	e. Improper choice of polymer results in no improvement
4. Excessive phosphorus in final effluent	Precipitate phosphorus from solution	Ahead of secondary clarifier, in aeration basin	Same as phosphorus removal in primary clarifier (see page 114)		
5. Fouling of weirs	Control of aquatic plant growth	Ahead of secondary clarifier	Chlorine	Very effective, relatively inexpensive; enhances disinfection	Adds TDS to effluent

* Before using chemicals, check process control procedures (Reference 1).
Problems with rising and bulking sludge are complex. Chemical solutions only provide temporary relief.

PROCESS: DISINFECTION

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Excessive bacteria in final effluent	Kill bacteria	Effluent from secondary clarifier, ahead of chlorine contact basin in tertiary treatment	a. Chlorine (liquid chlorine gas)	a. Economical for large plants; readily available; very effective	a. Expensive for small plants; corrosive when moisture present
			b. Sodium hypochlorite	b. Most economical for small plants; easy to handle	b. Deteriorates more rapidly than calcium hypochlorite; corrosive and requires higher dosages than chlorine or calcium hypochlorite
			c. Calcium hypochlorite	c. Relatively stable; has more available chlorine than sodium hypochlorite; economical for small plants; easy to handle	c. Corrosive; requires higher dosage than chlorine gas
			d. Chlorine dioxide	d. Very effective	d. Relatively expensive, must be generated on-site
			e. Ozone	e. More effective than chlorine; increases dissolved oxygen; produces no haloforms; eliminates odors and color	e. Expensive; leaves no residual; must be generated on-site

PROCESS: DECHLORINATION

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Excessive chlorine residual following disinfection	Dechlorinate*	Effluent from chlorine contact chamber	a. Sulfur dioxide	a. Most commonly used; can be fed with chlorinators and same handling equipment	a. Costly in small plants to purchase cylinders of sulfur dioxide
			b. Sodium sulfite	b. More economical than sulfur dioxide for small plants	b. Costly in large plants
			c. Sodium metabisulfite (sodium bisulfite)	c. More economical than sulfur dioxide for small plants	c. Costly in large plants; difficult to store
			d. Sodium thiosulfate	d. More economical than sulfur dioxide for small plants	d. Requires longer reaction time than sulfur metabisulfite; can contribute to taste and odor problems downstream
			e. Ammonia	e. Typically, lower cost than sulfur dioxide	e. Removes only free chlorine residual; requires longer reaction time (20-40 min); difficult to control
			f. Granular activated carbon	f. Very effective and reliable	f. Usually requires major construction to build a carbon contactor; relatively expensive

* Before using chemicals, check process control procedures (Reference 1). Problem may be improper chlorine dosage.

ADVANCED WASTE TREATMENT

PROCESS: TERTIARY CHEMICAL CLARIFICATION

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Excessive suspended solids, turbidity or phosphorus in secondary effluent	Precipitate solids using a coagulant	Rapid mix basin or first stage recarbonation	a. Lime	a. Commonly used, very effective; may not add salts to effluent	a. Very pH dependent; produces large quantities of sludge; overdose can result in poor effluent quality
			b. Alum	b. Easy to handle and apply; most commonly used; produces less sludge than lime; most effective between pH 6.8 - 7.5	b. Adds dissolved solids (salts) to water; effective over a limited pH range
			c. Ferric chloride	c. Effective between pH 4 - 11	c. Adds dissolved solids (salts) to water; consumes twice as much alkalinity as alum
			d. Ferric sulfate	d. Effective between pH 4-6 and 8.8 - 9.2	d. Adds dissolved solids (salts) to water; usually need to add alkalinity
			e. Ferrous sulfate	e. Not as PH sensitive as lime	e. Adds dissolved solids (salts) to water; usually need to add alkalinity
			f. Polymer	f. Small dosage usually needed; easy to handle and feed	f. Improper dose results in poor floc; not effective in many wastewaters
			g. Sodium aluminate	g. Effective in hard waters; small dosages usually needed	g. Often used with alum; high cost; ineffective in soft waters

PROCESS: TERTIARY CHEMICAL CLARIFICATION (Continued)

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
2. Poorly settling floc	Add a coagulant aid*	In rapid mix or flocculation basin	a. Polymer	a. Produces rapidly settling floc when used with coagulants; easy to handle	a. Improper selection or dosage produces poor floc
			b. Chlorine	b. Oxidizes many undesirable contaminants such as hydrogen sulfide and ferrous iron, enhancing color and odor removal	b. Caustic soda or lime usually needed to neutralize acidity
			c. Ozone	c. Oxidizes many undesirable contaminants such as hydrogen sulfide and ferrous iron, enhancing color and odor removal. Also increases dissolved oxygen, does not increase TDS	c. Must be generated on-site; relatively expensive
			d. Bentonite clay	d. Particularly effective for high color, low turbidity wastewater treated with alum or iron coagulant	d. May not be readily available
			e. Activated silica (sodium silicate)	e. Lowers required coagulant dose; increases coagulation rate	e. Difficult to control
			f. Carbon dioxide	f. Allows proper coagulation while adjusting pH	f. Highly corrosive in solution; expensive for small plants
			g. Sodium bicarbonate	g. Effective, and also adds alkalinity to system	g. Relatively expensive

* Before using chemicals, check process control procedures (Reference 1). Problem may be due to improper coagulant dosage.

PROCESS: NITROGEN REMOVAL

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Excessive ammonia in final effluent	Breakpoint chlorination	After secondary clarifier	a. Chlorine	a. Very effective in removing ammonia-N; disinfection enhanced; more economical for large plants	a. Caustic soda or lime must be added to neutralize acidity; dechlorination usually needed; process difficult to control; increase in TDS
			b. Sodium hypochlorite	b. More economical than chlorine for small systems; easy to handle	b. Costly in large plants; difficult to control; adds TDS; solution deteriorates
			c. Calcium hypochlorite	c. More economical than chlorine for small systems; easy to handle, also relatively stable	c. Costly in large plants; difficult to control; adds TDS
2. Excessive ammonia in final effluent	Biological nitrogen removal	Biological dentrification process	Methanol	Very effective	May require methanol removal system; costly

PROCESS: FILTRATION

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Poor filter performance due to floc breakup	Add a filter aid	Filter influent	a. Alum	a. Commonly used, very effective; easy to handle and feed	a. Produces more solids for disposal
			B. Polymer	b. Very effective, requires small dosage	b. Should not be used without surface wash or backwash facilities
			c. Diatomaceous earth	c. Very effective	c. Not commonly used
2. Filter backwashing does not adequately clean filter	Clean the filter through proper chemical addition	Filter influent	a. Sulfur dioxide	a. Easily fed with same equipment as for chlorine	a. Costly in small plants
			b. Sodium hydroxide	b. Effective, relatively inexpensive	b. Dangerous to handle
			c. Chlorine	c. Very effective; usually available at most plants; most commonly used	c. None known

PROCESS: ACTIVATED CARBON ADSORPTION

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Hydrogen sulfide generation in carbon bed	Prevent sulfate - reducing bacteria formation by maintaining aerobic conditions in carbon bed	Carbon column influent	a. Oxygen	a. Effective in upflow, fluidized bed operation	a. Stimulates biological growth and clogs carbon beds operated in downflow, packed mode
			b. Sodium nitrate	b. Effective in some cases	b. Adds sodium to water
			c. Ozone	c. Effective; no increase in dissolved solids	c. Must be generated on-site; expensive
2. Sulfide in carbon effluent	Remove sulfides by precipitation	Carbon effluent	a. Ferric chloride	a. May be useful for very high sulfide concentrations	a. Adds TDS to effluent; consumes alkalinity; only provides limited sulfide removal
			b. Chlorine	b. Effective in oxidizing H_2S odors	b. Adds TDS to effluent

SLUDGE TREATMENT AND CONDITIONING

PROCESS: ANAEROBIC DIGESTION

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Undesirable drop in digester pH	Raise pH	Digester influent	a. Lime	a. Commonly used; relatively low cost; lowers volatile acid concentration; recommended for small plants; effective in raising pH	a. Cannot be used to maintain pH above 6.5; overdosing causes formation of insoluble calcium carbonate which settles out and takes up space, also overdosing may create a vacuum as carbon dioxide is removed
			b. Ammonia	b. Effective in raising pH	b. Careful control necessary; overdosing can cause ammonia toxicity
			c. Sodium hydroxide (caustic soda)	c. Combines with carbon dioxide to form sodium bicarbonate; relatively inexpensive	c. Dangerous to handle
			d. Sodium carbonate (soda ash)	d. Highly soluble; easy to apply; effective	d. More expensive than lime
			e. Sodium bicarbonate	e. Neutral, difficult to overdose; effective	e. More expensive than lime
2. Sulfide toxicity	Precipitate sulfides	Digester influent	Ferric chloride	Very effective	Lowers digester pH; may require addition of other chemicals to add alkalinity

PROCESS: ANAEROBIC DIGESTION (Continued)

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
3. Heavy metal toxicity	Precipitate metals	Digester influent	a. Ferrous sulfate	a. Effective in precipitating heavy metals	a. Usually requires addition of alkalinity
			b. Ferric sulfate	b. Effective in precipitating heavy metals	b. Usually requires addition of alkalinity
			c. Sulfuric acid	c. More economical for small plants	c. Overdosing can create toxic sulfide level and upset digester; very difficult to control
			d. Lime	d. Removes many types of metals	d. Overdosing causes calcium carbonate formation which reduces digester capacity
			e. Sodium hydroxide	e. Relatively inexpensive	e. Can be dangerous to handle

PROCESS: AEROBIC DIGESTION

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Excessive foaming caused by organic overload	Control foam by chemical addition	Digester influent	Defoaming agents	Very effective	Check with manufacturer
2. Excessive foaming caused by filamenting bacterial growth	Control growth by adding oxidants	Digester	a. Chlorine	a. Usually readily available at most plants	a. Not always effective
			b. Hydrogen peroxide	b. Inexpensive	b. Not always effective
3. Aerobic digester pH drops to undesirable level due to nitrification and low wastewater alkalinity	Add alkalinity	Digester influent	a. Sodium bicarbonate	a. Neutral, very difficult to overdose; easy to handle	a. More expensive than lime
			b. Lime	b. Commonly used; relatively low cost; good for small plants	b. Overdosing causes calcium carbonate formation which reduces useful digester volume
			c. Sodium hydroxide (caustic soda)	c. Relatively inexpensive	c. Dangerous to handle
			d. Sodium carbonate	d. Highly soluble, easy to handle	d. More expensive than lime

PROCESS: GRAVITY THICKENING

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Sludge rising in thickener	Condition sludge	Thickener influent	a. Polymer	a. Very effective and easy to handle; improves solids capture and reduces solids overflow	a. May not be economical
			b. Lime	b. Most commonly used for raw primary sludge; aids in sludge disinfection	b. More difficult to handle and feed than polymer; increases sludge weight
			c. Ferric chloride	c. Most commonly used for activated sludge	c. More difficult to handle and feed than polymer
2. Sludge rising in thickener with septic odor	Add an oxidant to control odor	Thickener influent	Chlorine	Effectively oxidizes hydrogen sulfide and controls odors	Increases operation costs and not justified unless odor problem exists

PROCESS: FLOTATION THICKENING

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Poor thickener performance and solids capture	Add flocculating chemicals*	Ahead of flotation unit	Polymer	Increases solids capture and improves thickening; easy and economical to feed	Overdosing results in little improvement and increases operating costs

* Before using chemicals, check process control procedures (Reference 1).

PROCESS: CENTRIFUGATION

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Poor solids recovery from centrifuge	Condition sludge*	Sludge feed to centrifuge	Polymer (cationic, anionic and nonionic)	Very effective; degree of solids recovery is flexible depending on dosage	Wetter sludge cake is produced because additional fines are captured; increased operating costs

* Before using chemicals, check process control procedures (Reference 1).

PROCESS: SLUDGE DRYING BEDS

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Sludge difficult to dewater or beds overloaded	Add chemical conditioning agents	Sludge feed to drying beds	a. Alum	a. Can allow quicker draining from bed; easy to handle; relatively inexpensive	a. Requires higher dosage than polymer; overdosing blinds sand particles and lowers draining rate
			b. Ferric chloride	b. Can be effective in increasing drainage rate	b. Overdosing blinds sand particles and lowers drainage rate
			c. Polymer	c. Can be very effective with low dosage; easy and economical to use	c. Overdosing blinds sand particles and lowers drainage rate
2. Odors from open drying beds	Oxidize odors*	Inject into sludge bed, mix with sludge as placed on beds, or spray into atmosphere around beds	a. Lime	a. Effective in controlling odor and helps control flies	a. May clog sand if hydrated form used; increases operating costs
			b. Chlorine	b. Effective and aids in controlling flies	b. Increases operating costs
			c. Hydrogen peroxide	c. Relatively inexpensive in small dosages	c. Increases operating costs
3. Flies	Destroy flies in larvae stage	Add directly to bed	Chloride of lime	Effective in controlling flies and aids in odor control	Increases operating costs

* Before using chemicals, check process control procedures (Reference 1).

PROCESS: VACUUM FILTRATION

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Poor performance due to low filter yield	Add chemical conditioning agents	Before vacuum filter	a. Ferric chloride	a. Very effective for activated sludge; commonly used	a. Corrosive to steel; often used with lime resulting in higher costs than polymer
			b. Lime	b. Very effective for raw primary sludge; may be used with or without metal salts	b. Lime sludge difficult to dispose
			c. Polymer (usually cationic)	c. Often more economical and produces less solids than ferric chloride	c. May be expensive
			d. Alum	d. Less expensive than ferric salts	d. Not always effective
			e. Diatomaceous earth	e. Effective and improves overall economy of dewatering	e. Not always available
2. Odors	Add an oxygen source to the sludge or deodorizing chemicals to the atmosphere	Before vacuum filter	a. Lime	a. Relatively inexpensive; effective in improving filter performance	a. Lime sludge difficult to dispose
			b. Potassium permanganate	b. Effective in oxidizing odors; easy to apply	b. Fire hazard in storing large quantities

PROCESS: FILTER PRESS

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Low filter yield	Add chemical conditioning agents	Prior to sludge charging	a. Ferric chloride	a. Very effective for activated sludge, commonly used	a. Corrosive to steel; often used with lime resulting in higher costs than polymer
			b. Lime	b. Very effective for raw primary sludge, may be used with or without metal salts	b. Lime sludge difficult to dispose
			c. Polymer	c. Often more economical and produces less solids than ferric chloride	c. Not always effective; causes media blinding
			d. Alum	d. Less expensive than ferric salts	d. Not always effective
2. Filter blinding, cake difficult to release from medium	Apply a precoat material	Prior to sludge charging	Diatomaceous earth	Very effective, improves overall economy of dewatering operation	Not always available

PROCESS: LAND APPLICATION OF SLUDGE

PROBLEM	POSSIBLE SOLUTION	POTENTIAL APPLICATION POINT	POSSIBLE CHEMICAL	ADVANTAGES	DISADVANTAGES
1. Soil pH drops when sludge is applied to land	Raise soil pH	Directly to soil	Lime	Very effective	Increases operational costs

SECTION 5

References

1. "Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities," EPA 430/9-78-001, January 1978.

2. "Process Design Manual for Upgrading Existing Wastewater Treatment Plants," EPA, Technology Transfer, 625/1-71-004a, 1974.

3. "Process Design Manual for Phosphorus Removal," EPA, Technology Transfer, EPA 625/1-76-001a, April 1976.

4. "Process Design Manual for Suspended Solids Removal," EPA, Technology Transfer, EPA 625/1-75-003a, January 1975.

5. "Process Design Manual for Nitrogen Control," EPA, Technology Transfer, October 1975.

6. "Process Control Manual for Aerobic Biological Wastewater Treatment Facilities," EPA 430/9-77-006, March 1977.

7. "Process Design Manual for Sludge Treatment and Disposal," EPA, Technology Transfer, 625/1-79-011, September 1979.

APPENDIX

INFORMATION ON CHEMICALS

APPENDIX

INFORMATION ON CHEMICALS

General information on various chemicals is provided in this section, including uses of the chemical, trade and common names, available forms, commercial strength, feeders, storage, safety considerations, approximate 1979 cost, acceptable handling materials, and major chemical manufacturers. For easy reference, the chemicals are arranged in alphabetical order.

The information provided in this Appendix is intended to provide the operator with basic guidance on the use and handling of different chemicals. There is much useful information in the Appendix, but the operator must be aware of certain limitations. Most chemicals are shipped in a variety of forms, quantities, and commercial strengths which may differ with each manufacturer or supplier. Consequently, the Appendix describes the most commonly available form for each chemical. Storage and safety information described in the Appendix is not intended to be complete or absolute. Sufficient general information is provided to aid the operator in deciding whether or not to use a certain chemical; however, detailed information on specific chemicals should be obtained directly from the supplier before purchasing or using the chemical in question.

The cost quotations in this section are approximate 1979 costs obtained from the "Chemical Marketing Reporter," November 5, 1979. The costs reflect the list prices of merchant producers prevailing on November 2, 1979 for large lots, f.o.b., New York. The values do not represent bid and asked prices. Differences between high and low costs may be accounted for by differences in quantity, quality or locality.

Because it is not possible or practical to identify all manufacturers or suppliers of each chemical, the operator is strongly encouraged to add his own local supplier to the list wherever possible. A partial list of manufacturers is provided in the Appendix only as guidance for locating a possible source for chemicals which may otherwise be difficult to obtain.

APPENDIX INDEX

ACTIVATED CARBON

TRADE NAMES

Aqua Nuchar, Norit, Darco, Carbodur

USES

Taste, odor, color and organics removal, dechlorination, sludge stabilization, denitrification.

AVAILABLE FORMS

Bags - 35 lb.
Drums - 5, 25 lb.
Bulk - Carloads

COMMERCIAL STRENGTH

10% C (bone char) to 90% C (wood charcoal)

FEEDERS

Gravimetric - L-I-W
Volumetric - helix (Fig. 9)
Slurry - rotodip or diaphragm pump (Fig. 13)

STORAGE

Bags, bins

SAFETY CONSIDERATIONS

Dusty, smolders if ignited. Isolate from flammable materials such as rags, chlorine compounds, and all oxidizing agents.

APPROX. 1979 COST

$0.61-$0.65/lb

HANDLING MATERIALS

Dry - iron, steel
Wet - rubber, iron, steel

MAJOR MANUFACTURERS

American Norit Company, Inc., 6301 Glidden Way, Jacksonville, Florida 32208
Westvaco Corporation, Chemical Division, Covington, Virginia 24426
Whitco Chemical Corporation, 277 Park Avenue, New York, New York 10017
ICI United States, Inc., Wilmington, Delaware 19897
Calgon Corporation, P.O. Box 1346, Pittsburg, Pennsylvania 15230

ALUMINUM SULFATE

TRADE NAMES

Alum, filter alum

USES

Coagulation, sludge conditioning, precipitate PO_4, remove metals, oil, organics, BOD/SS.

AVAILABLE FORMS

Dry
- Bags - 100, 200 lbs
- Bbls - 300, 400 lbs
- Drums - 25, 100, 250 lbs
- Bulk - carloads, tank trucks

Liquid
- Rail or truck - 4000 gal (min)

COMMERCIAL STRENGTH

Powder - 17% Al_2O_3
Minimum Liquid - 8.3% as Al_2O_3 or 49% as $Al_2(SO_4)_3 \cdot 14H_2O$

STORAGE

Dry Alum - 30 days max, in dry location with dust collectors. Use 60° min hopper wall slope to prevent arching.
Liquid - corrosive, store without dilution above 25°F to prevent crystalization

FEEDERS

Gravimetric - belt, (Fig. 10, 11), L-I-W
Volumetric - helix (Fig. 9), universal (Fig. 7)
Solution - rotodip, plunger or diaphragm pump, (Figure 13)

APPROX. 1979 COST

$146-$165/ton

SAFETY CONSIDERATIONS

Dry alum is dusty, irritating to mucous membranes, can cause serious eye injury.

HANDLING MATERIALS

Solution - Stoneware, lead, rubber, acid-resisting tile, Duriron, plastics, stainless 316, asphalt, cypress, PVC, Fiberglass
Dry - concrete, steel, iron

MAJOR MANUFACTURERS

American Cyanamid, Berdan Avenue, Wayne, New Jersey 07470
Allied Chemical Corporation, P.O. Box 1139R, Morristown, New Jersey 07960
Ashland Chemical Company, P.O. Box 2219, Columbus, Ohio 43216
Dixie Chemical Company, 3635 W. Dallas Street, Houston, Texas 77019
Cities Service Company, 3445 Peachtree Road, Atlanta, Georgia 30302
Stauffer Chemical Company, New York, New York

ANHYDROUS AMMONIA

TRADE NAMES

Ammonia

USES

Chlorine-ammonia treatment, anaerobic digestion, nutrient for aerobic bacteria

AVAILABLE FORMS

Cylinders - 50, 100, 150 lb.

Tank Cars - 50,000 lb.

COMMERCIAL STRENGTH

99% to 100% NH_3

FEEDERS

Gas Feed

STORAGE

Pressure cylinders

SAFETY CONSIDERATIONS

Pungent, irritating odor, liquid causes burns. Prevent contact with chlorine compounds, mercury, iodine, and bromine.

APPROX. 1979 COST

$120-$140/ton

HANDLING MATERIALS

Iron, steel, glass, nickel, Monel, neoprene, Penton

MAJOR MANUFACTURERS

PPG Industries, Inc., Chemical Div., One Gateway Center, Pittsburgh, PA 15222

BENTONITE

TRADE NAMES
Colloidal clay, Wilkinite, Volclay

USES
Coagulation aid as a weighting agent.

AVAILABLE FORMS
Bags - 50, 100 lb
Bulk - carloads, railcars

COMMERCIAL STRENGTH
Not Applicable

FEEDERS
Gravimetric - L-I-W, belt (Fig. 10,11)
Solution - diaphragm pump, plunger pump (Fig. 13)
Volumetric - helix (Fig. 9), universal (Fig. 7)

STORAGE
Dry powder or granules. Provide hopper agitation.

SAFETY CONSIDERATIONS
No significant hazards

APPROX. 1979 COST
\$28-\$30/ton

HANDLING MATERIALS
Iron, steel, Hypalon, Tyril

MAJOR MANUFACTURERS
Dow Chemical Corp., 2030 Dow Center, Midland, MI 48840

CALCIUM CARBONATE

TRADE NAMES

Calcite, limestone, whiting, chalk

USES

Neutralizing agent, corrosion control

AVAILABLE FORMS

Bags - 50 lb
Drums -
Bulk - carloads

COMMERCIAL STRENGTH

96 to 99%

FEEDERS

Gravimetric - L-I-W,belt (Fig. 10,11)
Volumetric - helix (Fig. 9)
Slurry - diaphragm pump (Fig. 13)

STORAGE

Noncorrosive; store in concrete or steel bins.
Provide hopper agitation.

SAFETY CONSIDERATIONS

Slight dust hazard.
Use protective clothing and devices to avoid contact.

APPROX. 1979 COST

$54/ton

HANDLING MATERIALS

Iron, steel, rubber

MAJOR MANUFACTURERS

Clark Corp., P.O. Box 500, Windsor, WI 53598

CALCIUM HYDROXIDE

TRADE NAMES

Hydrated lime, slaked lime

USES

Coagulation, pH adjustment, acid neutralization, sludge conditioning, precipitate PO_4

AVAILABLE FORMS

Bags - 50 lb.
Bbls - 100 lb.
Bulk - carloads

COMMERCIAL STRENGTH

$Ca(OH)_2$ - 82-95%
CaO - 62-72%

FEEDERS

Gravimetric - L-I-W, belt (Fig. 10,11)
Volumetric - helix (Fig. 9), universal (Fig. 7)
Slurry - rotodip, diaphragm or plunger pump (Fig. 13)

STORAGE

Same as CaO but bin agitation must be provided. Hopper should slope 65°.

SAFETY CONSIDERATIONS

Caustic, irritant, dusty. Avoid eyes, nose and respiratory system.

APPROX. 1979 COST

$33-$43/ton

HANDLING MATERIALS

Rubber, iron, steel, cement, Hypalon, Penton, PVC, asphalt (no lead)

MAJOR MANUFACTURERS

Bethlehem Mines Corp., Annville, PA 17003
Mississippi Lime Co., 7 Alby Street, Alton, IL 62002
Ashland Chemical Co., P.O. Box 2219, Columbus, OH 43216
Flintkote Co., 1650 S. Alameda Street, Los Angeles, CA 90021

CALCIUM HYPOCHLORITE

TRADE NAMES

HTH, Perchloron, Pittchlor

USES

Disinfection, slime control, deodorization

AVAILABLE FORMS

Cans - 5 lb
Drums - 100, 300, 800 lb.
Bbls - 415 lb.

COMMERCIAL STRENGTH

65% available Chlorine

FEEDERS

LIQUID:
Rotodip, diaphragm pump (Fig. 13)

STORAGE

Must be stored dry and cool; avoid contact with organic matter

SAFETY CONSIDERATIONS

Corrosive

Avoid contact with organic matter.

APPROX. 1979 COST

$0.70/lb

HANDLING MATERIALS

Ceramic, glass, rubber, PVC, Penton, Tyril, Hypalon, vinyl, stoneware, wood (no tin)

MAJOR MANUFACTURERS

Ashland Chemical Co., P.O. Box 2219, Columbus, OH 43216
Dixie Chemical Co., 3635 W. Dallas St., Houston, TX 77019
PPG Industries, Inc., Chemical Div., One Gateway Center, Pittsburgh, PA 15222
Penwalt Corp., Inorganic Chemicals Div., Three Parkway, Philadelphia, PA 19102

CALCIUM OXIDE

TRADE NAMES

Quicklime, unslaked lime, burnt lime

AVAILABLE FORMS

Bags - 50, 100 lb.
Bbls - 100 lb.
Bulk - carload

STORAGE

Keep dry with container closed.
Store bags on pallets, 60 days maximum. Provide dust collectors for bin storage and slope bin outlet 60°.

APPROX. 1979 COST

$31-$33/ton

USES

Coagulation, pH adjustment, acid neutralization, sludge conditioning, precipitate PO_4

COMMERCIAL STRENGTH

70-96% CaO (can be poor quality below 85%)

FEEDERS

Gravimetric - belt (Fig. 10,11) or L-I-W
Volumetric - universal (Fig. 7), helix (Fig. 9)

Also see Fig. 15 and 16 for lime slakers.

SAFETY CONSIDERATIONS

Unstable, caustic, irritant, dusty. Lime dust and hot slurry can cause severe burns.

HANDLING MATERIALS

Rubber, iron, steel, concrete, Hypalon, Penton, PVC, asphalt

MAJOR MANUFACTURERS

Pfizer Inc., MPM Div., 235 E. 42nd Street, New York, NY 10017
Bethlehem Mines Corp., Annville, PA 17003
Mississippi Lime Co., 7 Alby Street, Alton, IL 62002
Martin Marietta Cement, Southern Div., 18th Floor, Daniel Bldg, Birmingham, AL 35233
Ohio Lime Co., Woodville, OH 43469
Flintkote Co., 1650 S. Alameda Street, Los Angeles, CA 90021
U.S. Gypsum Co., Chemicals Division, 101 S. Wacker Dr., Chicago, IL 60606

CARBON DIOXIDE

TRADE NAMES
Dry ice, carbonic acid gas

USES
Recarbonation, coagulation/floc aid, pH adjustment

AVAILABLE FORMS
Cylinders - 20, 50 lb.
Trucks - 10, 20 tons
Railcar - 30, 50 tons

COMMERCIAL STRENGTH
99.5%

FEEDERS
Gas feeder

STORAGE
Pressure cylinders
Liquid systems usually require on-site bulk storage.

SAFETY CONSIDERATIONS
Colorless, odorless, nonflammable gas. Solutions of CO_2 in water are very reactive and form carbonic acid.

APPROX. 1979 COST
$40-$80/ton (1974)

HANDLING MATERIALS
As dry gas: iron, steel

As moist gas: 316SS, plastic

MAJOR MANUFACTURERS
Airco, Inc., Hopewell, VA; Lawrence, KS
Air Products & Chemicals, Inc., Pensacola, FL
Allied Chemical Corp., Geismar, LA; South Point, OH; Omaha, NB
American Cyanamid Co., New Orleans, LA
Chemetron Corp., Delaware City, DE; Morris, IL; Toledo, OH; Woodstock, TN; others
Chevron Chemical Co., Richmond, CA; Fort Madison, IA
Church & Dwight Co., Inc., Green River, WY

CAUSTIC SODA

TRADE NAMES

See Sodium Hydroxide

USES

AVAILABLE FORMS

COMMERCIAL STRENGTH

FEEDERS

STORAGE

SAFETY CONSIDERATIONS

APPROX. 1979 COST

HANDLING MATERIALS

MAJOR MANUFACTURERS

CHLORINE

TRADE NAMES

Chlorine gas, liquid chlorine

USES

Disinfection, slime control, taste and odor control.

AVAILABLE FORMS

Cylinders - 100, 150, 200, 2,000 lb.
Tank cars - 16, 30, 55 tons

COMMERCIAL STRENGTH

99.8% Cl_2

FEEDERS

Gas chlorinator

STORAGE

Pressure cylinders

SAFETY CONSIDERATIONS

Pungent, noxious, corrosive gas, health hazard. Prevent contact with ammonia, acetylene, all petroleum gases, hydrogen, turpentine, and benzene.

APPROX. 1979 COST

$195 - $230/ton

HANDLING MATERIALS

Gas - Copper, iron, steel
Liquid - glass, rubber, lead, silver

MAJOR MANUFACTURERS

Allied Chemical Corp., P.O. Box 1139R, Morristown, NJ 07960
Ashland Chemical Co., P.O. Box 2219, Columbus, Ohio 43216
Pennwalt Corp., Organic Chemicals Div. Three Parkway, Philadelphia, PA 19102
PPG Industries, Inc., Chemical Div., One Gateway Center, Pittsburgh, PA 15222
Dixie Chemical Co., 3635 W. Dallas St., Houston, TX 77019

COPPER SULFATE

TRADE NAMES

Blue vitriol, blue stone, cupric sulfate

USES

Algae control, root control in sewers

AVAILABLE FORMS

Bags - 100 lb.
Bbls - 450 lb.
Drums -
Bulk - carloads

COMMERCIAL STRENGTH

99% $CuSO_4$

FEEDERS

Gravimetric - L-I-W
Volumetric - helix (Fig. 9)
universal (Fig. 7)
Solution - rotodip, diaphragm or plunger pump (Fig. 13)

STORAGE

Store as received; chemical and its solution are corrosive.

SAFETY CONSIDERATIONS

Poisonous in large amounts

APPROX. 1979 COST

$42/100 lb.

HANDLING MATERIALS

Rubber, ceramic, 316SS, vinyl, Hypalon, PVC, Viton, epoxy, Tyril, asphalt

MAJOR MANUFACTURERS

Easton R.S. Corp., 4907 Farragut Rd., Brooklyn, NY 11203
Cities Service Co., Chemical Group Marketing, 3445 Peachtree Rd., N.E. Atlanta, Georgia 30326
The Anaconda Co., Great Falls, MT
Southern California Chemical Co., Inc., Bayonne, NJ; Garland, TX; Santa Fe Springs, CA; Union, IL

DEFOAMER

TRADE NAMES

Exfoam 440, Wyandotte defoamer

USES

Foam removal in lagoons and activated sludge

AVAILABLE FORMS

Liquid - 5 and 55 gal. drums, bulk
Paste - 2 lb., bulk
Dry - 2 lb. bricks, bulk

COMMERCIAL STRENGTH

Not applicable

FEEDERS

Solution - diaphragm pump (Fig. 13)

STORAGE

Store in tight containers in cool, shaded areas.
(Check with manufacturer for specific defoamer)

SAFETY CONSIDERATIONS

Avoid excessive handling, contact with eyes, and ingestion. Some hydrocarbon base defoamers may be flammable.

APPROX. 1979 COST

$0.47-$0.66/lb.

HANDLING MATERIALS

Most common materials are acceptable.
Check with manufacturer for specific defoamer.

MAJOR MANUFACTURERS

Drew Chemical Corp., 701 Jefferson Rd., Parsippany, NJ 07054
Hercules Inc., Industrial Systems Dept., Wilmington, Delaware 19899
Dearborn Chemical Div., Chemed Corp., 300 Genessee St., Lake Zurich, IL 60047
BASF Wyandotte Corp, Wyandotte, Michigan 48192

DIATOMACEOUS EARTH

TRADE NAMES

Diatoms, celite, dicalite, celatom, supercel, speedex, speed flow

USES

Filter aid, sludge dewatering with pressure and vacuum filters

AVAILABLE FORMS

Bags - 50 lb.
Bulk

COMMERCIAL STRENGTH

Not applicable

FEEDERS

Volumetric - helix (Fig. 9)
Gravimetric - belt (Fig. 10,11), L-I-W
Slurry - diaphragm pump (Fig. 13)

STORAGE

Store dry as received

SAFETY CONSIDERATIONS

Do not breathe excessive amounts of dust.

APPROX. 1979 COST

Variable, check with supplier.

HANDLING MATERIALS

Iron, steel, rubber, Tyril, Hypalon

MAJOR MANUFACTURERS

Johns-Manville, Filtration & Industrial Minerals Div., P.O. Box 5108, Denver, Colorado 80217
Dicalite Div., GREFCO, Inc., 3450 Wilshire Blvd., Los Angeles, CA 90010

FERRIC CHLORIDE

TRADE NAMES

Ferrichlor, chloride of iron

USES

Coagulation at pH 4-11, sludge conditioning, precipitate PO_4

AVAILABLE FORMS

Solution
- Car boys - 5, 13 gal.
- Bulk - Truck, tank cars

Crystal
- Kegs - 100, 300, 450 lb.
- Drums - 150, 350, 650 lb.

COMMERCIAL STRENGTH

Solution - 35-45% $FeCl_3$, 12-17% Fe
Crystal - 60% $FeCl_3$, 20% Fe
Anhydrous - 98% $FeCl_3$, 34% Fe

STORAGE

Store in tight containers as shipped with free vent, corrosive in liquid form

FEEDERS

Solution - Diaphragm pump (Fig. 13), rotodip

No dry feed.

APPROX. 1979 COST

\$100-\$120/ton

SAFETY CONSIDERATIONS

Corrosive in liquid form, avoid contact with skin and eyes. Induce vomiting if ingested.

HANDLING MATERIALS

Epoxy, rubber, ceramic, Hypalon, PVC, Penton, vinyl, stoneware, synthetic resin

MAJOR MANUFACTURERS

Ashland Chemical Co., P.O. Box 2219, Columbus, Ohio 43216
Engineering Chemical Services, Inc., 40 Fulton St., New Brunswick, NJ 08902
Culf Chemical & Metallurgical Co., P.O. Box 2130, Highway 519, Texas City, Texas 77590
Dow Chemical Co., 2020 Dow Center, Midland, Michigan 48640
Pennwalt Corp., Inorganic Chemicals Div., Three Parkway, PA 19102
Imperial West Chemicals, Antioch, California

FERRIC SULFATE

TRADE NAMES

Ferrifloc, ferriclear, iron sulfate, ferrisul

AVAILABLE FORMS

Bags - 50, 100, 175 lb.
Drums - 200, 400, 425 lb.
Bulk - car loads and truck loads of 50, 100 lb. bags.

STORAGE

Store dry in tight containers of steel or concrete and avoid moisture. Hopper walls should slope 36% min. Do not mix with quicklime in conveying or dust vent systems.

APPROX. 1979 COST

\$60-\$74/ton

USES

Coagulation at pH 4-6 and 8.8-9.2, precipitate PO_4

COMMERCIAL STRENGTH

68-94% $Fe_2(SO_4)_3$
18.5-26% Fe

FEEDERS

Gravimetric - L-I-W
Volumetric - helix (Fig. 9), universal (Fig. 7)
Solution - rotodip, diaphragm or plunger pump (Fig. 13.)

SAFETY CONSIDERATIONS

Corrosive in solution, avoid body contact

HANDLING MATERIALS

316SS, glass, rubber, plastic, ceramic, PVC, Hypalon, lead, vinyl, Penton, epoxy, Tyril, synthetic resin

MAJOR MANUFACTURERS

Cities Service Co., I.C.D., 3445 Peachtree Rd., N.E., Atlanta, GA 30326
Gulf Chemical & Metallurgical Co., P.O. Box 2130, Hwy 519, Texas City, TX 77590

FERROUS CHLORIDE

TRADE NAMES

Waste pickle liquor

USES

PO_4 removal, sludge conditioning

AVAILABLE FORMS

Bulk - tank trucks, car loads at 2,000 gal.

Drums - 50 gal.

COMMERCIAL STRENGTH

20-25% $FeCl_2$ or 10% available iron

FEEDERS

Solution -

Diaphragm pump (Fig. 13),
Rotodip

STORAGE

Since ferrous chloride may not always be available, provide for storage and handling of ferric chloride.

SAFETY CONSIDERATIONS

Slightly less corrosive than ferric chloride

APPROX. 1979 COST

$95-$103/ton

HANDLING MATERIALS

MAJOR MANUFACTURERS

By-Products Management Inc., 5220 East Avenue, Countryside, IL 60525

FERROUS SULFATE

TRADE NAMES

Green vitriol, copperas, iron sulfate

USES

Odor control, precipitate PO_4, coagulation at pH 8.8-9.2, sludge conditioning

AVAILABLE FORMS

Bags - 50, 100 lb.
Bbls - 400 lb.
Bulk - Carloads and truckloads

COMMERCIAL STRENGTH

55-58% Fe SO_4 (20-21% Fe).

FEEDERS

Gravimetric - L-I-W
Volumetric - helix (Fig. 9), universal (Fig. 7)
Solution - diaphragm or plunger pump (Fig. 13)

STORAGE

Oxidizes in moist air, cakes in storage at temperatures above 68°F.

SAFETY CONSIDERATIONS

Solution is acidic, mixing with quicklime may cause fire, avoid body contact

APPROX. 1979 COST

$80/ton

HANDLING MATERIALS

Asphalt, concrete, lead, tin, wood, rubber, PVC, vinyl, Penton, epoxy, Hypalon, ceramic, Tyril
Solutions - Lead, rubber, iron, plastics, 304SS

MAJOR MANUFACTURERS

Ashland Chemical Co., P.O. Box 2219, Columbus, Ohio 43216
By-Products Management Inc., 5200 East Ave., Countryside, IL 60525
American Cyanamid Co., Berdan Ave., Wayne, NJ 07410
National Lead, St. Louis, Missouri
Gulf Chemical, P.O. Box 2130, Hwy 519, Texas City, Texas 77590

HYDROCHLORIC ACID

TRADE NAMES

Muriatic acid

USES

Neutralization of alkaline waste, pH adjustment

AVAILABLE FORMS

Glass bottles
Carboys
Drums
Tank cars

COMMERCIAL STRENGTH

Concentrated: 37%-38% HCl
18^{o}Be - 27.9% HCl, 20^{o}Be - 31.5% HCl
22^{o}Be - 35.2% HCl

FEEDERS

Solution - diaphragm pump (Fig. 13)

STORAGE

Store as received; highly corrosive to metals.

SAFETY CONSIDERATIONS

Fuming, pungent, toxic liquid; avoid skin contact, use rubber gloves and safety glasses.

APPROX. 1979 COST

\$35 - \$63/ton

HANDLING MATERIALS

Penton, rubber, polyethylene, vinyl, Hypalon, Viton, Tyril

MAJOR MANUFACTURERS

Allied Chemical Corp., Baton Rouge, LA; Danville, IL, Elizabeth, NJ; Moundsville, WV; Syracuse, NY
American Chemical Corp., Long Beach, CA
BASF Wyandotte Corp., Wyandotte, MI
Continental Oil Co., Baltimore, MD
Dow Chemical USA, Freeport, TX; Midland, MI; Plaquemine, LA
E.I. du Pont Inc., LaPort, TX; Cleveland, OH; Linden, NJ
Hercules, Inc., Hopewell, VA; Parlin, NJ; Brunswick, GA
Monsanto Co., Everett, MA; Sauget, IL
Pennwalt Corp, Calvert City, KY; Portland, OR; Tacoma, WA; Wyandotte, MI
Stauffer Chemical Co., Cold Creek, AL; Mt. Pleasant, TN; Dominguez, CA

HYDROGEN PEROXIDE

TRADE NAMES

Hydrogen peroxide

USES

Sulfide destruction, corrosion control, control of bulking, supplemental D.O.

AVAILABLE FORMS

Liquid
- Drums - 50 gal. (minimum)
- Tankcars

COMMERCIAL STRENGTH

35%, 50%, 70%

FEEDERS

Solution
- Diaphragm or plunger pump (Fig. 13)

STORAGE

Bulk storage should be vented, with tank constructed of 5254 aluminum alloy. Decomposes rapidly if contaminated. Do not use stainless steel except for very short term storage (24 hrs).

APPROX. 1979 COST

$0.16-$0.32/lb.

SAFETY CONSIDERATIONS

Prevent contact with most metals and their salts, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids, and combustible materials. Dilute spills with water.

HANDLING MATERIALS

Polyethylene plastic, aluminum.

MAJOR MANUFACTURERS

Ashland Chemical Co., P.O. Box 2219, Columbus, Ohio 43218
FMC Corp., Industrial Chemical Div., 2000 Market St., Philadelphia, PA 19103

LIME

TRADE NAMES

(See calcium hydroxide and calcium oxide)

USES

AVAILABLE FORMS

COMMERCIAL STRENGTH

FEEDERS

STORAGE

SAFETY CONSIDERATIONS

APPROX. 1979 COST

HANDLING MATERIALS

MAJOR MANUFACTURERS

MAGNESIUM HYDROXIDE

TRADE NAMES

Magnesium hydroxide

USES

Acid neutralization

AVAILABLE FORMS

Wooden barrel or drums, glass bottles, carboys

COMMERCIAL STRENGTH

Not applicable

FEEDERS

Gravimetric - L-I-W, belt (Fig. 10,11)
Volumetric - helix (Fig. 9)
Slurry - diaphragm pump (Fig. 13)

STORAGE

Absorbs CO_2 in presence of H_2O

SAFETY CONSIDERATIONS

No significant hazards

APPROX. 1979 COST

$0.54-$0.58/lb.

HANDLING MATERIALS

Steel, rubber, iron, Penton, Hypalon

MAJOR MANUFACTURERS

Basic Chemicals, 845 Hanna Bldg., Cleveland, OH 44115

METHANOL

TRADE NAMES
Methanol

USES
Denitrification

AVAILABLE FORMS
Tank Trucks
Tank cars
Drums
Bbls.
Cans

COMMERCIAL STRENGTH
99.9% CH_3 OH

FEEDERS
Solution feed only

STORAGE
Usually stored as received or in conventional fuel tanks.

SAFETY CONSIDERATIONS
Vapors and liquid toxic and flammable. Skin irritant. Liquid is colorless, and noncorrosive except to aluminum and lead. Poisonous.

APPROX. 1979 COST
\$0.56 - \$0.63/gal.

HANDLING MATERIALS
Steel

MAJOR MANUFACTURERS
E.I. du Pont de Nemours & Co., Beaumont, Tx; Orange, Tx.
Monsanto Co., Texas City, Tx.; plus others
Hercules, Inc., Plaquemine, La.
Air Products & Chemicals, Inc., Pensacola, Fla.
Tenneco Inc., Houston, Tx.

OXYGEN (LIQUID)

TRADE NAMES

Oxygen

USES

Odor control, oxidizing agent, ammonia and BOD removal

AVAILABLE FORMS

Cylinders
Tank cars
Gas bottles
Can also be generated on-site.

COMMERCIAL STRENGTH

99.0-99.99%

FEEDERS

Liquid is vaporized and fed as a gas.

STORAGE

Cylinders or spheres of double-walled construction, outer shell of carbon steel, inner pressure vessel of aluminum, SS, high nickel steel.

SAFETY CONSIDERATIONS

Colorless, odorless, tasteless gas. Hazardous in contact with oxidizable materials. Do not smoke near any oxygen source.

APPROX. 1979 COST

\$35-\$40/ton

HANDLING MATERIALS

Cast iron, stainless steel, bronze, monel

MAJOR MANUFACTURERS

Air Product & Chemicals, Inc., Box 538, Allentown, PA 18105
Air Co. Inc., Albany, NY; Huron, Ohio; New Orleans, La; Richmond, Cal; Vancouver, Wash; plus others.
Chemetron Corp., Bartonville, Ill; Chattanooga, Tenn; Richmond, Va; Oklahoma City, Okla; plus others.
Union Carbide Corp., Cape Kennedy, Fla.; E. Chicago, Ind.; Fontana, Calif.; Huntsville, Ala.; Kansas City, Mo.; Keasbey, NJ; plus others.

OZONE

TRADE NAMES

Ozone

USES

Taste and odor control, disinfection, oxidizing agent

AVAILABLE FORMS

Generated on-site by electrical discharge through dry air

COMMERCIAL STRENGTH

1-2%

FEEDERS

Ozonator (Fig. 17)

STORAGE

None,
Generated on-site

SAFETY CONSIDERATIONS

Toxic - do not breathe, explosive; fire hazard; keep from oil or readily combustible materials

APPROX. 1979 COST

Generated on-site

HANDLING MATERIALS

Glass, 316SS, ceramic, aluminum, Teflon

MAJOR MANUFACTURERS

Purification Sciences Inc., P.O. Box 311, Geneva, NY 14456

POLYMER

TRADE NAMES

Cat-floc, Drewfloc, Hercofloc, Aquafloc, Superfloc, Magnifloc, Purifloc

USES

Coagulant, filter aid, separates oily wastes, removes SS, sludge conditioning, sludge dewatering aid

AVAILABLE FORMS

Available in many container and package sizes -- check with manufacturer.

COMMERCIAL STRENGTH

Check with manufacturer.

FEEDERS

Dry - See Figures 19 and 20

Solution - metering pump, rotodip

STORAGE

Store in dry, cool, low humidity area. Use bags in proper rotation. Store solutions 1 to 3 days or less to prevent deterioration.

SAFETY CONSIDERATIONS

Polymer spills are slippery, clean up promptly. Polymers are generally low in toxicity and are nonirritating. Check with manufacturer for other safety information.

APPROX. 1979 COST

$0.60-$2.00/lb.

HANDLING MATERIALS

Depends on polymer type; however, 316SS, plastics generally are acceptable.

MAJOR MANUFACTURERS

Calgon Corp., P.O. Box 1346, Pittsburgh, PA 15230
Petrolite Corp., Tretolite Div., 369 Marshall Ave., St. Louis, MO 63119
American Cyanamid, Wayne, NJ 07470
Hercules Inc., Industrial Systems Dept., Wilmington, DE 19899
Philadelphia Quarts Systems Co., Inc., P.O. Box 840, Valley Forge, PA 19482
Rohm & Haas Co., Independence Mall West, Philadelphia, PA 19105
Drew Chemical Corp., 701 Jefferson Rd., Parsippany, NJ 07054
Dow Chemical Co., Midland, MD 48640
Zimmite Corp., 810 Sharon Dr., Cleveland, OH 44145
Garratt-Callahan Co., 111 Rollins Rd., Millbrae, CA 94030
Dearborn Chemical Div., Chemed Corp., 300 Genessee St., Lake Zurich, IL 60047

POTASSIUM PERMANGANATE

TRADE NAMES

Cairox, purple salt

USES

Taste and odor control, removes Fe, Mn, and Phenol, source of oxygen

AVAILABLE FORMS

USP
Steel Kegs - 25, 110, 125 lbs
Tech
Steel drums - 25, 110, 600 lbs

COMMERCIAL STRENGTH

Tech - 97% minimum
Reagent - 99% minimum

FEEDERS

Gravimetric - L-I-W
Volumetric - helix (Fig. 9)
Solution - diaphragm or plunger pump (Fig. 13)

STORAGE

Can cake in high humidity, strong oxidant

SAFETY CONSIDERATIONS

Toxic, keep from organics, glycerine, ethylene glycol, benzaldehyde, and sulfuric acid

APPROX. 1979 COST

$1.29-$1.66/lb

HANDLING MATERIALS

Steel, iron, PVC, 316SS, synthetic resins, Hypalon, Penton, Lucite, rubber

MAJOR MANUFACTURERS

Ashland Chemical Co., P.O. Box 2219, Columbus, Ohio 43216
Carus Chemical Co., 1500 8th St., La Salle, IL 61301
International Chemicals, Inc. 209 W. Central St., Natick, MA 01760

SODA ASH

TRADE NAMES

See sodium carbonate

USES

AVAILABLE FORMS

COMMERCIAL STRENGTH

FEEDERS

STORAGE

SAFETY CONSIDERATIONS

APPROX. 1979 COST

HANDLING MATERIALS

MAJOR MANUFACTURERS

SODIUM ALUMINATE

TRADE NAMES

Soda alum

USES

Coagulation, phosphorus removal

AVAILABLE FORMS

Dry
Bags - (ground) - 50, 100, 150 lb.

Liquid
Drums - 380 lb. (30 gal)
Bulk - tank car, tank truck

COMMERCIAL STRENGTH

Dry - 41-46% Al_2O_3
Liquid - 4.9 - 26.7% Al_2O_3

STORAGE

Dry - Store as received for 6 month maximum at 60-90°F. Deteriorates on exposure to atmosphere. Hopper agitation may be required.
Liquid - Store as received for 2-3 months maximum.

FEEDERS

Gravimetric - belt (Fig. 10,11), L-I-W
Volumetric - helix (Fig. 9), universal (Fig. 7)
Solution - rotodip, diaphragm pump or plunger pump (Fig. 13)

APPROX. 1979 COST

SAFETY CONSIDERATIONS

Exotheric heat of solution. Dust or solution spray should not be breathed. Safety measures similar to caustic soda. Avoid contact with eyes, skin and clothing.

HANDLING MATERIALS

Iron, plastic, 316SS, 304SS, Penton, concrete, Hypalon
Avoid the use of copper, copper alloys, rubber, aluminum.

MAJOR MANUFACTURERS

Nalco Chemical Co., 2901 Butterfield Road, Oak Brook, IL 60521
Reynolds Chemical Co., Bauxite, Arkansas
Vinings Chemical Co., Vinings, Georgia
Conservation Chemical Co., Kansas City, Missouri

SODIUM BICARBONATE

TRADE NAMES

Baking soda

USES

pH adjustment, acid neutralization

AVAILABLE FORMS

Bags - 100 lb.
Drums - 25 lb. kegs
Bbls - 112, 400 lb.
Bulk - carloads

COMMERCIAL STRENGTH

99% $NaHCO_3$

FEEDERS

Gravimetric - belt (Fig. 10,11), L-I-W
Volumetric - helix (Fig. 9)
Solution - rotodip, diaphragm pump (Fig. 13

STORAGE

Unstable in solution, (decomposes into CO_2 & $Na_2 CO_3$) Decomposes at 100°F

SAFETY CONSIDERATIONS

No significant hazards

APPROX. 1979 COST

$11 - $12/100 lb.

HANDLING MATERIALS

Iron, steel, rubber, saran, Hypalon, Tyril

MAJOR MANUFACTURERS

Church & Dwight Co., Inc., Two Pennsylvania Plaza, New York, New York 10001
BASF Wyandotte Corp., Wyandotte, Michigan 48192

SODIUM BISULFITE

TRADE NAMES

Sodium metabifulfite, sodium pyrosulfite, ABS

USES

Dechlorination, reducing agent in chromium treatment, pH control, bacteriocide

AVAILABLE FORMS

Bags - 100 lb.
Drums - 100, 400 lb.

COMMERCIAL STRENGTH

93-99% $Na_2S_2O_5$
62-65.8% SO_2

FEEDERS

Gravimetric - L-I-W
Volumetric - helix (Fig. 9), universal (Fig. 7)
Solution - rotodip, plunger or diaphragm pump (Fig. 13)

STORAGE

Store cool and dry in tight container (up to 6 mo.), vent solution tanks (storage difficult)

SAFETY CONSIDERATIONS

Irritating to eyes, skin and respiratory system. Use protective clothing and devices.

APPROX. 1979 COST

$16 - $18/100 lb.

HANDLING MATERIALS

Ceramic, chrome, glass, lead, 316SS, nickel, rubber, PVC, Penton, Tyril, Hypalon, synthetic resin

MAJOR MANUFACTURERS

Ashland Chemical Co., P.O. Box 2219, Columbus, Ohio 43216
Virginia Chemicals, Inc., 3340 W. Norfolk Road, Portsmouth, Virginia 23703
Allied Chemical Co., P.O. Box 1139R, Morristown, New Jersey 07960

SODIUM CARBONATE

TRADE NAMES

Soda ash

USES

pH adjustment, acid neutralization

AVAILABLE FORMS

Bags - 100 lb.
Bbls - 100 lb.
Drums - 25, 100 lb.
Bulk - carloads, box car, truck

COMMERCIAL STRENGTH

98-99% Na_2CO_3, 58% Na_2O

FEEDERS

Gravimetric - L-I-W, belt (Fig. 10, 11)
Volumetric - helix, (Fig. 9)
Solution - rotodip, diaphragm or plunger pump (Fig. 13)

STORAGE

Store in steel bins with dust collectors. In bulk and bagged form, absorbs CO_2 and H_2O. May cake in storage.

SAFETY CONSIDERATIONS

Dust and solution are irritating to eyes, nose, lungs and skin

APPROX. 1979 COST

$57-$87/ton

HANDLING MATERIALS

Iron, steel, rubber, Hypalon, Tyril

MAJOR MANUFACTURERS

Allied Chemical, P.O. Box 1139R, Morristown, New Jersey 07960
Dixie Chemical Co., 3635 W. Dallas Street, Houston, Texas 77019
PPG Industries, Inc., Chemical Div., One Gateway Center, Pittsburgh, PA 15222
FMC Corporation, Green River, Wyoming
Stauffer Chemical, Westend, California
Wyandotte Chemicals Corp., Wyandotte, Michigan 48192

SODIUM HYDROXIDE

TRADE NAMES

Caustic soda, Soda lye

USES

pH control, filter cleaning, neutralization

AVAILABLE FORMS

Bags - 100 lb.
Drums - 25, 50, 350, 400, 700 lb.
Bulk -
  Truckloads - 1,000 to 4,000 gal.
  Carloads - 8,000, 10,000, 16,000 gal.

COMMERCIAL STRENGTH

Solid - 99.9% NaOH, 74-76% Na_2O
Solution - 50, 73% NaOH

FEEDERS

Solution - plunger or diaphragm pump (Fig. 13), rotodip

STORAGE

Often stored at 20% concentration. Crystallizes at 53°F for 50% concentration, and 165°F for 73% solution.

SAFETY CONSIDERATIONS

Caustic poison, dangerous to handle. Prevent all body contact and protect eyes.

APPROX. 1979 COST

Liquid - $140-$175/ton
Solid - $350/ton

HANDLING MATERIALS

Cast iron, rubber, steel, Penton, PVC, 316SS, Hypalon, nickel

MAJOR MANUFACTURERS

Allied Chemical Corp., P.O. Box 1139R, Morristown, New Jersey 07960
Ashland Chemical Co., P.O. Box 2219, Columbus, Ohio 43216
PPG Industries, Inc., Chemical Div., One Gateway Center, Pittsburgh, PA 15222
Dow Chemical, 2020 Dow Center, Midland, Michigan 48640

SODIUM HYPOCHLORITE

TRADE NAMES

Javelle water, chlorine bleach

USES

Disinfection, slime control, odor control, cyanide distribution

AVAILABLE FORMS

Carboys - 5, 13 gal.
Drums - 30 gal.
Bulk - 1,300, 1,800, 2,000 gal tank trucks

COMMERCIAL STRENGTH

12-15% Available Cl_2

FEEDERS

Solution - diaphragm pump (Fig. 13)
rotodip

STORAGE

Store in cool place, away from light and vent containers at intervals. Can be stored about 60 days.

SAFETY CONSIDERATIONS

Corrosive. Avoid eye and skin contact; use protective clothing and devices.

APPROX. 1979 COST

$ 0.40 - $0.90/gal
depending on quantity

HANDLING MATERIALS

Rubber, ceramic, glass, Tyril, saran, PVC, vinyl, Hypalon, plastic

MAJOR MANUFACTURERS

Brenco Corp., 704 N. First Street, St. Louis, Missouri 63102
Ashland Chemical Co., P.O. Box 2219, Columbus, Ohio 43216
Dixie Chemical Co., 3635 W. Dallas Street, Houston, Texas 77019

SODIUM METABISULFITE

TRADE NAMES

See Sodium Bisulfite

USES

AVAILABLE FORMS

COMMERCIAL STRENGTH

FEEDERS

STORAGE

SAFETY CONSIDERATIONS

APPROX. 1979 COST

HANDLING MATERIALS

MAJOR MANUFACTURERS

SODIUM SULFITE

TRADE NAMES

Sulfite

USES

Dechlorination, reducing agent

AVAILABLE FORMS

Bags, Bbls, Drums, Kegs

COMMERCIAL STRENGTH

93-99%

FEEDERS

Solution - plunger or diaphragm pump (Fig. 13), rotodip

STORAGE

Store as received in cool, dry, well-ventilated area

SAFETY CONSIDERATIONS

Solution gives off SO_2. Avoid eye contact and prolonged or repeated skin contact. Use protective clothing and devices.

APPROX. 1979 COST

$0.04-$0.14/lb.

HANDLING MATERIALS

Cast iron, steel, 316SS, PVC, saran, vinyl, synthetic resin, Hypalon, Tyril

MAJOR MANUFACTURERS

Ashland Chemical Co., P.O. Box 2219, Columbus, Ohio 43216

SODIUM THIOSULFATE

TRADE NAMES

Hypo, sodium hyposulfite

USES

Dechlorination, reducing agent for Cl_2

AVAILABLE FORMS

Bags, Bbls, Drums, Kegs

COMMERCIAL STRENGTH

98-99%

FEEDERS

Solution - plunger or diaphragm pump (Fig. 13), rotodip

STORAGE

Store in cool, dry place

SAFETY CONSIDERATIONS

Avoid eye and skin contact.
Use dust mask for excessive handling.

APPROX. 1979 COST

$12 - $17/100 lb.

HANDLING MATERIALS

Cast iron, steel, stoneware.
For no contamination: 316SS, PVC, saran, vinyl, synthetic resin, Hypalon, Tyril.

MAJOR MANUFACTURERS

Allied Chemical Corporation, N. Claymont, Del; Chicago, Ill.; El Segundo, Calif.
Stauffer Chemical Company, South Gate, Calif.
Ashland Chemical Company, P.O. Box 2219, Columbus, Ohio 43216

SULFUR DIOXIDE

TRADE NAMES

Sulfur dioxide

USES

Dechlorination, filter cleaning, Cr^{+6} reduction, pH control, bacteriocide

AVAILABLE FORMS

Cylinders - 100, 150, 200 lb.
Bulk - tanks

COMMERCIAL STRENGTH

100% SO_2

FEEDERS

Gas - Rotameter, SO_2 feeder

STORAGE

Pressure cylinders

SAFETY CONSIDERATIONS

Colorless, suffocating odor, corrosive, poisonous

APPROX. 1979 COST

$168 - $210/ton

HANDLING MATERIALS

Glass, PVC, ceramic, Penton, Viton, Hypalon

MAJOR MANUFACTURERS

Cities Service Co., 3445 Peachtree Road, Atlanta, Georgia 30326
Virginia Chemicals, Inc., 3340 W. Norfolk Road, Portsmouth, Virginia 23703

SULFURIC ACID

TRADE NAMES

Vitriol, oil of vitriol

USES

pH adjustment, neutralize alkaline wastes

AVAILABLE FORMS

Bottles
Carboys - 5, 13 gal.
Drums - 55,110 gal.
Bulk - tankcars, trucks

COMMERCIAL STRENGTH

66°Be - 93.2% H_2SO_4
60°Be - 77.7% H_2SO_4
50°Be - 62.2% H_2SO_4

STORAGE

Very corrosive, store dry and cool in tight containers

FEEDERS

Liquid - plunger or diaphragm pump (Fig. 13), rotodip

APPROX. 1979 COST

$30 - $61/ton depending on quantity and strength.

SAFETY CONSIDERATIONS

Always add acid to water, never add water to acid. Avoid contact with potassium chlorate, potassium perchlorate, potassium permanganate, & other light metals: sodium & lithium

HANDLING MATERIALS

Concentrated - iron, steel, PVC, Penton, Viton
Dilute - Glass, lead, porcelain, rubber

MAJOR MANUFACTURERS

Allied Chemical Corp., P.O. Box 1139R, Morristown New Jersey 07960
Cities Services Co., 3445 Peachtree Road, Atlanta, Georgia 30302
American Cyanamid Co., Hamilton, Ohio; Joliet, Ill.; Kalamazoo, Mi; Savannah, Ga; plus others
Bethlehem Steel Corp., Sparrows Pt., Md.
E.I. du Pont Nemours & Co., Burnside, La; Newport, Ind; Richmond, Va; Wurtland, Ky; Linden, NJ; plus others
Monsanto Co., El Dorado, Ark; Avon, Calif; Everett, Mass.
Rohm & Haas Company, Philadelphia, Pa; Deer Park, Tx.

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