WATER AND WASTEWATER TREATMENT

C9 1B

TITLE: WASTEWATER TREATMENT

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Strength and Quantities of Wastewater

Size of Wastewater treatment Works depends on:

1. ***Strength of wastewater***
2. ***Rate of flow to be treated***

1. Strength of Wastewater

Oxygen Demand in Aerobic Oxidation

Organic compounds are generally unstable and may be oxidised biologically or chemically to stable, relatively inert end products such as CO_2, NO_3, H_2O. An indication of the organic content of a waste can be obtained by measuring the amount of oxygen required for its stabilisation using:

Biochemical Oxygen Demand, BOD, - a measure of the oxygen required by micro-organisms whilst breaking down organic matter - results in 5 days.
Typical values Crude sewage 200 mg/l
Final Effluent 20 mg/l

Chemical Oxygen Demand, COD, test measures the amount of oxygen required for chemical oxidation of organic matter in the sample to carbon dioxide and water. It involves an acid oxidation of the waste by potassium dichromate - results in a few hours.
Typical values Crude Sewage 700 mg/l
Final Effluent 90 mg/l

Ultimte Oxygen Demand
Vital that amount of organic matter present is known and the **total quantity of oxygen required** for its stabilisation is determined. Can be calculated on the basis of a complete chemical analysis of the wastewater. -difficult and time consuming.

Most common method relies on combining various characteristics of the wastewater so that :

Ultimate Oxygen Demand = 2.67× Organic carbon + 4.57(Org N +Amm. N) + 1.14× Nitrate N

Where all values are in mg/l

Total Organic Carbon, TOC, measures the organically bound carbon in the sample and is independent of the oxidation stage of the organic matter.
Typical values Crude Sewage 200 mg/l
Final Effluent 30 mg/l

Suspended and Dissolved Solids both organic and inert, refer to matter that is retained and passed through a filter respectively.

Settleable solids are determined by filling a 1 litre conical shaped container, Imhoff Cone, and allowing 1 hour for sedimentation.

Suspended Solids Typical values	Crude Sewage	250 mg/l
	Final Effluent	30 mg/l

Nitrogen and Phosphorous are both nutrients and so nitrogen data will be required to evaluate the treatability of wastewater by biological processes.

Total Nitrogen is comprised of organic nitrogen, ammonia, nitrite and nitrate.

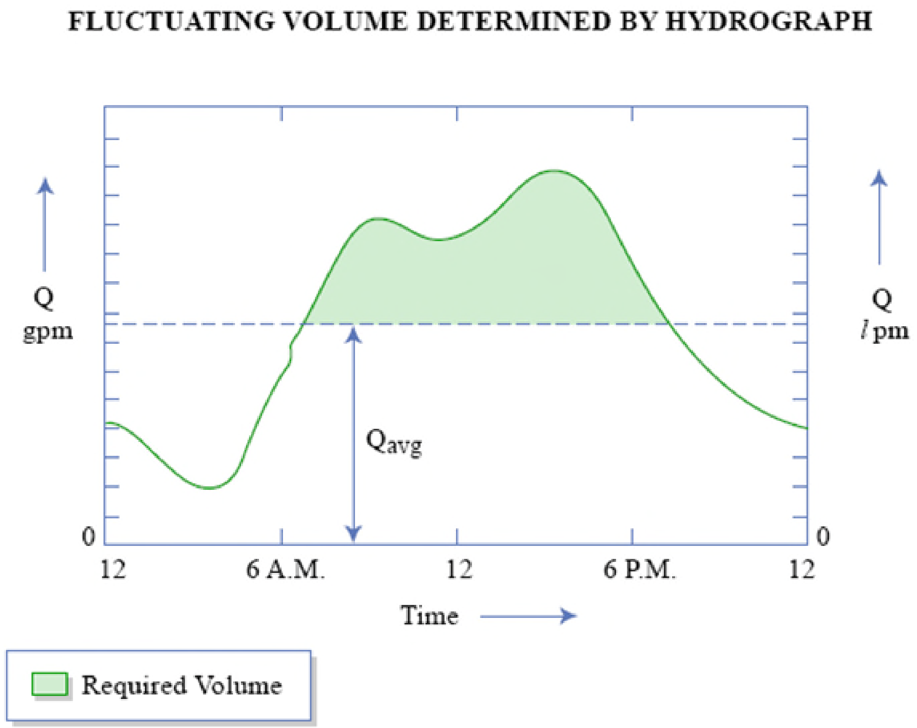
Organic nitrogen is determined by the Kjeldahl method. The sample is first boiled to drive off the ammonia and then is digested. During the digestion, the organic nitrogen is converted to ammonia. **Total Kjeldahl nitrogen** is determined in the same manner as organic nitrogen, except that the ammonia is not driven off before the digestion step. **Kjeldahl nitrogen** is, therefore, the total of the **organic and ammonia nitrogen**.

Typical values Ammonia nitrogen	Crude Sewage	40 mg/l
	Final Effluent	5 mg/l

2. Rate of Flow

Ave rate of flow / day = total flow in a year/ no. of days in the year
Not the same as DWF.
Ave rate of flow used to calculate total quantities of detritus, screenings, sludge, sludge gas. Pumping and power requirements.

DWF- mean rate of flow in dry weather (not more than 2.5mm rain in 24 hours)
Rate of flow and strength of wastewater varies as shown.



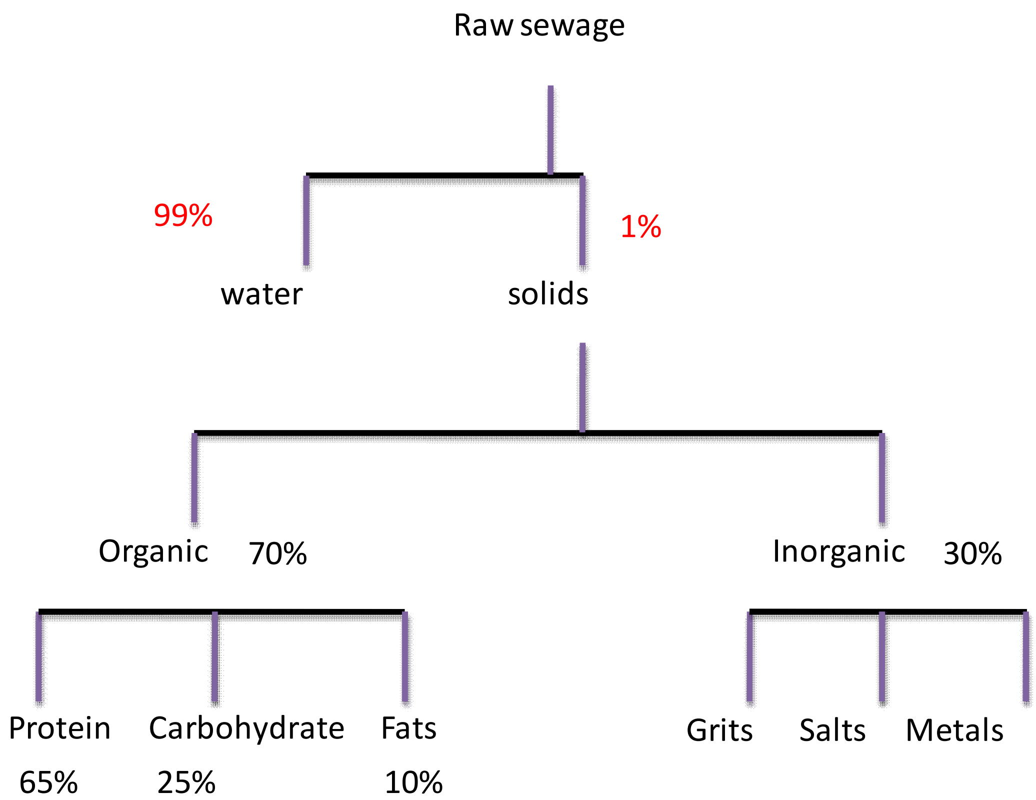
DWF = PG + I + E l/day

Max flow to works = PG + I + 2E + 1360P l/day

Max flow receiving full treatment = 3(PG+E) +I l/day

2. **Composition of Wastewater-**

Domestic wastewater, ground water and industrial effluent. It is 99% water



Domestic wastewater consists of dirty water, soap, detergents, food, urine, faeces and paper. It is a complex mixture of mineral and organic matter including large and small particles of solid matter, both floating and in suspension. It also contains living matter, bacteria, viruses and protozoa and is an excellent medium for the development of bacteria, some of which may be pathogenic.

Methods of Disposal

1. Sea Outfalls

Discharge to sea after preliminary treatment and primary sedimentation

2. Wastewater Treatment Works

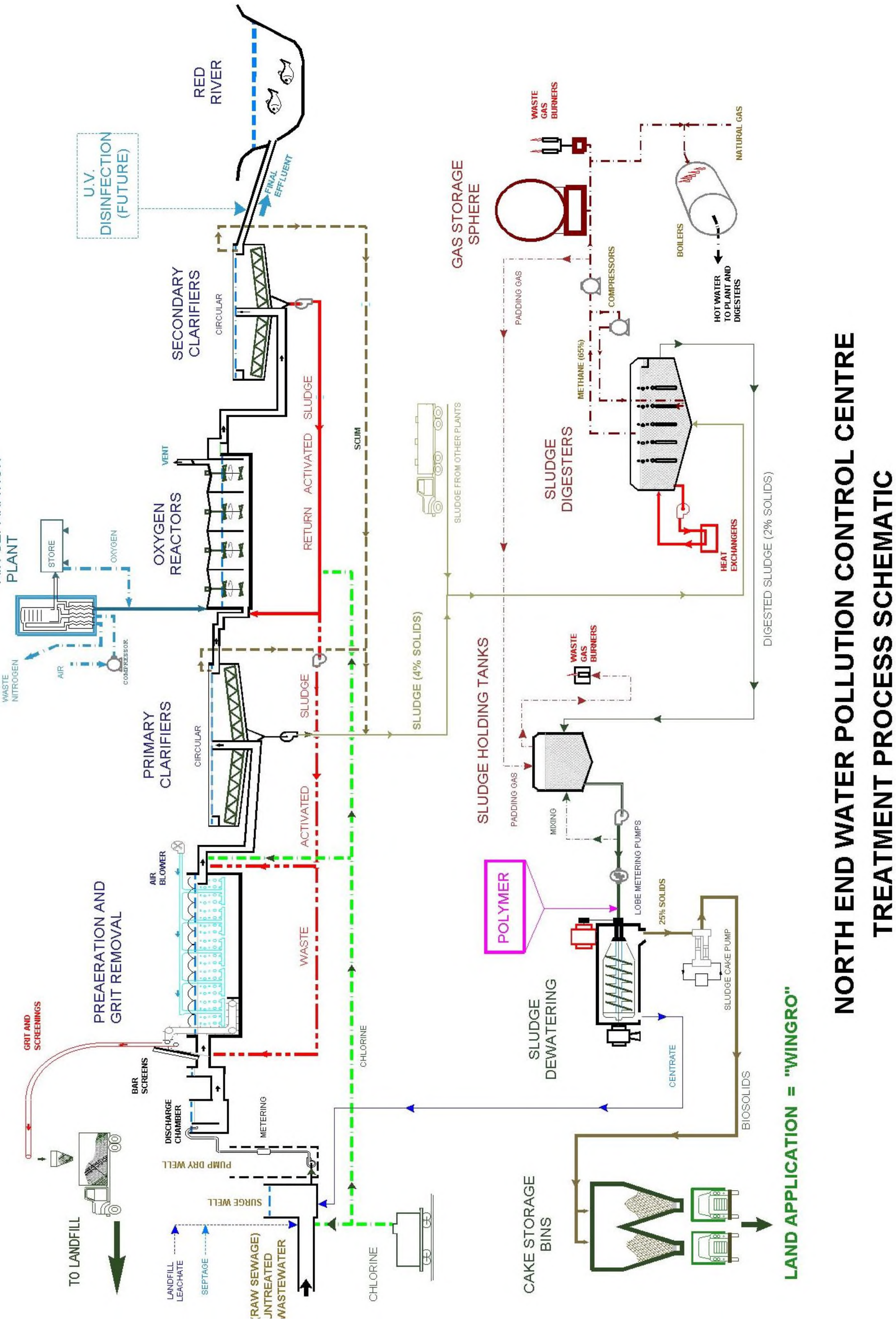
General Considerations

Choice of Site	Adjacent to river or stream to allow effluent to be discharged As low as possible to allow max. length of gravity sewer Away from houses To serve as large an area as possible
Choice of Treatment method	Head available from inlet to outfall Degree of treatment required Area of land available Size of works Extent to which nuisance will be caused Running costs

Types of Treatment

- Percolating Filters
- Activated Sludge
- Rotating Biological Contactors
- Extended Aeration
- Constructed Wetlands

A Wastewater Treatment Process Diagram

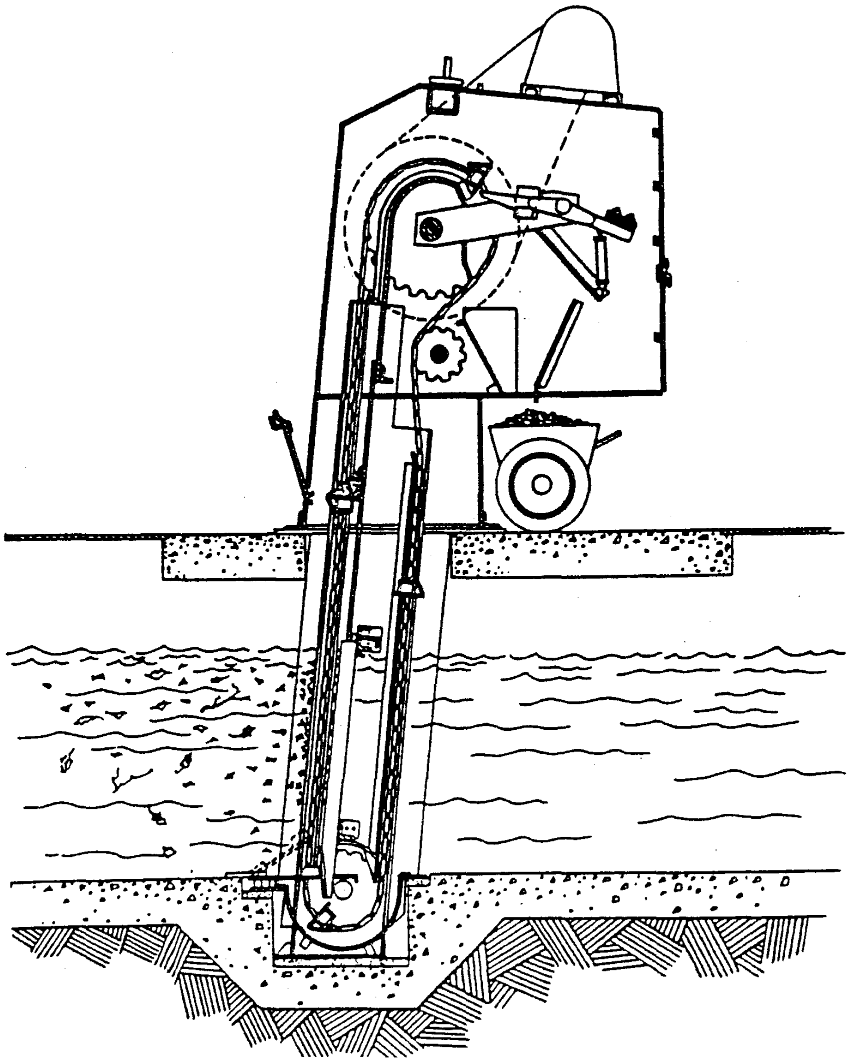


Preliminary Treatment: Screening, Grit Removal

Screening
Used to protect pumps and small pipelines from blockages
Types of screen

1. Hand raked bar screens
Used at small works only where incoming sewer shallow. Bars placed at 45^{o} to the horizontal in small detritus tanks. Cleaned 2 - 3 times a day.

2. Mechanically raked screens
Either vertical for deep sewers or inclined if shallow.
Operation - either clock control (a few minutes every once or twice an hour) or differential float control (floats either side of screen to indicate sewage level which are connected to a drum which moves laterally. When difference in levels reaches 150mm automatically starts raking mechanism).



Mechanically clean bar screen

Size of Screens and Chamber
Detritus must not settle in chamber therefore velocity must reach 0.7 m/s at least once a day.
Velocity through screens restricted

Disposal of screenings
Large works Carried to surface by raking mechanism, washed by wastewater and discharged into small sump, broken into fine particles by disintegrator pump and returned to flow.
Small works Buried on site

3. Comminuters

Combined screen and disintegrator, large head loss.
Installed directly in a flow channel and are provided with a bypass so that the section containing the shredder can be isolated and drained for maintenance. Consists of a revolving slotted drum screen submerged in a flow channel such that the wastewater passes into the drum through slots and is discharged from the bottom of the unit. Solids too large to enter the slots are cut into pieces small enough to pass through. Accumulated solids are shredded and flushed through with wastewater.

Grit removal

Regulate flow such that grit settles but organic matter is kept in suspension.
Designed to remove high density organic and inorganic matter such as sand, gravel, cinders, coffee grounds, egg shells.

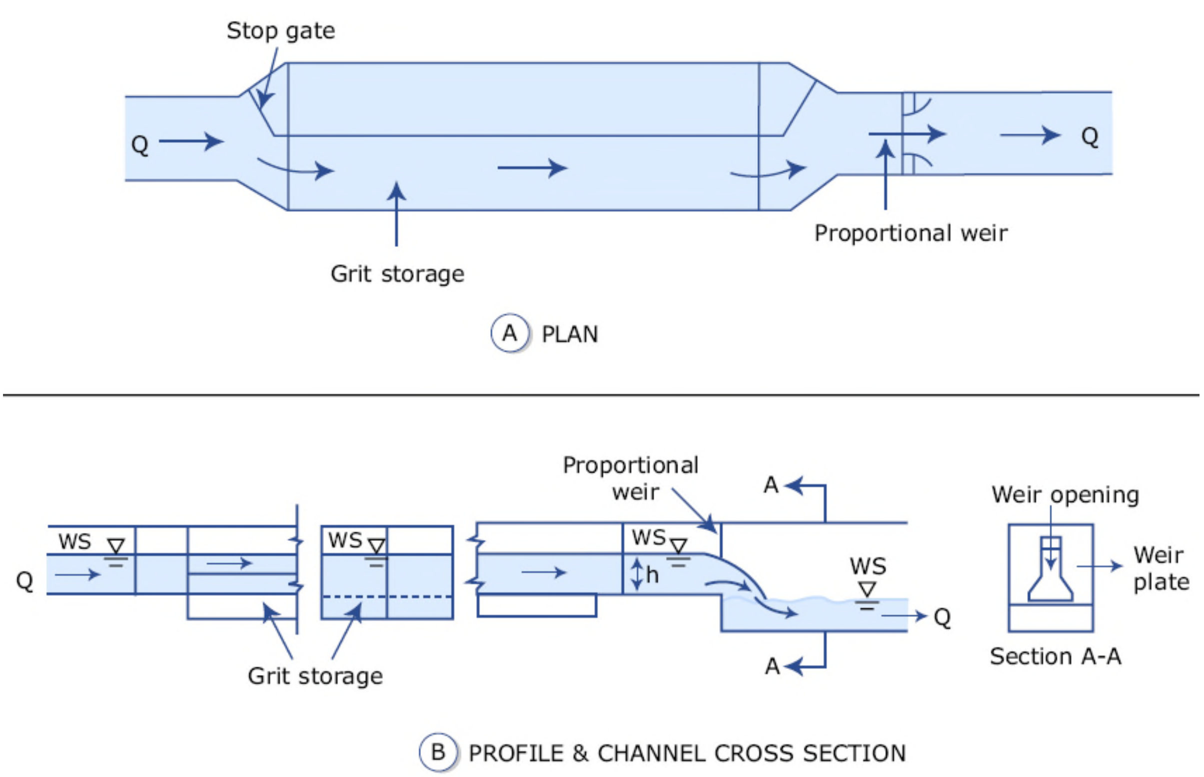
Purpose:
1. Protect moving equipment from abrasion
2. Reduce deposition in pipelines, channels

Grit characteristic:
0.004-0.04 m^3 grit/m^3 wastewater
Solids content = 35-80%
Volatile content = 1-55%
Total density = 1600 kg/m^3

Design goal: Provide sufficient detention time for grit to settle. Maintain constant velocity to scour organics.

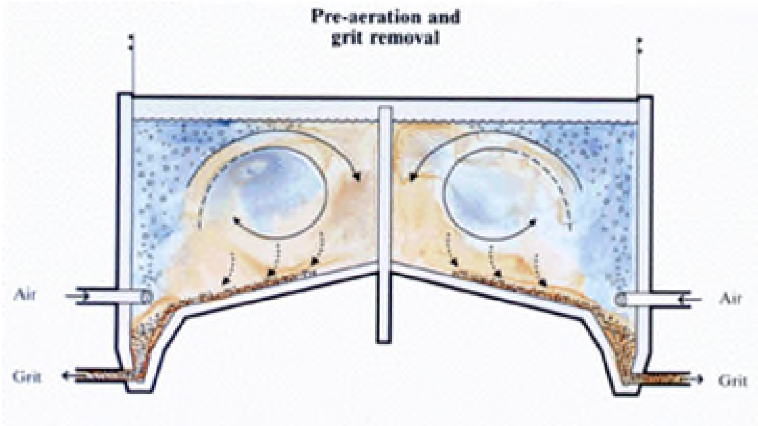
Constant Velocity Grit Channels
Parabolic section to achieve uniform velocity of 0.3 m/s throughout depth of channel.
Grit removed by pumps or dredgers on travelling bridges
Horizontal –flow grit chamber can be analysed by means of type I sedimentation.

A Horizontal-Velocity Grit Settling Chamber with a Proportional Weir Control Section



Dorr Detritor
Maintain constant flow velocity
Inlet along whole of one side with gates to maintain constant velocity
Outlet weir on opposite side
Grit settles on tank bottom is pushed to outside by travelling rakes and finally into sump.
Grit drawn from sump by reciprocating rake, washed and collected.

Aerated Grit Channels
Air bubbled through wastewater
Velocity of flow not critical
Clean grit obtained



Advantages

- Can be used for chemical addition, mixing, and flocculation ahead of primary treatment
- Fresh wastewater, thus reduce odors and remove BOD_5
- Minimal headloss
- Grease removal by providing a skimming device
- Oxidise some organic matter by air supply
- Remove any desired size by controlling the air supply

Volatile organic compound (VOC) and odor emission
Due to a health risk, covers may be required or non-aerated type grit chambers may be used.

Vortex Grit Trap
Consists of a cylindrical vessel with flat top, dished base and grit pot below.

Primary sedimentation

Primary sedimentation is expected to reduce
Suspended solids: 65%
BOD: 40%

Primary sedimentation basins are Type II settling. Particles change in size and shape during settling process, so Stokes equation can not be applied to it.

Engineering design

Usually achieved if provide

6 hours detention at D.W.F ***(gives volume required)***
Max. surface loading rate of 30m^3/m^2/day at 3DWF ***(gives surface area required)***
weir overflow rate of 230m^3/m length of weir/day (at DWF)

Typical design

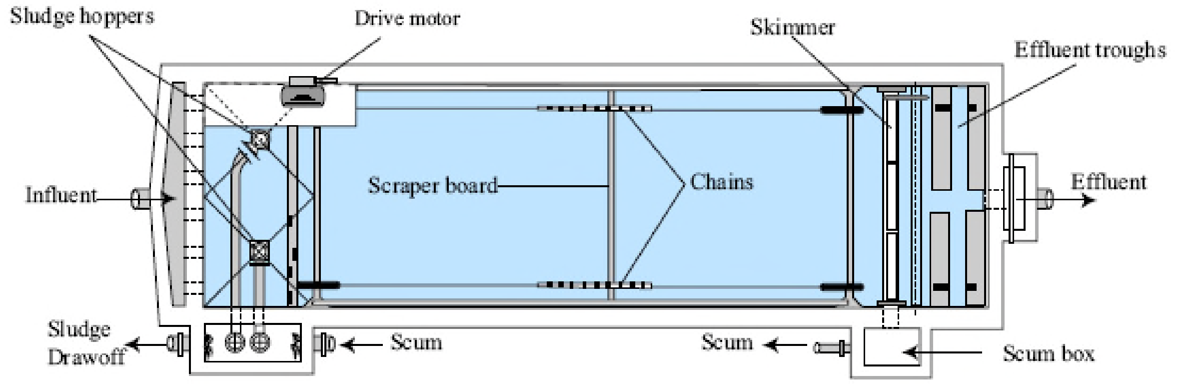
Detention time = 1.5-2.5 hr, overflow rate 30-50 m^3/d m^2

Rectangular tanks
Floors virtually flat with inverted pyramid-shaped hoppers at inlet, scraper consists of power--driven bridge spanning tank from which scraper is hung and sweeps sludge from floor of tank into hopper. One scraper used for a number of tanks, speed of scraper 5mm/sec to prevent disturbance of sludge. Length to breadth ratio of 3 or 5:1
Length: 15-100 m
Width: 3-24 m
Average depth 3 – 5 m, typically 4 m.

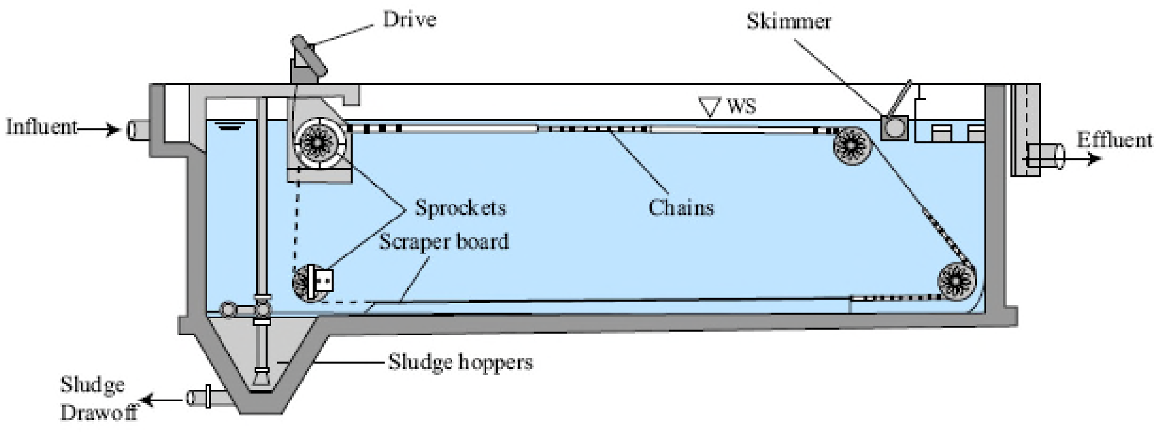
Either **manually desludged** where sludge collects at inlet, floor slope - 1:25, to desludge, flow stopped, allowed to settle then physically brushed to sludge outlet.

mechanically desludged where sludge collects on floor and is continually brushed towards the central sludge hopper by slow moving brushes. The sludge hopper is emptied periodically, usually once a day.

RECTANGULAR SETTLING TANK



(A) Plan



(B) Longitudinal Section

Upward flow tanks

Sewage enters below T.W.L-. but above maximum sludge level. Direction of flow upwards but weight of particles reduces their vel. until virtually stationary. Sludge blanket forms across tank - acts as filter-particles form floc and sink to bottom of tank
Upward flow vel. of 1.2 - 1.8m/hr at max. flow. Square or circular tanks.
central feed pipe in baffle box to prevent turbulence
slope of hopper < 60° sludge drawn off by hydrostatic head. Settled sewage passes over perimeter weir

Radial Flow Tanks

Central feed pipe discharges just below T.W.L. Overflow weir around perimeter
Range of dimensions

diameter	10 - 30m
side walls	2 - 3m
floor slope	7.5^{o} - 15^{o}

sludge hopper to hold 1 days sludge, sludge removed either by hydrostatic head or pumps, sludge concentration 4% dry matter.

Biological treatment

Biological treatment is a key in wastewater treatment:

- microbes in wastewater can decompose organic compounds (contributing to BOD) naturally. biological treatment is an enhanced natural self-purification;

- Basic approach is to use *aerobic* biological degradation:
  organic carbon + $O_2 \rightarrow CO_2$
- Objective is to allow the BOD to be exerted in the treatment plant rather than in the stream or river.

The aim of biological treatment

- Flocculate and degrade the suspended solids;
- Remove or stabilise organic compounds in wastewater

- convert the colloidal and dissolved organic matter into microbial biomass or inert gases;
- the density of biomass is slightly greater than that of water, which allows to remove by gravity settling.

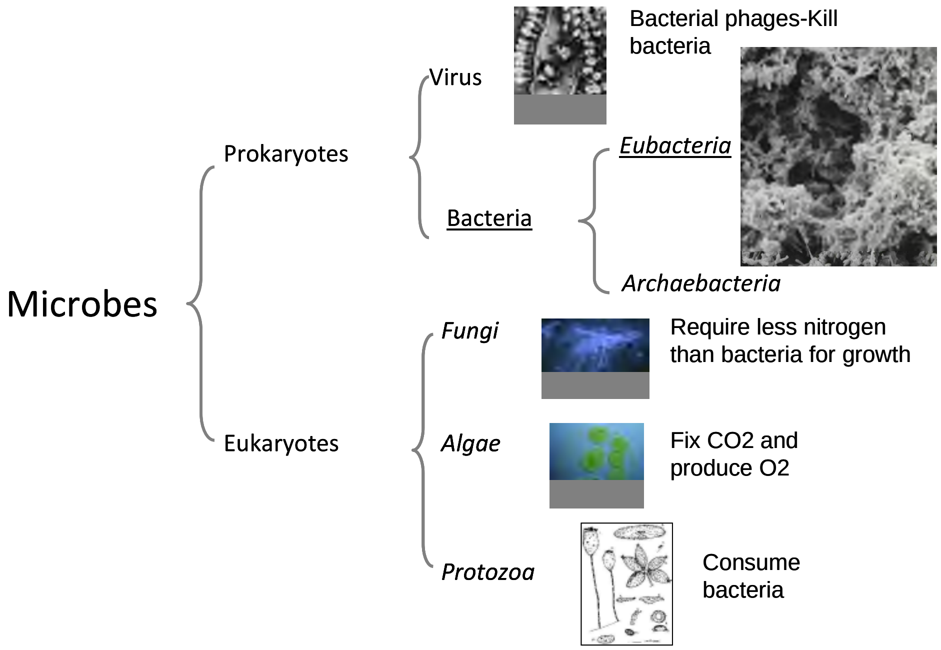
- Remove N and P

It should be noted that biomass must be removed because it is measured as BOD in the effluent.

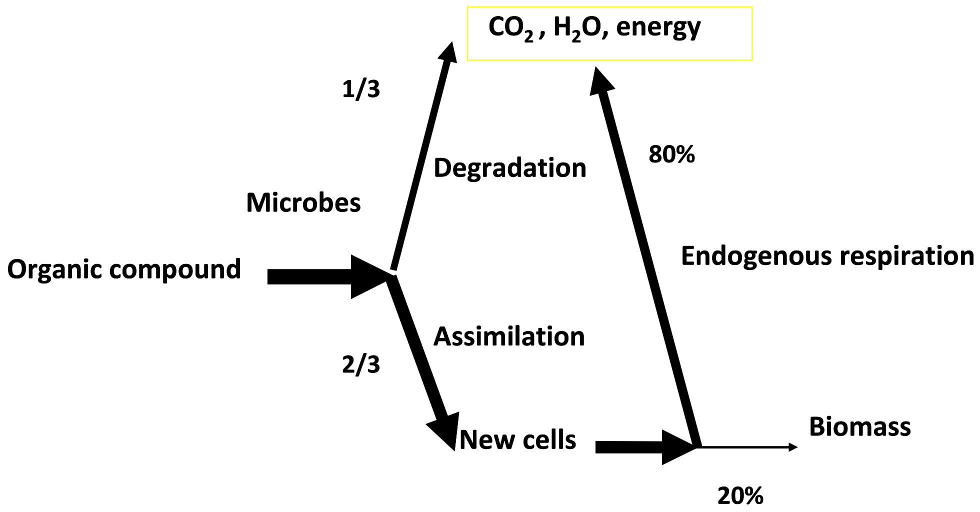
The roles of microorganisms in wastewater treatment

- Microorganisms account for about half of total carbon in global biomass and are the foundation of our biosphere and biogeochemical cycles;
- Microorganisms remove organic compounds (COD, BOD) as well as N and P;
- Sludge contains a wide variety of microorganisms. Heterotrophic bacteria are dominant in sludge and are the primary consumers of organic wastes;
- Microorganisms flocculate, degrade and promote precipitation of suspended solid. Aeration of sewage leads to formation of flocculent suspended particles (sludge).
- Stabilise organic compounds

Microbes in wastewater treatment plant



Microbial metabolism



Basic ingredients

- High density of microorganisms (keep organisms in system)
- Good contact between organisms and wastes (provide mixing)
- Provide high levels of oxygen (aeration)
- Favorable temperature, pH, nutrients (design and operation)
- No toxic chemicals present (control industrial inputs)

Biological Treatment Methods
Attached growth (biofilm) process
The microorganisms responsible for the conversion of organic matters and nutrients are attached to an inert packing material.

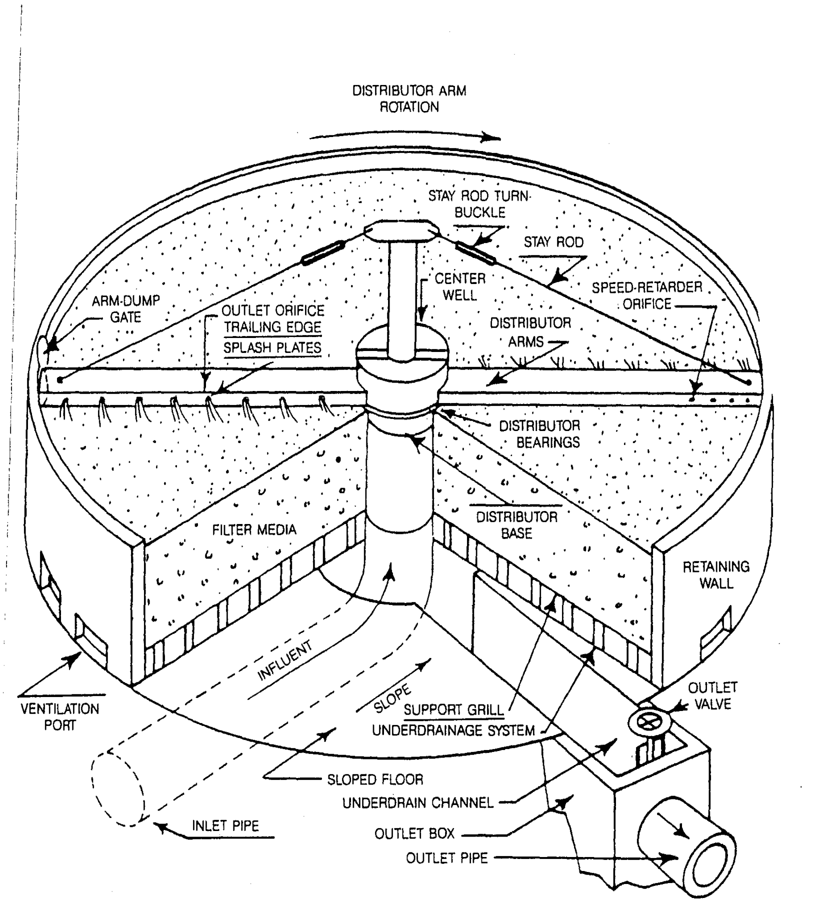
Suspended growth (activated sludge) process
The suspended-growth microorganisms are used to clean wastewater. The microorganisms are activated by an input of oxygen.

Attached growth (biofilm) process

Percolating Filters
First introduced in 1893, consist of circular or rectangular beds of well-graded media
depth of filter bed 1.4m - 2.8m (1.8m)
Advantages of percolating filters
low running costs
little attention
easy to increase capacity
Disadvantages of percolating filters
large area of land required
lots of flies
Filter media
conventional - slag, clinker, stone, gravel, slag the best,
70% voids, 40 - 60mm diameter except bottom drainage layer of 150mm dia.
synthetic - plastic media - lighter 90% voids, lesser degree of purification

Operation

Settled sewage sprinkled onto filter beds by rotation distributors driven by motors or effected by reaction.
Dosing siphons used to regulate flow.



Trickling filter parts (California State, 1988)

Biological processes

Media covered with an active gelatinous film containing bacteria, protozoa, fungi etc., which in the presence of sufficient oxygen bring about biological purification.
Time for filter to mature - few weeks - summer. several months - winter

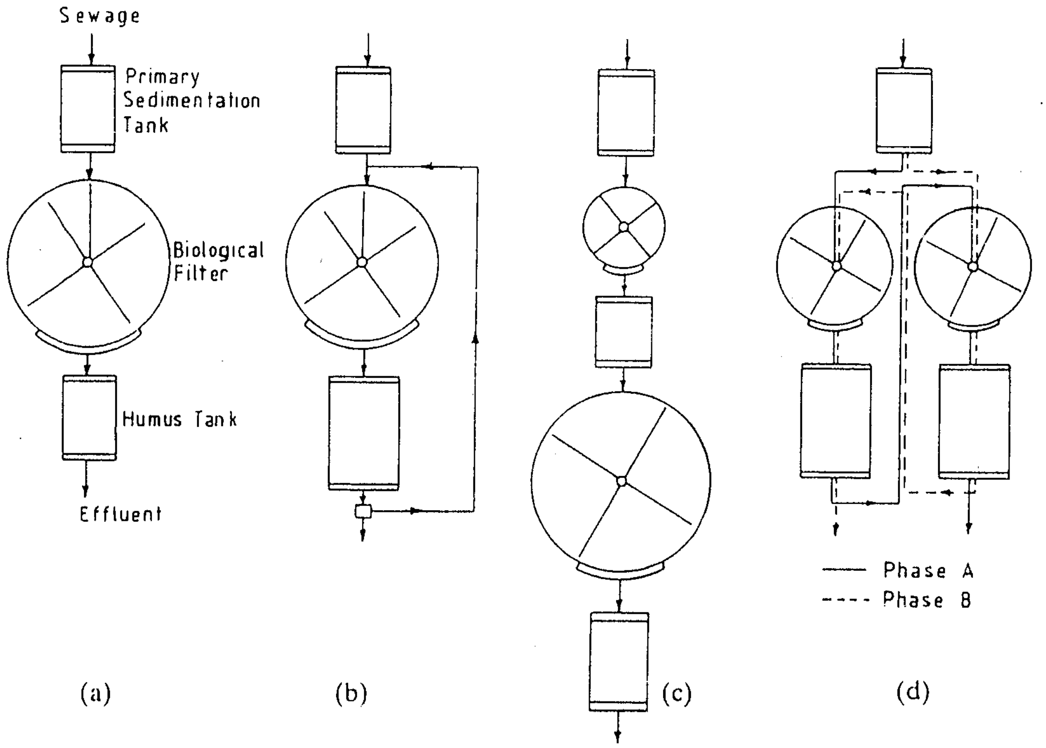
Effluent contains much dark brown suspended matter (humus sludge) washed off the filter media which requires settlement in humus tanks before discharge to river.
Filters contain large numbers of scouring organisms - worms, flies, insect larvae etc. which feed upon biological film. During winter. these organisms retreat into bed of filter ,and filter becomes choked. This is called Ponding also caused by overloading filter dosing with wastewater containing too much suspended solids.

Can be overcome by:
forking the bed surface
flush with plant effluent
dose with chlorine

slow down distributor speed
change to alternating double filtration (A.D F.) or recirculation.

Alternating Double Filtration (ADF)

helps to restore a ponded filter by dosing it with purified effluent from another filter
increases filter capacity
filters operated in series, the alternating period varying between 1 day and 1 week
pumps, larger channels and pipework required
2 humus tanks required
More control required



(a) Single stage filtration;
(b) Single stage filtration with recirculation;
(c) Two stage filtration;
(d) Alternating Double Filtration (ADF)

Recirculation

Reduction of BOD loading by diluting settled sewage with recycled final effluent
Increases hydraulic loading but decreases film growth
Increases filter capacity
Often used for strong trade wastes
Pumps, larger channels and pipework require
More control required
N.B. Usual to design new works on single filtration but with provisions to convert to A.D.F. or recirculation to deal with future increases in volume or load.

Design Criteria Single Filtration
media size 40-60mm
hydraulic loading. 500 1/day/m^3 at DWF. (range 400-700)
BOD. loading. 0. 12Kg/day/m^3 media (range 0.09-0.12)

Design Criteria - A D F
larger media 65mm
Hydraulic loading . 1800 1/day/m^3 media at D.W.F. **(**range 1200-1800)
BOD loading. 0.24Kg/day/m^3 media (range 0. 18-0.26)

Design Criteria Recirculation
larger media 65 mm
Hydraulic loading 1200 1/d/m^3 media (D.W.F.) (range 120O-1800)
BOD. loading. 0. 18Kg/day/m^3 media (range 0. 18-0.24)

Activated Sludge Processes

First introduced in 1913
Object - to reduce the BOD of a sewage by mixing the wastewater with a biologically active sludge in the presence of an adequate supply of dissolved oxygen.
The active sludge absorbs the organic matter in the wastewater and converts it into stable end products.

Advantages of Activated sludge
Smaller area of land
No filter flies
Small head loss through works

Disadvantages of Activated sludge
High running costs as use large amount of power
Requires skilled operation
Large quantity of secondary sludge produced
Can cause foaming
Types of Aeration Systems

Diffused Air System

Compressed air introduced at base of tank
Air provides aeration and agitation to bring activated sludge flocs and wastewater into contact

Design criteria
Detention period 6-12 hours at D.W.F. (8 hours)
B.O.D loading 0.65Kg/day/m^3 tank capacity
suspended solids mixed liquor 1000-4000 mg/1 (3500mg/1)

air diffusers arranged along tank bottom either as ridge and furrow system - diffusers set at bottom of depressions, sludge cannot settle on surfaces spiral flow system - diffusers set near one side of wall - induce spiral turbulence

BOD removal 90-95%.

Mechanical, aeration systems

Surface aeration

An inversed rapidly rotating cone with steel blades draws the wastewater up a pipe from the hopper-bottomed tank and sprays it across the liquid surface.

Kessener Brush System

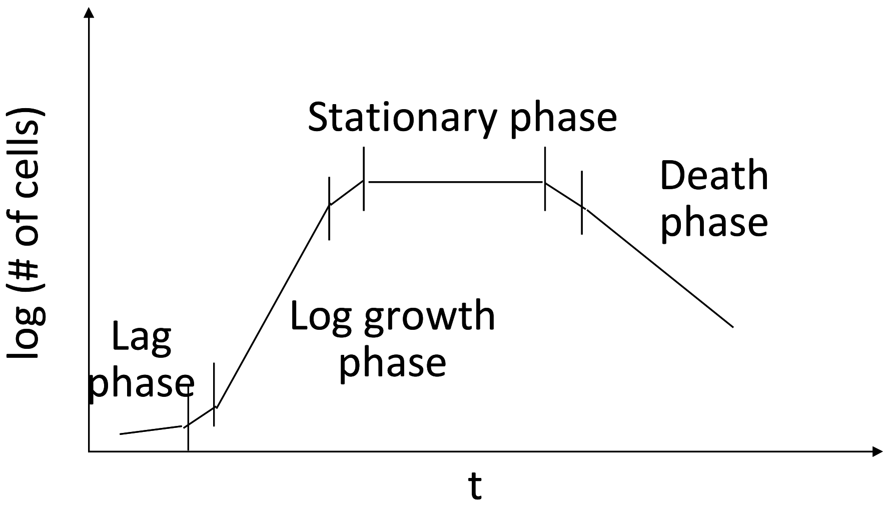
Revolving stainless steel brushes partly submerged produce a spray of fine droplets and waves

Biological Processes
Wastewater from settlement tanks mixed with sufficient returned activated sludge to give suspended solids content of
1000-5000 mg/1 - determined from experience
Resulting mixed liquor aerated
Mixed liquor allowed to settle in settlement tanks
Part of the activated sludge returned to aeration tank inlet
Surplus activated sludge disposed of

Extended aeration

Used on small remote works where supervision minimal
Long detention period 24-48 hours (24 hr)
High rate of returned sludge (50-100%)
Oxidation of sewage and aerobic digestion of activated sludge solids achieved.
BOD loading 0.16 -0.48 Kg B.O.D./day/m^3 (0.25)
Suspended solids of mixed Liquor-. 3000-6000 mg/1 (5000mg/1)
BOD removal 80-95%

Basic Kinetics of Biological Growth



In the log growth phase, the growth rate of biomass increase is

$$r_g = \frac{dX}{dt} = \mu X$$

μ = growth rate constant, t^{-1}, X = concentration of biomass, mg/L.

It is difficult to measure μ directly.
Monod developed a model that assumes the biomass growth rate is limited by the rate of enzyme reactions involving the limiting food compound. The Monod equation is

$$\mu = \frac{\mu_m S}{K_s + S}$$

Where
μ_m = the maximum growth rate constant t^{-1},
S = concentrations of the limiting food (BOD5) in solution, mg/L,
K_s = half saturation constant, mg/L (or concentration of limiting food when $\mu=0.5\ \mu_m$).

$$r_g = \frac{dX}{dt} = \mu X = \frac{\mu_m S X}{K_s + S}$$

Consider the microbial natural decay;
Assumption: decrease in cell mass is proportional to conc. of organisms present (first order).

$$r_d = \left(\frac{dX}{dt}\right)_{endog.decay} = -k_d X$$

k_d = endogenous decay rate constant, t^{-1}

Net growth rate is

$$r'_g = r_g + r_d$$

$$\left(\frac{dX}{dt}\right)_{net\_growth} = \left(\frac{dX}{dt}\right)_{biomass\_produced} + \left(\frac{dX}{dt}\right)_{endog.\_decay}$$

$$\left(\frac{dX}{dt}\right)_{net\_growth} = \mu X - k_d X = \frac{\mu_m SX}{K_s + S} - k_d X$$

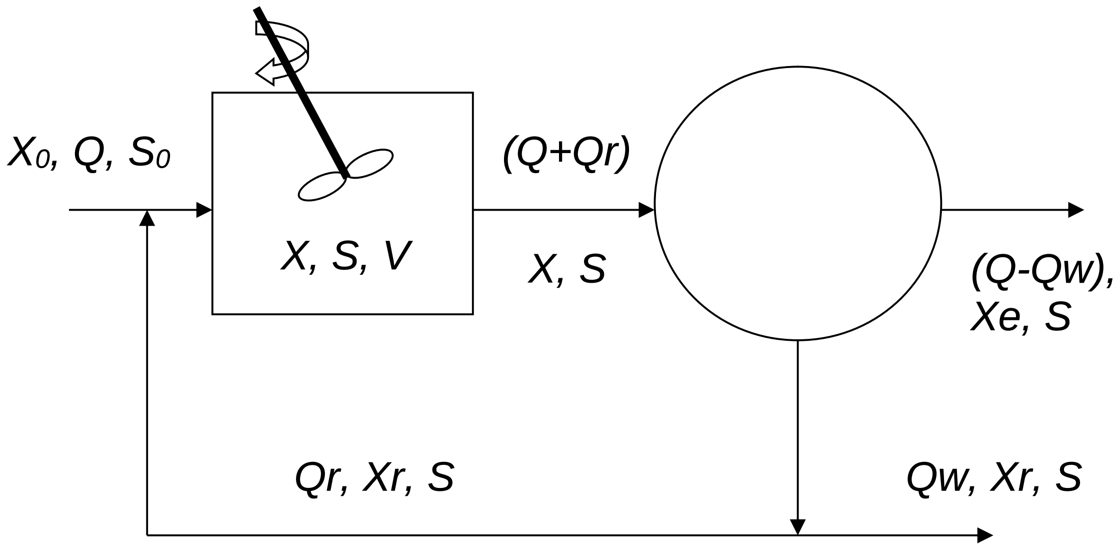
Food (BOD or COD): converted to new cells oxidized to inorganic and organic end product
Only a part of the food is converted to the biomass

$$r_{su} = \frac{dS}{dt} = -\frac{1}{Y} r_g$$

$$\frac{dS}{dt} = -\frac{1}{Y}\left(\frac{dX}{dt}\right)_{biomass\_produced} = -\frac{1}{Y}\frac{\mu_m SX}{K_s + S}$$

Y = yield coefficient, mass biomass produced/ mass substrate (food, BOD, COD) utilized
r_{su} = substrate utilization rate

Kinetics of Completely mixed activated sludge process



Q: flow rate, m3/d;
Q_w: flow rate of liquid containing biomass to be wasted, m3/d;
Q_r: flow rate of returned sludge, m3/d;
X_0: biomass concentration (VSS) entering aeration tank, mg/L;
X: biomass concentration (MLVSS), mg/L;
X_e: biomass concentration (VSS) in effluent from secondary settling tank, mg/L;
X_r: biomass concentration (VSS) returned to aeration tank, mg/L;
S_0: substrate concentration entering aeration tank, mg/L;
S: substrate concentration in aeration tank and effluent, mg/L.

Monod equation

$$\mu = \frac{\mu_m S}{K_s + S}$$

Net growth rate of biomass

$$r_g' = (\frac{dX}{dt})_{net\_growth} = \mu X - k_d X = \frac{\mu_m SX}{K_s + S} - k_d X$$

Food (BOD or COD) utilization rate

$$r_{su} = \frac{dS}{dt} = -\frac{1}{Y}(\frac{dX}{dt})_{biomass\_produced} = -\frac{1}{Y}\frac{\mu_m SX}{K_s + S}$$

Equation summary

t_R = the hydraulic retention time

$$t_R = \frac{V}{Q} = \frac{S - S_0}{UX}$$

θ_c= Sludge age (the sludge retention time)

$$\frac{1}{\theta_c} = \frac{Y(S_0 - S\ )}{t_R X} - k_d = YU - k_d$$

P_x = activated sludge production rate

$$P_x = Y_{obs} Q(S_0 - S) = \frac{QY(S_0 - S)}{1 + k_d \theta_c}$$

Mo_2 = oxygen requirement

$$M_{O2} = Q(S_0 - S) - 1.42 P_x$$

Effluent S, soluble BOD5 in aeration tank and effluent (mg/L)

$$S = \frac{K_s(1 + k_d \theta_c)}{\theta_c(\mu_m - k_d) - 1}$$

Biomass in aeration tank (mg/L)

$$X = \frac{\theta_c (Y)(S_0 - S)}{t_R (1 + k_d \theta_c)}$$

Food : microbes ratio

$$F / M = \frac{QS_0}{VX}$$

The rate of sludge recycle

$$R = \frac{1 - \frac{t_R}{\theta_c}}{\frac{X_r}{X} - 1}$$

Ammonia removal

Bacteria - simplest forms of plant life that use soluble food and are capable of self-reproduction.

Heterotrophic bacteria

Use organic compounds as an energy and carbon source for synthesis (reduce BOD)

Autotrophic bacteria

Use carbon dioxide as a carbon source and oxidise inorganic compounds for energy (reduce Ammonia)

e.g. nitrifying bacteria

NH_3 (ammonia)+ oxygen → NO_2 + energy

NO_2 (nitrite) + oxygen → NO_3 + energy
nitrate

Nitrogen removal

Nitrogen 40% ammonia

60% bound in organic matter

Conventional primary and secondary treatment extracts approximately 40% of the total nitrogen leaving most of the remainder as ammonia in the effluent.

Nitrogen forms of interest, organic, inorganic, gaseous

i) Bacterial decomposition releases ammonia by deamination of nitrogenous organic compounds

organic N $\xrightarrow{\text{bacterial decomposition}}$ ammonia (NH3)

ii) Continued aerobic oxidation results in nitrification

$NH_3 + O_2 \xrightarrow{\text{nitrifying bacteria}} NO_2$

$NO_2 + O_2 \xrightarrow{\text{nitrifying bacteria}} NO_3$

iii) Biochemical denitrification occurs with heterotrophic metabolism in an anaerobic environment

$$NO_3 \xrightarrow{\text{bacterial denitrification}} N_2\uparrow \text{(Nitrogen)}$$

Tracing nitrogen through treatment works

conventional activated sludge plant

	Inflow	Settled Sewage	Activated Sludge	Nitrification
BOD (mg/l)	200	130	20	20
SS (mg/l)	240	120	30	30
Org N (mg/l)	20	15	2	2
NH_3 (mg/l)	15	15	24	5
NO_3 (mg/l)	0	0	0	15
tN (mg/l)	35	30	26	

Nitrification depends on:
temperature, dissolved oxygen concentration, sludge age, pH

Types of Nitrification Units

Continuous flow aeration systems - long sludge age required to prevent excessive loss of viable bacteria.

Supply of organic matter controls growth of heterotrophic bacteria, quantity of ammonia applied governs synthesis of nitrifiers, High organic loading - increases sludge wasting - reduces sludge retention time removes heterotrophs and nitrifiers from system

typical wastewater BOD: total nitrogen

200mg/l: 35mg/l

growth rate of nitrifying bacteria much lower than decomposers

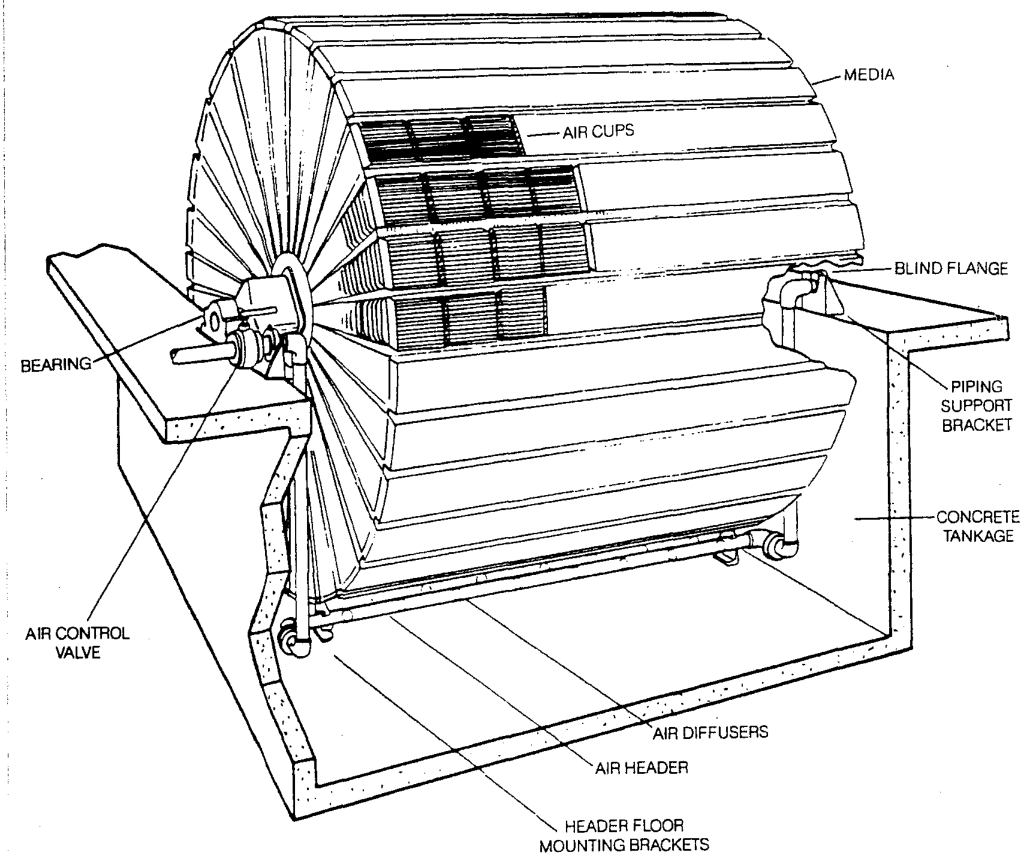
Activated sludge process under normal operating conditions nitrification limited because of loss of autotrophic populations.

therefore need a 2-stage process

Stage 1: reduce BOD without oxidation of ammonia-nitrogen to produce effluent with BOD/ammonia ratio 40/25

Stage 2: Second-stage nitrification unit provides adequate growth potential for nitrifiers relative to hetereotrophs since operated at increased sludge age.

Rotating Biological Contactors (RBC)
Constructed of bundles of plastic packing attached radially to a shaft, forming a cylinder of media.
Shaft placed over a contoured bottomed tank so that the media are submerged approximately 40%. Contactor surfaces are spaced so that during submersion wastewater can enter voids in packing. When rotated out of tank, the liquid trickles out of voids between the surfaces and is replaced by air. A fixed-film biological growth, similar to that on a trickling filter adheres to the media surfaces. Alternating exposure to organics in the wastewater and oxygen in the air during rotation is like the dosing of a trickling filter.



Constructed Wetlands

Two types - free water surface systems(FWS) and sub-surface flow systems (SFS)

FWS systems typically consist of parallel basins or channels with relatively impermeable bottom soil or subsurface barrier, emergent vegetation and shallow water depths of 0.1 -0.6 m. Pretreated wastewater is normally applied continuously to such systems and treatment occurs as the water flows slowly through the stems and roots of the emergent vegetation.

FWS systems may also be designed with the objective of creating new wildlife habitats or enhancing nearby existing natural wetlands.

SFS systems consist of channels or trenches with relatively impermeable bottoms filled with sand or rock media to support emergent vegetation. Normally used for secondary or tertiary treatment.

Final settlement tanks

The mixture from the aeration tanks is settled in final settlement tanks and a proportion of the sludge returned to the aeration tanks.
Use mechanically de-sludged circular tanks to provide a continuous flow of activated sludge for return to aeration tanks.

Size

Diameter	10-25m
Wall depth	2-3m
Floor slope	7.5-30^o

Design Criteria
Detention period 1.5 hours at max. flow
Surface loading 30-60m^3/m^2/day (40m^3/m^2/day)
Weir overflow rate 150-300m^3 / m / day (230m^3 / m /day)

Humus tanks

To remove the settleable suspended solids produced in the percolating filters
Either rectangular or circular - usually the same size as primary tanks but with steeper floors 7.5-30^o.
Wall depth 1.5-3.O m

Design Criteria
Same as final settlement tanks

Tertiary treatment

Used when dilution of final effluent in receiving watercourse low
When discharging to watercourse used for water supply
Involves the elimination of suspended matter (fine humus or activated sludge) which has been left by the traditional processes.

Mechanical flocculation

used for humus tank effluents
wastewater stirred gently and the finely divided matter coalesces into larger particles which settle more easily

Design Criteria
flocculation time 15-30 mins
settlement time 30mins
paddle speed 0.07m/sec
reduction of suspended solids 50-60%

Micro-strainers
A drum of woven stainless steel fabric (minute orifices) rotating on a horizontal axis and partly submerged in the liquid to be filtered
typical values 100,000 orifices (645/mm^2) of 0.045mm dia.
need to "back-wash" the micro-strainers with high-pressure jets of final effluent
biological film forms on mesh-washed with chlorine solution
small area of land required
small head loss 30Omm
small running costs

Sand filters
Rapid gravity sand filters - effluent filters through a sand bed, backwashing required 1 or 2 times a day
slow sand filtration - better effluent, consist of basins containing 0.3 - 0.76m of sand and coarser material resting on under drainage system. - less backwashing

Upward flow gravel clarifier
Incorporated into existing humus tank
bed of pea-gravel 6-10mm dia approx 15Omm deep supported on perforated floor
upward flow rate 980 1 / m^2 / hr
solids removed by backwashing

Clarification lagoon

Provide a shallow lake (1m deep)
Natural purification by micro-organisms in the presence of sufficient dissolved oxygen
Uses large area of land

Grass Plots

effluent sprayed onto grass
dosed up to 8.4 x 10^6 l/hectare/day
land to fall to river
large area of land

Sludge Treatment

Large quantities of sem-liquid sludge produced

Aim is to reduce quantity and then dispose of it

The main problem in sewage treatment, composed of' screenings, grit, primary sludge, secondary sludge
An evil-smelling thick liquid containing solid matter. dispersed in many times its weight of water
solids and water difficult to separate
accounts for. about 2/5 of cost of wastewater treatment

Methods of treatment

Disposal on land

Large area of land required, must be non-toxic
Trenching - trenches dug, partly filled with sludge then refilled with soil - small works only
Land plots - land ploughed, sludge run into furrows, allowed to dry then re-ploughed
Lagoons - a natural depression or an area surrounded by high banking, liquid sludge run into lagoon and allowed to dry, supernatant liquid decanted. If enough land available, leave sludge in lagoon, if not after drying dig out and use as fertiliser.

Chemical conditioning

to facilitate drying or filter pressing
lime added before filter pressing 5-10% of dry sludge solids
Copperas added in conjunction with lime 5 -10% of dry sludge solids
Aluminium Chlorohydrate - facilitates vacuum and pressure filtration dewatering
Polyelectrolytes separate solids and liquids sometimes prevent coagulation

Sludge digestion

When sludge stored and not aerated it becomes septic and undergoes fermentation or- digestion
Acid conditions develop, foul odours produced eventually alkaline reaction prevails.
At this point sludge digests rapidly, odour unobjectionable, sludge gas (methane) produced
Solid content reduced
If cold-slow process 3-6 months, when heated (30-40ºC) reduced to 28 days

Digestion Process
Early stages - animal and vegetable fats content much reduced producing methane and carbon dioxide
2 fermentation stages proceed concurrently - acid fermentation (pH 4.0-6.5)
alkaline fermentation (pH 7.0-7.8)
must not overload digester, gas production stops, causes pH to drop
removal of digested sludge, addition of raw sludge $\cong$ 4% digester contents
economical limits - solids reduced by 1/3, sludge inoffensive, easy to dry, high gas production, governing factor - temperature

Design

Circular closed tank with fixed or floating roof
25-30 days sludge capacity (28)
Gas collection
Heating by external heat exchanger
Gas used as heat source

Sludge well-mixed, stirrers, pumps, gas
Pipes to draw off separated liquor

Utilisation of Sludge Gas

67% methane 33% carbon dioxide
Calorific value of sludge gas 2.2 x 10^4 KJ/m^3
Wt of sludge gas produced =- wt. of solids destroyed, 1/3 of gas lost through exhaust etc. the rest used to fuel heat exchanger may be used to produce electricity

Heat exchanger
Sludge pipe passed through hot water. pipes to heat sludge
Sludge dewatering and incineration
Sludge heated to 40^oC approximately by waste heat

Filter pressing and incineration

Sludge conditioned with lime and copperas to flocculate the sludge solids to aid mechanical dewatering
Sludge pumped to filter press, plates covered with filter cloths with central feed hole
Plates pushed together under pressure and water squeezed from sludge through filter cloths and pumped to inlet
After 6 hours sludge cake produced (30-35% solids), presses open and sludge cake transported to incinerator
Burnt on multi-hearth furnaces
Ash tipped on Local Authority tip
Exhaust gases cleaned

Centrifuge and Incineration

As used at Blackburn Meadows
Sludge stored in tanks containing picket fence thickeners
Sludge heated to 40oC by waste heat from predryer and then conditioned by a polyelectrolyte solution then passed into centrifuge where a sludge cake of approximately 28 % solids produced
Cake fed to a fluidised sand bed incinerator where it is burnt producing ash and waste gases.
Ash and gases cleaned before ash buried on site and gases discharged to atmosphere

Reference

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