CE 370

Wastewater Characteristics

Quality

1

Wastewater Quality

- The degree of treatment depends on:
  - Influent characteristics
  - Effluent characteristics
- Impurities come from:
  - Domestic activities
  - Industrial activities
  - Commercial activities
- Typical characteristics are shown in the following Table

2

Constituents	Concentration		
	Strong	Medium	Weak
Total Solids	1250	800	450
TDS	890	560	350
TSS	360	240	100
Settleable Solids (ml/l)	7	5	3
BOD_5	400	200	100
TOC	290	145	75
COD	910	455	230
Total Nitrogen	75	40	16
Organic Nitrogen	40	20	8
Ammonia	35	20	8
Total Phosphorous	15	8	4
Organic Phosphorous	5	3	1
Inorganic Phosphorous	10	5	3
Chlorides	83	42	21
Alkalinity ($CaCO_3$)	200	100	50
Grease	40	20	5

3

Wastewater Quality Characteristics

- The wastewater quality characteristics may be classified according to the following:
  - **Physical**
    - Turbidity, Color, Oder, Total solids, Temperature
  - **Chemical**
    - COD, TOC, Nitrogen, Phosphorus, Chlorides, Sulfates, Alkalinity, pH, Heavy metals, trace elements, and Priority pollutants.
  - **Biological**
    - BOD, Oxygen required for nitrification, and Microbial population.

4

Physical Characteristics

- Turbidity
  - Caused by the presence of organic suspended solids
- Color
  - Has a light tan color if fresh (2 to 6 hours old)
  - Grey if older than 6 hours due to biochemical oxidation in collection system
  - Dark grey or black if undergone extreme biochemical oxidation under anaerobic conditions (production of sulfides, particularly ferrous sulfide)
  - Hydrogen sulfide is produced under anaerobic condition, which reacts with ferrous ions and produce ferrous sulfide (black color)

5

Physical Characteristics

- Odor
  - Soapy or oily odor if fresh (not offensive)
  - Stale, very offensive, if undergone extreme anaerobic biochemical oxidation, due to production of compounds such as hydrogen sulfide
- Total solids
  - Suspended
  - dissolved
  - Volatile (evaporate at 550° C)
  - Fixed (remain after ignition)
  - settleable

6

Physical Characteristics

- Temperature
  - Higher than that of water supply
  - Important parameter, particularly for biological processes

Physical characteristics of industrial wastewater vary depending on the type of industry.

7

Chemical Characteristics

- Chemical Oxygen Demand (COD)
  - A measure of organic materials in a wastewater in terms of the oxygen required to oxidize the organic materials chemically.

- Total Organic Carbon (TOC)
  - Is a measure of organic materials (based on measurement of carbon in the organic materials by combustion and measurement of CO_2 evolves)

8

Chemical Characteristics

- Nitrogen
  - **Organic Nitrogen**: The amount of nitrogen present in organic compounds, such as protein and urea.
  - **Ammonia nitrogen** (NH_3/NH_4^+)
  - **Nitrite nitrogen** (NO_2^-)
  - **Nitrate nitrogen** (NO_3^-)
- Phosphorous
  - **Organic Phosphorous** (in protein)
  - **Inorganic phosphorous** (phosphates, PO_4^-)
- Chlorides (Cl^-)
- Sulfates (SO_4^{-2})

9

Chemical Characteristics

- Grease
  - (interferes with oxygen transfer in activated sludge processes)
- Heavy metals such as
  - Mercury (Hg)
  - Arsenic (As)
  - Lead (Pb)
  - Zinc (Zn)
  - Cadmium (Cd)
  - Copper (Cu)
  - Nickel (Ni)
  - Chromium (Cr)
  - Silver (Ag)

10

Chemical Characteristics

- Priority Pollutants (organic and inorganic) are:
  - Carcinogenic
  - Mutagenic
  - High acute toxic

11

Biological Characteristics

- Biochemical Oxygen Demand (BOD_5)
  - The amount of oxygen needed to stabilize organic matter by micro-organisms
    - Time (5 days)
    - Temperature (20° C)
- Nitrogenous Oxygen Demand
  - The amount of oxygen needed to convert organic and ammonia nitrogen to nitrates by nitrifying bacteria

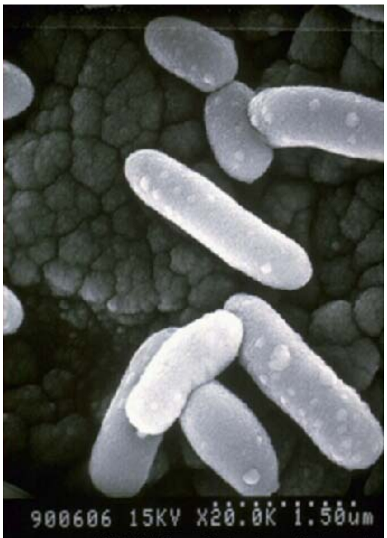
12

Wastewater Microbial Life

- Wastewater contains
  - Bacteria
  - Protozoa
  - Fungi
  - Viruses
  - Algae
  - Rotifers
  - nematodes
- Sources
  - Soil (through infiltration)
  - Human intestines

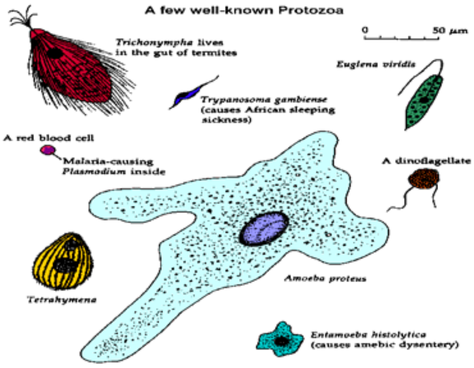
13

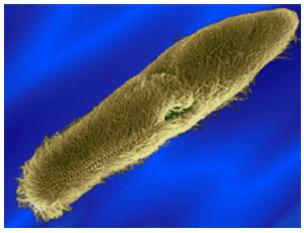
Wastewater Microbial Life _ Bacteria

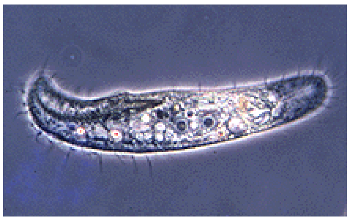


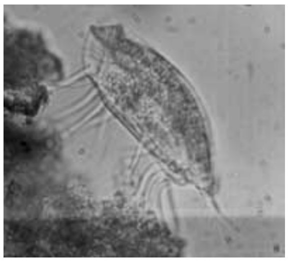
14

Wastewater Microbial Life _ Protozoa

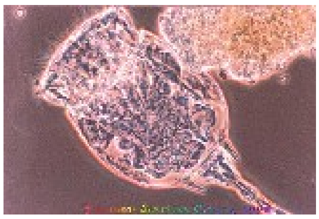


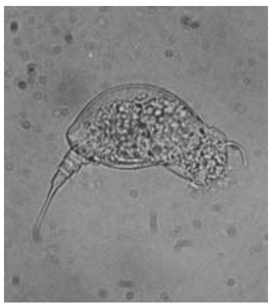






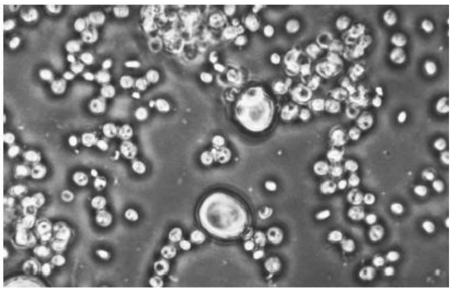
Wastewater Microbial Life _ rotifers

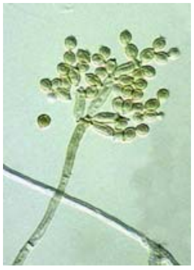


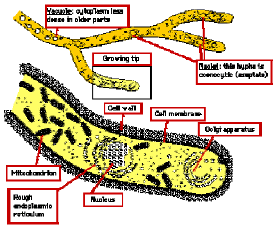


16

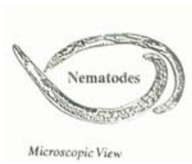
Wastewater Microbial Life _ Fungi

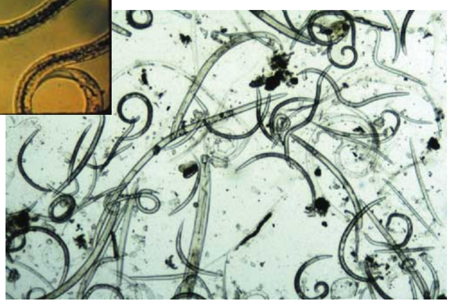






Wastewater Microbial Life _ Nematodes





Measurement of Waste Organic Material

- The measurement of the concentration of waste organic materials in a wastewater is important in the design of the treatment plant and in the control of its operation. Following are the different tests used to measure organic waste:
  - Biochemical Oxygen Demand (BOD)
  - Chemical Oxygen Demand (COD)
  - Total Organic Carbon (TOC)

19

Biochemical Oxygen Demand (BOD)

- Definition
  - Microorganisms oxidize (feed on) organic material and while doing so, they consume dissolved oxygen (DO).
  - BOD is a measure of the DO required for the utilization of organic matter as food by the aerobic microorganisms.
  - BOD is measured by DO determination before and after an incubation period of 5 days at 20°C
- BOD is conducted under aerobic conditions

$$Organics + O_2 \xrightarrow[\text{microbes}]{\text{Aerobic}} CO_2 + H_2O + NH_3 + new\,cells$$

20

Biochemical Oxygen Demand

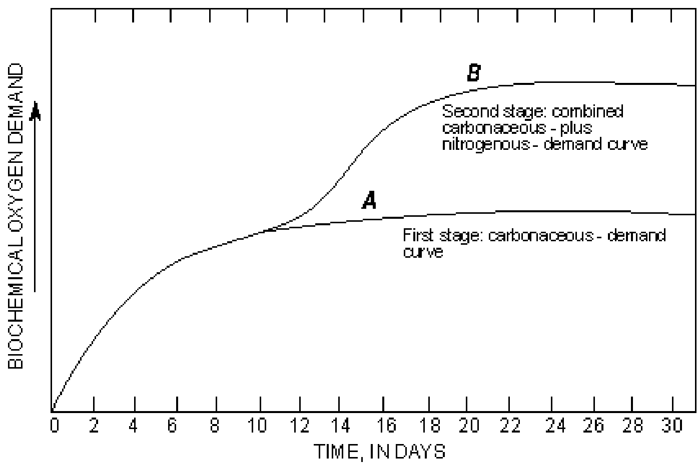
- After 10 to 12 days, the NH_3 will be oxidized to nitrite and then nitrate

$$2NH_3 + 3O_2 \xrightarrow[(Nitrosomonas)]{\substack{Nitrite\\bacteria}} 2NO_2^- + 2H^+ + H_2O + new\ cells$$

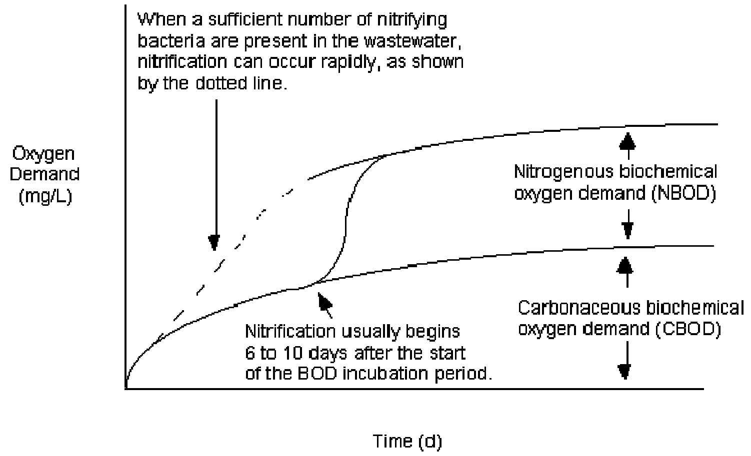
$$2NO_2^- + O_2 + 2H^+ \xrightarrow[(Nitrobacter)]{\substack{Nitrate\\bacteria}} 2NO_3^- + 2H^+ + new\ cells$$

- The next two Figures show:
  - the BOD curve for both stages
  - Carbonaceous stage

21



22



Carbonaceous Stage

- Removal of organic matter is a first-order reaction

$$-\frac{dC}{dt} = kC$$

- dC/dt = rate of removal of organic matter
- k = rate constant to the base e
- C = concentration of organic matter remaining at time (t)

Carbonaceous Stage

- Rearrange and integrate the equation

$$\int_{C_0}^{C} \frac{dC}{C} = -k \int_{0}^{t} dt$$

$$\ln C \,]_{C_0}^{C} = -kt$$

$$\frac{C}{C_0} = e^{-kt}$$

  - C_0 = concentration of organic matter initially
  - C = oxidizable organic matter remaining at time (t)
  - t = test duration

Carbonaceous Stage

- Since the amount of organic matter oxidized is proportional to the amount of oxygen required, then:
  - $C \propto L$ (where L is the BOD remaining at time t)
  - Similarly $C_0 \propto L_0$
- Then,

$$\frac{L}{L_0} = e^{-k_1 t} = 10^{-K_1 t}$$

  - L = BOD remaining at time t
  - L_0 = ultimate first-stage or carbonaceous BOD
  - k_1 = rate constant to the base e
  - t = test duration
  - K_1 = rate constant to the base 10

Carbonaceous Stage

- Thus:

$$L = L_0 e^{-k_1 t}$$
$$and$$
$$L = L_0 10^{-K_1 t}$$

- So, BOD exerted (y) up to time (t) is:

$$y = L_0 - L_0 e^{-k_1 t} = L_0 (1 - e^{-k_1 t})$$
$$or$$
$$y = L_0 - L_0 10^{-K_1 t} = L_0 (1 - 10^{-K_1 t})$$

Example

Example

A wastewater has a BOD_5 of 200 mg/l, and the k_1 value is 0.34 day^{-1}. Determine the ultimate first-state BOD, L_0.

Solution

$y = L_0 (1 - e^{-k1t})$

$200 = L_0 [1 - e^{-(0.34)(5)}]$

Thus, L_0 = 245 mg/l