Wastewater Characteristics

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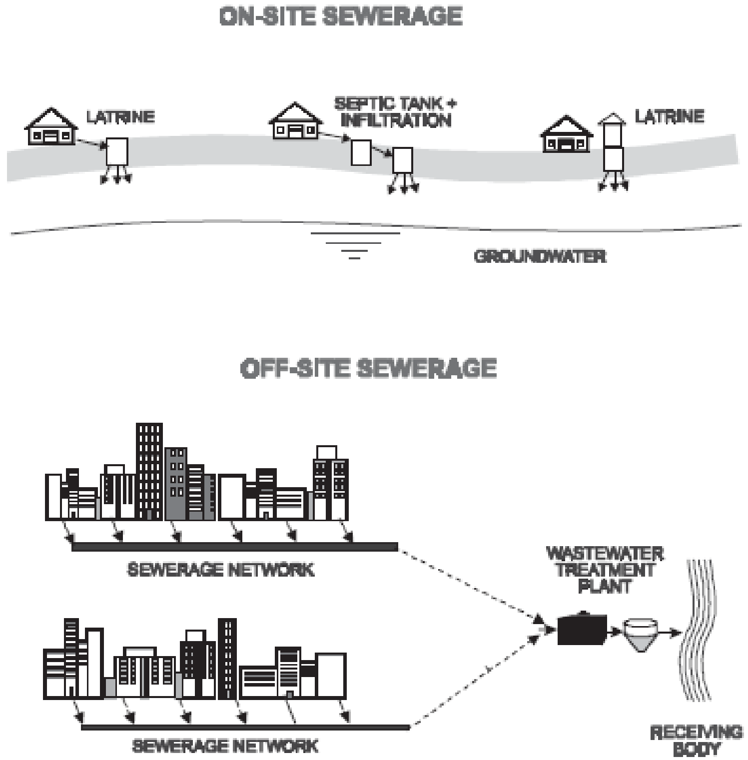
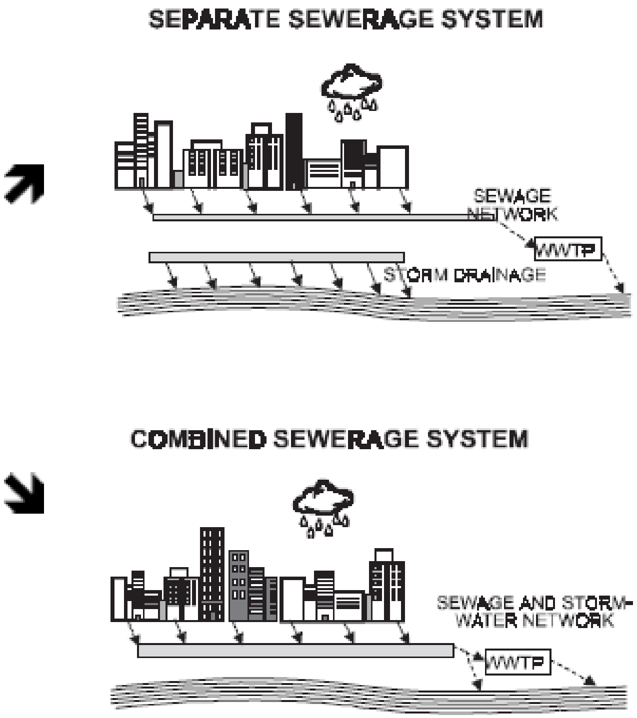
Wastewater flowrates

Wastewater sewerage systems:

- Off-site sewerage: with a waterborne sewerage collection and transportation network:
    - Separate sewerage system: which separates storm water from sewage, both being transported by independent pipeline systems.
    - Combined sewerage system: which directs sewage and storm water together into the same system. Storm water does contribute to the wastewater treatment plant (WWTP), and the pipelines have a larger diameter.
- On-site sewerage: latrines and septic tanks.





(a) Sewerage systems: on-site and off-site

(b) Off-site sewerage systems: separate and combined

Average water consumption

- Domestic flow is a function of the water consumption.
- Typical values of per capita water consumption for populations provided with household water connections are:

Community size	Population range (inhabitants)	Per capita water consumption (L/inhab.d)
Rural settlement	<5,000	90–140
Village	5,000–10,000	100–160
Small town	10,000–50,000	110–180
Average town	50,000–250,000	120–220
Large city	>250,000	150–300

Note: in places with severe water shortages, these values may be smaller
Source: Adapted from CETESB (1977; 1978), Barnes et al (1981), Dahlhaus & Damrath (1982), Hosang & Bischof (1984)

Typical ranges of per capita water consumption

Factors that influence water consumption

Influencing factor	Comment
• Water availability	• In locations of water shortage consumption tends to be less
• Climate	• Warmer climates induce a greater water consumption
• Community size	• Larger cities generally present a larger per capita water consumption (to account for strong commercial and institutional activities)
• Economic level of the community	• A higher economic level is associated with a higher water consumption
• Level of industrialisation	• Industrialised locations present a higher consumption
• Metering of household consumption	• Metering inhibits greater consumption
• Water cost	• A higher cost reduces consumption
• Water pressure	• High pressure in the distribution system induces greater use and wastage
• System losses	• Losses in the water distribution network imply the necessity of a greater water production

Typical water consumption in some commercial establishments

Establishment	Unit	Flow range (L/unit.d)
Airport	Passenger	8–15
Accommodation (lodging house)	Resident	80–150
Public toilet	User	10–25
Bar	Customer	5–15
Cinema/theatre	Seat	2–10
Office	Employee	30–70
Hotel	Guest	100–200
	Employee	30–50
Industry (sanitary sewage only)	Employee	50–80
Snack bar	Customer	4–20
Laundry – commercial	Machine	2,000–4,000
Laundry – automatic	Machine	1,500–2,500
Shop	Toilet	1,000–2,000
	Employee	30–50
Department store	Toilet	1,600–2,400
	Employee	30–50
	m^2 of area	5–12
Petrol station	Vehicle attended	25–50
Restaurant	Meal	15–30
Shopping centre	Employee	30–50
	m^2 of area	4–10

Source: EPA (1977), Hosang and Bischof (1984), Tchobanoglous and Schroeder (1985), Qasim (1985), Metcalf & Eddy (1991), NBR-7229/93

Typical water consumption in some institutional establishments

Establishment	Unit	Flow range (L/unit.d)
Rest home	Resident	200–450
	Employee	20–60
School	Student	50–100
– with cafeteria, gymnasium, showers	Student	40–80
– with cafeteria only	Student	20–60
– without cafeteria and gymnasium		
Hospital	Bed	300–1000
	Employee	20–60
Prison	Inmate	200–500
	Employee	20–60

Source: EPA (1977), Hosang and Bischof (1984), Tchobanoglous and Schroeder (1985), Qasim (1985), Metcalf & Eddy (1991)

Average domestic sewage flow calculation

The average domestic sewage flow calculation is given by:

$$Q_{d_{av}} = \frac{Pop.L_{pcd}.R}{1000} \qquad (m^3/d)$$

$$Q_{d_{av}} = \frac{Pop.L_{pcd}.R}{86400} \qquad (L/s)$$

where:

Qdav= average domestic sewage flow (m3/d or L/s)
Lpcd = per capita water consumption (L/inhab.d)
R = sewage flow/water flow return coefficient

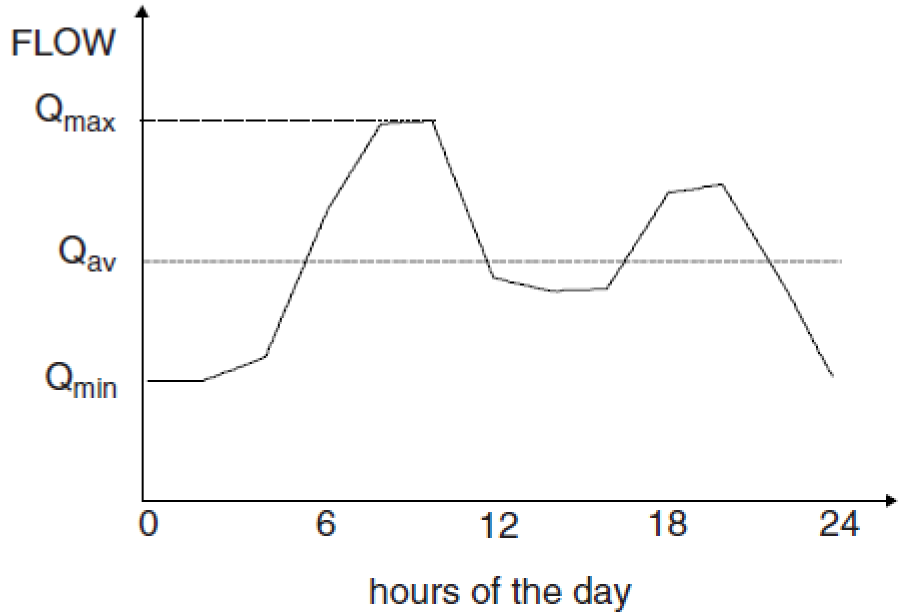
It is important to notice that the water flow to be considered is the flow actually consumed, and not the flow produced by the water treatment works. The water flow produced is higher than that consumed due to unaccounted water losses in the distribution system, which can vary typically from 20 to 50%. Thus in a locality where the loss is 30%, for each 100 m3 of water produced, 30 m3 are unaccounted for and only 70 m3 are consumed. Of this 70 m3, around 80% (56 m3/d) return in the form of sewage to the sewerage system.

Flow variations

- Water consumption and wastewater generation in a locality vary throughout the day (hourly variations), during the week (daily variations) and throughout the year (seasonal variations).

$$Q_{max} = Q_{av} \,.\, K_1 \,.\, K_2 = 1.8\, Q_{av}$$

$$Q_{min} = Q_{av} \,.\, K_3 = 0.5\, Q_{av}$$



- $K_1 = 1.2$ (peak coefficient for the day with the highest water consumption)
- $K_2 = 1.5$ (peak coefficient for the hour with the highest water consumption)
- $K_3 = 0.5$ (reduction coefficient for the hour with the lowest water consumption)

Industrial wastewater flow

- Water consumption:
  - Total volume consumed (per day or month)
  - Volume consumed in the various stages of the process
  - Internal recirculations
  - Water origin (public supply, wells, etc.)
  - Internal systems of water treatment

- Wastewater production:
  - Total flow
  - Number of discharge points (with the corresponding industrial process associated with each point)
  - Discharge pattern (continuous or intermittent; duration and frequency) in each discharge point
  - Discharge destination (sewerage system, watercourse)
  - Occasional mixing of wastewater with domestic sewage and storm water

- [ ] Effluent flow measurements must be carried out throughout the working day, to record the discharge pattern and variations.

Specific average flows from some industries

Type	Activity	Unit	Water consumption per unit (m^3/unit) (*)
Food	Canned fruit and vegetables	1 tonne product	4–50
	Sweets	1 tonne product	5–25
	Sugar cane	1 tonne sugar	0.5 – 10.0
	Slaughter houses	1 cow or 2,5 pig	0.5–3.0
	Dairy (milk)	1000 L milk	1–10
	Dairy (cheese or butter)	1000 L milk	2–10
	Margarine	1 tonne margarine	20
	Brewery	1000 L beer	5–20
	Bakery	1 tonne bread	2–4
	Soft drinks	1000 L soft drinks	2–5
Textiles	Cotton	1 tonne product	120–750
	Wool	1 tonne product	500–600
	Rayon	1 tonne product	25–60
	Nylon	1 tonne product	100–150
	Polyester	1 tonne product	60–130
	Wool washing	1 tonne wool	20–70
	Dyeing	1 tonne product	20–60
Leather / tanneries	Tannery	1 tonne hide	20–40
	Shoe	1000 pairs of shoes	5
Pulp and paper	Pulp fabrication	1 tonne product	15–200
	Pulp bleaching	1 tonne product	80–200
	Paper fabrication	1 tonne product	30–250
	Pulp and paper integrated	1 tonne product	200–250
Chemical industries	Paint	1 employee	110 L/d
	Glass	1 tonne glass	3–30
	Soap	1 tonne soap	25–200
	Acid, base, salt	1 tonne chlorine	50
	Rubber	1 tonne product	100–150
	Synthetic rubber	1 tonne product	500
	Petroleum refinery	1 barrel (117 L)	0.2–0.4
	Detergent	1 tonne product	13
	Ammonia	1 tonne product	100–130
	Carbon dioxide	1 tonne product	60–90
	Petroleum	1 tonne product	7–30
	Lactose	1 tonne product	600–800
	Sulphur	1 tonne product	8–10
	Pharmaceutical products (vitamins)	1 tonne product	10–30

∗ Consumption in m3 per unit produced or L/d per employee

Source: CETESB (1976), Downing (1978), Arceivala (1981), Hosang and Bischof (1984), Imhoff & Imhoff (1985), Metcalf & Eddy (1991), Der´ısio (1992)

Wastewater Composition

Quality parameters

- Domestic sewage contains approximately 99.9% water. The remaining part includes organic and inorganic, suspended and dissolved solids, together with microorganisms It is because of this 0.1% that water pollution takes place and the wastewater needs to be treated.

- The composition of the wastewater is a function of the uses to which the water was submitted. These uses, and the form with which they were exercised, vary with climate, social and economic situation and population habits.

Main characteristics of wastewater

The main physical, chemical and biological characteristics of domestic sewage:

Physical characteristics

Parameter	Description
Temperature	• Slightly higher than in drinking water • Variations according to the seasons of the years (more stable than the air temperature) • Influences microbial activity • Influences solubility of gases • Influences viscosity of the liquid
Colour	• Fresh sewage: slight grey • Septic sewage: dark grey or black
Odour	• Fresh sewage: oily odour, relatively unpleasant • Septic sewage: foul odour (unpleasant), due to hydrogen sulphide gas and other decomposition by-products • Industrial wastewater: characteristic odours
Turbidity	• Caused by a great variety of suspended solids • Fresher or more concentrated sewage: generally greater turbidity

Chemical characteristics

Parameter	Description
TOTAL SOLIDS	*Organic and inorganic; suspended and dissolved; settleable*
• *Suspended*	• Part of organic and inorganic solids that are non-filterable
• *Fixed*	• Mineral compounds, not oxidisable by heat, inert, which are part of the suspended solids
• *Volatile*	• Organic compounds, oxidisable by heat, which are part of the suspended solids
• *Dissolved*	• Part of organic and inorganic solids that are filterable. Normally considered having a dimension less than 10^{-3} µm.
• *Fixed*	• Mineral compounds of the dissolved solids.
• *Volatile*	• Organic compounds of the dissolved solids
• *Settleable*	• Part of organic and inorganic solids that settle in 1 hour in an Imhoff cone. Approximate indication of the settling in a sedimentation tank.
ORGANIC MATTER	*Heterogeneous mixture of various organic compounds. Main components: proteins, carbohydrates and lipids.*
Indirect determination	
• *BOD_5*	• Biochemical Oxygen Demand. Measured at 5 days and 20 °C. Associated with the biodegradable fraction of carbonaceous organic compounds. Measure of the oxygen consumed after 5 days by the microorganisms in the biochemical stabilisation of the organic matter.
• *COD*	• Chemical Oxygen Demand. Represents the quantity of oxygen required to chemically stabilise the carbonaceous organic matter. Uses strong oxidising agents under acidic conditions.
• *Ultimate BOD*	• Ultimate Biochemical Oxygen Demand. Represents the total oxygen consumed at the end of several days, by the microorganisms in the biochemical stabilisation of the organic matter.
Direct determination	
• *TOC*	• Total Organic Carbon. Direct measure of the carbonaceous organic matter. Determined through the conversion of organic carbon into carbon dioxide.

TOTAL NITROGEN	*Total nitrogen includes organic nitrogen, ammonia, nitrite and nitrate. It is an essential nutrient for microorganisms' growth in biological wastewater treatment. Organic nitrogen and ammonia together are called Total Kjeldahl Nitrogen (TKN).*
• *Organic nitrogen*	• Nitrogen in the form of proteins, aminoacids and urea.
• *Ammonia*	• Produced in the first stage of the decomposition of organic nitrogen.
• *Nitrite*	• Intermediate stage in the oxidation of ammonia. Practically absent in raw sewage.
• *Nitrate*	• Final product in the oxidation of ammonia. Practically absent in raw sewage.
TOTAL PHOSPHORUS	*Total phosphorus exists in organic and inorganic forms. It is an essential nutrient in biological wastewater treatment.*
• *Organic phosphorus*	• Combined with organic matter.
• *Inorganic phosphorus*	• Orthophosphates and polyphosphates.

Parameter	Description
pH	*Indicator of the acidic or alkaline conditions of the wastewater. A solution is neutral at pH 7. Biological oxidation processes normally tend to reduce the pH.*
ALKALINITY	*Indicator of the buffer capacity of the medium (resistance to variations in pH). Caused by the presence of bicarbonate, carbonate and hydroxyl ions.*
CHLORIDES	*Originating from drinking water and human and industrial wastes.*
OILS AND GREASE	*Fraction of organic matter which is soluble in hexane. In domestic sewage, the sources are oils and fats used in food.*

Biological characteristics

Organism	Description
Bacteria	• Unicellular organisms • Present in various forms and sizes • Main organisms responsible for the stabilisation of organic matter • Some bacteria are pathogenic, causing mainly intestinal diseases
Archaea	• Similar to bacteria in size and basic cell components • Different from bacteria in their cell wall, cell material and RNA composition • Important in anaerobic processes
Algae	• Autotrophic photosynthetic organisms, containing chlorophyll • Important in the production of oxygen in water bodies and in some sewage treatment processes • In lakes and reservoirs they can proliferate in excess, deteriorating the water quality
Fungi	• Predominantly aerobic, multicellular, non-photosynthetic, heterotrophic organisms • Also of importance in the decomposition of organic matter • Can grow under low pH conditions
Protozoa	• Usually unicellular organisms without cell wall • Majority is aerobic or facultative • Feed themselves on bacteria, algae and other microorganisms • Essential in biological treatment to maintain an equilibrium between the various groups • Some are pathogenic
Viruses	• Parasitic organisms, formed by the association of genetic material (DNA or RNA) and a protein structure • Pathogenic and frequently difficult to remove in water or wastewater treatment
Helminths	• Higher-order animals • Helminth eggs present in sewage can cause illnesses

Note: algae are normally not present in untreated wastewater, but are present in the treated effluent from some processes (e.g. stabilisation ponds)

Main parameters defining the quality of wastewater

The main parameters predominantly found in domestic sewage that deserve special consideration are:

- ❑ Solids
- ❑ Indicators of organic matter
- ❑ Nitrogen
- ❑ Phosphorus
- ❑ Indicators of faecal contamination

Solids

- All the contaminants of water, with the exception of dissolved gases, contribute to the solids load.

- In wastewater treatment, the solids can be classified according to:

  - Classification by size and state
    - ✓ Suspended solids
    - ✓ Dissolved solids

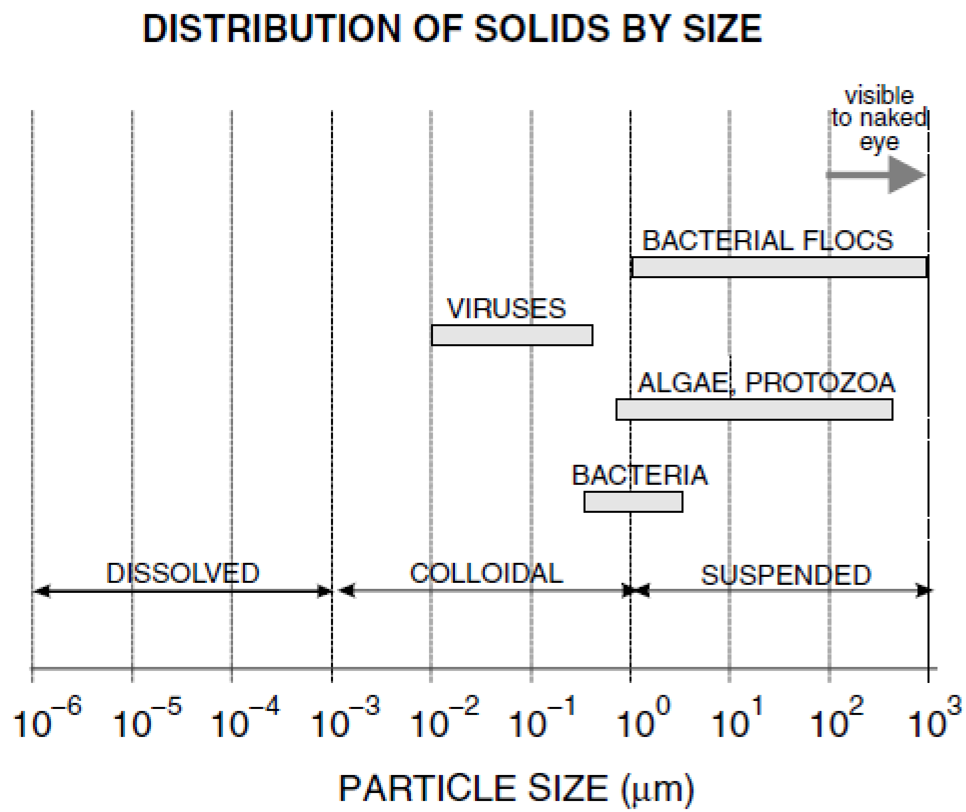
  - Classification by chemical characteristics
    - ✓ Volatile solids (organic)
    - ✓ Fixed solids (inorganic)

  - Classification by settleability
    - ✓ Settleable suspended solids
    - ✓ Non-settleable suspended solids

Solids: Classification by size

- Particles of smaller dimensions capable of passing through a filter paper of a specific size correspond to the **dissolved solids**, while those with larger dimensions and retained by the filter are considered **suspended solids**.

- Sometimes the term **particulate** is used to indicate that the solids are present as **suspended solids**. In this context, expressions as particulate BOD, COD, phosphorus, etc. are used, to indicate that they are linked to suspended solids. In contrast, soluble BOD, COD and phosphorus are associated with **dissolved solids**.



Solids: Classification by chemical characteristics

- If the solids are submitted to a high temperature (550°C), the organic fraction is oxidized (volatilized), leaving after combustion only the inert fraction (unoxidized).

- The volatile solids represent an estimate of the organic matter in the solids, while the non-volatile solids (fixed) represent the inorganic or mineral matter.

Total solids
- ↗ Volatile solids (organic matter)
- ↘ Fixed solids (inorganic matter)

Solids: Classification by settleability

- Settleable solids are considered those that are able to settle in a period of 1 hour.
- The volume of solids accumulated in the bottom of a recipient called an Imhoff Cone is measured and expressed as mL/L.
- The fraction that does not settle represents the non-settleable solids (usually not expressed in the results of the analysis).

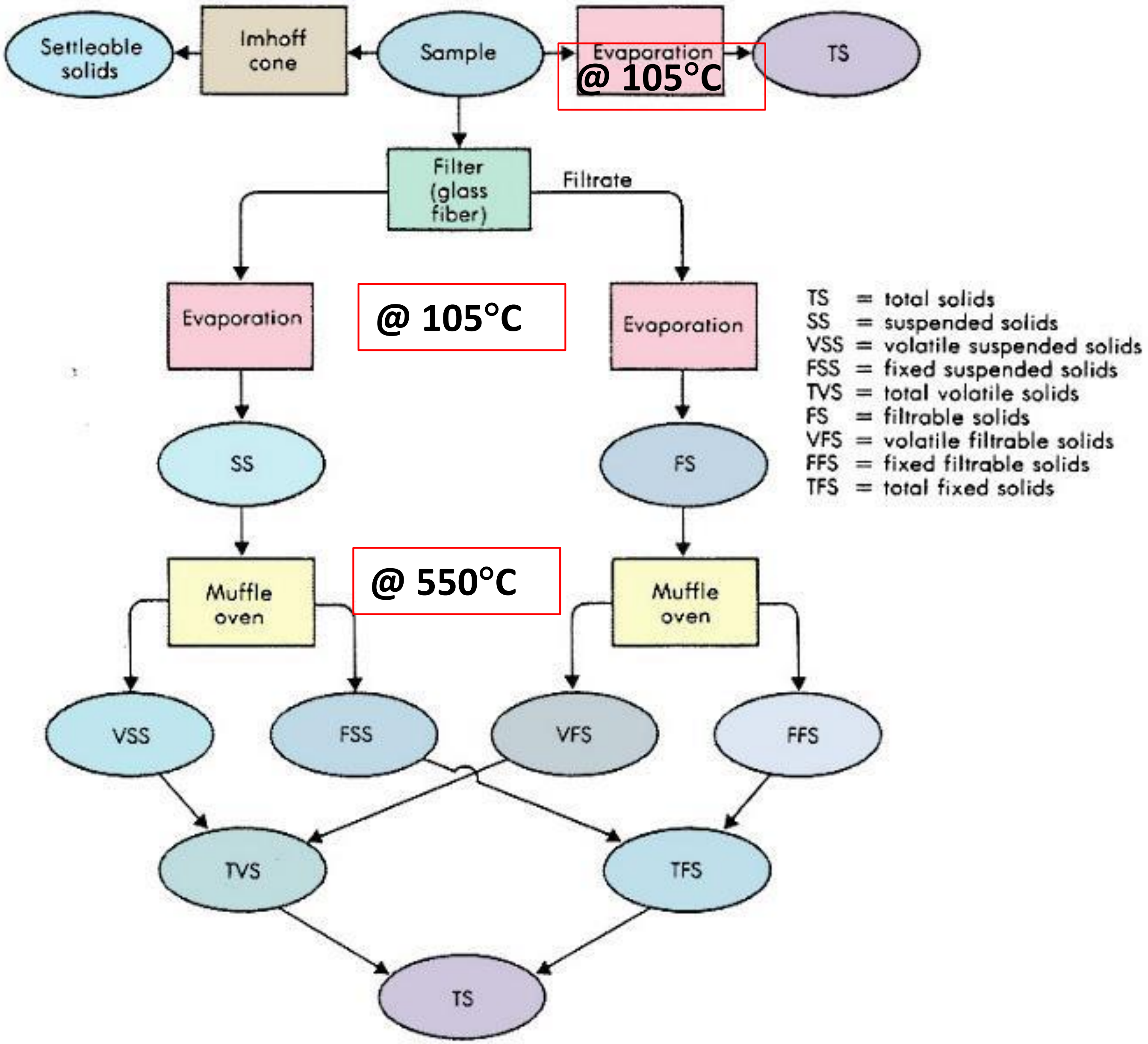


FIGURE 2.7

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.

Carbonaceous organic matter

- The organic matter present in sewage is a characteristic of substantial importance, being the cause of one of the main water pollution problems: consumption of dissolved oxygen by the microorganisms in their metabolic processes of using and stabilizing the organic matter.

- The organic substances present in sewage consist mainly of:

  - Protein compounds (≈ 40%)
  - Carbohydrates (≈ 25 to ≈ 50%)
  - Oils and grease (≈ 10%)
  - Urea, surfactants, phenols, pesticides and others (lower quantity)

- The carbonaceous organic matter (based on organic carbon) present in the influent sewage to a WWTP can be divided into the following main fractions:

  - ➢ classification: in terms of form and size
    - ✓ Suspended (particulate)
    - ✓ Dissolved (soluble)
  - ➢ classification: in terms of biodegradability
    - ✓ Inert
    - ✓ Biodegradable

- Direct or indirect methods can be adopted for the quantification of organic matter:

  - Indirect methods: measurement of oxygen consumption
    - ✓ Biochemical Oxygen Demand (BOD)
    - ✓ Ultimate Biochemical Oxygen Demand (BOD_u)
    - ✓ Chemical Oxygen Demand (COD)

  - Direct methods: measurement of organic carbon
    - ✓ Total Organic Carbon (TOC)

Biochemical Oxygen Demand (BOD)

- The main ecological effect of organic pollution in a water body is the decrease in the level of dissolved oxygen.
- Similarly, in sewage treatment using aerobic processes, the adequate supply of oxygen is essential, so that the metabolic processes of the microorganisms can lead to the stabilization of the organic matter.
- This quantification could be obtained through stoichiometric calculations based on the reactions of oxidation of the organic matter. If the substrate was, for example, glucose ($C_6H_{12}O_6$), the quantity of oxygen required to oxidize the given quantity of glucose could be calculated through the basic equation of respiration. This is the principle of the so-called **Theoretical Oxygen Demand (TOD)**.
- In practice, however, a large obstacle is present: the sewage has a great heterogeneity in its composition, and to try to establish all its constituents in order to calculate the oxygen demand based on the chemical oxidation reactions of each of them is totally impractical.
- The solution found was to measure in the laboratory the consumption of oxygen exerted by a standard volume of sewage or other liquid, in a predetermined time. It was thus introduced the important concept of **Biochemical Oxygen Demand (BOD)**.

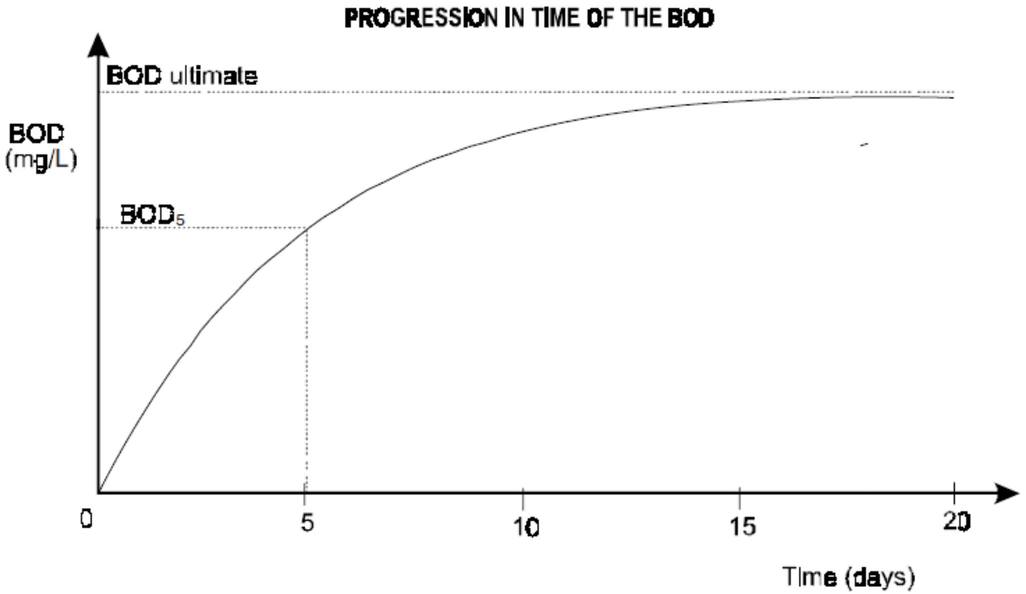
- The BOD represents the quantity of oxygen required to stabilize, through biochemical processes, the carbonaceous organic matter. It is an indirect indication, therefore, of the biodegradable organic carbon.

- Complete stabilization takes, in practical terms, various days (around 20 days or more for domestic sewage). This corresponds to the **Ultimate Biochemical Oxygen Demand (BOD_u).** However, to shorten the time for the laboratory test, and to allow a comparison of the various results, some standardizations were established:

    - the determination is undertaken on the 5th day. For typical domestic sewage, the oxygen consumption on the fifth day can be correlated with the final total consumption (BOD_u);

    - the test is carried out at a temperature of 20◦C, since different temperatures interfere with the bacteria's metabolism, modifying the relation between BOD at 5 days and BOD Ultimate.

Ultimate Biochemical Oxygen Demand (BOD_u)



Origin	BOD_u/BOD_5
High concentration sewage	1.1–1.5
Low concentration sewage	1.2–1.6
Primary effluent	1.2–1.6
Secondary effluent	1.5–3.0

Source: Calculated using the coefficients presented by Fair et al (1973) and Arceivala (1981)

Various referencess adopt the ratio BODu/BOD5 equal to 1.46. This means that, in the case of having a BOD5 of 300 mg/L, the BODu is assumed to be equal to

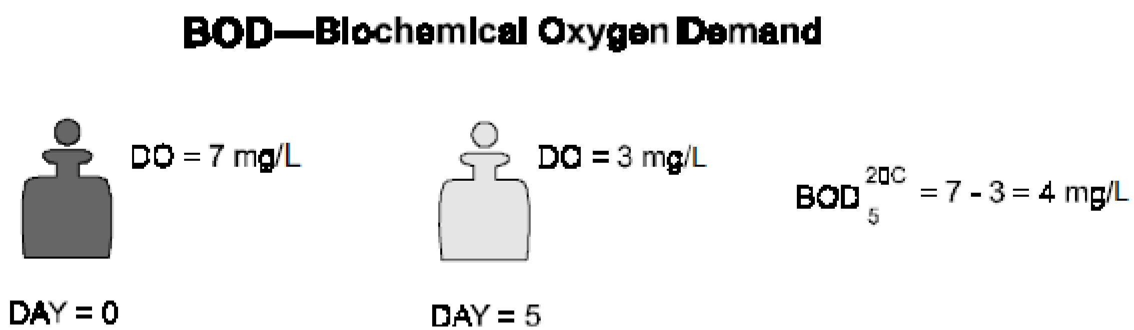
$1.46 \times 300 = 438$ mg/L.

BOD test

- The BOD test can be understood in this simplified way: on the day of the sample collection, the concentration of dissolved oxygen (DO) in the sample is determined. Five days later, with the sample maintained in a closed bottle and incubated at 20◦C, the new DO concentration is determined.

- For example:

DO on day 0: 7 mg/L
DO on day 5: 3 mg/L
$BOD_5 = 7 - 3 = 4$ mg/L



Special Case:

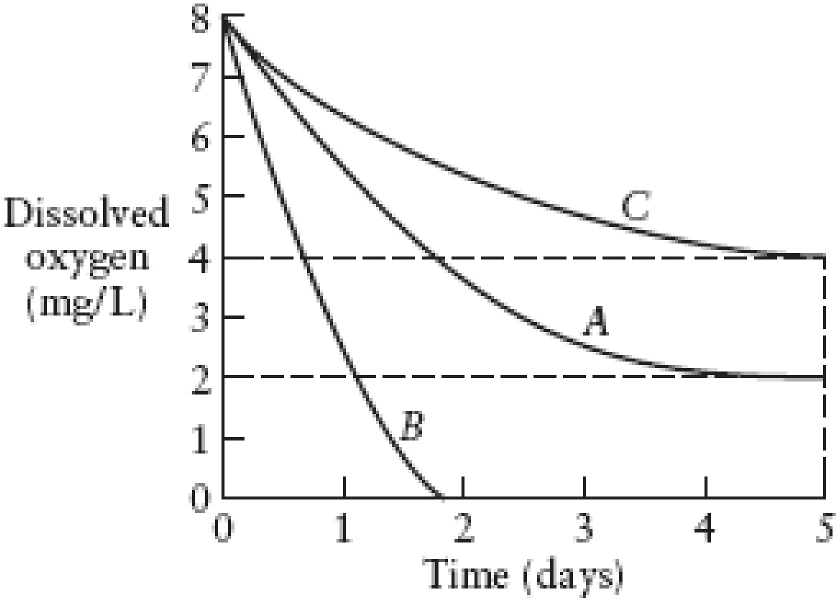
What if the F is =0?

Dilution of the sample is required when F = 0.

If F = 0 we don't know how much DO would have been used.

For sewage, some practical aspects require some adaptations. Sewage, having a large concentration of organic matter, consumes quickly (well before the five days) all the dissolved oxygen in the liquid medium.

Thus, it is necessary to make **dilutions** in order to decrease the concentration of the organic matter, such that the oxygen consumption at 5 days is numerically less than the oxygen available in the sample (the sample is lost if, at day 5, the DO concentration is zero, because it will not be possible to know when the zero concentration was reached)



$BOD_5 = I - F$

Where;

I = initial DO, mg/L

F = final DO, mg/L

Dilution

BOD = (I – F)D

where, D = dilution

$$D = \frac{\text{total volume of bottle}}{[\text{total volume of bottle}] - [\text{volume of dilution water}]}$$

$$D = \frac{\text{Total volume of bottle}}{\text{Volume of sample}}$$

Example

Determine the BOD_5 for a 15 ml sample that is diluted with dilution water to a total volume of 300 ml when the initial DO concentration is 8 mg/l and after 5 days, has been reduced to 2 mg/l.

I=8

F=2

D= 300/15=20

BOD_5 = (8-2)*20= 120

Remark: The assumption in the dilution method is that the results from each dilution of a single sample will yield the same BOD value **(No Sliding Scale)**

Examples: 9.4 9.5

Seeding: The addition of active microorganisms that take up oxygen

- May be required in samples that do not have their own,
- it is usually necessary to introduce a seed, containing microorganisms, to allow a faster start of the decomposition process,
- If seeding is necessary, any BOD that is contributed by the seed must be subtracted,

$$BOD_t = \left[(I - F) - (I' - F')\left(X/Y\right)\right]D$$

where BOD_t = biochemical oxygen demand measured at some time, t, mg/L
I = initial DO of bottle with sample and seeded dilution water, mg/L
F = final DO of bottle with sample and seeded dilution water, mg/L
I' = initial DO of bottle with only seeded dilution water, mg/L
F' = final DO of bottle with only seeded dilution water, mg/L
X = seeded dilution water in sample bottle, mL
Y = volume of BOD bottle, mL
D = dilution of sample

Example

Standard BOD test with a 1:30 dilution with seeded dilution water is run. Both bottles begin at saturation, 9.2 mg/L. After five days, the bottle with waste has a DO of 2 mg/L, while the DO of the seed = 8 mg/L. Find the BOD_5.

$$BOD_t = \left[(9.2 - 2) - (9.2 - 8)\left(290/300\right)\right]30$$

$$= 181\ mg/L$$

BOD Kinetics

Thus the mass balance is:

Rate of DO Accum. = Rate of DO consumed

dz/dt = -r

z = dissolved oxygen, mg/L

Assume that it is a first-order reaction

$$\frac{dz}{dt} = -k_1 z \Rightarrow \frac{dz}{z} = -k_1 dt \Rightarrow z = z_o e^{-k_1 t}$$

As O_2 is used, the amount still to be used is **z**, the amount already used is **y**

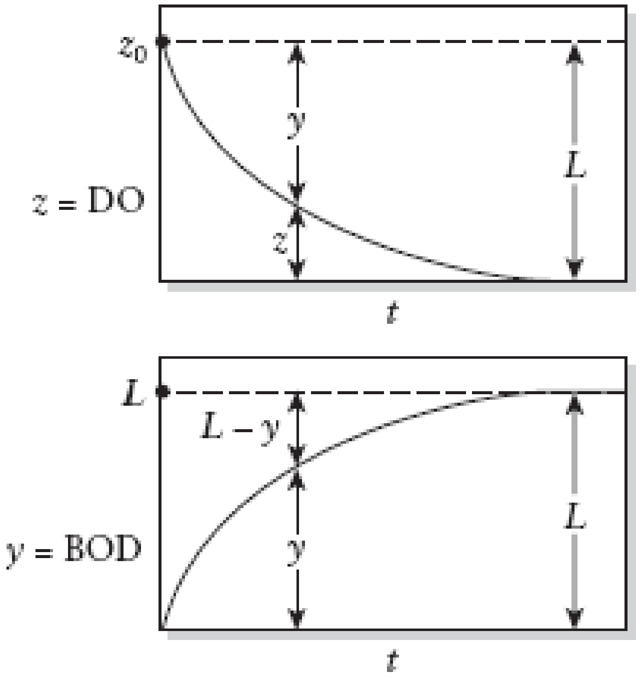
$L = y + z$ @ $t=0$, $y=0$, $L=z_{t=0}$

Where, **L**= ultimate demand

$$z = L - y$$

$$L - y = z_o e^{-k_1 t}, z_o = L$$

$$y = L - Le^{-k_1 t} = L(1 - e^{-k_1 t})$$



Where;

y = BOD at any time t

L = ultimate BOD

k_1 = deoxygenation constant, day^{-1}

Average k

TABLE 1.4
Average BOD rate constants at 20°C

Substance	k_{10}, day^{-1}
Untreated wastewater	0.15–0.28
High-rate filters and anaerobic contact	0.12–0.22
High-degree biotreatment effluent	0.06–0.10
Rivers with low pollution	0.04–0.08

Numerical value of the rate constant *k* depends on:

- Nature of waste
- Ability of organisms in the system to use the waste
- Temperature

Temperature Effect on k

- The BOD rate constant is adjusted to the temperature of receiving water using this:

$$k_T = k_{20}(\theta)^{T-20}$$

- Where;
  - k_t = BOD rate constant at the temperature of interest
  - k_{20} = BOD rate constant determined at 20°C
  - T = temperature in °C
  - Θ = Temperature coefficient (For domestic WW, 1.135 and 1.024 for reaeration)

Example 9.8: Find the BOD_5 for a waste with an ultimate BOD = 282 mg/L and a k_1 = 0.348 /day

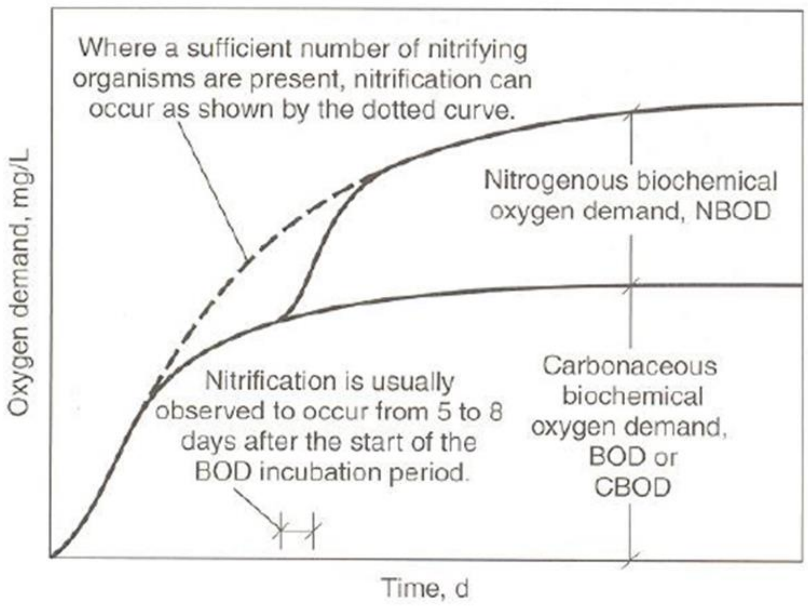
$$y = L(1 - e^{-k_1 t})$$

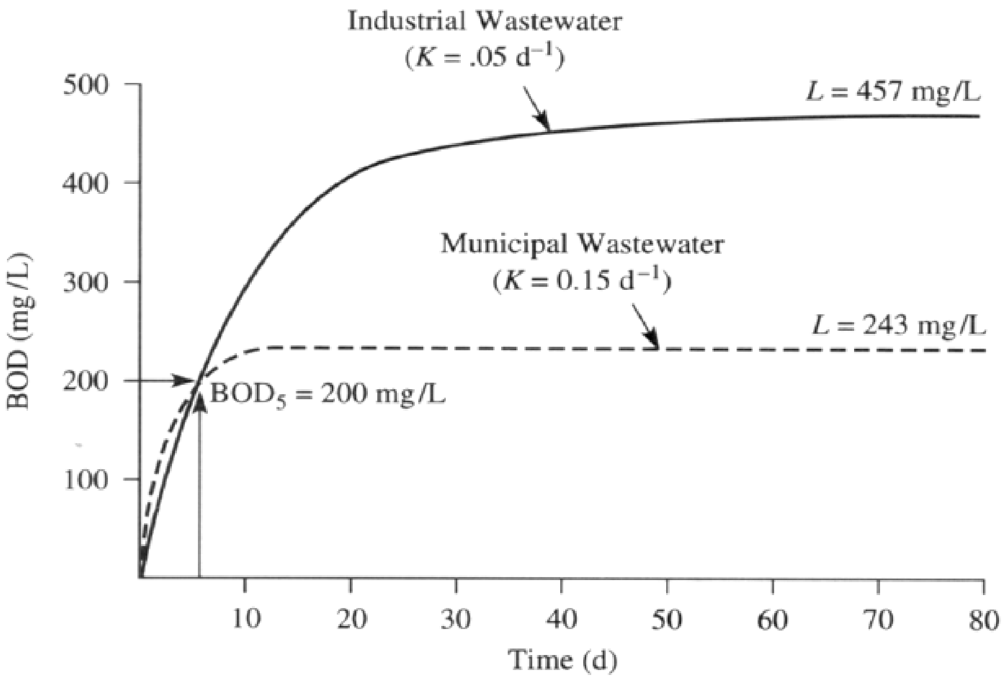
$$= 282\ \mathrm{mg/L}(1 - e^{-0.348/day*5})$$

$$= 50\ \mathrm{mg/L}$$

✓ **Example 9.8 9.9**

To measure only the carbonaceous oxygen demand, an inhibitor for nitrification (nitrogenous oxygen demand, associated with the oxidation of ammonia to nitrate) can be added.





Ref: Davis, Cornwell, 1998, Introduction to Environmental Engineering

BOD test: Advantages

The main advantages of the BOD test are related to the fact that the test allows:

- ✓ an approximate indication of the biodegradable fraction of the wastewater;
- ✓ an indication of the degradation rate of the wastewater;
- ✓ an indication of the oxygen consumption rate as a function of time;
- ✓ an approximate determination of the quantity of oxygen required for the biochemical stabilization of the organic matter present.
- ✓ the design criteria for many wastewater treatment processes are frequently expressed in terms of BOD;
- ✓ the legislation for effluent discharge in many countries, and the evaluation of the compliance with the discharge standards, is normally based on BOD.

Chemical Oxygen Demand (COD)

- The COD test measures the consumption of oxygen occurring as a result of the chemical oxidation of the organic matter. The value obtained is, therefore, an indirect indication of the level of organic matter present.
- The main difference with the BOD test is clearly found in the nomenclature of both tests. The BOD relates itself with the biochemical oxidation of the organic matter, undertaken entirely by microorganisms.
- The COD corresponds to the chemical oxidation of the organic matter, obtained through a strong oxidant (potassium dichromate) in an acid medium.
- For raw domestic sewage, the ratio COD/BOD_5 varies between 1.7 and 2.4.

- *Low COD/BOD_5 ratio* (less than 2.5 or 3.0):
  - the biodegradable fraction is high
  - good indication for biological treatment
- *Intermediate COD/BOD_5 ratio* (between 2.5 and 4.0):
  - the inert (non-biodegradable) fraction is not high
  - treatability studies to verify feasibility of biological treatment
- *High COD/BOD_5 ratio* (greater than 3.5 or 4.0):
  - the inert (non-biodegradable) fraction is high
  - possible indication for physical–chemical treatment

Depending on the value of the ratio, conclusions can be drawn about the biodegradability of the wastewater and the treatment process to be employed

COD: advantages and limitations

The main **advantages** of the COD test are:

- the test takes only two to three hours;
- because of the quick response, the test can be used for operational control;
- the test results give an indication of the oxygen required for the stabilization of the organic matter;
- the test allows establishment of stoichiometric relationships with oxygen;
- the test is not affected by nitrification, giving an indication of the oxidation of the carbonaceous organic matter only (and not of the nitrogenous oxygen demand).

The main **limitations** of the COD test are:

- in the COD test, both the biodegradable and the inert fractions of organic matter are oxidized. Therefore, the test may overestimate the oxygen to be consumed in the biological treatment of the wastewater;
- the test does not supply information about the consumption rate of the organic matter along the time;
- certain reduced inorganic constituents could be oxidized and interfere with the result.

(BOD_u/BOD_5 and COD/BOD_5) Indication

Relationship between the representative parameters of oxygen consumption:

In samples of raw and treated domestic sewage, the usual ratios between the main representative parameters of oxygen consumption (BOD_u/BOD_5 and COD/BOD_5) indicate the following:

- The ratios can never be lower than 1.0.
- The ratios increase, from the condition of untreated to biologically treated wastewater.
- The higher the treatment efficiency, the higher the value of the ratio.

Total Organic Carbon (TOC)

- In this test the organic carbon is directly measured, in an instrumental test, and not indirectly through the determination of the oxygen consumed, like BOD, COD, etc.
- The TOC test measures all the carbon released in the form of CO_2.
- To guarantee that the carbon being measured is really organic carbon, the inorganic forms of carbon (like CO_2, HCO^{-3} etc) must be removed before the analysis or be corrected when calculated.

Nitrogen

- Nitrogen is a component of great importance in terms of generation and control of the water pollution, principally for the following aspects:

➢ **Water pollution**

  - ✓ nitrogen is an essential nutrient for algae leading, under certain conditions, to the phenomenon of eutrophication of lakes and reservoirs;
  - ✓ nitrogen can lead to dissolved oxygen consumption in the receiving water body due to the processes of the conversion of ammonia to nitrite and this nitrite to nitrate;
  - ✓ nitrogen in the form of free ammonia is directly toxic to fish;
  - ✓ nitrogen in the form of nitrate is associated with illnesses such as methaemoglobinaemia

➢ **Sewage treatment**

  - ✓ nitrogen is an essential nutrient for the microorganisms responsible for sewage treatment;
  - ✓ nitrogen, in the processes of the conversion of ammonia to nitrite and nitrite to nitrate (nitrification), which can occur in a WWTP, leads to oxygen and alkalinity consumption;
  - ✓ nitrogen in the process of the conversion of nitrate to nitrogen gas (denitrification), which can take place in a WWTP, leads to (a) the economy of oxygen and alkalinity (when occurring in a controlled form) or (b) the deterioration in the settleability of the sludge (when not controlled).

Forms of nitrogen under different conditions

Condition	Prevailing form of nitrogen
Raw wastewater	• Organic nitrogen • Ammonia
Recent pollution in a water course	• Organic nitrogen • Ammonia
Intermediate stage in the pollution of a water course	• Organic nitrogen • Ammonia • Nitrite (in lower concentrations) • Nitrate
Remote pollution in a water course	• Nitrate
Effluent from a treatment process without nitrification	• Ammonia
Effluent from a treatment process with nitrification	• Nitrate
Effluent from a treatment process with nitrification/ denitrification	• Low concentrations of all forms of nitrogen

Note: organic nitrogen + ammonia = TKN (Total Kjeldahl Nitrogen)

TKN can be subdivided in a soluble fraction (dominated by ammonia) and a particulate fraction (associated with the organic suspended solids – nitrogen participates in the constitution of practically all forms of particulate organic matter in sewage).

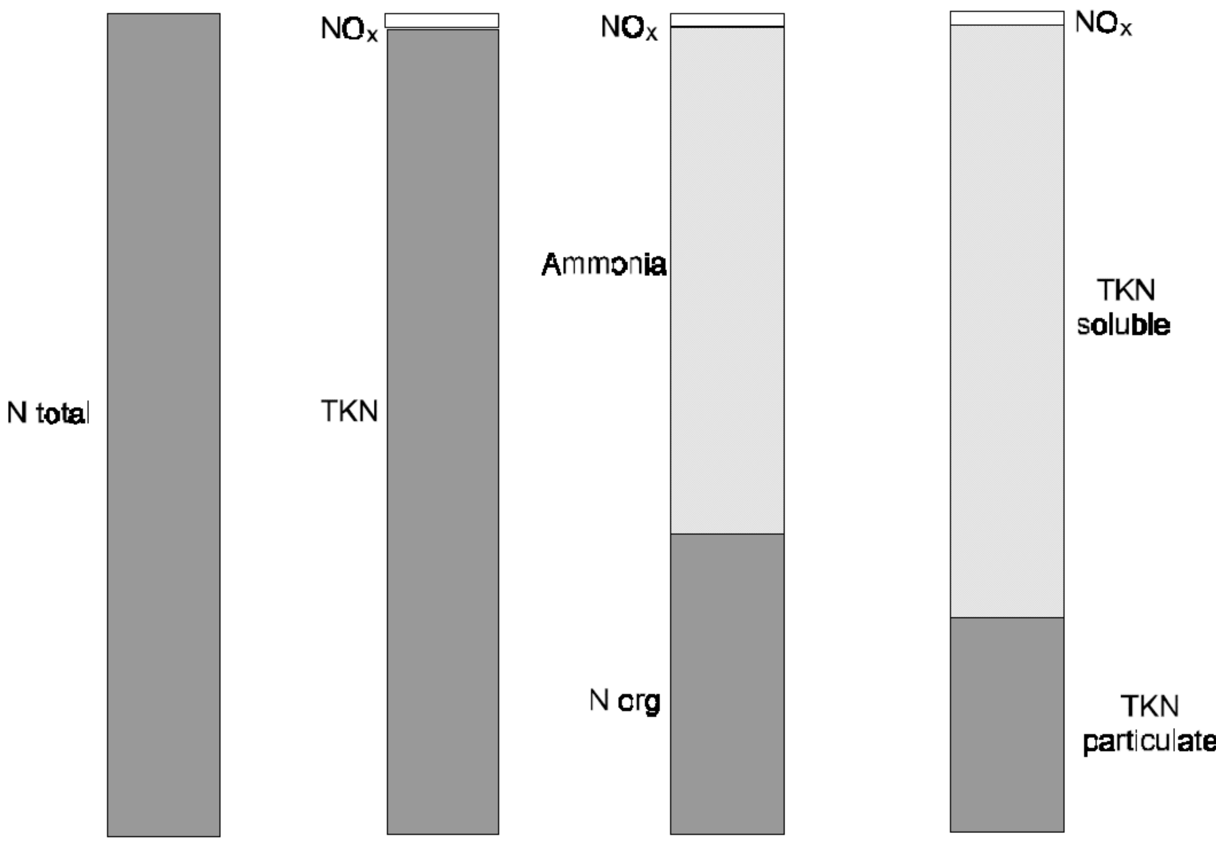
- TKN = ammonia + organic nitrogen *(prevailing form in domestic sewage)*
- $TN = TKN + NO_2^- + NO_3^-$ *(total nitrogen)*

In a watercourse or in a WWTP, the ammonia can undergo subsequent transformations:

In the process of **nitrification** the ammonia is oxidized to nitrite and the nitrite to nitrate.

In the process of **denitrification** the nitrates are reduced to nitrogen gas.

NITROGEN DISTRIBUTION IN RAW DOMESTIC SEWAGE



- Ammonia exists in solution in the form of the ion (NH_4^+) and in a free form, not ionized (NH_3), according to the following dynamic equilibrium:

$NH_3 + H^+ \leftrightarrow$	NH_4^+
free ammonia	ionised ammonia

- The relative distribution has the following values, as a function of the pH values.

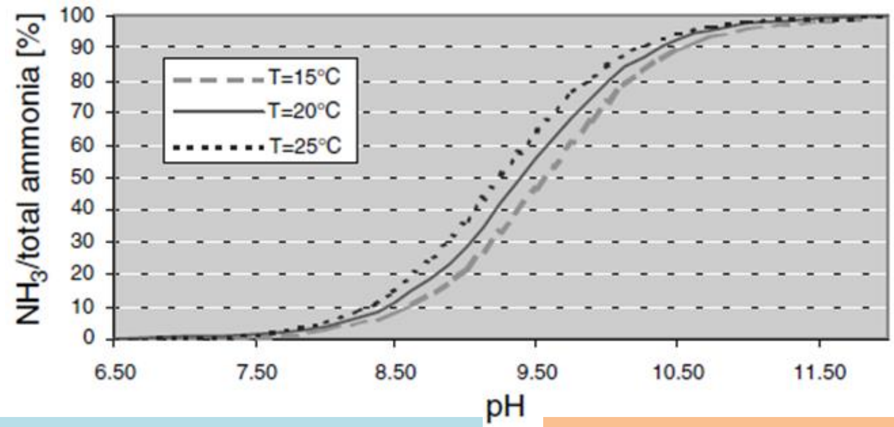
Distribution between the forms of ammonia

- $pH < 8$ Practically all the ammonia is in the form of NH_4^+
- $pH = 9.5$ Approximately 50% NH_3 and 50% NH_4^+
- $pH > 11$ Practically all the ammonia in the form of NH_3

$$\frac{\text{Free } NH_3}{\text{Total ammonia}}(\%) = \left\{1 + 10^{0.09018+[2729.92/(T+273.20)]-pH}\right\}^{-1} \times 100$$

where:

T = liquid temperature (°C)



Phosphorus

- Total phosphorus in domestic sewage is present in the form of phosphates, according to the following distribution:

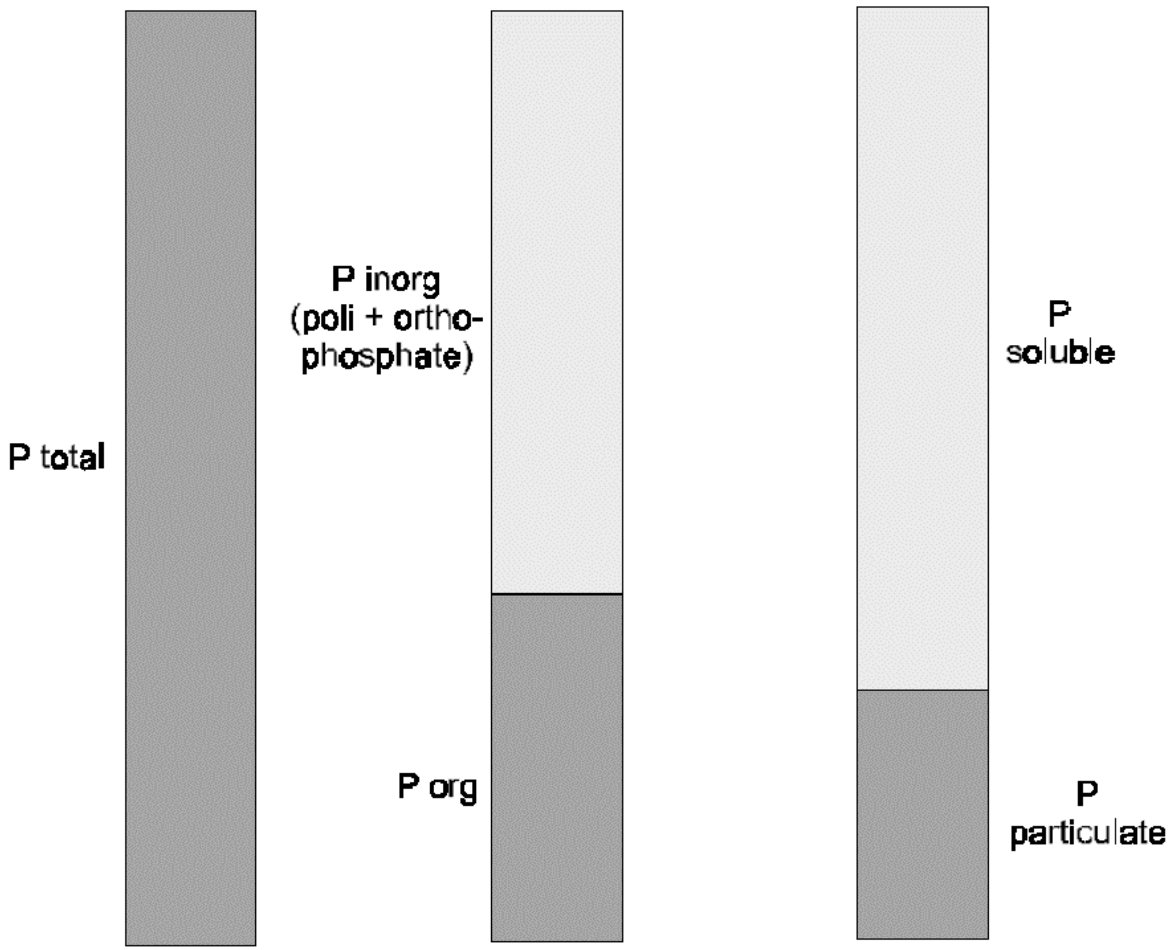
    - **inorganic** (polyphosphates and orthophosphates) – main source from detergents and other household chemical products.
    - **organic** (bound to organic compounds) – physiological origin.

  - Phosphorus in detergents is present, in raw sewage, in the form of soluble polyphosphates or, after hydrolysis, as orthophosphates.
  - Orthophosphates are directly available for biological metabolism without requiring conversion to simpler forms.
  - The forms in which orthophosphates are present in the water are pH dependent, and include PO_4^{3-}, HPO_4^{2-}, $H_2PO_4^-$, H_3PO_4.

- Another way of fractionating phosphorus in wastewater is with respect to its form as solids:

  - **soluble phosphorus** (predominantly inorganic) – mainly polyphosphates and orthophosphates (inorganic phosphorus), together with a small fraction corresponding to the phosphorus bound to the soluble organic matter in the wastewater
  - **particulate phosphorus** (all organic) – bound to particulate organic matter in the wastewater

DISTRIBUTION OF PHOSPHORUS IN RAW SEWAGE



Physical–chemical characteristics of raw domestic sewage

	Per capita load (g/inhab.d)		Concentration (mg/L, except pH)	
Parameter	Range	Typical	Range	Typical
TOTAL SOLIDS	120–220	180	700–1350	1100
Suspended	35–70	60	200–450	350
• *Fixed*	7–14	10	40–100	80
• *Volatile*	25–60	50	165–350	320
Dissolved	85–150	120	500–900	700
• *Fixed*	50–90	70	300–550	400
• *Volatile*	35–60	50	200–350	300
Settleable	–	–	10–20	15
ORGANIC MATTER				
BOD_5	40–60	50	250–400	300
COD	80–120	100	450–800	600
BOD ultimate	60–90	75	350–600	450
TOTAL NITROGEN	6.0–10.0	8.0	35–60	45
Organic nitrogen	2.5–4.0	3.5	15–25	20
Ammonia	3.5–6.0	4.5	20–35	25
Nitrite	≈ 0	≈ 0	≈ 0	≈ 0
Nitrate	0.0–0.3	≈ 0	0–2	≈ 0
PHOSPHORUS	0.7–2.5	1.0	4–15	7
Organic phosphorus	0.7–1.0	0.3	1–6	2
Inorganic phosphorus	0.5–1.5	0.7	3–9	5
pH	-	-	6.7–8.0	7.0
ALKALINITY	20–40	30	100–250	200
HEAVY METALS	≈ 0	≈ 0	≈ 0	≈ 0
TOXIC ORGANICS	≈ 0	≈ 0	≈ 0	≈ 0

Sources: Arceivala (1981), Jordão & Pessoa (1995), Qasim (1985), Metcalf & Eddy (1991), Cavalcanti et al (2001) and the author's experience.

Characteristics of industrial wastewater

- The generalization of typical industrial wastewater characteristics is difficult because of their wide variability from time to time and from industry to industry.

The following concepts are important in terms of the biological treatment of industrial wastewater:

- **Biodegradability:** capacity of the wastewater to be stabilized through biochemical processes by microorganisms.
- **Treatability:** suitability of the waste to be treated by conventional or existing biological processes.
- **Biodegradable organic matter concentration:** BOD of the wastewater, which can be: (a) higher than in domestic sewage (predominantly biodegradable organic wastewater, treatable through biological processes), or (b) lower than in domestic sewage (predominately inorganic or unbiodegradable wastewater, in which there is less need for BOD removal, but in which the pollution load can be expressed in terms of other quality parameters).
- **Nutrient availability:** biological wastewater treatment requires a balanced equilibrium between the nutrients C:N:P. This equilibrium is usually found in domestic sewage.
- **Toxicity:** certain industrial wastewaters have toxic or inhibitory constituents that can affect or render biological treatment unfeasible.

Pollutants of importance in industrial wastewaters

- Industrial effluents, depending on the type of the industrial process, can contain in greater or lesser degrees, the various pollutants:

a) Metals: the main implications of metals are:

- Toxicity to human beings and other forms of plant or animal life, as a result of the discharge or disposal of wastewaters to receiving water bodies or land.
- Inhibition to the microorganisms responsible for the biological treatment of wastewater.

- Heavy metals can be understood as those that, under certain concentrations and exposure time, offer risks to human health and the environment, impairing the activity of living organisms, including those responsible for the biological treatment of wastewater.

- The main chemical elements that fit into this category are: Ag, As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Se and Zn. These elements may be naturally found in soils or waters in variable concentrations, but lower than those ones considered toxic to different living organisms. Among these, As, Co, Cr, Cu, Se and Zn are essential to organisms in certain small quantities, while others have no function in biological metabolism, being toxic to plants and animals.

Sources of contamination and the effects on human health by metals

Metal	Sources of contamination	Effects on health
Cadmium	Refined flours, cigarettes, odontological materials, steel industry, industrial gaseous effluents, fertilisers, pesticides, fungicides, coffee and tea treated with agrotoxics, ceramics, seafood, bone meal, welding, casting and refining of metals such as zinc, lead and copper. Cadmium derivatives are used in pigments and paintings, batteries, electroplating processes, accumulators, PVC stabilisers, nuclear reactors.	Carcinogenic, causes blood pressure rise and heart swelling. Immunity decreases. Prostate growth. Bone weakening. Joint pains. Anaemia. Pulmonary emphysema. Osteoporosis. Smell loss. Decrease in sexual performance.
Lead	Car batteries, paints, fuels, plants treated with agrotoxics, bovine liver, canned foods, cigarettes, pesticides, hair paint, lead-containing gas, newsprint and colour advertisements, fertilisers, cosmetics, air pollution.	Irritability and aggressiveness, indisposition, migraines, convulsions, fatigue, gum bleed, abdominal pains, nausea, muscular weakness, loss of memory, sleeplessness, nightmares, unspecific vascular cerebral accident, alterations of intelligence, osteoporosis, kidney illnesses, anaemia, coagulation problems. It affects the digestive and reproductive system and is a teratogenic agent (causes genetic mutation).
Mercury	Thermometers, pesticides and agrotoxics, dental alloy, water, mining, polishers, waxes, jewels, paints, sugar, contaminated tomato and fish, explosives, mercury fluorescent lamps, cosmetic products, production and delivery of petroleum by-products, salt electrolysis cells for chlorine production.	Depressive illness, fatigue, tremors, panic syndrome, paresthesias, lack of motor control, side walking, speech difficulties, loss of memory, loss of sexual performance, stomatitis, loose teeth, pain and paralysis in the edges, headache, anorexia in children, hallucination, vomiting, mastication difficulties, sweating, and pain sense loss.

Metal	Sources of contamination	Effects on health
Arsenic	Fuel oil, pesticides and herbicides, metallurgy, sea plants and animals.	Gastrointestinal disturbances, muscular and visceral spasms, nausea, diarrhoea, inflammation of mouth and throat, abdominal pains.
Aluminium	Water, processed cheese, white wheat flour, aluminium kitchenware, cosmetics, anti-acids, pesticides and antiperspirant, baker's yeast, salt.	Intestinal constipation, loss of energy, abdominal colics, infantile hyperactivity, loss of memory, learning difficulties, osteoporosis, rickets and convulsions. Related diseases: Alzheimer's and Parkinson's.
Barium	Polluted water, agrotoxics, pesticides and fertilisers.	Arterial hypertension, cardiovascular diseases, fatigue and discouragement.

Sources: http://www.rossetti.eti.br; http://www.greenpeace.org.br

Metal	Sources of contamination	Effects on health
Nickel	Kitchenware, nickel–cadmium batteries, jewels, cosmetics, hydrogenated oils, pottery works, cold permanent wave, welding.	Carcinogenic, may cause: contact dermatitis, gingivitis, skin rash, stomatitis, dizziness, joint pains, osteoporosis and chronic fatigue.
Zinc	Metallurgy (casting and refining), lead recycling industries.	Sense of sweetish taste and dryness in the throat, cough, weakness, panalgia, shivering, fever, nausea, vomiting.
Chromium	Leather tanning, electroplating.	Dermatitis, cutaneous ulcers, nose inflammation, lung cancer and perforation in the nose septum.

b) Toxic and dangerous organic compounds:

- Toxic and dangerous organic compounds, even though they usually do not represent a concern in domestic sewage, may be of concern in municipal wastewaters that receive industrial effluents.

- When wastewaters containing toxic organic compounds are disposed of in the receiving water body without adequate treatment, severe damage may occur, both to the aquatic life and to human beings, who use it as a source of water supply.

- Most of these compounds are very slowly biodegraded, persisting in the environment for a long period.

- These compounds are able to penetrate the food chain and, even if they are not detectable in the receiving body, they may be present in large quantities in the higher trophic levels, owing to their bioaccumulation characteristics.

- Besides, since wastewaters have a complex composition and normally contain more than one organic pollutant, synergistic effects may take place (the combined effect may be higher than the sum of the individually exerted effects).

- Several dangerous pollutants are volatile because of their low solubility, low molecular weight and high vapor pressure. Therefore, they may be transferred to the atmosphere in open units in the WWTP, such as aeration tanks, equalization tanks and clarifiers, and also pumping stations. If adequate control means are not taken, their volatilization represents a potential health risk to the population and workers who are frequently exposed to it.

- The structural integrity of the sewerage collection system is also affected, because many compounds are corrosive, inflammable and explosive (methanol, methyl-ethylketone, hexane, benzene, among others).

- Other pollutants are adsorbed and concentrated in the biological flocs in the treatment process, and might cause inhibition to sludge digestion or generate sludge with dangerous characteristics which, if not adequately disposed of, could contaminate groundwater.

- Consequently, the treatment plant effluent may still contain these pollutants and, when discharged into the receiving body, may cause damages to the aquatic life and human beings.

- **The main sources of organic compounds are:**

- Chemical and plastic industries,
- mechanical products,
- pharmaceutical industries,
- pesticide formulation,
- cast houses and steel industries,
- oil industry,
- laundries and lumber industries.

- **The most commonly found organic pollutants in industrial effluents are:**

Phenol, methyl chloride, 1,1,1-trichloroethane, toluene, ethyl benzene, trichloroethylene, tetrachloroethylene, chloroform, bis-2-ethyl-hexyl phthalate, 2,4-dimethyl phenol, naphthalene, butylbenzylphthalate, acrolein, xylene, cresol, acetophenone, methyl-sobutyl-acetone, diphenylamine, aniline and ethyl acetate.

Relationship between load and concentration

- **Per capita load** represents the average contribution of each individual (expressed in terms of pollutant mass) per unit time.

- A commonly used unit is grams per inhabitant per day (g/inhab.d).
- For example, when the BOD contribution is 54 g/inhab.d, it is equivalent to saying that every individual discharges 54 grams of BOD on average, per day.
- The influent load to a WWTP corresponds to the quantity of pollutant (mass) per unit time.

In this way, import relations are

$$\text{load (kg/d)} = \frac{\text{population (inhab)} \times \text{per capita load (g/inhab.d)}}{1000\,\text{(g/kg)}}$$

or

$$\boxed{\textbf{load} = \textbf{concentration} \times \textbf{flow}}$$

$$\text{load (kg/d)} = \frac{\text{concentration (g/m}^3\text{)} \times \text{flow (m}^3\text{/d)}}{1000\,\text{(g/kg)}}$$

Note: $g/m^3 = mg/L$

- **The concentration** of a wastewater can be obtained through the rearrangement of the same dimensional relations:

$$\boxed{\textbf{concentration} = \textbf{load/flow}}$$

$$\text{concentration (g/m}^3\text{)} = \frac{\text{load (kg/d)} \times 1000 \text{ (g/kg)}}{\text{flow (m}^3\text{/d)}}$$

Example

Calculate the total nitrogen load in the influent to a WWTP, given that:

- concentration = 45 mgN/L
- flow = 50 L/s

Solution:

Expressing flow in m^3/d, :

$$Q = \frac{50\ \text{L/s} \times 86400\ \text{s/d}}{1000\ \text{L/m}^3}$$

The nitrogen load is:

$$\text{load} = \frac{45\ \text{g/m}^3 \times 4320\ \text{m}^3\text{/d}}{1000\ \text{g/kg}} = 194\ \text{kgN/d}$$

b) In the same works, calculate the total phosphorus concentration in the influent, given that the influent load is 40 kgP/d.

$$\text{concentration} = \frac{40\ \text{kg/d} \times 1000\ \text{g/kg}}{4320\ \text{m}^3\text{/d}} = 9.3\ \text{gP/m}^3 = 9.3\ \text{mgP/L}$$

Population equivalent

- Population equivalent (PE) is an important parameter for characterizing industrial wastewaters.
- PE reflects the equivalence between the polluting potential of an industry (commonly in terms of biodegradable organic matter) and a certain population, which produces the same polluting load.
- For instance, when an industry is said to have a population equivalent of 20,000 habitants, it is the equivalent to saying that the BOD load of the industrial effluent corresponds to the load generated by a community with a population of 20,000 inhabitants.

- The formula for the calculation of population equivalent based on BOD is:

$$\text{PE (population equivalent)} = \frac{\text{BOD load from industry (kg/d)}}{\text{per capita BOD load (kg/inhab.d)}}$$

- In the case of adopting the value frequently used in the international literature for the per capita BOD load of 54 gBOD/inhab.d, PE may be calculated by:

$$\text{PE (population equivalent)} = \frac{\text{BOD load from industry (kg/d)}}{0.054 \text{ (kg/inhab.d)}}$$

Example

Calculate the Population Equivalent (PE) of an industry that has the following data:

- flow = 120 m^3/d
- BOD concentration = 2000 mg/L

Solution:

The BOD load is:

$$\text{load} = \text{flow} \times \text{concentration} = \frac{120\ \text{m}^3/\text{d} \times 2000\ \text{g/m}^3}{1000\ \text{g/kg}} = 240\ \text{kgBOD/d}$$

The Population Equivalent is:

$$\text{PE} = \frac{\text{load}}{\text{per capita load}} = \frac{240\ \text{kg/d}}{0.054\ \text{kg/hab.d}} = 4{,}444\ \text{inhab}$$

Thus, the wastewater from this industry has a polluting potential (in terms of BOD) equivalent to a population of 4,444 inhabitants.

Characteristics of the wastewater from some industries

Type	Activity	Unit of production	Specific wastewater flow (m^3/unit)	Specific BOD load (kg/unit)	BOD population equivalent [inhab/(unit/d)]	BOD concentration (mg/L)
Food	Canning (fruit/vegetables)	1 t processed	4–50	30	500	600–7,500
	Pea processing	1 t processed	13–18	16–20	85–400	300–1,350
	Tomato processing	1 t processed	4–8	1–4	50–185	450–1,600
	Carrot processing	1 t processed	11	18	160–390	800–1,900
	Potato processing	1 t processed	7.5–16	10–25	215–545	1,300–3,300
	Citrus fruit processing	1 t processed	9	3	55	320
	Chicken meat processing	1 t produced	15–60	4–30	70–1600	100–2400
	Beef processing	1 t processed	10–16	1–24	20–600	200–6,000
	Fish processing	1 t processed	5–35	3–55	300–2300	2,700–3,500
	Sweets / candies	1 t produced	5–25	2–8	40–150	200–1,000
	Sugar cane	1 t produced	0.5–10	2.5	50	250–5,000
	Dairy (without cheese)	1000 L milk	1–10	1–5	20–100	300–5,000
	Dairy (with cheese)	1000 L milk	2–10	5–40	100–800	500–8,000
	Margarine	1 t produced	20	30	500	1,500
	Slaughter house	1 cow / 2.5 pigs	0.5–3	0.5–5	10–100	1,000–5,000
	Yeast production	1 t produced	150	1100	21,000	7,500
Confined animal breeding	Pigs	live t.d	0.2	2	35–100	10,000–50,000
	Dairy cattle (milking room)	live t.d	0.02–0.08	0.05–0.10	1–2	370–2,300
	Cattle	live t.d	0.15	1.6	65–150	10,000–50,000
	Horses	live t.d	0.15	4–8	65–150	20,000–50,000
	Poultry	live t.d	0.38	0.9	15–20	2,000–3,000
Sugar–alcohol	Alcohol distillation	1 t cane processed	60	220	4,000	3,500
Drinks	Brewery	1 m^3 produced	5–20	8–20	150–350	500–4,000
	Soft drinks	1 m^3 produced	2–5	3–6	50–100	600–2,000
	Wine	1 m^3 produced	5	0.25	5	–

Type	Activity	Unit of production	Specific wastewater flow (m^3/unit)	Specific BOD load (kg/unit)	BOD population equivalent [inhab/(unit/d)]	BOD concentration (mg/L)
Textiles	Cotton	1 t produced	120–750	150	2,800	200–1,500
	Wool	1 t produced	500–600	300	5,600	500–600
	Rayon	1 t produced	25–60	30	550	500–1,200
	Nylon	1 t produced	100–150	45	800	350
	Polyester	1 t produced	60–130	185	3,700	1,500–3,000
	Wool washing	1 t produced	20–70	100–250	2,000–4,500	2,000–5,000
	Dyeing	1 t produced	20–60	100–200	2,000–3,500	2,000–5,000
	Textile bleaching	1 t produced	–	16	250–350	250–300
Leather and tanneries	Tanning	1 t hide processed	20–40	20–150	1,000–3,500	1,000–4,000
	Shoes	1000 pairs produced	5	15	300	3,000
Pulp and paper	Pulp	1 t produced	15–200	30	600	300
	Paper	1 t produced	30–270	10	100–300	
	Pulp and paper integrated	1 t produced	200–250	60–500	1,000–10,000	300–10,000
Chemical industry	Paint	1 employee	0.110	1	20	10
	Soap	1 t produced	25–200	50	1000	250–2,000
	Petroleum refinery	1 barrel (117 L)	0.2–0.4	0.05	1	120–250
	PVC	1 t produced	12.5	10	200	800
Non-metallic industry	Glass and by-products	1 t produced	50	–	–	–
	Cement (dry process)	1 t produced	5	–	–	–
Steelworks	Foundry	1 t pig iron produced	3–8	0.6–1.6	12–30	100–300
	Lamination	1 t produced	8–50	0.4–2.7	8–50	30–200

Note: data not filled in (-) means non-significant data or data not obtained; t = metric ton (1000 kg)
In various cases the water consumption is considered equal to the wastewater flow produced
Sources: CETESB (1976), Braile and Cavalcanti (1977), Arceivala (1981), Hosang & Bischof (1984), Salvador (1991), Wentzel (without date), Mattos (1998)

Example

A slaughterhouse processes 30 heads of cattle, Estimate the characteristics of the effluent. Adopting an average value of 3.0 kgBOD/cattle slaughtered

a) BOD load produced

$$-\text{cows: } \frac{3\text{ kgBOD}}{\text{cow}} . \frac{30\text{ cow}}{\text{d}} = 90\text{ kgDBO/d}$$

b) Population Equivalent (PE)

$$\text{PE} = \frac{\text{BODload}}{\text{per capita BODload}} = \frac{90\text{ kgDBO/d}}{0.054\text{ kgDBO/inhab.d}} =$$ **1.777 Inhab**

c) Wastewater flow

adopting an average value of 2.0 m^3/cattle slaughtered (or for 2.5 pigs slaughtered):

$$-\text{cows: } \frac{2.0\text{ m}^3}{\text{cow}} . \frac{30\text{ cow}}{\text{d}} = 60\text{ m}^3/\text{d}$$

d) BOD concentration in the wastewater

$$\text{concentration} = \frac{\text{load}}{\text{flow}} = \frac{90\text{ kgDBO/d}}{100\text{ m}^3/\text{d}} .1000\text{ g/kg} = 1{,}500\text{ g/m}^3$$

$$= 1{,}500\text{ mg/L}$$