An Introduction to Control and Chemical Feeding for Wastewater Treatment

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J. Paul Guyer, P.E., R.A., Fellow ASCE, Fellow AEI

CED engineering.com
PDH FOR THE PROFESSIONAL

Continuing Education and Development, Inc.
9 Greyridge Farm Court
Stony Point, NY 10980

P: (877) 322-5800
F: (877) 322-4774

info@cedengineering.com

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J. Paul Guyer, P.E., R.A.

Paul Guyer is a registered civil engineer, mechanical engineer, fire protection engineer, and architect with over 35 years experience in the design of buildings and related infrastructure. For an additional 9 years he was a senior advisor to the California Legislature on infrastructure and capital outlay issues. He is a graduate of Stanford University and has held numerous national, state and local positions with the American Society of Civil Engineers and National Society of Professional Engineers.

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(Figures, tables and formulas in this publication may at times be a little difficult to read, but they are the best available. ***<u>DO NOT PURCHASE THIS PUBLICATION IF THIS LIMITATION IS UNACCEPTABLE TO YOU.)</u>***

1. INTRODUCTION. This publication contains criteria on metering, instrumentation, controls, and chemical feeding devices used in wastewater disposal systems.

2. RELATED CRITERIA. Certain criteria related to the subject matter appear elsewhere.

3. USE OF CRITERIA. These criteria indicate simple recommended practices applicable to plants with up to 5 Mgd average flow.

3.1 SPECIAL CASES. Specific design problems may require departures from these practices; therefore, use these criteria with discretion. For example, use of computers and microprocessors for data logging, indication, and process control is considered an emerging technology. This technology is presently primarily applicable to large wastewater treatment plants with adequately trained staff to maintain the hardware (greater than 10 Mgd size). However, improvements in electronics, hardware, software, and sensing devices (primarily sensing elements) will make this technology more desirable for smaller plants. Detailed information is not included for such emerging technology because of its state of rapid change and because additional development and application experience need to occur before application to the smaller naval facilities is justified.

3.2 LETTERS IN TABLES. To further clarify terms in the tables, the letters (E), (O), and (S) are used to mean:

(E) = Essential Items described are required wherever particular applications occur.

(O) = Optional Items described may be required (contingent on specific plant needs).

(S) = Special Cases Items are sometimes used in large installations or where process variable control is critical.

4. POLICIES. Devices and systems should be as simple as possible. In any installation or facility, equipment procurement should be limited to the smallest practicable number of manufacturers.

4.1 PRIMARY MEASUREMENT. Provide elements to measure any function essential to proper operating control and evaluation of plant performance.

4.2 INSTRUMENTATION. Provide remote readouts only where operating convenience and cost savings outweigh added maintenance needs or where hazardous wastes are being treated. Record functions that significantly affect public health, the environment, or economy of operation. Consider data logging devices where costs can be offset by reduced operating manpower needs.

4.3 CONTROLS. Consider automatic controls where significant improvement in performance will result or where cost can be offset by reduced operating manpower needs or where treating hazardous wastes; otherwise, keep controls as simple as possible. Wherever feasible, use fixed or manual controls (for example, weirs, launders, siphons, or throttling valves) in preference to mechanical devices. Use direct acting controls (for example, float valves) in preference to electrically or pneumatically actuated devices. Always consider the effects of possible control malfunctions.

4.4 STANDARDIZATION. Standardize equipment wherever possible. Use identical or similar components to the maximum extent. Instrumentation, control, and feeding equipment should be homogeneous (that is, all self-powered, all pneumatic, and so forth).

4.5 EQUIPMENT ACCURACY. Equipment accuracy tolerances should be as low as possible and consistent with the functions desired.

4.6 EQUIPMENT RANGES. Before selecting equipment such as meters or feeders, compute the required maximum and minimum capacities, and keep ranges as narrow as possible for any piece of equipment.

4.7 NEW PRODUCTS. New products and applications are constantly being developed.

5. INFORMATION REQUIRED. Obtain the following information to assist in equipment selection:

a) Type of treatment.
b) Chemical, physical, and bacteriological qualities of raw wastewater, treated wastewater, and permissible discharge limits.
c) Variations of flow rate for raw wastewater.
d) Ranges of other related variables.
e) Size of treatment plant.
f) Effluent disposal conditions.

6. WASTEWATER TREATMENT SYSTEMS

6.1 PRIMARY MEASURING DEVICES

6.1.1 LOCATION AND PURPOSE. Primary measuring devices are required at critical locations in wastewater treatment systems to sense and measure flow, pressure, elevation, temperature, weight, and physical and chemical characteristics of process streams. For type of device, see Table 1. For examples of location of measuring devices and types of measurements for industrial waste treatment systems, see Table 2.

6.1.2 USE LIMITATIONS. Different types of measuring devices are available for each application. The listed capacity of a device includes most sizes and types of the device that are available. The range is the useful turndown ratio of a particular device.

6.1.3 DISCRETE VERSUS ANALOG DEVICES. Alarm functions and many control functions require only the presence or absence of a process variable input for their operation. For example, a sump pump may start if the liquid level is above a certain point or a tank heater may start if the temperature is below a selected point. Control these functions by discrete devices such as flow switches, temperature switches, level switches, and pressure switches. If the actual status of the process variable is required, rather than on/off for indication or control, an analog primary device should be used. Some alarm switches are not included in the tables; for example, clarifier torque switches, speed switches, and other equipment protection switches that are normally supplied with the equipment.

6.1.4 SPECIAL CONSIDERATIONS. Primary measuring devices for wastewater systems must meet more rigorous operational requirements than those for water supply systems. Select devices constructed of materials impervious to the corrosive effects of the wastewater. Consider plugging of impulse or sampling lines and buildup of solids and grease on analytical probes when specifying these devices.

6.2 INSTRUMENTATION. Instrumentation covers all secondary instruments (such as gages, indicators, recorders, or totalizers) needed for efficient operation of wastewater treatment systems. Information sensed by a primary device is translated by instruments into an operator usable form called "readout." Most analog primary devices require secondary instruments, although a few (such as displacement meters) contain built-in counters.

6.2.1 USE LIMITATIONS. Instruments may be obtained in any combination of totalizing, indicating, or recording of information developed by primary devices. Other more sophisticated forms of instruments (such as summation and multiplication of variables) are possible, but are not normally needed.

6.2.2 TRANSMISSION. Select means of transmitting information from primary measuring devices to secondary instruments from the following:

6.2.2.1 MECHANICAL. Transmission distance is limited to a few feet. Consider the effects of corrosion, wear, or icing on mechanical linkages.

6.2.2.2 PNEUMATIC. Transmission distance can be up to 1,000 feet (304.8 m). Reaction time of pneumatic loops is relatively long if transmission distance is long.

6.2.2.3 ELECTRICAL. There is no limitation on distance. Analog signals may require amplification for transmission distances greater than 1,000 feet (304.8 m).

6.2.3 REMOTE INDICATION. Remote indicators should provide the operator with the status of any function necessary for remote operation of the plant. Panel lights should indicate the on/off status of pumps or other discrete devices, alarm functions, and operator-actuated functions (for example, initiate backwash, fill day tank).

Primary Measurement and Type of Device	Use Examples	General	Capacity	Range
Open Channel Flow:		Accuracy is dependent on piping configuration. Consult vendor data on specific device.		
Flume (Parshall or Palmer-Bowlis)	Plant influent, bypass lines.	Suspended matter does not hinder operation, More costly than weir.	10 gpm (0.6 L/s) and up.	75:1
Weir	Plant influent, plant effluent.	Requires free fall for discharge and greater head loss than flume. Influent weirs may plug.	0.5 gpm (0.03 L/s) and up.	100:1 and up
Pressure Pipeline Flow:				
Differential producers	Filled lines. Fluids under positive head at all times. Not generally for water supply service.			
Venturi tube or flow tube	Most fluid lines where solids build up and scale will not be a problem.	Long laying length required. Costly in large pipe sizes.	5 gpm (0.03 L/s) and up for liquid; 20 ft^3/min (9.4 L/s) and up for gas.	10:1
Orifice plate	Air and gas lines, water except filter effluent.	Clean fluids only.	5 gpm (0.03 L/s) and up for liquid; 20 ft^3/min (9.4 L/s) and up for gas.	5:1
Flow nozzle	Water except filter effluent.	Clean fluids only.	Determined by pipe sizes.	3:1
Displacement meters	Plant water and distribution system service connections.	Different types available. Maximum flow volume somewhat limited. May be in conjunction with chemical feed pump. Clean fluids only.	0.1 to 9,000 gpm (0.006 L/s to 568 L/s) for liquid; 0 to 100 ft^3/min for gas.	10:1
Target meters	Plant effluent, sludge, dirty fluids.	Suspended matter does not hinder operation.	0.07 gpm (0.004 L/s) and up.	10:1
Velocity meters, propeller meter	Water, clean liquids.	Insertion turbine or full bore types available.	0.001 to 40,000 gpm(6.3×10^{-5} to 2524 L/s) for liquids, to 10,000,000 ft^3/min (630,900 L/s) for gas.	10:1 to 50:1

Table 1

Types of Measuring Devices Applicable to Wastewater Treatment Systems

Primary Measurement and Type of Device	Use Examples	General	Capacity	Range
Magnetic meter, sonic or ultrasonic meter	Plant influent, sludge, clean to dirty liquids, plant effluent.	No obstruction in flow stream. Well suited for suspended matter and solids. Sonic meters are subject to interference by air bubbles. Suitable for confined piping systems.	0.001 to 500,000 gpm (6.4 x 10^{-5} to 31,545 L/s).	10:1
Vortex shedding meter	Heat exchanger water lines.		3 to 5,000 gpm (0.2 to 315 L/s).	15:1
Variable area rotameter	Gas and gas solution feeders, chemical dilution systems, influent lines to ion exchange units, water and clean liquids.	Available in very small to very large flow rates at lowest cost for flow indicator.	0.01 mL/min to 4,000 gpm (252 L/min) to 1,300 ft^3/min(614 L/s) for gas.	5:1 to 12:1
Open flow nozzle	Plant influent or effluent, sludge.	Requires free fall from end of pipeline.	5 to 11,000 gpm (0.3 to 694 L/s).	5:1 to 10:1
Level:				
Staff gauge	Wet wells, floating cover digesters, water supply intake.	Indication only.	Unlimited.	100:1
Float	Wet wells, sumps.	Indication near tank, has moving parts.	Unlimited.	100:1
Capacitance probes, RF probes	Wet wells, elevated tanks, tanks, most level applications.	Many types immune to conductive build-up and coating on probe.	Unlimited.	100:1
Sonic or ultrasonic meters	Wet wells, supply intake, batch tanks.	Continuous type does not contact the liquid, may not be suitable for foaming liquids. Gap type for on/off applications.	Unlimited.	50:1
Differential pressure	Batch tanks, chemical tanks.	Specific gravity should be fairly constant. Build-up may be a problem.	Unlimited.	20:1
Bubble tube	Water supply wells.	Requires air supply for automatic. Manual (hand pump type) available for indication only.	Depth limited by air pressure if automatic.	10:1

Table 1 (continued)

Types of Measuring Devices Applicable to Wastewater Treatment Systems

Primary Measurement and Type of Device	Use Examples	General	Capacity	Range
Pressure:				
Pressure gauge	Pump discharge, transmission mains, elevated tanks, digester gas, aeration air.	Seals or diaphragm may be required to prevent corrosion of plugging impulse connections.	Vacuum to 1,500 psig (10,342 kPA)	10:1
Loss of head gauge	Gravity filters		Unlimited.	3:1
Temperature:				
Thermometer or resistance thermal device	Plant influent, clearwell, atmosphere, digester, digester heating system.			
Analytical Instruments:	Plant influent or effluent, pH precipitator, neutralization, oxidation or reduction processes.		0 to 14 units.	
Oxidation on Reduction Potential (ORP)	Precipitator, oxidation, or reduction processes.	May also be used for free residual chlorine.	-400 mV to +400 mV[1]	
Dissolved oxygen	Mixed liquor, aerobic digester, aeration basin, plant effluent.		0 to 20 mg/L	
Turbidity	Filter influent/effluent. Settling basin effluent.		0 to 1,000 NTU	
Residual chlorine, residual ozone	Treatment unit effluent		0 to 2 mg/L[1]	
Specific ion electrodes	Treatment unit effluent		0 to 2 mg/L[1]	
Ultraviolet photometer	Oil treatment unit influent or effluent.		0 to 50 mg/L	
Sand expansion:				
Float	Gravity filter		Unlimited.	20:1
Weight:				
Scales	Chem. feed and storage equip., grit chamber, sludge cake conveyor.	Weighing devices may be integral to gravimetric feeders.	1 to unlimited.	12:1

Table 1 (continued)

Types of Measuring Devices Applicable to Wastewater Treatment Systems

Primary Measurement and Type of Device	Use Examples	General	Capacity	Range
Gas Concentration:				
Concentration indicator or alarm	Chlorine rooms, digester operating room, wet wells, lift stations.		0 to 100%	
Time:				
Elapsed time meter (ETM)	Motors requiring periodic service, motors driving principal pumps.		0 to 10,000 h	100,000:1
Revolutions:				
Counter	Positive displacement sludge pumps.	May be used for primary metering of sludge flow.	0 to 100 million.	100 million:1
Electric Power Use:				
Watt-hour meter	Plant power.	Public utility may have governing requirements.	Unlimited.	10,000:1

Table 1 (continued)

Types of Measuring Devices Applicable to Wastewater Treatment Systems

Location and Use	Type of Measurement	Type of Instrument Readout	Range of Measurement and/or Readout	Controls Item Regulated	Controls Type
Pumping:					
Lift station discharge	Flow	Indicator(O)	Minimum to maximum pumping		
		Totalizer (E)	capacity		
		Recorder (O)			
	Pressure	Indicator (E)	0 to 1.5 times shutoff pressure		
Suction	Pressure	Indicator (O)	Full vacuum to 1.5 times static suction head		
Transfer pumps suction	Pressure	Indicator (O)	Full vacuum to 1.5 times static suction head		
Transfer pump discharge	Pressure	Indicator (E)	0 to 1.5 times shutoff pressure		
Major pumps	Temperature	Indicator (O)	32° to 200°F (0° to 93°F)		
	Running time	Totalizer (O)	At least 2 times maintenance period		
Surge Tank:	Level	Indicator (E)	Depth of tank	Lift pumps	Automatic (E)
Batch Treatment Tank:	Level	Indicator (E)	Depth of tank	Transfer pump	Manual (O)
Chrome or cyanide waste	pH	Indicator (E)	0 to 14 units	Chemical addition	Automatic (E)
		Recorder (O)			Automatic (O)
	ORP	Indicator (E)	-200 to +200 mV	Chemical addition	Manual (E) Proportional-automatic (O)
Metal waste	pH	Indicator (E)	0 to 14 units	Chemical addition	Manual (E) Proportional-automatic (O)
Neutralization Tank:					
(batch type)	Level	Indicator (E)	Depth of tank		
	pH	Indicator (E)	0 to 14 units	Chemical addition	Automatic (O)
Clarified Water Storage:	Level	Indicator (E)	Depth of stack		
Filters:					
Influent line to each filter	Flow	Indicator (E)	1 to 4	Filtration rate	Manual (E)
Individual filters	Pressure differential	Indicator (E)	1 to 3	Backwash frequency	Manual (E)
Backwash pump	Flow	Indicator (E)	1 to 4	Backwash rate	Manual (E)

Table 2

Metering, Instrumentation, and Control Requirements for Industrial Wastewater Treatment Systems

Location and Use	Type of Measurement	Type of Instrument Readout	Range of Measurement and/or Readout	Controls Item Regulated	Type
Spent backwash storage tank	Level	Indicator (E)	Depth of tank		
Sludge Storage Tank:	Level	Indicator (E)	Depth of tank		
Gas feeder:					
Chlorine or sulfur dioxide	Flow	Indicator (E)	1 to 10	Application rate	Manual (E) Proportional-automatic (O)
On-line chlorine cylinder or on-line sulfur dioxide cylinder	Flow	Indicator (E)	3 times full cylinder weight	Chlorine supply	Manual (E)
Chemical bulk storage	Level	Indicator (E)	Depth of tank	Chemical supply	Manual (E)
	Temperature	Indicator (O)	Depends on chemical	Tank heater (if required)	Automatic (E)
Chemical day tanks	Level	Indicator (O)	Depth of tank	Day tank supply	Manual (E)
Oil emulsion breaking tank	Temperature	Indicator (E)	1 to 10	Tank content temperature	Automatic (E)

Table 2 (continued)

Metering, Instrumentation, and Control Requirements for
Industrial Wastewater Treatment Systems

6.3 CONTROLS. Controller devices are needed to regulate the functions of equipment throughout the process. Controls may be classified by the degree of automation.

6.3.1 MANUAL. Use this type of control where the operator will start, stop, or adjust rates of operations based on instrument observations, laboratory tests, or indicated conditions.

6.3.2 AUTOMATIC. Use this type to automatically start, stop, or regulate rates of operations in response to changes in a measured variable or other input. All equipment must also have manual control to override automatic control regardless of the degree of automation provided.

6.3.3 DESIGN CONSIDERATIONS. Many controls combine manual and automatic operations. The operator may initiate an automatic-timed cycle backwash system, or adjust set points of a proportional controller based on instrument observation. Controls that seldom require adjustment (rate of flow to filters, for example) should be manual. Controls requiring frequent adjustment (starting sump pumps, proportional chemical feeding) should be automatic. Whether the automation is on/off timed cycle, or proportional, it must be based on analysis of plant requirements.

7. CHEMICAL HANDLING AND FEEDING

7.1 INTRODUCTION. See Table 3 for function of chemicals used for cyanide, oil, and metal removal. See Table 4 for the usual chemical strengths and other data on chemicals.

7.2 CHEMICAL HANDLING AND FEEDING

7.2.1 HANDLING. See Table 5 for handling precautions. Provide the following:

a) Roofed unloading platforms.
b) Mechanical handling aids for unloading and transporting chemicals to the storage area, feed hoppers, and solution tanks.
c) Dust control equipment for dry, dusty chemicals.
d) Washdown and cleanup. Facilities for dry and liquid chemical spills.

Chemical	Cyanide Removal		Metal Removal					Oil Removal	
	pH	O	A	pH	R	PR	C	pH	C
1. Activated Carbon			X						
2. Aluminum Sulfate							X		X
3. Calcium Carbonate (limestone)				X					
4. Calcium Hydroxide (hydrated lime)	X			X		X		X	
5. Calcium Oxide (quick lime)	X			X		X		X	
6. Calcium Hydrochlorate (HTH, perchlorane)		X							
7. Chlorine		X							
8. Chlorine Dioxide		X							
9. Ferric Chloride							X		
10. Ferrous Sulfate							X		X
11. Ferrous Sulfide						X			
12. Hydrochloric Acid	X			X				X	
13. Hydrogen Peroxide		X							
14. Ozone		X							
15. Polymers (polyelectrolytes)							X		X
16. Sodium Carbonate				X		X			
17. Sodium Chlorite		X							
18. Sodium Hypochlorite		X							
19. Sodium Hydroxide	X			X		X		X	
20. Sodium Meta Bisulfate					X				
21. Sulfur Dioxide					X				
22. Sulfuric Acid	X			X				X	

Key: A = Adsorption; C = Coagulation; O = Oxidizing Agent; pH = pH Adjustment; PR = Precipitant; R = Reducing Agent

Table 3

Function of Chemicals for Industrial and Oily Wastewater Treatment

Chemical	Available Form	Shipping Container	Bulk Weight lb/ft^3 (kg/m^3)	Commercial Strength	Water Solubility lb/gal (kg/L)	Feeding Form	Feeder Type	Accessory Equipment	Suitable Handling Materials	Comments
Activated Carbon C	Powder	Bag, bulk	Varies		Insoluble	Dry or slurry	Volumetric metering pump	Slurry tank, dust control services	Dry-iron, steel	Combustible dust
	Granular	Bag, bulk	20 to 35 (320 to 560)			Static or fluidized bed			Wet-scrubber, plastic, stainless steel	
Aluminum Sulfate (Alum), $Al_2(SO_4)_3$ $0.14H_2O$	Slab, lump, powder	Bag(100 to 200 lb[45 to 90 kg]), drum	60 to 75 (960 to 1,200)	17% Al_2O_3	5.2 @ 32 °F (0.6 @ 0 °C) 5.5 @ 0 °F (0.65 @ 10 °C) 5.9 @ 68 °F (0.7 @ 20 °C)	Dry or solution	Volumetric metering pump	Dissolver of solution tank	Dry iron, steel, concrete	
	Liquid	Bulk	10.71 lb/gal (1.3 kg/L)	5.8 to 8.5% Al_2O_3	Complete	Solution	Metering pump	Solution tank	Wet-lead, rubber, plastic	
Ammonia NH_3	Liquefied gas	Cylinder (100, 150 lb [45, 70 kg]), bulk		99 to 100%	3.9 @ 32 °F (0.5 @ 0 °C)	Gas			Dry-steel, iron	
		Carboy, drum, bulk		15 to 30%	3.1 @ 60 °F (0.4 @ 15 °C)	Solution	Metering pump	Solution tank	Wet-stainless steel	
Ammonium Sulfate $(NH_4)_2$ SO_4	Crystals	Bag(100 lb [45 kg])	54 (865)		5.9 @ 32 °F (0.7 @ 0 °C) 6.1 @ 50 °F (0.73 @ 10°C)	Solution	Metering pump	Solution tank	Plastic	

Table 4

Data on Chemicals for Wastewater Treatment

Chemical	Available Form	Shipping Container	Bulk Weight lb/ft^3 (kg/m^3)	Commercial Strength	Water Solubility lb/gal (kg/L)	Feeding Form	Feeder Type	Accessory Equipment	Suitable Handling Materials	Comments
Calcium Carbonate $CaCO_3$	Powder, crushed (various sizes)	Bag, barrel, bulk	Powder: 48 to 71 (769 to 1,137); crushed: 70 to 110 (1,120 to 1,760)		Nearly insoluble	Dry slurry used in fixed beds	Volumetric metering pump	Slurry tank	Iron, steel	
Calcium Hydroxide $Ca(OH)_2$	Powder, granules	Bag (50 lb [22 kg]), bulk	25 to 50 (400 to 800)	Normally 13% $Ca(OH)_2$	Nearly insoluble	Dry or slurry	Volumetric metering pump	Slurry tank	Iron, steel, plastic, rubber hose	
Calcium Oxide CaO	Lump, pebble, ground	Bag (80 lb [36 kg]), barrel, bulk	40 to 70 (640 to 1120)	75 to 99% normally 90% CaO	Nearly insoluble	Dry or slurry (must be slaked to $Ca(OH)_2$) bed	Dry-volumetric Wet-slurry (centri-fugal pump)	Slurry tank, slaker	Iron, steel, plastic, rubber hose	Provide means for cleaning slurry transfer pipes
Calcium Hypochlorite $Ca(OCl)_2$ $0.4H_2O$	Granules, tablets	Can (5 lb [2 kg]), drums (100, 300, 800 lb[45,136, 362 kg])	50 to 55 (800 to 880)	70% available chlorine	1.8% @ 32 °F (1.8% @ 0 °C)	Solution or dry	Solution metering pump, Dry tablet contact feeder	Solution tank	Glass, plastic, rubber	Soft water required for solution
Chlorine Cl_2	Liquefied gas	Cylinder (100, 150, 200 lb [45, 68, 90 kg] bulk	Liquid: 91.7 (1,470) Gas: 0.19 @60 °F (3 @16 °C) and atm. pressure	99.8%	0.12 @ 32 °F (0.014 @ 0 °C) 0.047 @ 87 °F (0.006 @ 31 °C)					

Table 4 (continued)

Data on Chemicals for Wastewater Treatment

Chemical	Available Form	Shipping Container	Bulk Weight lb/ft^3 (kg/m^3)	Commercial Strength	Water Solubility lb/gal (kg/L)	Feeding Form	Feeder Type	Accessory Equipment	Suitable Handling Materials	Comments
Chlorine Dioxide ClO_2	Gas	Prepared on site using chlorine and sodium chlorite, solution pump, and contractor column			0.07 @ 60 °F (0.008 @ 16 °C) 0.4 @ 100 °F (0.005 @ 38 °C)	Water solution of gas	Chlorinator plus sodium chlorite solution pump	Scales, switch over devices, leak detectors, reactor tower	Sched. 80 steel for gas under pressure. Plastic or rubber-lined for gas under vacuum or water solution.	
Ferric Chloride $FeCl_3$	Powder	Drum (135, 350 lb [61, 159 kg])	175 (2,800)	98%	4.6 @ 32 °F (0.55 @ 0 °C)	Liquid	Metering pump	Solution tank	Glass, rubber, plastic	Dilution limited due to iron hydrolysis
	Liquid	Bulk	87 to 94 (1390 to 1500)	39 to 45%	5.8 @ 55°F (0.7 @ 13 °C)	Liquid	Metering pump			
Ferric Sulfate $Fe(SO_4)_3 .xH_2O$	Powder	Bag (50, 100, 175 lb [23, 45, 79 kg])	70 to 72 (1120 to 1150) soluble iron	21%	Very soluble	Liquid pump	Metering tank	Solution plastic	Glass, rubber	Dilution limited due to iron hydrolysis
Ferrous Sulfate $FeSO_4$ $0.7H_2O$	Crystals, powder, lumps	Bag (50, 100 lb[23, 45 kg]); Drum (55 gal [208 L]; bulk	62 to 66 (990 to 1060)	55 to 58%		Liquid	Metering pump	Solution tank	Glass, rubber, plastic	Dilution limited due to iron hydrolysis
	Liquid	Bulk	Varies, consult producer	Varies, consult producer		Liquid	Metering pump			
Ferrous Sulfide	Liquid solution	Prepared on site by mixing ferrous sulfate, a soluble sulfide and lime			Nearly insoluble	Slurry	Metering pump			

Table 4 (continued)

Data on Chemicals for Wastewater Treatment

Chemical	Available Form	Shipping Container	Bulk Weight lb/ft^3 (kg/m^3)	Commercial Strength	Water Solubility lb/gal (kg/L)	Feeding Form	Feeder Type	Accessory Equipment	Suitable Handling Materials	Comments
Hydrochloric acid HCL	Liquid	Barrel, drum, bulk	27.9%, 0.53 lb/gal (0.06 kg/L) 31.45%, 9.65 lb/gal (1.16 kg/L)	27.9% 31.45% 35.2%	Complete	Liquid	Metering pump	Dilution	Hastel-lory A, selected plastic and rubber types	
Hydrogen Peroxide H_2O_2	Liquid	Drum (30, 55 gal [113, 208 L]), bulk	35%, 9.4 lb/gal (1.13 kg/L) 50%, 10 lb/gal (1.2 kg/L) 70%, 10.8 lb/gal (1.3 kg/L)	35%, 50%, 100%	Complete	Liquid	Metering pump		Type 304 stainless steel, poly-ethylene	Strong oxidizing agent
Ozone O_3	Gas	Generated on site from air or oxygen				Gas solution		Consult equipment supplier	Unplasti-cized PVC, stainless steel	Toxic, irritant
Polymers	Liquid, powder	Drum, bulk	See note 1			Solution		Storage and dilution tanks	Consult supplier	See note 2
Phosphoric Acid H_3PO_4	Liquid	Carboy, barrel, keg, bulk	75%, 13.1 lb/gal (1.6 kg/L)	75%	Complete	Liquid	Metering pump		Type 316 or alloy 20 stainless steel, selected plastics	
Potassium Permanganate $KMnO_4$	Crystals	Drum (110, 220, 550 lb [50, 100, 250 kg])	100 (1,600)	95 to 99%	0.525 @ 68 °F (0.06 @ 20 °C)	Liquid pump	Metering tank	Dissolving	Iron, steel, PVC	
Sodium Aluminate $NaAlO_2$	Powder	Bag (100, 150, 250, 440 lb[45, 68, 113, 200 kg])	50 to 60 (800 to 960)	72 to 90%	2.45 @ 32 °F (0.3 @ 0 °C) 2.8 @ 50 °F (0.34 @ 10 °C) 3.1 @ 68 °F (0.37 @ 20 °C)	Dry	Volumetric	Dissolving tank	Wet or dry-iron, steel	

Table 4 (continued)

Data on Chemicals for Wastewater Treatment

Chemical	Available Form	Shipping Container	Bulk Weight lb/ft³ (kg/m³)	Commercial Strength	Water Solubility lb/gal (kg/L)	Feeding Form	Feeder Types	Accessory Equipment	Suitable Handling Materials	Comments
	Liquid	Drum	Varies	Varies	3.3 @ 86 °F (0.4 @ 30 °C)	Liquid	Metering pump			
Sodium Bicarbonate $NaHCO_3$	Granular, powder Bulk	Bag	44 to 55 (705 to 880)	99.8%	0.57 @ 32 °F (0.07 @ 0 °C) 0.68 @ 50 °F (0.08 @ 10 °C) 0.80 @ 68 °F (0.10 @ 20 °C)	Dry Liquid	Volumetric Metering Pump	Dissolving tank	Iron, steel, stainless steel	Tends to decompose and absorb moisture
Sodium Carbonate Na^2CO^3	Powder	Bag (100 lb [45 kg]), bulk	34 to 62 (545 to 993)	99.2%	0.58 @ 32 °F (0.07 @ 0 °C) 1.04 @ 50 °F (0.12 @ 10°C) 1.79 @ 68 °F (0.21 @ 20 °C) 3.33 @ 86 °F (0.40 @ 30 °C)	Dry Liquid	Volumetric feeder Metering pump	Dissolving	Iron, steel	Can cake
Sodium Chloride NaCl	Rock, evaporated	Bag, barrel, bulk	50 to 70 (800 to 1,120)	Varies	2.97 @ 32 °F (0.356 @ 0 °C) 2.97 @ 50 °F (0.356 @ 10°C) 3.00 @ 68 °F (0.359 @ 20 °C) 3.02 @ 86 °F 0.362 @ 30 °C)	Solution	Pump	Dissolving tank	Plastic, iron, steel	
Sodium Chlorite $NaClO_2$	Flake Liquid	Drum (100 lb [45kg]) Drum, bulk	 Varies	 Varies		Solution	Metering pump	Dissolving tank	Plastic (avoid cellu-lose)	Use to produce chlorine dioxide
Sodium Hypochlorite (NaOCl)	Liquid	Carboy (5, 13, 59 gal. [19, 49, 223 L]); bulk (1,300, 2,000 gal[4,920 , 7,570 L]);truck-load		12 to 15% available chlorine	Complete	Solution	Metering pump	Solution tank	Plastic, glass, rubber	

Table 4 (continued)

Data on Chemicals for Wastewater Treatment

Chemical	Available Form	Shipping Container	Bulk Weight lb/ft^3 (kg/m^3)	Commercial Strength	Water Solubility lb/gal (kg/L)	Feeding Form	Feeder Type	Accessory Equipment	Suitable Handling Materials	Comments
Sodium Hydroxide $NaOH$	Solid flake, ground flake, liquid	Drum (735, lb [333 kg]); drum (100 lb [45 kg]); drum (450 lb [204 kg])	Varies	98%	3.5 @ 32 °F (0.4 @ 0 °C) 4.3 @ 50 °F (0.5 @ 10 °C) 9.1 @ 68 °F (1.09 @ 20 °C) 9.2 @ 86 °F (1.10 @ 30 °C)	Solution	Metering pump	Solution tank	Iron, steel	Dissolving solid forms generates much heat
Sodium Meta-bisulfite $Na_2S_2O_5$	Lump, ground	Bag (100 lb [45 kg]); drum (100 and 300 lb [45 and 136 kg])	84 to 95 (1346 to 1522)		2.3 @ 68 °F (0.28 @ 20 °C)	Solution	Metering	Solution	Plastic, Type 316 stainless steel	
Sulfur Dioxide SO_2	Liquefied gas	Cylinder (150, 2,000 lb [68907 kg])	Liquid-89.6 (1435) Gas @ 32 °F and 1 atm.-0.183(0 °C and 101 kPA-2.9)	99%	1.0 @ 60 °F (0.014 @ 16 °C)	Water solution of gas	Vacuum-sulfur-meter	Scales, switch over devices	Dry-316 stainless steel Wet and low pressure plastic, rubber	
Sulfuric Acid H_2SO_4	Liquid	Carboy, drum (825 lb [374 kg]). Bulk	106 (1700) 114 (1830)	77.7% 93.2%	Complete	Liquid	Metering pump			Provide for spill cleanup and neutral-ization

ıtes:
he various cationic, anionic, and nonionic polymers vary in composition, density and other characteristics. Consult a supplier for data.
olyelectrolytes have relatively short periods of chemical potency once mixed and diluted. Most ıanufacturers will advise mixing no more than a 1 to 3 day supply in the solution feed tank. 'herefore, a protected area must be provided for storage of sealed bugs or containers of dry ıolyelectrolyte or sealed containers of concentrated liquid polyelectrolyte.

Table 4 (continued)

Data on Chemicals for Wastewater Treatment

7.2.2 STORAGE. See Table 6 for space criteria and Table 7 for type criteria. Refer to American Concrete Institute (ACI), Concrete Sanitary Engineering Structures, for criteria on protection of concrete against chemicals.

a) Store materials in original containers in dry rooms on boards or pallets.

b) Locate storage for dry chemicals at the level of feed hopper inlets if possible.

c) Do not exceed safe floor load limits.

d) For liquefied gas cylinders, provide cool, dry, well ventilated, aboveground storage rooms of noncombustible construction, remote from heat sources, walkways, elevators, stairways, and ventilating system intakes.

e) Determine compatibility of all chemicals stored. Store incompatible chemicals separately.

f) Observe personnel safety precautions.

7.2.3 ON-SITE GENERATION AND FEEDING EQUIPMENT

7.2.3.1 OZONE. Ozone can be generated from air or from high-purity oxygen.

a) Generation from air requires the air to be filtered and dried to a dew point less than -58°F (-50°C) by desiccation and refrigeration.

b) When using oxygen for the production of ozone, refrigeration and desiccation are not required except when recycling is used. Use oxygen for the generation of ozone where savings are indicated. Power consumption is halved when oxygen is used to generate ozone, but oxygen must be recycled or used for aeration to achieve overall economy.

Class of Chemicals	Noninterruptible	Interruptible
Examples of class	All chemicals used for disinfection. Chemicals used for coagulation in treatment plants where raw water is polluted. Softening chemicals.	Chemicals used for corrosion control. Taste and odor fluoridation.
Minimum stock to be maintained, in days.[1]	30	10
Additional allowance based on shipping time, in days.[1,2]	2 times shipping time.	1-1/2 times shipping time.

[1]Based on maximum use expected for total consecutive days plus additional allowance.
[2]Additional allowance based on shipping time, in days.

Table 5

Chemical Storage Space Criteria

c) For ozone feeding equipment, use porous diffusers, injectors, or emulsion turbines to ensure optimum contact.

7.2.3.2 HYPOCHLORITE. Compare the cost of hypochlorite generated from brine with the cost of purchased hypochlorite solution delivered to site. Generation is generally cheaper and may compare favorably with the cost of gaseous chlorine.

Type of Storage	Dry	Wet
Handling requirements	Allow for access corridors between stacks of packaged chemicals.	Provide agitation for slurries such as carbon or lime (not less than 1 hp mixing for 100 ft^3)
	Palletize and use forklift truck only in large installations.	Check manufacturers of feed and mixing equipment for pumps, pipe sizing, and materials selection.
Safety and corrosion requirements	Provide separated storage spaces for combustibles and for toxic chemicals, such as carbon or chlorine gas.	Double-check corrosion resistance of bulk storage linings, pipe, mixing, and pumping materials.
	Provide ample space between stores of materials that may interact, such as ferrous sulfate and lime.	Isolate hazardous or toxic solutions such as fluosilicic acid. Prefer below ground or outdoor storage.

Table 6

Chemical Storage Type Criteria

7.2.3.3 CHLORINE DIOXIDE. Chlorine dioxide can be generated using a solution of sodium chlorite ($NaClO_2$) and a solution feed-type gas chlorinator.

a) Solutions are fed through packed media reactor for generation of chlorine dioxide in solution.

b) Optimum operating conditions are pH $\leq$ 4; chlorine solution 500 milligram per liter (mg/L); 1:1 weight ratio of pure chlorite to chlorine; and reaction time $\geq$ 1.0 minute.

c) Reactor effluent will contain approximately 70 percent hypochlorite and 30 percent chlorine dioxide. Approximate yield is 0.4 lb ClO_2/lb Cl_2. Near 100 percent conversion to chlorine dioxide can be achieved by available recycle equipment. (Yield = 1.0 lb ClO_2/lb Cl_2)

d) Practical dosage range of 6:1. System operating as flow proportional should provide acid injection directly upstream from the chlorinator injector to maintain optimum pH.

e) Chlorine dioxide solutions are unstable in open vessels. Solution lines and diffusers must be designed so there is minimum possibility of chlorine dioxide coming out of solution.

7.2.4 CHEMICAL FEEDERS. See Table 7 for applications of various types of feeders.

a) Dry Feeder Accessories. Dry feeders may require specific auxiliary equipment or accessories when the chemical to be fed has unusual characteristics. Accessories and the conditions under which they are used are as follows:

Accessory	Characteristics of Material Requiring Use of Accessory
Agitator	Arches in hoppers
Rotolock mechanism	Tends to flood
Dissolving chamber	To be fed in solution
Dust collector	Dusty
Vapor collector	Noxious or irritating fumes

b) Feeder Construction. Mechanisms of feeders must be constructed out of materials resistant to substances to be handled. See Table 4 for guidance on materials selection.

c) Feeder Accuracy. The accuracy of feeders should be in these ranges:

Type of Feeder	Use	General	Limitations Capacity ft^3/hr (m^3/hr)	Range
Dry Feeder:				
Volumetric:				
Oscillating plate	Any material, granules or powder		0.01 to 35 (2.83×10^{-4} to 0.99)	40 to 1
Oscillating throat (universal)	Any material, any particle size		0.002 to 100 (5.66×10^{-5} to 2.83)	40 to 1
Rotating disc	Moist materials including NaF, granules or powder	Use disc unloader for arching.	0.01 to 1.0 (2.83×10^{-4} to 0.028)	20 to 1
Rotating cylinder (star)	Any material, granules or powder		8 to 2,000 (0.23 to 56.6)	or 10 to 1
Screw	Dry, free flowing material, powder or granules		0.05 to 18 (1.41×10^{-3} to 0.51)	20 to 1
Ribbon	Dry, free flowing material, powder, granules, or lumps		0.0006 to 0.16 (1.7×10^{-5} to 4.53×10^{-3})	10 to 1
Belt	Dry, free flowing material up to 1-1/2-inch (3.8 cm) in size. Powder or granules.		0.01 to 3,000 (2.83×10^{-4} to 85.0)	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 (5.7×10^{-4})	100 to 1
Loss in weight	Most materials, powder, granules or lumps		0.02 to 80 (5.66×10^{-4} to 2.27)	100 to 1

Table 7

Types of Chemical Feeders for Wastewater Treatment Systems

Type of Feeder	Use	General	Limitations Capacity ft^3/hr (m^3/hr)	Range
Proportioning Pump:				
Diaphragm	Most solutions. Special unit for 5% slurries[1]		0.004 to 0.15(1.13 x 10^{-4} to 4.25 x 10^{-3})	100 to 1
Piston	Most solution, light slurries		0.01 to 170(2.83 x 10^{-4} to 4.81)	20 to 1
Gas Feeders:				
Solution feed	Chlorine		8,000 lb/day maximum (3629 kg/day maximum)	20 to 1
	Ammoni a		2,000 lb/day maximum (907 kg/day maximum)	20 to 1
	Sulfur dioxide		7,600 lb/day maximum (3447 kg/day maximum)	20 to 1
Direct feed	Chlorine		300 lb/day maximum (136 kg/day)maximum	10 to 1
	Ammonia		120 lb/day maximum (54 kg/day)maximum	7 to 1

Table 7 (continued)

Types of Chemical Feeders for Wastewater Treatment Systems

(1) Volumetric feeders, accuracy of ±3 percent.

(2) Gravimetric feeders, accuracy of ±1 percent.

Gravimetric feeders are more expensive than volumetric feeders.

7.2.5 SAFETY PRECAUTIONS. Provide the following safety factors as a minimum:

a) First aid kits.

b) Continuous toxic gas monitors with alarms and pressure demand self-contained breathing apparatus (SCBA) for emergency gas situations.

c) A readily accessible potable water supply to wash away chemical spills. Locate emergency shower and eyewash facilities where they are easily accessible to those in need.

d) Special handling clothing and accessories, such as gloves, goggles, aprons, and dust masks.

e) Adequate ventilation as determined by the medical activity industrial hygienist.

f) No electrical convenience outlets in activated carbon storage or feeding rooms. Store activated carbon in a separate room with adequate fire protection.

g) Entry into confined spaces will require adherence to a gas-free engineering program.

7.2.6 CHEMICAL FEEDER CAPACITY AND STANDBY REQUIREMENTS. Base feeder capacity on maximum expected instantaneous flow and dosage. Essential (noninterruptible) chemical feeders such as disinfection units must have a standby unit having capacity equal to the largest unit. The need for standby units on other treatment processes depends on raw water quality and the specific treatment scheme. Where two chemical feed systems could use the same spare chemical feeder, one standby unit to serve both is adequate. Refer to EPA 430-99-74-001, Design Criteria for Mechanical, Electrical, and Fluid System Component Reliability (MCD-29).

7.3 SAMPLING. Institute sampling programs only as needed to obtain data for the design and operation of wastewater treatment facilities, or to determine compliance with standards and the effect of waste streams (both raw and treated) on receiving waters. Refer to American Society for Testing and Materials (ASTM) D 3370, Sampling Water, for general discussion of sampling water and wastewater.

7.3.1 SAMPLING TECHNIQUES

a) Collection Point. Collect all samples in conduits or channels at a point where flow is highly turbulent. Collect a sample from the process tank only if tank contents are well mixed. Consider width, length, and depth when selecting the sampling point from the process tank.

b) Type of Sample. Use samples composited on the basis of time and flow, but take single grab samples when:

(1) Wastewater stream is intermittent or concentration is highly variable.

(2) Obtaining information for which time between collection and analysis of sample must be minimized (for example, sampling for dissolved oxygen, temperature, pH, chlorine demand, and residual chlorine).

(3) Ascertaining characteristics at extreme conditions.

(4) Samples for oil and grease may be manually composited. Automatic sampling is not normally accurate.

c) Method of Sampling. Use widemouthed containers to take grab samples. At small plants (up to 1 Mgd [3.8 x 106 L/d]), take composite samples manually by combining a series of regularly collected grab samples, such that the contribution from a particular grab sample is proportional to the flow at the time it was taken. At large plants and industrial wastes use automatic sampling devices that can be programmed for desired sampling method, that is, grab, continuous, or flow proportional composite.

7.3.2 SAMPLE VOLUME AND PRESERVATION. Volume and preservation requirements depend on: (1) the analytical determinations to be carried out on the sample, and (2) the time between sample collection and analysis. See Table 8 for recommendations for sampling and sample preservation. Refer to American Public Health Association (APHA) Examination of Water and Wastewater and EPA PB 84-128677, Manual of Methods for Chemical Analysis of Water and Wastes, for specific recommendations regarding sample containers, volumes, and methods of sample preservation for each analytical measurement.

7.4 ANALYTICAL METHODS. Analytic methods available for quantitative determination of physical, biological, inorganic chemical, and organic chemical characteristics of wastewater samples are summarized in Table 9. Refer to APHA Examination of Water and Wastewater for detailed laboratory procedures.

7.4.1 ROUTINE TESTING DURING PLANT OPERATION. A routine sampling and analysis program to maintain plant operability and performance is required. This program is unique to the individual industrial and oily wastewater treatment facilities and a general program cannot be developed by this manual. The program should be fully developed in the Operations and Maintenance Manual and revised accordingly after plant startup and the 30-day performance certification period. The program should include the following: sample locations and method, sample type (grab or composite), sampling frequency, and analyses required per sample. The Operations Manual should also identify minimum reporting requirements for regulatory compliance and should provide operating log sheets for recording operating data.

Measurement	Volume mL	Container[1]	Preservative	Holding Time[2]
Physical Properties:				
Color	50	P,G	Cool, 4°C (39.2°F)	24 h
Conductance	100	P,G	Cool, 4°C (39.2°F)[3]	24 h
Hardness	100	P,G	Cool, 4°C (39.2°F) HNO_3 to pH<2[4]	6 mo
Odor	200	G only	Cool, 4°C (39.2°F)	24 h
pH	25	P,G	Determine on site	6 h
Residue:				
Filterable	100	P,G	Cool, 4°C (39.2°F)	7 d
Nonfilterable	100	P,G	Cool, 4°C (39.2°F)	7 d
Total	100	P,G	Cool, 4°C (39.2°F)	7 d
Volatile	100	P,G	Cool, 4°C (39.2°F)	7 d
Settleable Matter	1000	P,G	None required	24 h
Temperature	1000	P,G	None	No holding
Turbidity	100	P,G	Cool, 4°C (39.2°F)	7 d
Metals:				
Dissolved	200	P,G	Filter on site HNO_3 to pH <2[4]	6 mo
Suspended	200	P,G	Filter on site	6 mo
Total	100	P,G	HNO_3 to pH<2[4]	6 mo
Mercury:				
Dissolved	100	P,G	Filter on site HNO_3 to pH <2[4]	38 d (glass) 13 d (hard plastic)
Total	100	P,G	HNO_3 to pH<2[4]	38 d (glass) 13 d (hard plastic
Inorganics, Nonmetallics:				
Acidity	100	P,G	None required	24 h
Alkalinity	100	P,G	Cool, 4°C (39.2°F)	24 h
Bromide	100	P,G	Cool, 4°C (39.2°F)	24 h
Chloride	50	P,G	None required	7 d
Chlorine	200	P,G	None	No holding
Cyanides	500	P,G	Cool, 4°C (39.2°F) NaOH to pH 12	24 h
Fluoride	300	P,G	None required	7 d
Iodine	100	P,G	Cool, 4°C (39.2°F)	24 h

Table 8

Recommendations for Sample Collection and Preservation According to Measurement

Measurement	Volume mL	Container[1]	Preservative	Holding Time[2]
Nitrogen:				
Ammonia	400	P,G	Cool, 4°C (39.2°F) H_2SO_4 to pH<2	24 h
Total Kjeldahl	500	P,G	Cool, 4°C (39.2°F) H_2SO_4 to pH<2	24 h[5]
Nitrate plus nitrite	100	P,G	Cool, 4°C (39.2°F) H_2SO_4 to pH<2	24 h[5]
Nitrate	100	P,G	Cool, 4°C (39.2°F)	24 h
Nitrite	50	P,G	Cool, 4°C (39.2°F)	48 h
Dissolved Oxygen:				
Probe	300	G only	None	No holding
Winkler	300	G only	Fix on site	4 to 8 h
Phosphorous:				
Orthophosphate, dissolved	50	P,G	Filter on site	24 h
Hydrolyzable	50	P,G	Cool, 4°C (39.2°F) H_2SO_4 to pH<2	24 h[5]
Total	50	P,G	Cool, 4°C (39.2°F) H_2SO_4 to pH<2	24 h[5]
Total, dissolved	50	P,G	Filter on site Cool, 4°C (39.2°F) H_2SO_4 to pH<2	24 h[5]
Silica	50	P only	Cool, 4°C (39.2°F)	7 d
Sulfate	50	P,G	Cool, 4°C (39.2°F)	7 d
Sulfide	500	P,G	2 ml zinc acetate	24 h
Sulfite	50	P,G	None	No holding
Organics:				
BOD	1000	P,G	Cool, 4°C (39.2°F)	24 h
COD	50	P,G	H_2SO_4 to pH<2	7 d[5]
Oil and Grease	1000	G only	Cool, 4°C (39.2°F) H_2SO_4 or HCL to pH<2	24 h
Organic carbon	25	P,G	Cool, 4°C (39.2°F) H_2SO_4 or HCL to pH<2	24 H
H_2SO_4 or HCL				
Phenolics	500	G only	Cool, 4°C (39.2°F) H_3PO_4 to pH<4 1.0 g $CuSO_4$/1	24 h
MBAS	250	P,G	Cool, 4°C (39.2°F)	24 h
NTA	50	P,G	Cool, 4°C (39.2°F)	24 h

Table 8 (Continued)

Recommendation for Sample Collection and Preservation According to Measurement

1) Plastic (P), Glass (G). For metals, polyethylene with a polypropylene cap (no liner) is preferred.
2) Recommended holding times for properly preserved samples based on currently available data. Extension or reduction of these times may be possible for some sample types and measurements. Where shipping regulations prevent the use of proper preservation techniques or the holding time is exceeded, reported analytical data should indicate the variation in recommended procedures.
3) If the sample is preserved, it should be warmed to 25°C (77°F) for measurement or temperature correction made and results reported at 25°C (77°F).
4) Where HN03 cannot be used because of shipping restrictions, the sample may be initially preserved by icing and immediately shipped to the laboratory. Upon receipt in the laboratory, the sample must be acidified to a pH<2 with HN03 (normally 3 mL 1:1 HN03/L is sufficient). At the time of analysis, the sample container should be thoroughly rinsed with 1:1 HN03 and the washings added to the sample. A volume correction may be required.
5) Data from National Enforcement Investigations Center, Denver, Colorado, support a 4-week holding time for this parameter in sewerage systems (SIC 4952).

Characteristics	Method of Analytic Determination
Physical Parameters:	
Color	Photometric
Odor	Physiological
Temperature	Thermometric
Turbidity	Nephelometric
Total suspended solids	Gravimetric
Specific conductance	Conductivity meter
Biological Parameters	
Total coliform bacteria	Fermentation tube or membrane filter
Fecal coliform bacteria	Fermentation tube or membrane filter
Inorganic Chemical Parameters[1]:	
Alkalinity	Potentiometric or colorimetric titration
Ammonia nitrogen	Spectrophotometric, or titratmetric
Arsenic	AA spectroscopy
Boron	Colorimetric
Cadmium	AA spectroscopy
Chloride	Titrametric
Chlorine residual	Colorimetric or potentiometric titration
Hexavalent chromium	AA spectroscopy
Copper	AA spectroscopy
Fluoride	Colorimetric or ion selective probe
Hardness	Titrametric
Iron	Colorimetric or AA spectroscopy
Lead	AA spectroscopy
Manganese	Colorimetric
Mercury	AA spectroscopy
Nitrates	Colorimetric or ion selective probe
Nitrites	Spectrophotometric
pH	Electrometric
Phosphorous	Colorimetric
Selenium	AA spectroscopy
Silver	AA spectroscopy
Sulfate	Gravimetric or nephelometric
Sulfide	Colorimetric
Total dissolved solids	Gravimetric
Zinc	AA spectroscopy
Organic Chemical Parameters:	
Cyanide	Colorimetric
Methylene blue active substances	Spectrophotometric
Oil and grease	Hexane extraction
Pesticides	Solvent extraction plug gas chromatographic analysis
Phenols	Photometric
Biochemical oxygen demand	Chemical oxidation

[1]Atomic absorption spectroscopy and flame emission photometry are recommended for most metals analyses. These are designated "AA spectroscopy."

Table 9

Analytical Methods