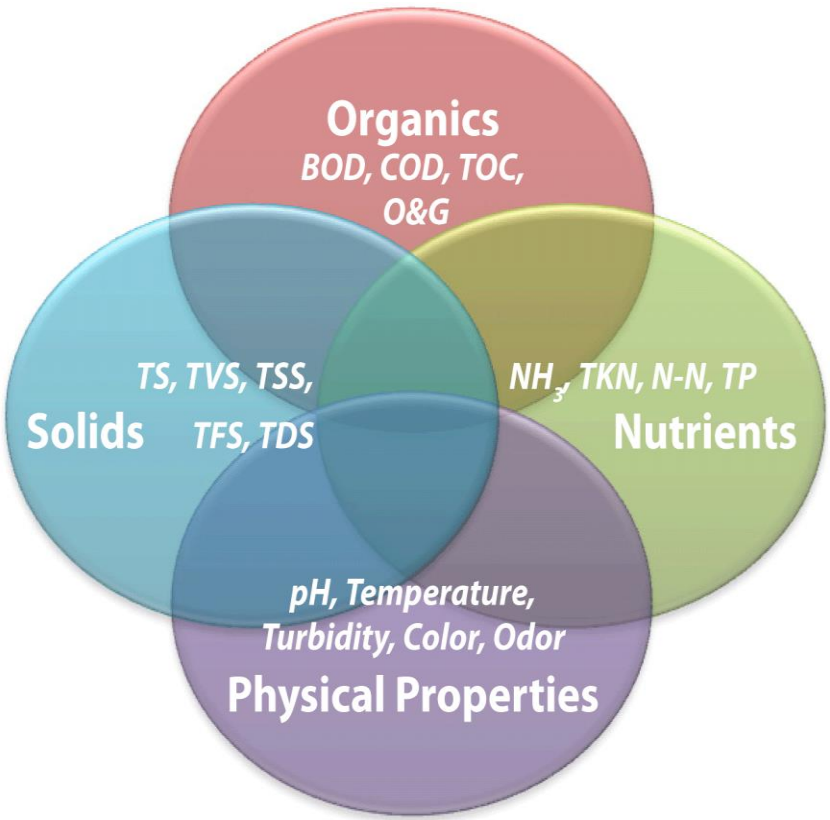
Chapter (2)

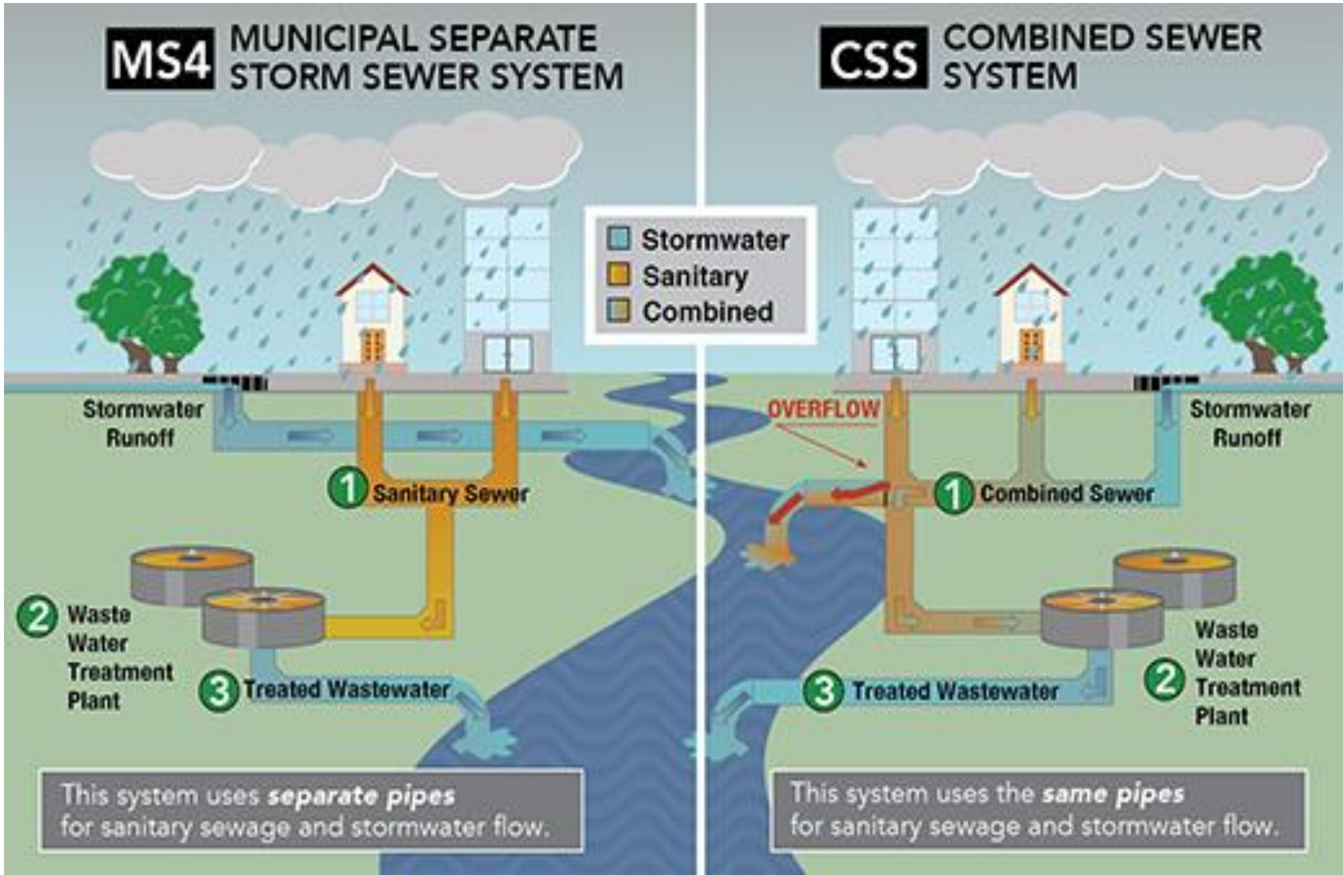
Characteristics of Wastewaters



Main Types of wastewater flows:

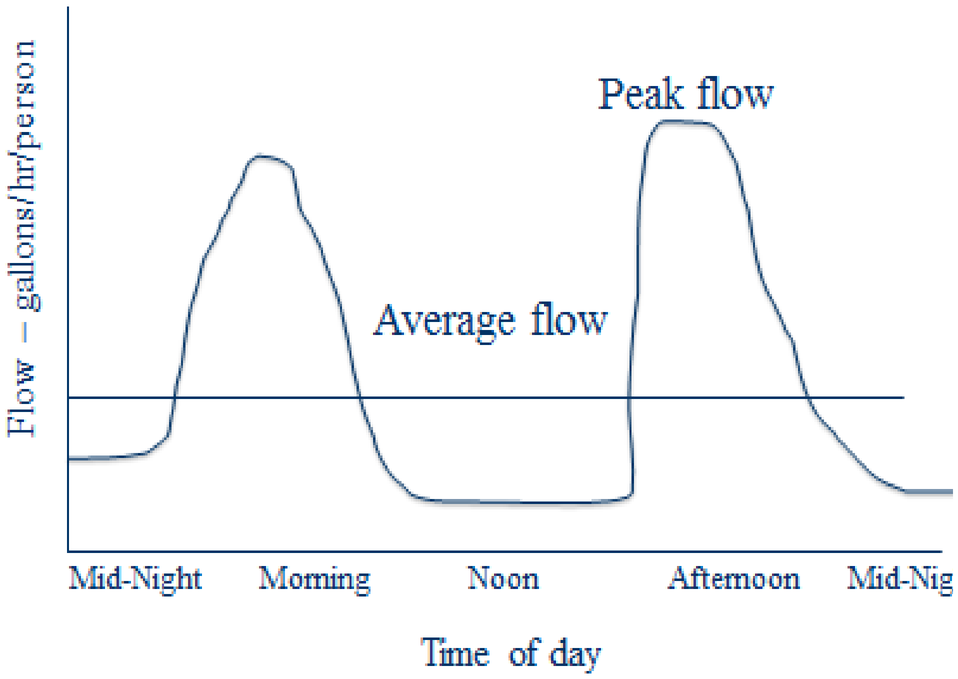
1) **Municipal** or Sanitary: Domestic sewage from urban areas. In large cities, non-toxic organic containing *industrial influents* may be discharged to municipal sewers.
2) **Industrial**: Effluents from manufacturing plants or factories

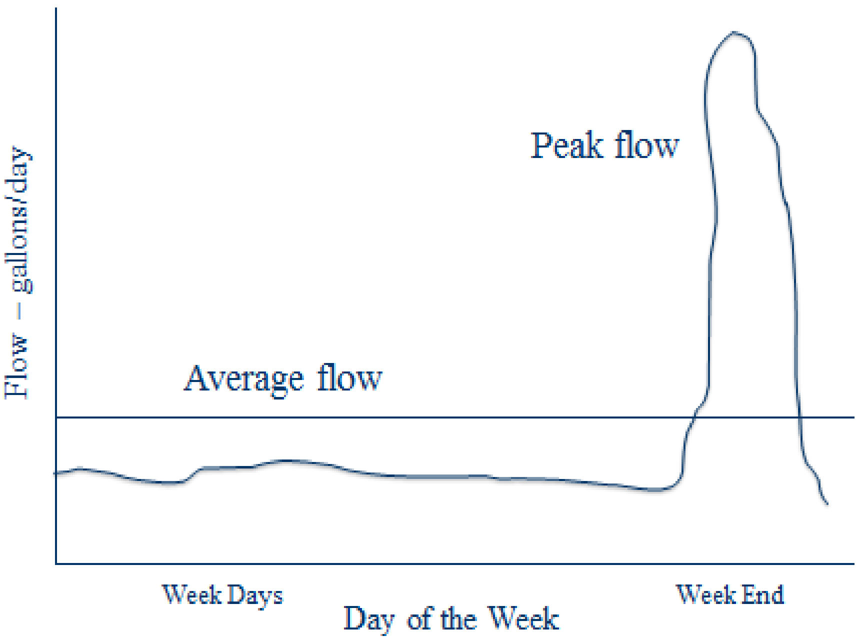
WW Conveyance: Sewer Systems



Characteristics of Wastewater

- Wastewater characterization involves Quantity, Quality & Variation of above properties with time:
  - municipal (sanitary) waste water is almost constant in flow and average composition.
  - Changes in flow of municipal wastewater is related to connection of new sewer systems, due to population increase.

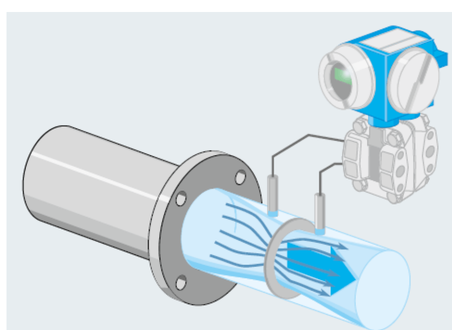


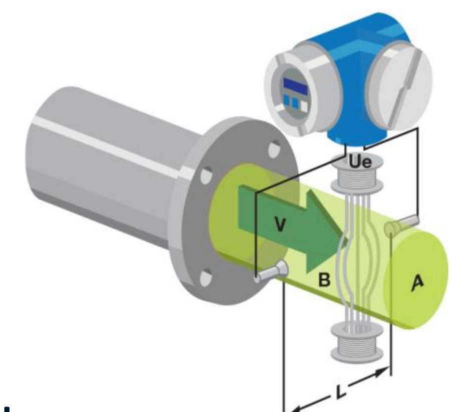


Characteristics of Wastewater: Flow

1. Collection and conveyance system design.
2. Treatment system design:
   - Hydraulic criteria: must be able to pass peak flows.
   - Treatment criteria: meeting treatment standards depends often on "hydraulic residence time: $\theta = V/Q \quad m^3/(m^3/s) \rightarrow s$
3. Growth projections (population, development).

- Flows Measurement:
- There is a variety of methods for estimating flowrates.





Ultrasonic, electromagnetic, wier, orifice, venturi, etc…

Characterization: Composition

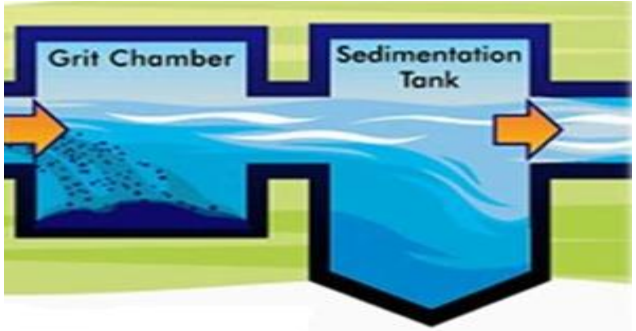
- **Physical Parameters:**
  1. Total Suspended Solids: TSS
  2. Fat, oil & greases: FOG
  3. Turbidity: NTU
  4. Color and Odor

- **Biological Parameters**
  1. MPN of microorganisms virus, bacteria, protozoa,…) /10mL
  2. Number of eggs/L (parasites)

- **Chemical Parameters**
  1. Dissolved Oxygen: DO
  2. Dissolved Organics: BOD, COD
  3. Nutrients: TKN, total P
  4. Toxic Metals (Pb, Ni, Cr, Hg, ….)
  5. Priority Organics: phenols
  6. pH (acidity, alkalinity)
  7. Total Dissolved Solids: TDS

(See Water Quality Section in Environmental Eng. Course)

Importance of solids



1. Biological treatment demand
   - Lots of organics are associated with solids

   (there is non-soluble, nsBOD & soluble, sBOD)
   - Has to be accounted for <u>in design.</u>

2. Physical demand
   - Solids take up space in tanks
   - Settleable solids dictate initial treatment steps
   - Sand and grit cause wear in pumps and pipes
   - Attenuate UV light during disinfection

3. Quantity of ultimate residue (sludge or biosolids) is a function of influent solids

Example: Analysis of Solids Data

Determine the concentration of total solids(TS), total dissolved solids (TDS), total suspended solids (TSS), and volatile suspended solids (VSS) in 50mL of wastewater based on data given;

Mass of dry dish = 53.5433 g
Mass of dry dish + residue after drying at 105^{o}C = 53.5794 g
Mass of dry dish + residue after ignition at 550^{o}C = 53.5625 g

Mass of Whatman GF/C filter = 1.5433 g
Mass of Whatman GF/C filter + residue after drying at 105^{o}C = 1.5554 g
Mass of Whatman GF/C filter + residue after ignition at 550^{o}C = 1.5476 g

Answers :

Total solids(TS) = 722 mg/L
Total dissolved solids (TDS) = 480 mg/L
Total suspended solids (TSS) = 242 mg/L
Volatile suspended solids (VSS) = 156 mg/L

Chemical Characteristics

Total Kjeldahl Nitrogen (TKN)

Chemical Characteristics: Organic Matter

- Predominant biodegradable fraction, **BOD**:
  - Proteins,
  - Fats, Oils and Greases (FOG),
  - Carbohydrates,
  - Urea,
  - Surfactants (detergents).

- Priority pollutants:
  - Industrial solvents,
  - pesticides,
  - dyestuffs, etc.

Presence of organic matter is troublesome:

1) Color formation,
2) Taste and odor problems,
3) Oxygen depletion in streams,
4) Interference with water treatment processes,
5) The formation of halogenated compounds when chlorine is added to disinfect water

Estimating the organic content

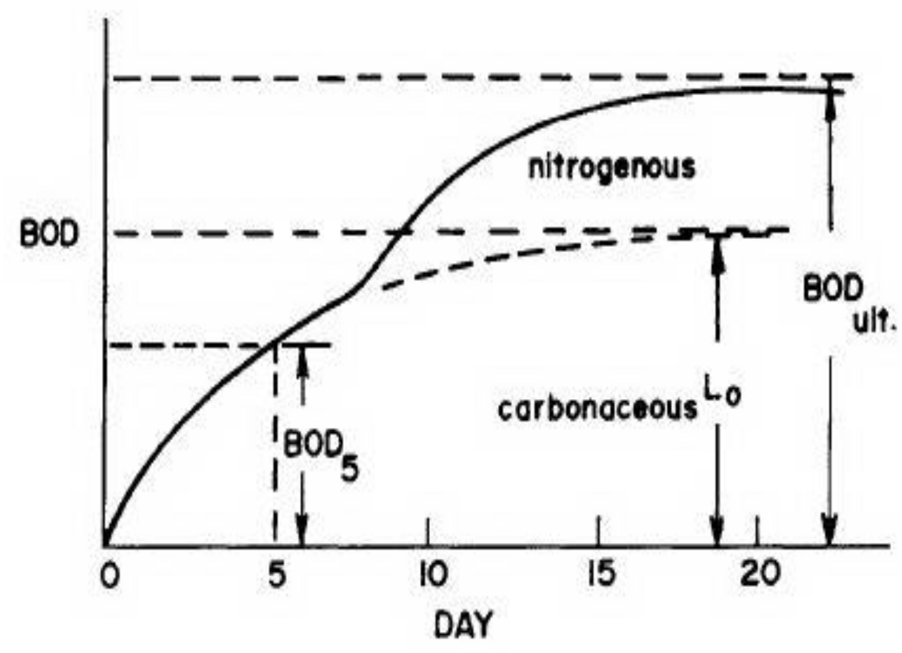
1. The BOD_5 test measures the biodegradable organic carbon.
2. The COD test measures the total organic carbon with the exception of certain aromatics, *in addition to some oxidizable inorganics.*
3. The TOC test measures *all carbon* as CO_2. (Inorganic carbon, e.g. CO_3^{2-}, HCO_3^- *must be removed* prior to the analysis).
4. The ThOD test measures organic carbon as well as un-oxidized nitrogen and sulfur (NO_2^-, NH_3, H_2S,...).

Estimating the organic content

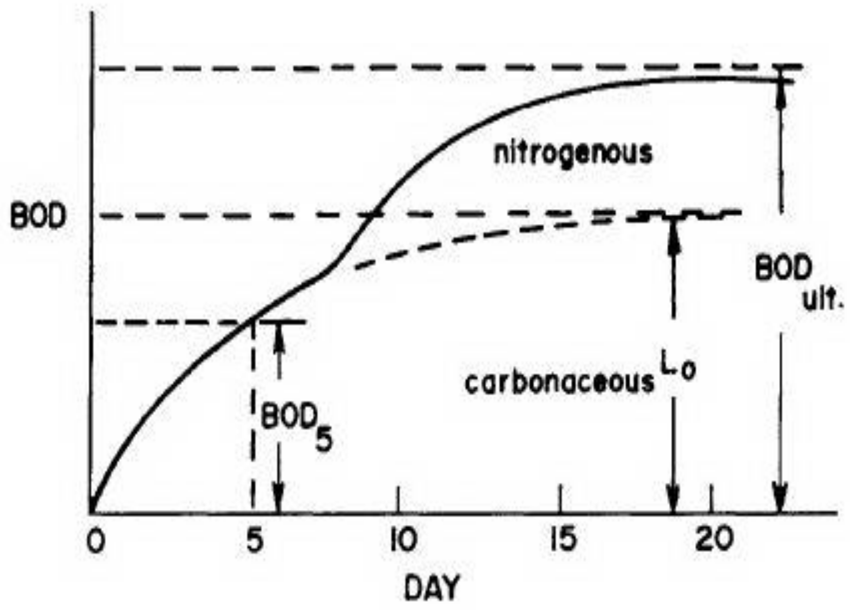
- ❑ Biochemical oxygen demand (BOD)
- ❑ Chemical oxygen demand (COD)
- ❑ Total organic carbon (TOC)
- ❑ Theoretical oxygen demand (ThOD)

BOD :

- ✓ **5-day (BOD_5)**
- ✓ **ultimate (uBOD)**
- ✓ **Carbonaceous (CBOD)**
- ✓ **Nitrogenous (NBOD)**



Mass Loading of Oxygen Demanding Materials



Assume :

CBOD = 375 mg/L

Nitrogen = 75 mg/L

Flow = 300 m^3/d

CBOD = 375 x (300 x 10^{-3}) = 112.5 kg/d

NBOD = 75 x (300 x 10^{-3}) = 22.5 kg/d

Total oxygen demand = 135 kg/d

Conversion: 1 mg/L = 10-3 kg/m3

Chemical Oxygen Demand (COD)

- The COD test is used to measure the oxygen equivalent of the organic material in wastewater that can be oxidized chemically using *dichromate in an acid solution*.

$$C_nH_aO_bN_c + dCr_2O_7^{2-} + (8d + c)H^+ \rightarrow$$

$$nCO_2 + \frac{a + 8d - 3c}{2} H_2O + cNH_4^+ + 2dCr^{3+}$$

$$where\ \ \mathrm{d} = \frac{2\mathrm{n}}{3} + \frac{a}{6} - \frac{b}{3} - \frac{c}{2}$$

- The COD is performed by refluxing a sample of the wastewater with potassium dichromate for <u>no more than 2hr</u> and measuring the change in the concentration of dichromate.

Chemical Oxygen Demand

- **Reasons for the observed differences between BOD and COD:**
  1. Many organic substances that are difficult to oxidize biologically, such as lignin, can be oxidized chemically,
  2. Inorganic substances that are oxidized chemically increase the apparent organic content of the sample,
  3. Certain organic substances may be toxic to the microorganism used in the BOD test.

- **Advantage of the COD over BOD:**
  - COD can completed in about 2.5 hr compared to 5 days for the BOD_5 test.
  - A rapid COD test that takes only about 15 minutes has also been developed.

Estimating the organic content

Theoretical Oxygen Demand (ThOD)

- When considering routine plant control or investigational programs, the BOD is not a useful test due to the long incubation time.
- The theoretical oxygen demand (ThOD) of a wastewater is calculated at the oxygen required to oxidize the organics to end products:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

$$\text{THOD} = \frac{6M_{O_2}}{M_{C_6H_{12}O_6}} = 1.07$$

- Where the chemical formula of the organic compound is *known*, the ThOD can be estimated from stoichiometric consideration of the combustion reaction equation:
- Example: *Glycine*

$$CH_2(NH_2)COOH + \frac{3}{2}O_2 \rightarrow 2CO_2 + NH_3 + H_2O$$

Estimating the organic content

Theoretical Oxygen Demand (ThOD)

Oxygen Demand Specifies how much oxygen is required to completely oxidize the organic matter present in wastewater sample

Stoichiometry: $$C_6H_{12}O_6 + 6O_2 \Rightarrow 6CO_2 + 6H_2O$$

For 1 mM glucose 180 mg/L 192 mg/L

A wastewater containing 1mM glucose solution can be quantified in two ways:

a) A solution with glucose concentration of 180 mg/L

b) A solution with **theoretical oxygen demand** of 192 mg/L

Experimental determination is possible; does not require quantification of each one of the individual organic component; value is somewhat less than the theoretical oxygen demand

Derived from the chemical formula, difficult when the formula or type of organic is unknown

Estimating the organic content**

- Values of BOD, COD, and TOC for a variety of organics and wastewaters is shown in Table 1.5.

- The calculations relative to BOD, COD, and TOC are illustrated in Example 1.2.

- The BOD, COD, and TOC tests are gross measures of organic content and as such do not reflect the response of the wastewater to various types of biological treatment technologies.

- It is therefore desirable to partition the wastewater into several categories, as shown in Fig. 1-13.

***REFERENCE: Eckenfelder's Industrial Water Pollution Control, McGraw-Hill.*

Estimating the organic content

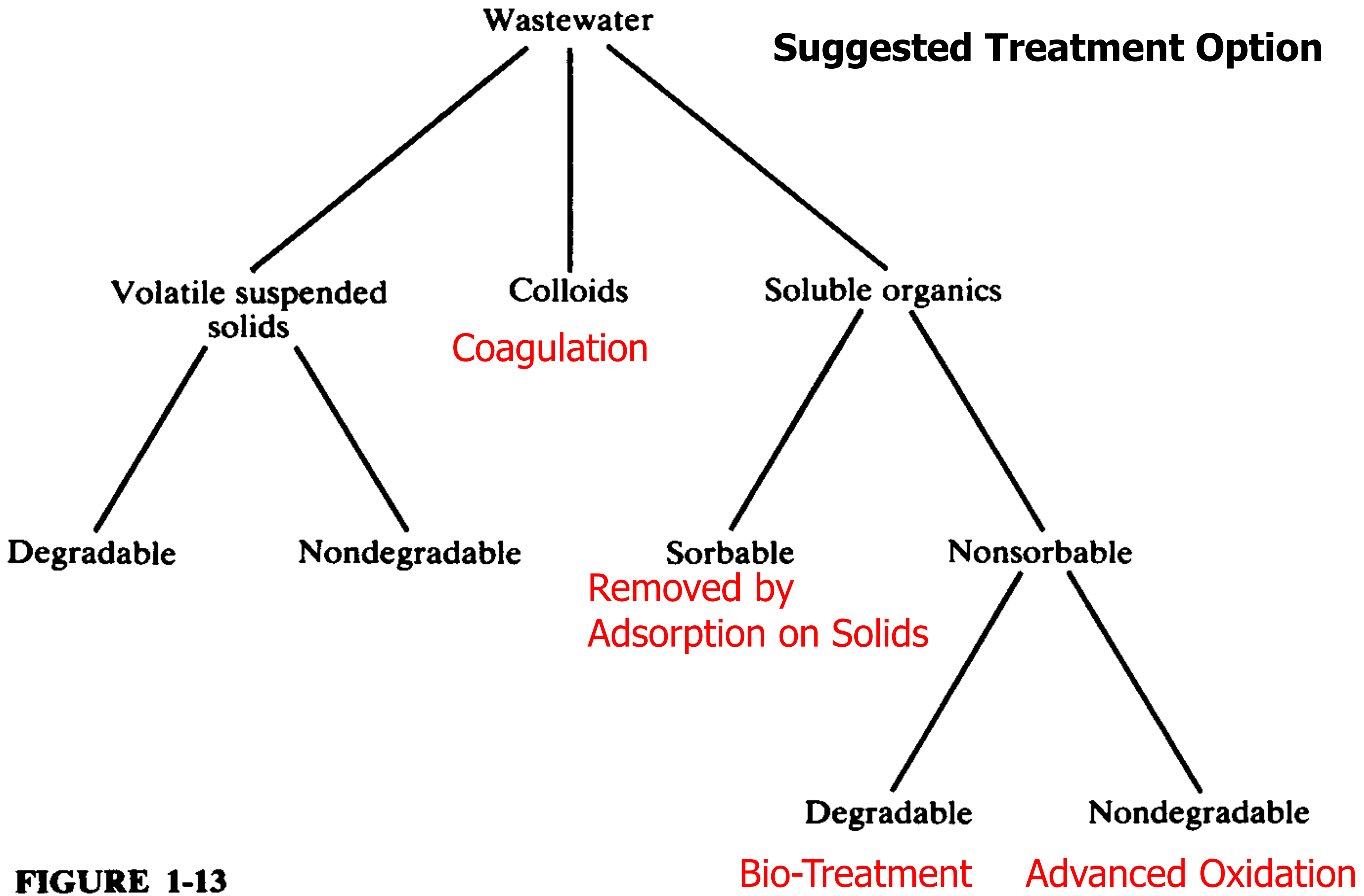


FIGURE 1-13
Partition of organic constituents of a wastewater.

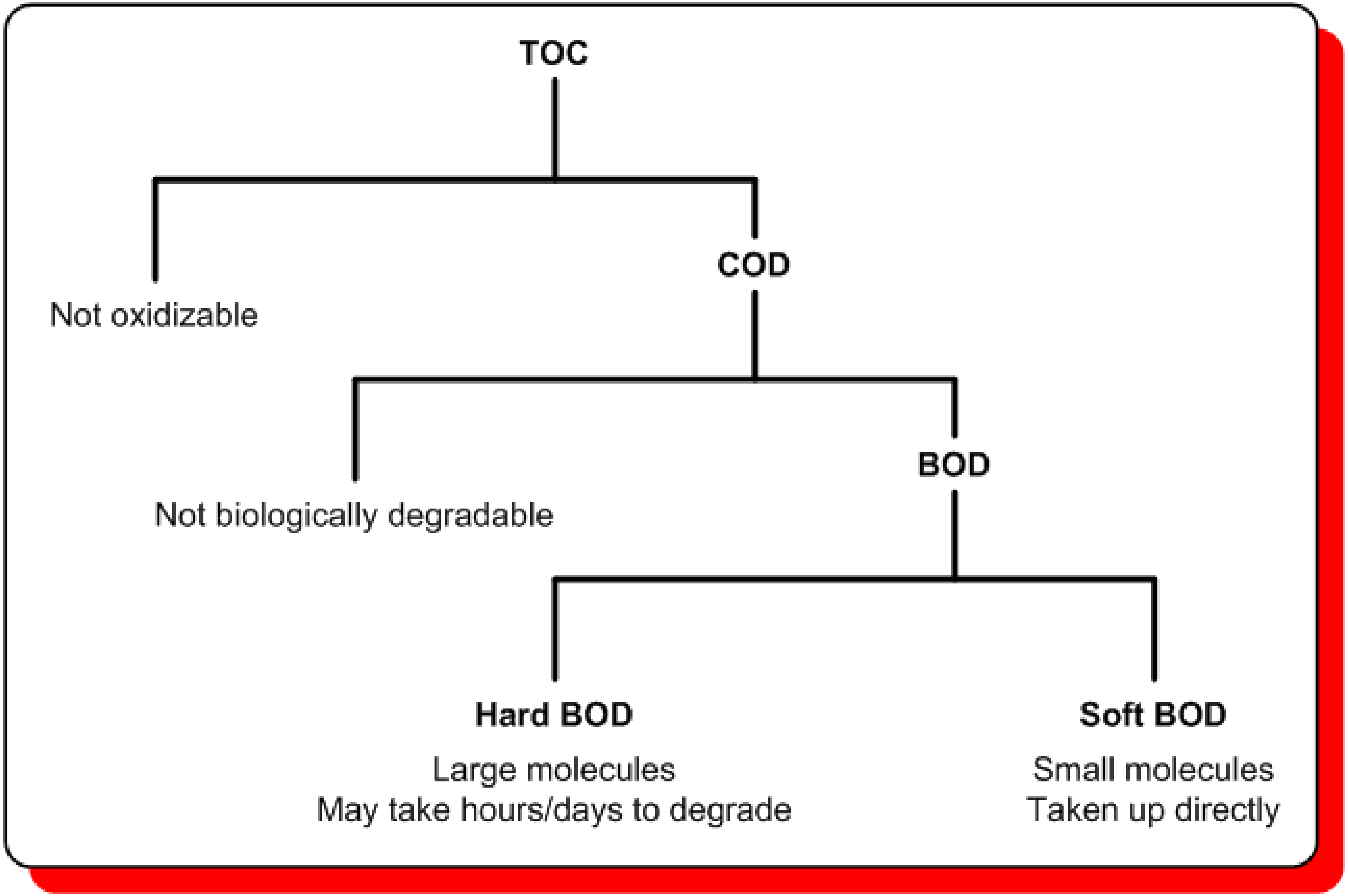
Estimating the organic content

TABLE 1.5
Oxygen demand and organic carbon of industrial wastewaters[4]

Waste	BOD_5, mg/l	COD, mg/l	TOC, mg/l	BOD/TOC	COD/TOC
Chemical†	—	4,260	640	—	6.65
Chemical†	—	2,410	370	—	6.60
Chemical†	—	2,690	420	—	6.40
Chemical	—	576	122	—	4.72
Chemical	24,000	41,300	9,500	2.53	4.35
Chemical—refinery	—	580	160	—	3.62
Petrochemical	—	3,340	900	—	3.32
Chemical	850	1,900	580	1.47	3.28
Chemical	700	1,400	450	1.55	3.12
Chemical	8,000	17,500	5,800	1.38	3.02
Chemical	60,700	78,000	26,000	2.34	3.00
Chemical	62,000	143,000	48,140	1.28	2.96
Chemical	—	165,000	58,000	—	2.84
Chemical	9,700	15,000	5,500	1.76	2.72
Nylon polymer	—	23,400	8,800	—	2.70
Petrochemical	—	—	—	—	2.70
Nylon polymer	—	112,600	44,000	—	2.50
Olefin processing	—	321	133	—	2.40
Butadiene processing	—	359	156	—	2.30
Chemical	—	350,000	160,000	—	2.19
Synthetic rubber	—	192	110	—	1.75

† High concentration of sulfides and thiosulfates.

Relationship Between the Organic Carbon Fractions in Wastewater



Source: Davis, Peter Spencer. "The Biological Basis of Wastewater Treatment." Strathkelvin Instruments, Ltd., 2005.

Relationship between BOD, COD, TOC and ThOD

$$BODu = 0.9ThOD$$

Where BODu = ultimate BOD

- **BODu = 0.9ThOD** because (approximately ten percent of the original organics remain as non-biodegradable cellular residues after biological oxidation)

$$BOD5 = 0.77BOD\mathit{u}$$

- BODu is much greater than BOD5 because much of the easily degraded material would have been removed in the sewage treatment process and many industrial processes discharge difficult to degrade organic molecules
- For most wastewaters: **ThOD = COD**
- Stoichiometrically, the COD/TOC ratio should be approximately the molecular ratio of oxygen to carbon:

$$\frac{COD}{TOC} = \frac{32}{12} = 2.66$$

- The BOD5 to COD ratio for domestic waste and certain biodegradable industrial wastes can be computed as follows:

$$BOD_5 = 0.7\ COD$$

$$BOD5 = 0.7\ ThOD$$

Example 1.2. A wastewater contains the following:

Estimating the organic content

150 mg/l ethylene glycol
100 mg/l phenol
40 mg/l sulfide (S^{2-})
125 mg/l ethylene diamine hydrate (ethylene diamine is essentially nonbiodegradable)

(*a*) Compute the COD and TOC.
(*b*) Compute the BOD_5 if the k_{10} is 0.2/day.
(*c*) After treatment, the BOD_5 is 25 mg/l. Estimate the COD ($k_{10} = 0.1$/day).

Solution

(*a*) The COD is computed:

Ethylene glycol

$$C_2H_6O_2 + 2.5O_2 \rightarrow 2CO_2 + 3H_2O$$

$$COD = \frac{2.5(32)}{62} \times 150 \text{ mg/l} = 194 \text{ mg/l}$$

Phenol

$$C_6H_6O + 7O_2 \rightarrow 6CO_2 + 3H_2O$$

$$COD = \frac{7(32)}{94} \times 100 \text{ mg/l} = 238 \text{ mg/l}$$

Ethylene diamine hydrate

$$C_2H_{10}N_2O + 2.5O_2 \rightarrow 2CO_2 + 2H_2O + 2NH_3$$

$$COD = \frac{2.5(32)}{78} \times 125 \text{ mg/l} = 128 \text{ mg/l}$$

Sulfide

$$S^{2-} + 2O_2 \rightarrow SO_4^{2-}$$

$$COD = \frac{2(32)}{32} \times 40 \text{ mg/l} = 80 \text{ mg/l}$$

Estimating the organic content

The total COD is 640 mg/l.

The TOC is computed:

Ethylene glycol

$$\frac{24}{62} \times 150 \text{ mg/l} = 58 \text{ mg/l}$$

Phenol

$$\frac{72}{94} \times 100 \text{ mg/l} = 77 \text{ mg/l}$$

Ethylene diamine

$$\frac{24}{78} \times 125 \text{ mg/l} = 39 \text{ mg/l}$$

The total TOC is 174 mg/l.

BODu/COD* = 0.9 or 0.92

COD* exlude non-biodegradable

(*b*) The ultimate BOD can be estimated:

$$(194 \text{ mg/l} + 238 \text{ mg/l} + 80 \text{ mg/l}) \times 0.92 = 471 \text{ mg/l}$$

Thus

$$\frac{BOD_5}{BOD_{ult}} = (1 - 10^{-(5 \times 0.2)}) = 0.9$$

BOD5 = 0.7 ThOD

BOD_5 is 471 mg/l × 0.9 = 424 mg/l.

(*c*) The BOD_{ult} of the effluent is

$$\frac{25 \text{ mg/l}}{1 - 10^{-(5 \times 0.1)}} = \frac{25 \text{ mg/l}}{0.7} = 36 \text{ mg/l}$$

The COD is 36/0.92 = 39 mg/l. Therefore the COD will be 128 mg/l + 39 mg/l + residual byproducts.

Exercise:

Determine the ThOD for glycine ($CH_2(NH_2)COOH$) using the following assumption:

a) If the 1st step, the organic carbon & nitrogen are converted to carbon dioxide (CO_2) and ammonia (NH_3), respectively

b) In the 2nd and 3rd steps, the ammonia is oxidized sequentially to nitrite and nitrate.

c) The ThOD is the sum of the oxygen required for all three steps.

Answer :

Exercise:

Determine the theoretical BOD/COD, BOD/TOC, and TOC/COD ratios for the following compound $C_5H_7NO_2$.

Assume the value of the BOD first-order reaction rate constant is 0.23 d-1 (base ***e***).

Answer:

Estimating the organic content

- **<u>For Sludge Treatment:</u>**
- An approximation of the oxygen demand of the biomass sludge (wasted cells) may be made by assuming cell oxidation can be described by the following reaction:

$$C_5H_7NO_2 + 5O_2 \rightleftharpoons 5CO_2 + 2H_2O + NH_3 + \text{energy}$$

- The ratio of gram molecular weights is: **5 (32)/113= 1. 42**
- Thus the oxygen demand of the waste may be estimated as 1.42(*Px*).
- The mass of oxygen required may be estimated as:

$$M_{O_2} = Q(S_o - S)(10^{-3}\ \text{kg/g}) - 1.42\ (P_x)$$

Estimating the organic content

<u>Total Organic Carbon (TOC)</u>

- Theoretical Estimation

  $TOC = (M_{carbon}/M_{compound}) \times CONCENTRATION$

  Where M: Molar Mass

➢ <u>**Example:** for 150 mg/L of ethylene glycol $C_2H_6O_2$</u>:

$TOC = [(2 \times 12)/62] \times CONCENTRATION$

$= 0.387 \times 150 = 58$ mg/L

- Laboratory Instrumental Analysis

(measures <u>all carbon</u> as CO_2) →

Relationship between BOD, COD, TOC and ThOD

$$BODu = 0.9ThOD$$

Where BODu = ultimate BOD

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$$BOD5 = 0.77BOD\mathit{u}$$

- BODu is much greater than BOD5 because much of the easily degraded material would have been removed in the sewage treatment process and many industrial processes discharge difficult to degrade organic molecules
- For most wastewaters: **ThOD = COD**
- Stoichiometrically, the COD/TOC ratio should be approximately the molecular ratio of oxygen to carbon:

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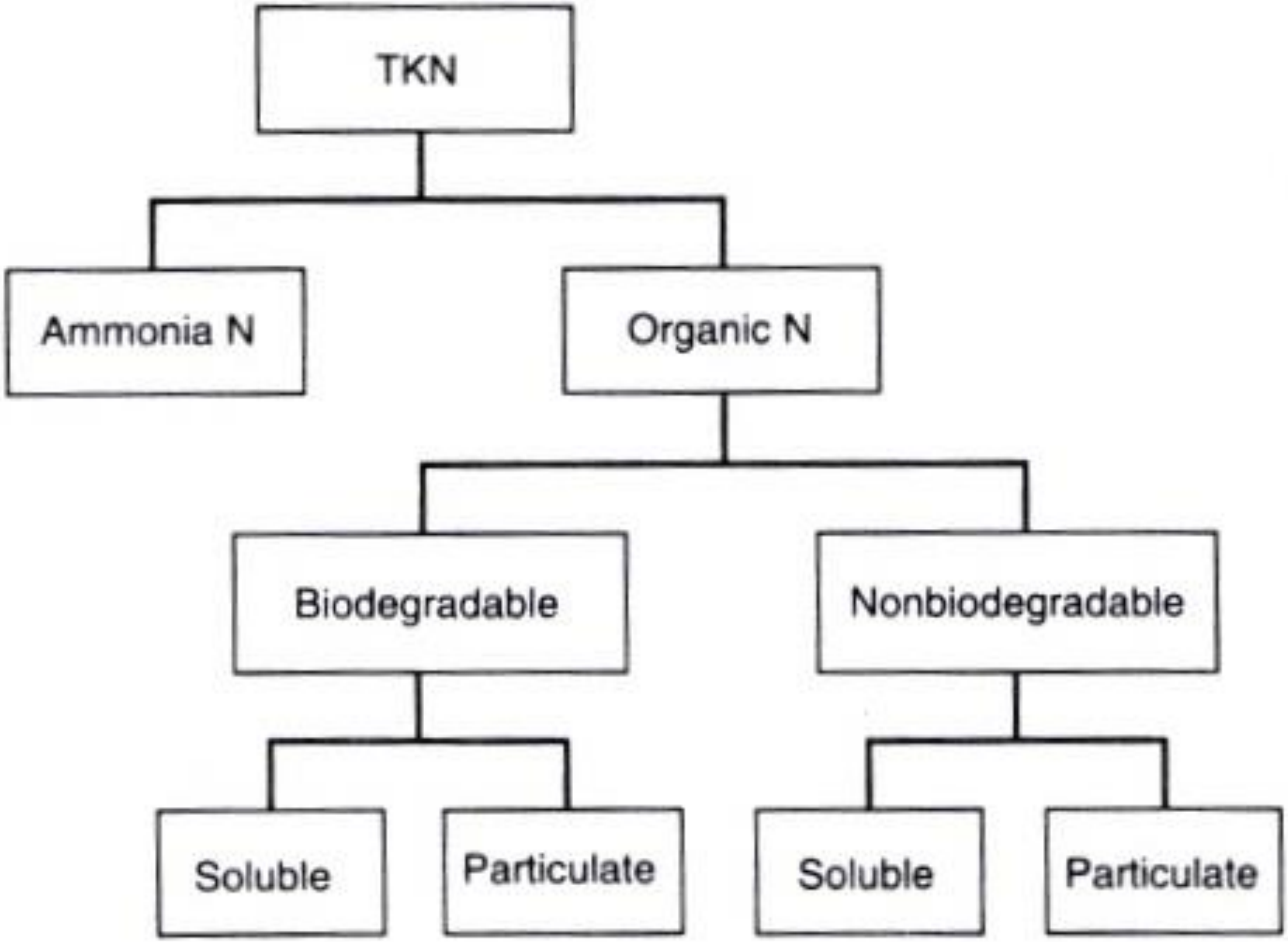
$$BOD_5 = 0.7\ COD$$

$$BOD5 = 0.7\ ThOD$$

NUTRIENTS: NITROGEN

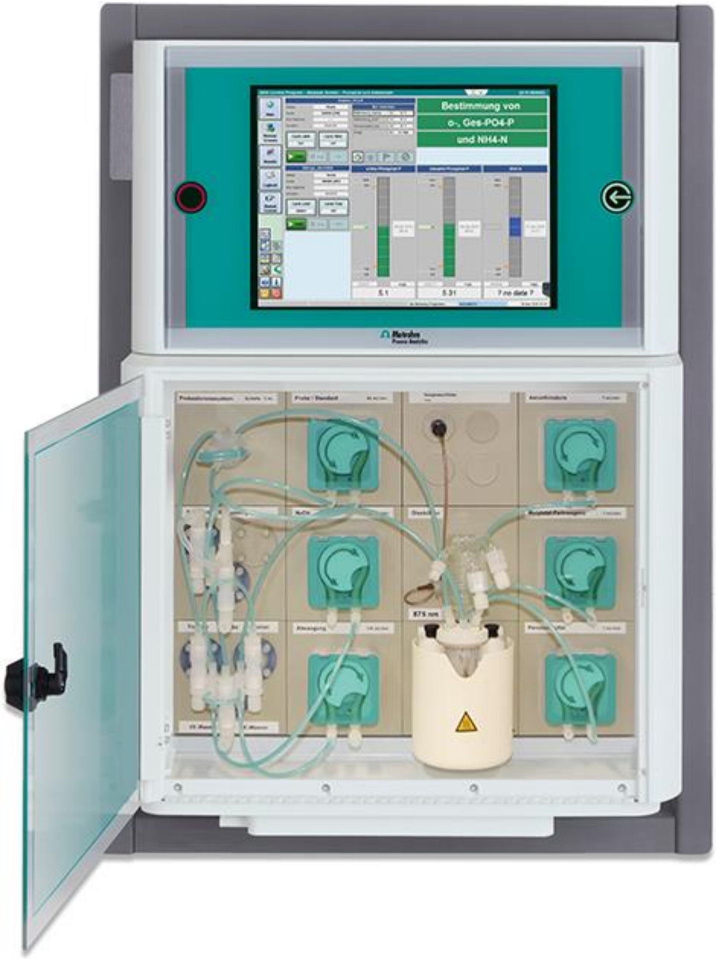
1) Nitrogen is often the limiting nutrient in ocean waters and some streams. It is O2-demanding.
2) Nitrogen can exist in numerous forms, but nitrate (NO_3^-), nitrite (NO_2) , ammonia (NH_3) are most commonly measured
3) Sources: domestic waste, fertilizers & acid deposition.
1) Most common test is TKN (combined organic and ammonia nitrogen). This excludes nitrites and nitrates.

NUTRIENTS: NITROGEN



NUTRIENTS: PHOSPHORUS

- Sources and Types include solid organic-bound form and soluble inorganic form, usually orthophosphates (PO_4^{3-}).
- Can be analyzed using wet chemistry or instrumentation.



Chemical Characteristics

Total dissolved solids (TDS)

- Total dissolved solids (TDS) comprise inorganic salts and *small amounts of organic matter that are dissolved in water (smaller than 2 microns)*.
- In "clean" water, TDS is approximately equal to salinity.
- In wastewater or polluted areas:
  - TDS can include organic solutes in addition to the salt ions.
  - Organic matter from wastewater treatment plants may contribute higher levels of nitrate or phosphate ions.
- TDS measurement is commonly for the specific conductivity with a conductivity probe that detects the presence of ions in water.

Typical composition of untreated municipal WW

CONSTITUENT	CONCENTRATION Strong	Medium	Weak
Solids, total:	1250	800	450
Dissolved, total:	890	560	350
Fixed	295	295	185
Volatile	595	265	165
Suspended, total:	360	240	100
Fixed	145	75	25
Volatile	215	165	75
Settleable solids, mℓ/ℓ	7	5	3
Biochemical oxygen demand, 5-day, 20°C (BOD_5, 20°C)	400	200	100
Total organic carbon (TOC)	290	145	75
Chemical oxygen demand (COD)	910	455	230
Nitrogen (total as N):	75	40	16
Organic	40	20	8
Free ammonia	35	20	8
Nitrites	0	0	0
Nitrates	0	0	0
Phosphorus (total as P):	15	8	4
Organic	5	3	1
Inorganic	10	5	3
Chlorides[a]	83	42	21
Alkalinity (as $CaCO_3$)[a]	200	100	50
Grease	40	20	5

All values except settleable solids are expressed in mg/ℓ.
1 mg/ℓ = 1 g/m^3

Biological Constituents are part of the suspended solids

Municipal WW: Summary

- Domestic wastewater is a well balanced, nutrient- rich medium for bacterial decomposition.
- After primary treatment, biodegradation is the most cost effective secondary treatment.
- Effective biodegradation requires:

  BOD: N: P = 100: 5: 1

- Domestic wastewater contains:

  100: 20: 5

- Organics (BOD) limits N and P reduction.
- Advanced treatment is required to remove excessive N and P. This can be:
  - biological (e.g. extended aeration), or
  - physicochemical (coagulation, filtration and adsorption).

WASTEWATER COLLECTION AND TREATMENT: GENERAL DESIGN CONSIDERATIONS

- A fundamental prerequisite to begin the design of wastewater facilities is a determination of the design capacity. This, in turn, is a function of the wastewater flow rates, considering the variability and average values of such rates.
- For industrial wastewater, if water requirements or consumption of the industry is known, estimates of wastewater flow may be assumed as 85-95% of the water used becomes wastewater when internal recycle is not practiced.
- A typical design value for estimating the flows from industrial estates that have few wet processes is in the range:
  - 7.5-14 m3/ha.d for light industrial development, and
  - 14-28 m3/ha.d for medium industrial development

  (Metcalf & Eddy, 2003).

Characteristics of Industrial Wastewater

1) Industrial processes generate a wide variety of wastewater pollutants. The characteristics and levels of pollutants vary significantly from industry to industry.
2) The Environmental Protection Agency (EPA) has grouped the pollutants into three categories: conventional pollutants, non-conventional pollutants, and priority pollutants.
3) Examples on the concentrations of these pollutants are given in listed in Tables 18-7 and 18.8.

Examples on the Pollutant Concentrations in IWW

TABLE 18-7
Examples of industrial wastewater concentrations for BOD_5 and suspended solids

Industry	BOD_5, mg/L	Suspended solids, mg/L
Ammunition	50–300	70–1,700
Fermentation	4,500	10,000
Food processing	100–6,900	30–3,500
Pulp and paper (kraft)	100–350	75–300
Slaughterhouse (cattle)	400–2,500	400–1,000
Tannery	700–7,000	4,000–20,000

TABLE 18-8
Examples of industrial wastewater concentrations for nonconventional pollutants

Industry	Pollutant	Concentration, mg/L
Coke by-product (steel mill)	Ammonia (as N)	200
	Organic nitrogen (as N)	100
	Phenol	2,000
Metal plating	Chromium VI	3–550
Nylon polymer	COD	23,000
	TOC	8,800
Plywood-plant glue waste	COD	2,000
	Phenol	200–2,000
	Phosphorus (as PO_4)	9–15

Variability of Industrial Effluents

1. Industrial processes generate a wide variety of wastewater pollutants.
2. The characteristics and levels of pollutants vary significantly from industry to industry, some that are difficult and/or costly to treat.
3. Wastewater characteristics and levels of pollutants vary significantly by industry.
4. Additionally, fluctuations may occur in the wastewater's daily and hourly **flow, temperature, and composition.**
5. In some instances, several waste streams from different processes at an industry location may discharge at the same location.

Water Use in Industry

- Sources of feed water for production process and utilities at the manufacturing plant (factory):

  1. Surface water
  2. Ground water and Brackish wells
  3. Sea water
  4. Recycled (treated) wastewater
  5. Combination of the above

- Needless to say, wastewater properties are strongly dependent on the patterns of fresh water use in various industrial activities, as well as the type and extent of treatment.

Water Use in Industry

- The above sources differ in several aspects; selection of one is affected by:
  1. Availability (municipal tap, private well, desalination plant, …)
  2. Serving as multi-purpose (potable) or restricted use (recycled)
  3. Quality for the intended use (potable, process feed, boiler water, general wash, …)
  4. Method of treatment onsite (removal of turbidity, hardness, salinity, …).
  5. Cost.
- These contributes to the characteristics of industrial wastewater generated.

Sources of Wastewater in Industry

Two main categories of sources are:

I. Process / production activities:

Even with pollution prevention or waste minimization, no process is 100% efficient. Therefore, all processes will produce some waste:

a) Un-recovered product
b) Un-reacted feed stocks
c) Un-usable byproducts
d) fugitive emissions (leaks from pipes & equipment)

Sources of Wastewater in Industry

II. Non-production sources:

Utilities, maintenance, out-of-control, cleaning, use by personnel:

1) Cooling water: around 90% of the total water used by industries is used for cooling
2) Saline effluents from feed water treatment:

   RO membrane reject AND Ion exchange resin wash

3) Boiler bleed and blow-down
4) Equipment and floor wash
5) Spills and operational upsets
6) Storm runoff
7) Sanitary waste (domestic sewage)

Characteristics of Industrial Wastewater (IWW)

1. Quantity, volume or flow rate
   - Flow patterns: batch, continuous, semi-batch
2. Quality: composition & Concentration of pollutants
   - Composition: content or relative concentrations of pollutants:
     - Gross Concentration: e.g. COD
     - Individual compounds: e.g. [phenol].
3. Variation of above properties (both flow & composition) with time:
   - in regular operation, or in contingency.
   - Presence of priority pollutants – acute toxicity: This has special consideration in design and operation.

Characteristics of Industrial Wastewater (IWW)

1. Flow characteristics of IWW depends on:
   a) Type of industry.
   b) Number of working factories and units.
   c) Type and level of the technology applied:
      - low-level technology produce more effluent than high-level technology.
2. Variations in:
   - ❑ Composition is highly variable depending on industry type.
   - ❑ Concentrations (BOD, TSS) per industry vary significantly throughout the day and over the weak.
   - ❑ Temperature.

Characteristics of Industrial Wastewater (IWW)

- Discharges from industrial facilities can be direct or indirect:
  1. Direct discharges are made directly to a stream or water body.
  2. Indirect discharges are usually made to the public municipal treatment network (POTWs):
     - The discharge is treated by the POTWs completely.
     - A pretreatment of industrial discharge is done to make it acceptable by POTWs (municipal sewer).

Temperature

- Temperature significantly *higher or lower* than the ambient or a standard level is an indicator of bad quality for a particular use or discharge.
- Temperature should be moderate (20-35 °C) for normal bacterial growth and hence *degradation of organics* in wastewater.
- Temperature differences can be adjusted by mixing, dilution and equilibration with ambient.

Color and Odor

- True color is due to *dissolved solids*
- Apparent color is due to *suspended solids*
- Industrial Sources:
  - effluents from food, dyestuff, textile, … industries.
- Color is important in water quality:
  1. for process water feed in industries such as food, pharmaceuticals, dyestuff and textiles.
  2. Thus it affects reuse of treated wastewater.
- Odor is an aesthetic wastewater parameter.
  - It is due to the organic content. Some organics, e.g. sulfur-containing have offensive odor.

Chemical Characteristics of IWW

Atomic Absorption Spectrophotometer

Gas Chromatograph

Chemical Characteristics

- For BOD, COD, TOD, TDS, Pathogens:

  (See Municipal WW Characterization, above).

- Priority Organic Pollutants:

  Unlike domestic wastewater, usually IWW contains:

  VOCs and other toxic organics may be present in industrial wastewater in significant concentrations.

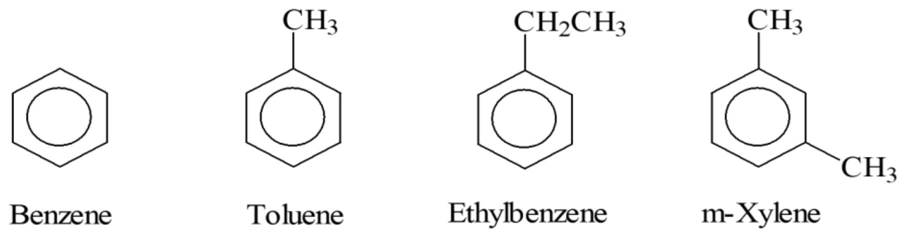
- Organics in IWW Can be either:

  A. Biodegradable, but nutrient deficient (N & P should be added)

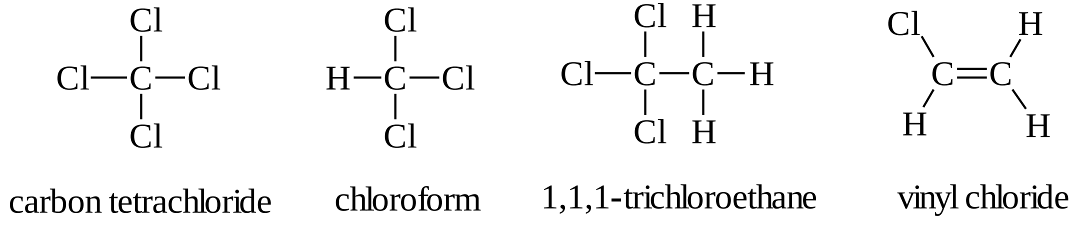
  B. Non-biodegradable, hence treated by physical-chemical methods (advanced oxidation processes (AOPs), adsorption, etc.)

Volatile Organic Compounds (VOCs)

- Petroleum constituents:
  - benzene and substituted benzenes



  - prevalent in gasoline, diesel fuel, heating oil
  - most easily transported, slow degradation, toxic
- Chlorinated solvents: C1 and C2 aliphatic
  - widely used in degreasing, dry cleaning, extraction
  - somewhat soluble in water, volatile, difficult to degrade



Total dissolved solids (TDS)

- Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matter that are dissolved in water (smaller than 2 microns).
- In "clean" water, TDS is approximately equal to salinity.
- In wastewater or polluted areas:
    - *TDS can include organic solutes in addition to the salt ions.*
    - *Organic matter in from wastewater treatment plants may contribute higher levels of nitrate or phosphate ions.*
- TDS measurement is commonly for the specific conductivity with a conductivity probe that detects the presence of ions in water.

Total dissolved solids (TDS)

- **Dissolved solids, mainly salts present as ions:**
  - Cations: Na^+, K^+, Mg^{2+}, Ca^{2+}
  - Anions: Cl^-, SO_4^{2-}, HCO_3^-
- **Typically measures as TDS, sometimes as EC (electrical conductivity).**
- **Water classification (mg/L TDS):**
  - freshwater <1500
  - brackish water 1500 – 5000
  - saline water >5000
  - sea water 30000-35000

- **Sources:**
  - Evaporative losses
  - Water treatment rejects
  - Boiler bleed and blowdown
  - Process discharge, e.g. desalting of crude oil in refinery
- **Effects:**
  - Interferes with biological treatment of wastewater
  - limits water reuse as irrigation for some crops
  - soil poisoning upon discharge of wastewater

Wastewater Characterization Analysis

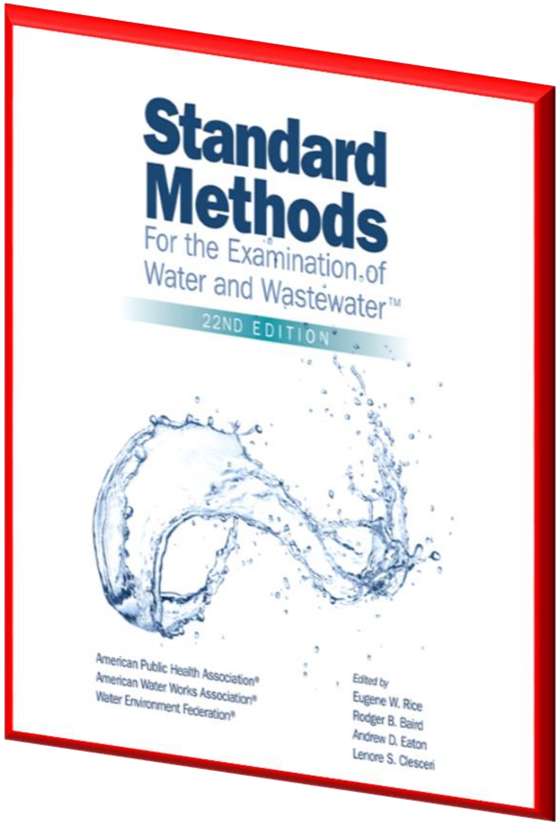
- Done according to :

"Standard Methods for the Examination of Water and Wastewater"

published by APHA, WPCF

- Performed routinely to characterize :

1. Influent for designing and protecting treatment works
2. Effluent for permit compliance



Industrial wastewater survey

This Involves a procedure designed to develop a flow and material balance of all processes using water and producing wastes.

Objectives :

To establish the variation in waste characteristics and waste loading.

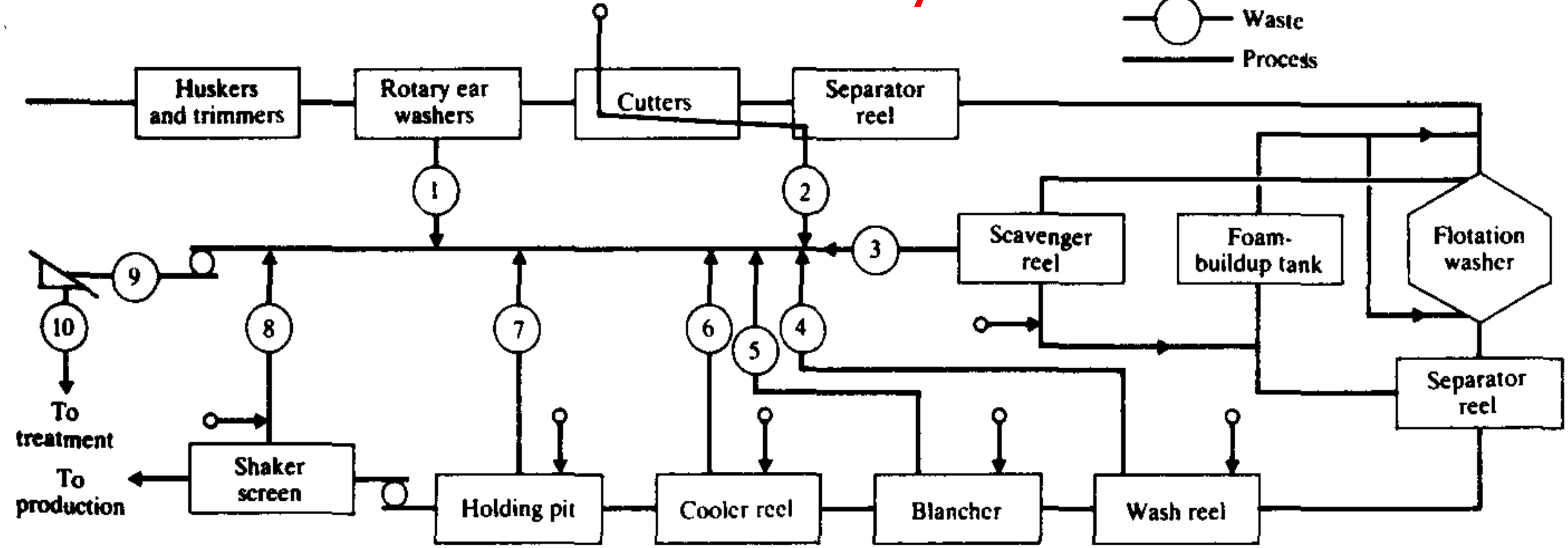
General Procedure (summarized in *four steps):*

1. **Develop a sewer map**
2. **Establish sample and analysis schedules**
3. **Develop a flow and material balance diagram**
4. **Establish statistical variation in significant waste characteristics.**

Results of survey should establish possibilities for:

1. **Water conservation** **2. Water reuse and**
3. **Control of flow and strength to undergo wastewater treatment**
   - **Usually require equalization /neutralization / homogenization of wastewater before treatment.**

Industrial wastewater survey



Line from →	1 Washer	2 Cutters	3 Reel	4 Reel	5 Blanch	6 Cool	7 Hold	8 Shaker	9 Sewer	10 Screen
to →				Sewer					Screen	Treatment
Flow, g/min	21.7	27.0	10.4	18.0	4.5	24.5	16.9	2.1	125.1	121
BOD, lb/d	2,500	2,300	390	973	610	1630	186		8,600	6250
COD, lb/d	3,640	4,640	555	1030	870	2140	192		13,000	9980
SS, lb/d	1,820	2,480	184	281	144	530	50		5,500	1700
VSS, lb/d	1,740	2,360	95	91	92	266	38		4,700	1900
Analysis:										
BOD, mg/l	9,830	7,112	3130	4600	11,300	5630	918		5,730	6200
COD, mg/l	14,000	14,400	4450	4780	16,100	7280	950		3,670	6030
SS, mg/l	6,950	7,660	1460	1300	2,670	1830	250		3,670	1170
VSS, mg/l	6,690	7,290	760	420	1,710	910	190		3,140	1030

Note:
gal/min = 3.78×10^{-3} m^3/min
lb/d = 0.45 kg/d

For more details, see Eckenfelder's Book: Water Pollution Control

FIGURE 1-5
Waste flow diagram and material balance at a corn plant.

REFERENCES

1) Metcalf & Eddy: Wastewater Engineering, McGraw-Hill. 5th edition, 2013.
2) Eckenfelder, W.W. Industrial Water Pollution Control, McGraw-Hill, 3rd edition, 1999.