CIVL 406

PART II

Municipal Wastewater Treatment

Text: Water Supply and Pollution Control, 7^{th} Ed.
Viessman and Hammer

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2.0 MUNICIPAL WASTEWATER TREATMENT

2.1 An overview of Wastewater Engineering

WASTEWATER: A combination of the liquid- or water-carried wastes removed from residences, institutions, and commercial and industrial establishments, together with such groundwater, surface water, and storm water as may be present.

WASTEWATER ENGINEERING: The branch of environmental engineering in which the basic principles of science and engineering are applied to the problems of water pollution control.

ENVIRONMENTAL ENGINEERING: A branch of engineering in which the basic principles of science and engineering are applied to the problems of pollution control. It may be subdivided into:

- **Wastewater engineering**
- **Solid waste engineering**
- **Air pollution control engineering**

2.2 Sources of Pollution

2.2.1 Point Source

Pollution being emitted from a single, identifiable source. Given its nature, point source pollution is quantifiable. Examples include:

- Municipal sewerage systems.

- Industrial waste discharges (*two types:* on-site treatment and disposal/discharge, and treatment to appropriate standard and discharge to sewerage system).
- Pipe into a receiving water.

2.2.2 Non-Point Source (NPS)

Pollution with no single, identifiable source. NPS is not quantifiable, and most often arises from the transport of contaminants by runoff and overland flow. According to the USEPA, non-point source pollution is the greatest threat to water quality. Examples include:

- Agriculture (feedlot runoff, pesticide spraying, fertilizer runoff, etc).
- Mining activities (heavy metal leachate, acid drainage, silts).
- Poor construction practices (silt transport and deposition).
- Forestry clearcutting (silt transport and deposition).
- Irrigation return flow (agri-chemicals, salts, silts, fertilizers).
- Boating and marinas (nutrients from bilge water, hydrocarbons, metals).
- Urban runoff (silts, grit, hydrocarbons, nutrients, metals).
- Septic tanks and tile fields (dysfunctional tanks release untreated sewage).
- Acid rain (NO_x and sulphur compounds).

2.3 *Urban Runoff and Wastewater Composition*

2.3.1 Comparison of Urban Runoff with Municipal Wastewaters

Table 2.1 Wastewater characteristics

	Suspended Solids (SS)	Biochemical Oxygen Demand (BOD_5)	Total Nitrogen	Total Phosphorus (P)	Fecal coliforms
Background levels	5-100	0.5-3	0.05-0.5	0.01-0.2	....
Stormwater runoff	415	20	3-10	0.6	14,500
Combined sewer overflow	370	115	9-10	1.9	670,000
Untreated Municipal	200	200	40	5	1,000,000
Primary Effluent	80	135	35	8	200,000
Secondary Eff.	15	25	11	4	1,000
Tertiary Eff.	< 10	< 5	< 3	< 2	

Adapted from US EPA, 1977

SS, BOD_5, N, P in mg/L
Fecal coliforms in MPN/100 mL

2.3.2 Typical Composition of Domestic Sewage

Total Solids (TS) is the sum of **Total Suspended Solids (TSS) and Total Dissolved Solids (TDS)**, i.e. **TS = TSS + TDS**

Suspended solids are particulate and can be removed by settling or filtration. Dissolved solids may be atoms or compounds that are in solution, for instance sugar may be dissolved in water.

When placed in a muffle furnace at 550°C for one hour, a portion of the solids will volatilize (burn off) and the remainder will not. This is how volatile and fixed solids are defined. Volatile solids are typically smaller organic compounds.

Table 2.2

Constituent	Concentration		
	Strong	Medium	Weak
Solids, total	1200	700	350
Dissolved, total	850	500	250
Fixed	525	300	145
Volatile	325	200	105
Suspended, Total	350	200	100
Fixed	75	50	30
Volatile	275	150	70
Settleable Solids (ml/liter)	20	10	5
Biochemical oxygen demand, 5-day, 20°C	300	200	100
Total organic carbon (TOC)	300	200	100
Chemical oxygen demand (COD)	1000	500	250
Nitrogen, (total as N)	85	40	20
Organic	35	15	8
Free ammonia	50	25	12
Nitrites	0	0	0
Nitrates	0	0	0
Phosphorus (total as P)	20	10	6
Organic	5	3	2
Inorganic	15	7	4
Chlorides†	100	50	30
Alkalinity (as $CaCO_3$)†	200	100	50
Grease‡	152	100	50

All values except settleable solids are expressed in mg/liter

† *Values should be increased by amount in carriage water*

‡ *Problematic for treatment plant operation*

2.3.3 Biochemical Oxygen Demand from Selected Industries

Recall that the biochemical oxygen demand (BOD) is defined as "the quantity of oxygen used by microorganisms in the aerobic stabilization of wastewaters and polluted waters" (Viessman & Hammer, page 317). In other words, biochemical oxygen demand is an indirect measure of the quantity of organic compounds in the sample that can be degraded aerobically by microoganisms.

Table 2.3

Source of Waste	5-day, 20C BOD of waste, mg/liter
Beet sugar refining	450-2,000
Brewery	500-1,200
Beer slop	11,500
Cannery	300-4,000
Grain distilling	15,000-20,000
Molasses distilling	20,000-30,000
Laundry	300-1,000
Milk procesing	300-2,000
Meat packing	600-2,000
Pulp and paper	
Sulfite	20
Sulfite-cooker	16,000-25,000
Tannery	500-5,000
Textiles	
Cotton processing	50-1,750
Wool scouring	200-10,000

2.3.4 Population Equivalent Defined

Population Equivalent is the per capita per day BOD_5 loading (approx 0.2 lb/day·cap). This measure is used to easily compare the organic pollution potential of industries presenting large BOD loads to the system. This is important in determining treatment plant capacity – waste streams include both household and industrial wastewaters.

Table 2.4

Origin of the Waste	*Population Equivalent*[†]*, in terms of:*	
	Biochemical Oxygen Demand	Suspended Solids
Domestic sewage	1	1
Paper-Mill waste	16 - 1330	6100
Tannery waste	24 - 48	40 - 80
Textile-mill waste	0.4 - 360	130 - 580
Cannery waste	8 - 800	3 - 440

[†] *persons per unit daily production*

2.3.5 Variations in Waste Characteristics for Some Industrial Wastes

Table 2.5

Waste	Flow, gal/production unit			BOD, lb/production unit			Suspended Solids, lb/production unit		
	% frequency			% frequency			% frequency		
	10	50	90	10	50	90	10	50	90
Pulp and paper[1]	11,000	43,000	74,000	17	58	110	26	105	400
Paperboard[1]	7,500	11,000	27,500	10	28	46	25	48	66
Slaughterhouse[2]	165	800	4,300	3.8	13	44	3	9.8	31
Brewery[3]	130	370	600	0.8	2	44	.25	1.2	2.45
Tannery[4]	4.2	9.0	13.6	575	975	1,400	600	1,900	3,200

[1] tons paper production

[2] 1000 lb live weight kill

[3] bbl beer

[4] pounds of hides

2.3.6 Physical Characteristics of Domestic Wastewater

Table 2.6

Characteristic	Cause	Significance	Measurement
Temperature	Ambient air temperature. Hot water discharged into sewer from home or industry.	Influences rate of biological activity. Governs solubility of oxygen and other gases. Affects magnitude of density, viscosity, surface tension, etc.	Standard centigrade or Fahrenheit scale.
Turbidity	Suspended matter such as sewage solids, silt, clay, finely divided organic matter of vegetable origin, algae, microscopic organisms.	Excludes lights, thus reducing growth of oxygen-producing plants. Impairs aesthetic acceptability of water. May be detrimental to aquatic life, e.g. algae.	Light scatter and absorption on an arbitrary standard scale.
Colour	Dissolved matter such as organic extractives from leaves and other vegetation (tannins, glucosides, iron, etc.), industrial wastes.	Harmless generally, but impairs aesthetic quality of receiving waters.	Light absorption on an arbitrary standard scale.
Odour	Volatile substances, dissolved gases, often produced by decomposition of organic matter. In water it may result from the essential oils in microorganisms. E.g. mercaptans, H_2S, CH_4.	May indicate presence of decomposing sewage. Affects aesthetic quality of water. As a test of sewage it may serve, for example, as a guide to condition of sewage when it reaches the treatment plant.	Human sense of smell, qualitative scale, and concentration at threshold of odour.
Taste	Materials producing odors. Dissolved matter and various ions.	Impairs aesthetic quality of water.	Not measured in unpotable water.
Solid Matter	Dissolved and suspended organic and inorganic salts.	Measures amount of organic solids, silts, etc., hence is a measure of the extent of sewage pollution or the concentration of a sewage.	By gravimetric analysis techniques for the following: total solids, total volatile solids, total fixed solids, suspended solids and dissolved solids.

As a rule of thumb, every increase in temperature by 10°C increases the rate of reaction by 100%.

SOLIDS (TS,SS,VSS,FSS,TVS,FS,TVS,FS,VFS,FFS,&TFS)

Total Solids: All the matter that remains as residue upon evaporation at 104°C. [can be further classified as nonfiltrable (suspended) or filtrable].

Settleable Solids: Solids that will settle to the bottom of an Imhoff cone in a 60-minute period (mg/L).

Filtrable Solids: This fraction consists of colloidal and dissolved solids.

Colloidal Fraction: The particulate matter with a size range of 0.001 – 1 μm. [Since it cannot be removed by settling, bio-oxidation or coagulation followed by sedimentation is required to remove these particles from suspension.]

Dissolved Solids: Both organic and inorganic molecules and ions that are present in true solution in water.

Volatile xxxx: Based on the volatility at 550°C, each category can be further classified into "volatile xxxx" and "fixed xxxx", referring, respectively, to the organic and inorganic (or mineral) content of the xxxx.

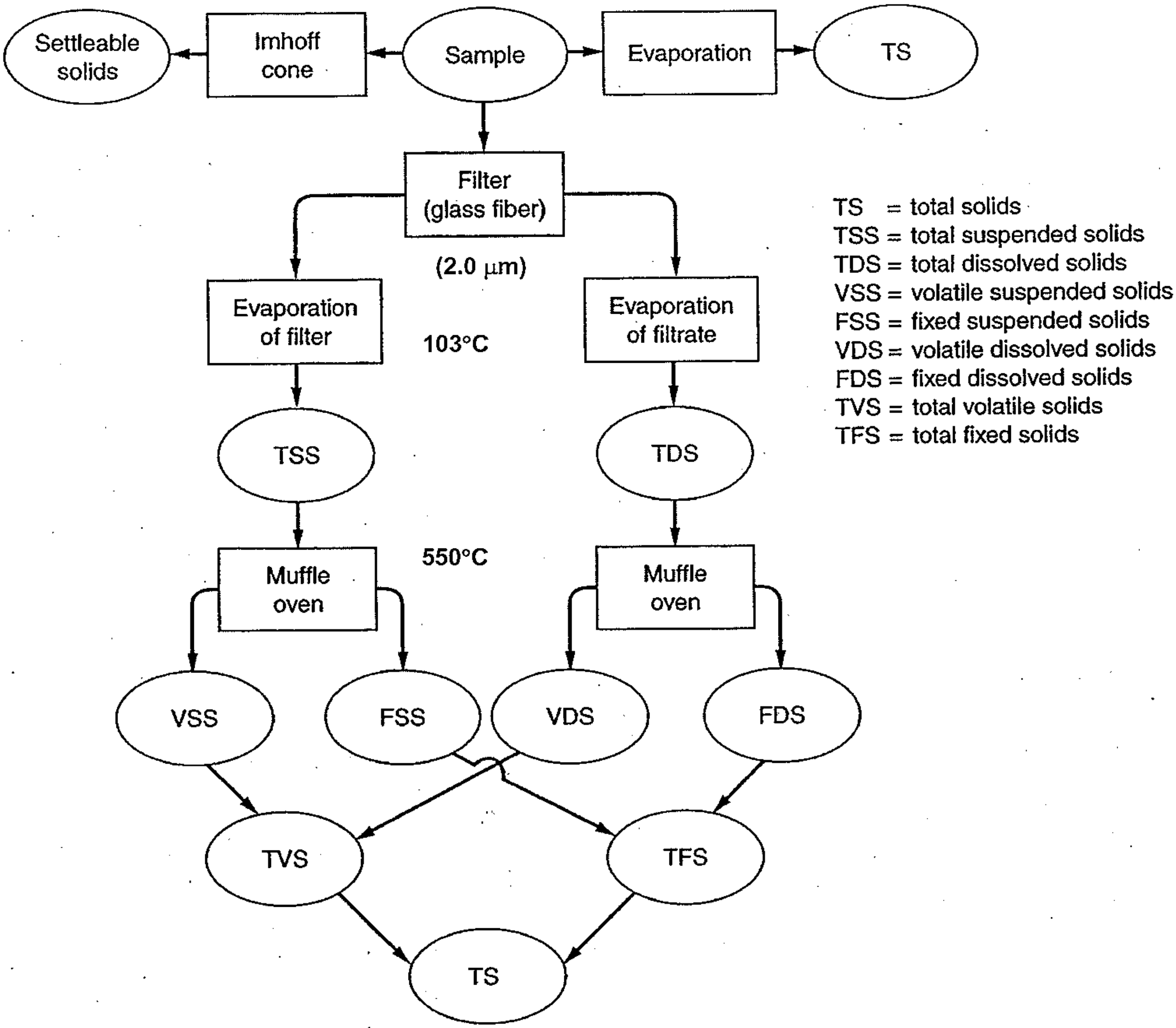


Figure 2.1 Interrelationships of solids found in water and wastewater. In much of the water quality literature, the solids passing through the filter are called dissolved solids. (Tchobanoglous and Schroeder, 1985.)

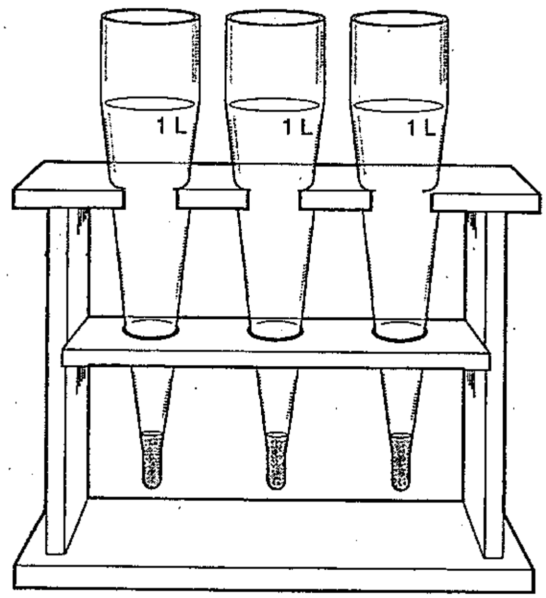


Figure 2.2 Imhoff cone used to determine settleable solids in wastewater. Solids that accumulate in the bottom of the cone after 60 min are reported as mL/L.

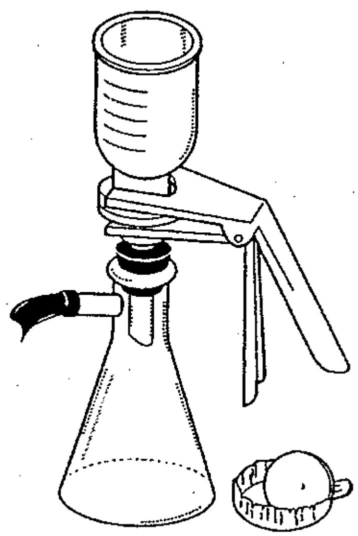


Figure 2.3 Apparatus use for the determination of total suspended solids. After wastewater sample has been filtered, the preweighted filter paper is placed in an aluminium dish for drying before weighing.

2.3.7 Harmful effects of Domestic and Industrial Waters

Table 2.7

Type of material	Effect
Biodegradable organic matter	Deoxygenate water kill fish, objectionable odors.
Suspended matter	Deposit on riverbed; if organic, may putrify and float masses to surface by gas; blanket bottom and interfere with fish spawning or disrupt food chain.
Corrosive substances (e.g., cyanides, phenols, metal ions)	May kill fish and other aquatic life; destroy bacteria and so interrupt self-purification of streams.
Pathogenic micro-organisms	Sewage may carry pathogens; tannery wastes, anthrax.
Substances causing turbidity, temperature, color, odor, etc.	Temperature rise may injure fish; color, odor, turbidity may render water aesthetically unacceptable for public use.
Substances or factors which upset biological balance	May cause excessive growth of fungi or aquatic plants which choke stream, cause odors, etc.
Mineral constituents	Increase hardness, limit use in industry without special treatment, increase salt content to level deleterious to fish or vegetation, lead to eutrophication of water.

Source: PH McGauhey, Engineering Management of Water Quality, Table 5-8 (1968)

2.4 *Wastewater Treatment Processes*

2.4.1 Steps in the Development of Wastewater Treatment Systems

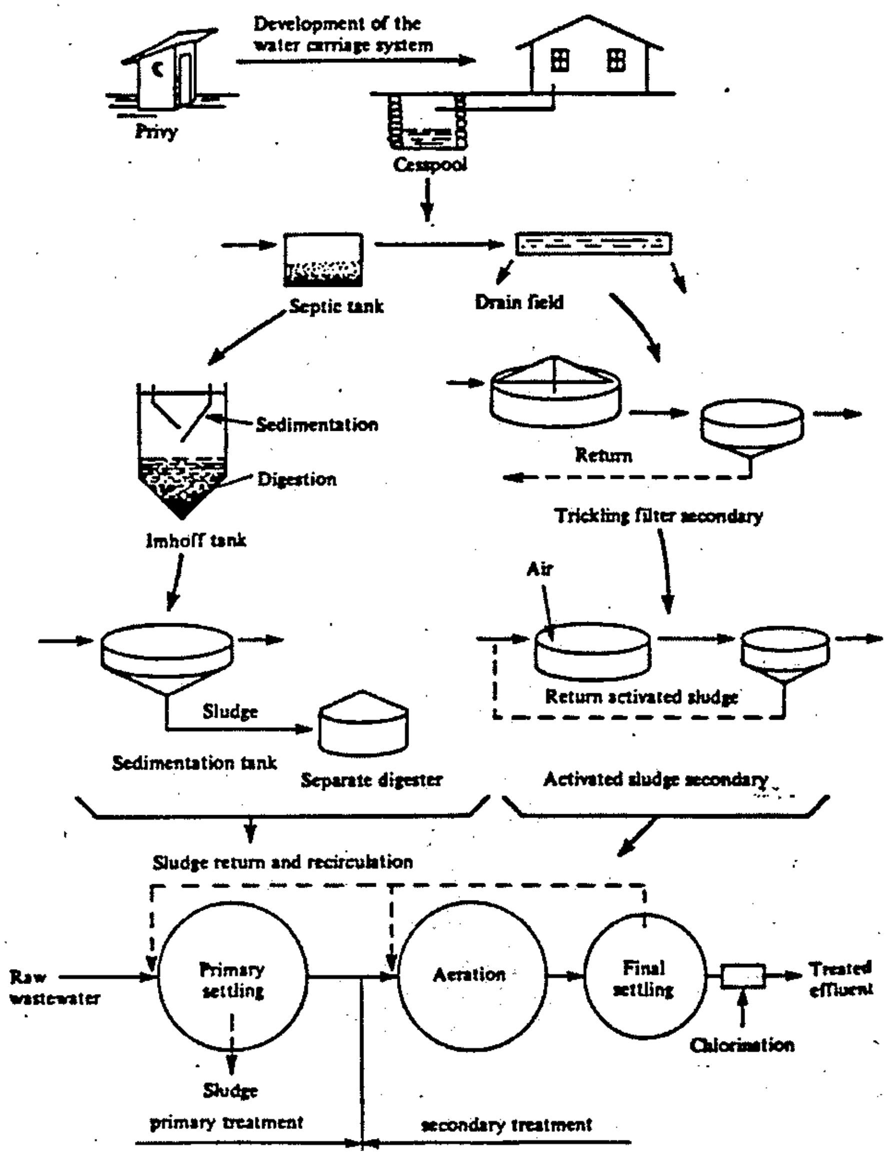


Figure 2.4
Source: Viessman & Hammer, Water Supply and Pollution Control, 5th Ed., Figure 11-19

2.4.2 WASTEWATER TREATMENT

BACKGROUND: "The solution to pollution is (was) dilution"?

CURRENT STATUS: Primary, secondary and advanced (tertiary) treatment.

UNIT OPERATIONS: methods of treatment in which the application of physical forces predominates.

UNIT PROCESSES: methods of treatment in which the removal of contaminants is brought about by chemical or biological reactions.

Primary Treatment: physical operations such as screening and sedimentation are used to remove the floating and settleable solids found in the wastewater.

Secondary Treatment: biological and chemical processes are used to remove most of the organic matter.

Advanced Treatment: additional combinations of unit operations and processes are used to remove other constituents, such as N and P that are not reduced significantly by secondary treatment.

Natural Systems: "Land treatment" and/or "wetlands" combining physical, chemical and biological treatment mechanisms can produce water with quality similar to or better than that from advanced wastewater treatment.

2.4.3 Generic Flow Schematic for Wastewater Treatment

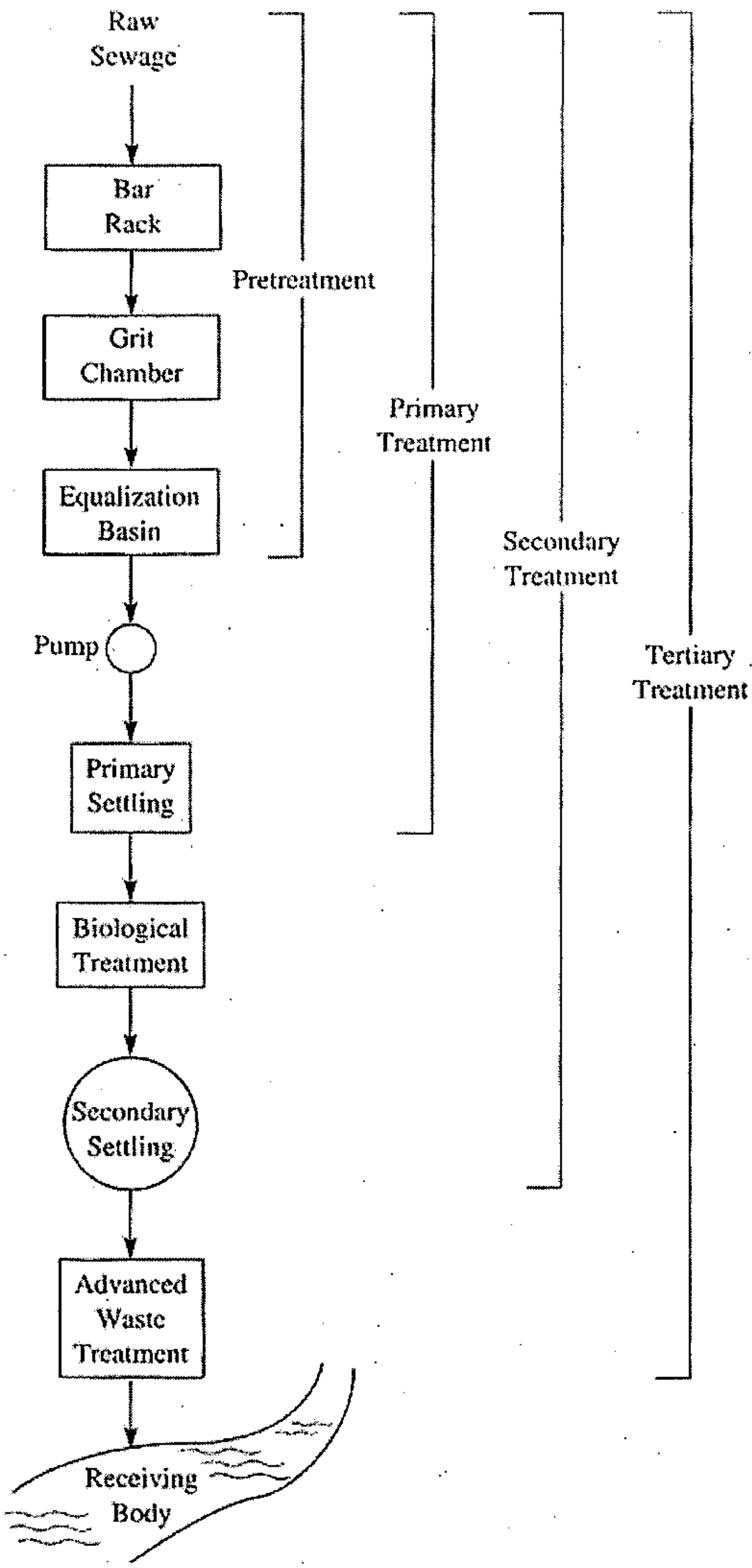


Figure 2.5
Source: Davis & Cornwell, Introduction to Environmental Engineering, Fig 5-10 (1998)

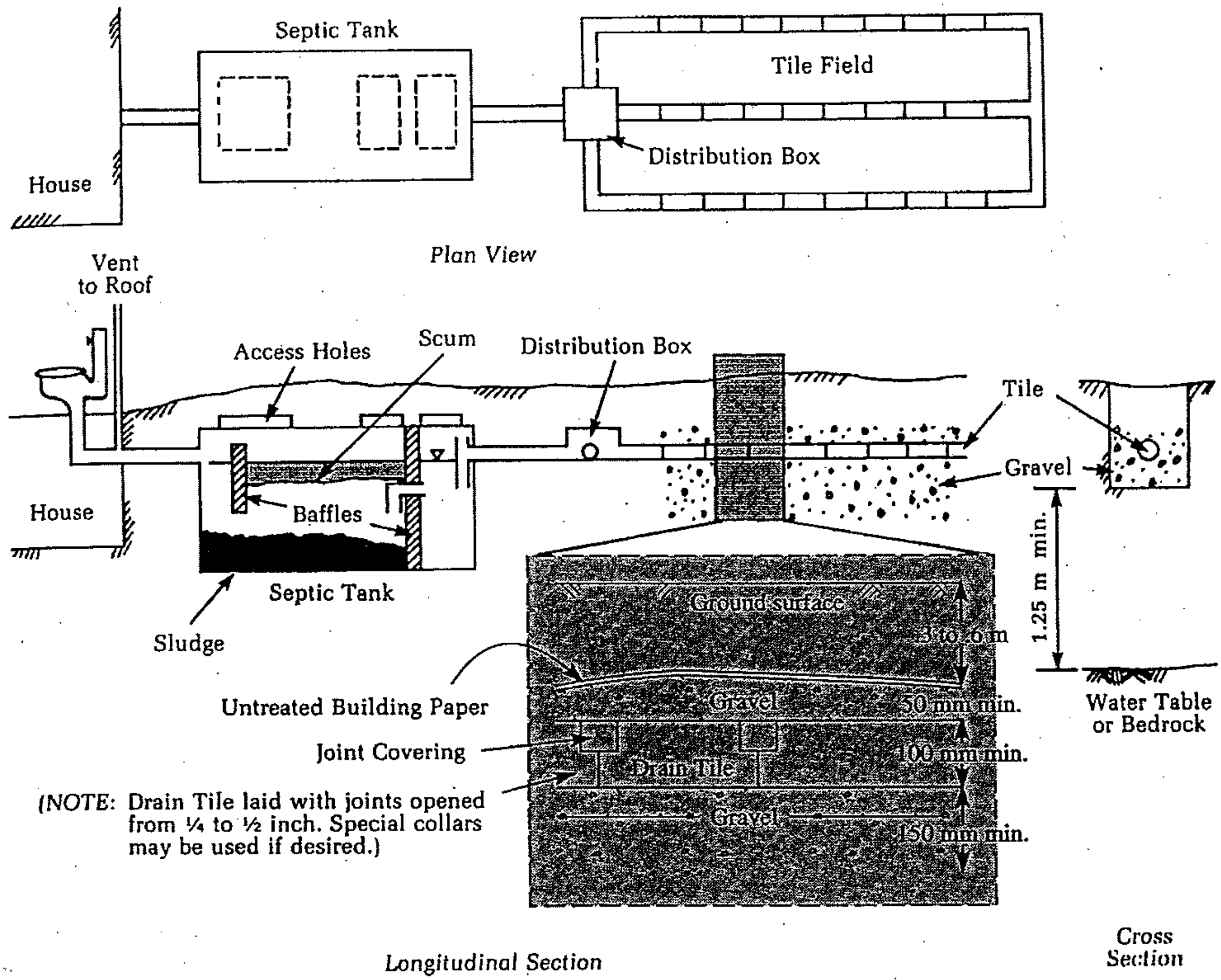


Figure 2.6 Schematic layout of a septic tank and tile field.

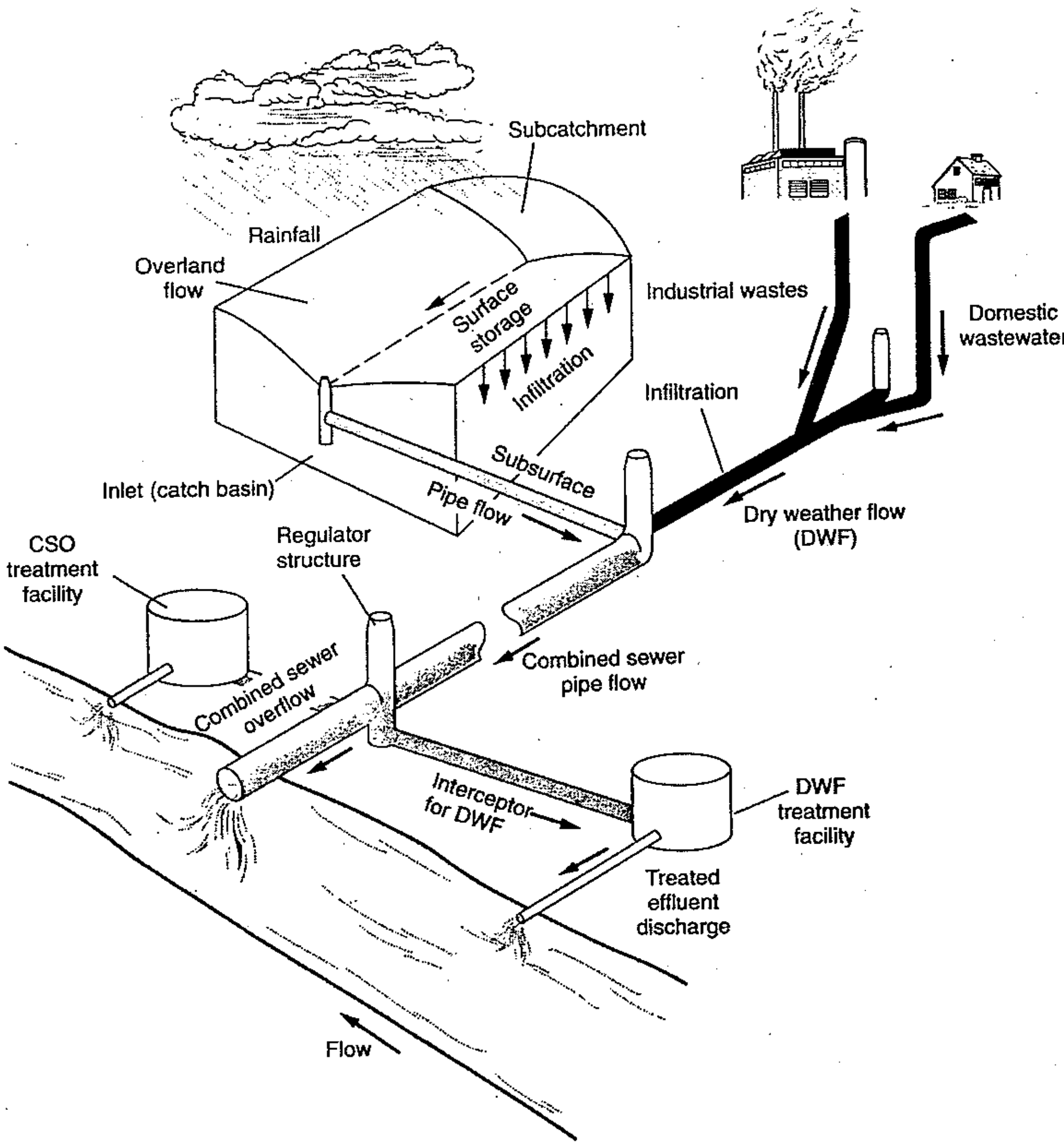
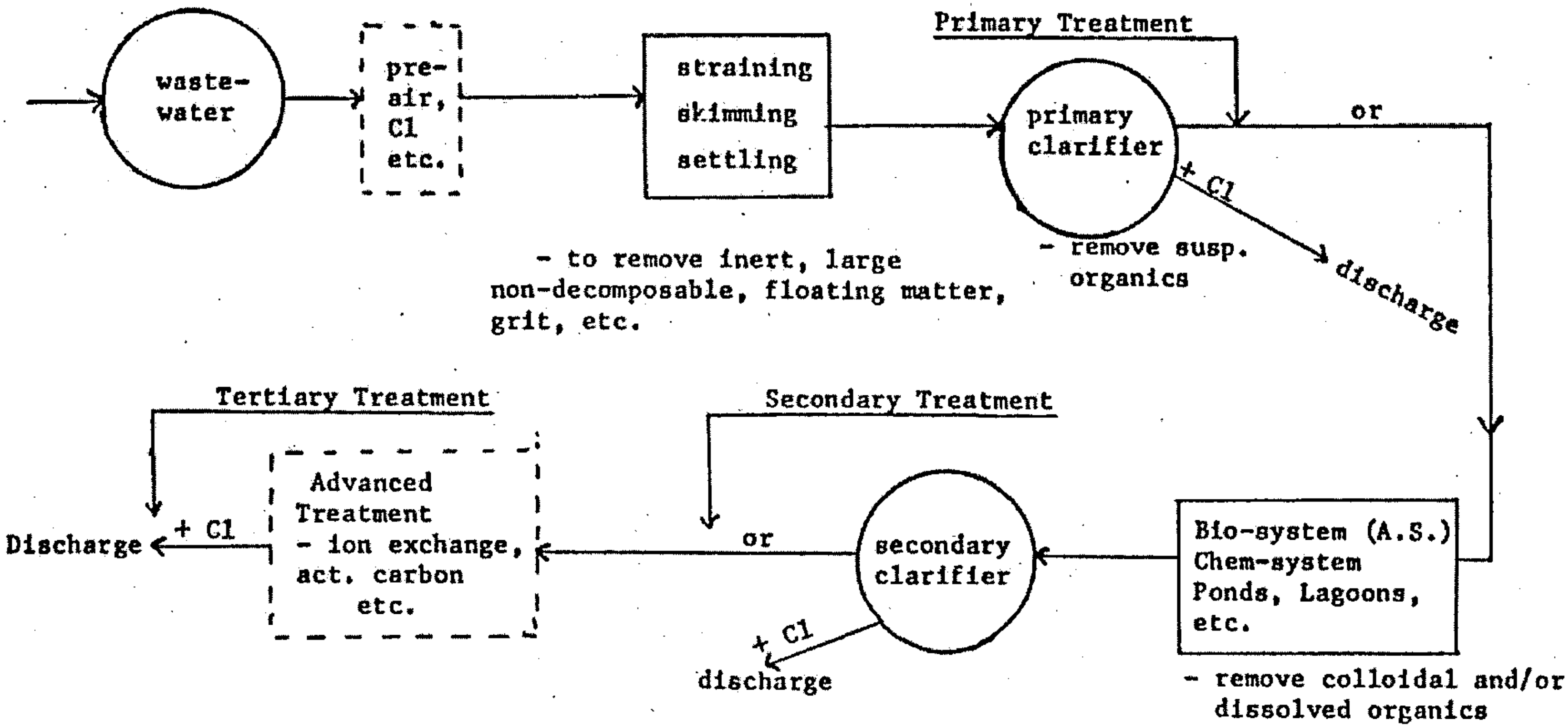


Figure 2.7 Schematic diagram of a wastewater management infrastructure (Metcalf & Eddy, 2003).



Note: settled sludges from the clarifiers usually treated in aerobic and/or anaerobic digesters.

Figure 2.8 Typical Flow Diagram

Table 2.8 Approximate Composition of an Average Domestic Wastewater (mg/l)

	Before Sedimentation	After Sedimentation	Biologically Treated
Total solids	800	680	530
Total volatile solids	440	340	220
Suspended solids	240	120	30
Volatile suspended solids	180	100	20
BOD	200	130	30
Ammonia nitrogen as N	22	22	24
Total nitrogen as N	35	30	26
Soluble phosphorus as P	4	4	4
Total phosphorus as P	7	6	5