WASTEWATER

Core Notes for Module 6 (Elective) of the Course
"Environmental Engineering – Sustainable Development in Coastal Areas"

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The material for this Lecture also includes:

- Synopsis
- Case Study
- Newspaper articles
- Self-test
- Sources of Reference

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1 Introduction

Wastewater Treatment is not a new concept. One historic sewer was the *Cloaca Maxima* built many centuries BC in Rome. Greeks and Romans in ancient times used water borne sewerage systems. Each person on average produces between 0.4 to 1.5kg of solid waste and 1 to 2 litres of wastewater per day.

Wastewater consists of liquid waste from domestic origin as well as parts that originate from industrial processes.

Domestic wastewater are essentially the waste of community living, which has been collected in the homes where it arises and conveyed by means of water from the dwelling to the place of treatment and final disposal. The chief components of domestic wastes are body wastes (Faeces and urine), bath and shower water, kitchen wash water and laundry wastes.

Industrial wastes pose a greater environmental threat than domestic wastewater. They consists of discharges from various industries eg mines, garages, laundries, chemical plants, abattoirs, dairies, tanneries, food processing plants, textile mills, dye houses, breweries, etc. The discharge from each and every industrial premises is governed by various legislation and permission to discharge must be sought from the local authority concerned. Some industries produce waste which are unacceptable for sewer discharge and must be treated or disposed of separately. The discharge from industry is usually controlled by means of Municipal by-laws. Certain discharges are prohibited in terms of these by-laws for discharge into the sewerage system and require some other form of treatment, e.g. co-disposal on landfill, pre-treatment, encapsulation or the use of evaporation pans.

2 The objectives of wastewater treatment

The objectives of wastewater treatment are two-fold:

- The reduction of organically bound energy to a level such that heterotrophic (organisms which obtain their energy from organic matter) growth and the associated deoxygenation effects in the receiving water body are acceptably low.
- Reduction of phosphates, ammonia and nitrates to levels such that photosynthetic growths and their ability to fix solar energy as organic energy in the receiving water body are low.

Living organisms require a continuous throughput of matter and energy. Hydrogen, oxygen, carbon, nitrogen, phosphorous and sulphur are the most important life sustaining elements. Energy is derived from three sources: solar energy, organic and inorganic compounds. Photosynthetic cells fix a small amount of the solar energy by forming complex high energy organic compounds and oxygen. Carbon, hydrogen and oxygen are freely available from the compounds H2O (water) and CO2 (carbon dioxide), whereas phosphorous, nitrogen and sulphur are derived from the dissolved salts of these elements. The availability of phosphorous and nitrogen are normally limited and this restricts the amount of life a body of water can generate.

Phosphorous and nitrogen are thus termed eutrophic (life giving). Ammonia is the main source of nitrogen and can be generated from dissolved molecular nitrogen by certain micro-organisms. It is for this reason that the control of phosphorous in a water body takes a greater significance than that of nitrogen.

The presence of organic compounds form the basic source of energy for certain cells. This energy, if present in surface waters gives rise to fungal growth, resulting in deoxygenation of the water thereby rendering it unsuitable for higher life forms such as fish. The resulting anaerobic condition causes smells and the reduction of the aesthetic appearance of the water, rendering it unsuitable for recreational or other uses.

The wastewater treatment process utilises vast quantities of oxygen in support of bacterial activity. This demand for oxygen is fundamental wherever aerobic bacteria exist, and if this oxygen cannot be obtained as free oxygen, then it can be obtained biochemically whereby certain types of bacteria utilise oxygen from dissolved chemical matter, eg sulphate (SO4) or nitrate (NO3). If sulphate is reduced to sulphide, septic conditions will prevail.

Oxygen demand in a water body continues as long as the water contains organic matter that can be oxidised by bacteria. Any dissolved oxygen (DO) utilised can be replaced quickly in acceptable river conditions by surface aeration and oxygen produced by green plant photosynthesis. The oxygen-consuming capability of wastewater is a measure of the pollution level in the water. This oxygen demand can therefore be used to determine the strength of wastewater. The most common laboratory test to determine oxygen demand is the Chemical Oxygen Demand (COD) and the Biological Oxygen Demand (BOD) test.

3 An overview of the treatment processes of a wastewater treatment plant

Two processes of the treatment will utilise different organisms to perform the treatment process, viz.

- Aerobic and
- Anaerobic

The aerobic process (in presence of free oxygen) is utilised to treat the sewage water, and the anaerobic process (in the absence of oxygen) to stabilise the major part solids content of the raw sewage. The aerobic process is quicker than the anaerobic process, but if the solids also have to be treated in the aerobic process, the treatment becomes very expensive due to the energy that needs to be added to introduce larger volumes of oxygen to the water. For this reason the solids are separated from the water and treated separately.

Non degradable impurities are separated from the sewage as it enters the treatment works. This is done by means of screens which will retain the paper, rags and other objects.

Sand and gravel is removed from the sewage by means of grit channels or other means. This is done on the principle that sand is heavier than water and is deposited on the bottom of the channel when the water flows slowly through the channel. All the unbiodegradable materials are then disposed on solid waste landfill sites, incinerated or buried.

In the primary settling tanks the solids are settled out of the raw sewage, from where the solids (sludge) is transferred to sludge digesters, and the water to the aerobic biological reactors. The main process stream is the aerobic biological process since the liquid component makes out the major portion of the wastewater.

To recap, wastewater contains a mixture of organic and inorganic solids, suspended and dissolved in water. On arrival at the waste-water treatment works, the larger solids are removed by the screens. The heavier, inorganic solids (grit) are removed in the grit removal unit. The waste-water normally passes next into the primary sedimentation tank (PST) where settle able materials are allowed to settle out. The settled material is withdrawn at the base of the PST as underflow and is known as Primary Sludge or Raw Sludge.

When secondary treatment is by biological filtration (trickling filters), some of the organic load is converted into Secondary Sludge, also known as Humus Sludge which is allowed to settle out in a Secondary Settling Tank (clarifier or humus tank).

Often this sludge is returned to the head of the works and is allowed to settle out with primary sludge. If the secondary treatment is by the activated sludge process, the quantity of secondary sludge increases continuously due to the conversion of influent organic material into biomass. To maintain the biomass constant, secondary sludge (Waste Activated Sludge) must be regularly withdrawn from the system.

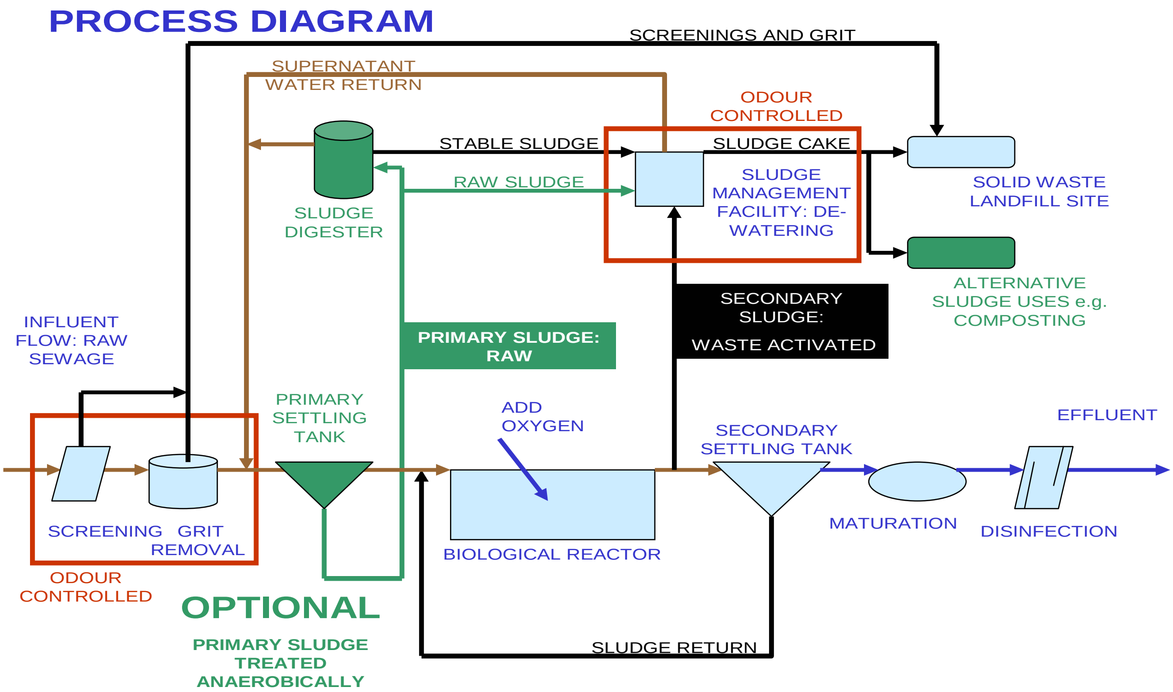
Due to the difficulty in withdrawing various sludges from the sedimentation tanks at optimum solids content – separate stage in sludge treatment process known as Sludge Thickening. Solids content usually in the range 3 – 6%. The sludge after anaerobic digestion is known as Digested Sludge. After anaerobic digestion, it is usually necessary to increase solid content further to reduce the volume to be transported or ultimately disposed of. Sludge with a solid content above 10% is usually referred to as De-watered Sludge. When solid content is above 30%, it is known as Dried Sludge

Volume of primary sludge removed represents 2% of influent waste-water being treated, but 40% 0f organic load received (CID) or 60% of influent loading expressed as suspended solids.

In Biological filtration works, the mixture of primary and humus sludge removed represents only 4 – 5% of influent volume, but 80% of influent suspended solids.

Sludge handling accounts for over 50% of overall treatment costs.

The treated water flows into shallow maturation ponds where ultraviolet light kills the major part of the faecal coli and removal of some nitrogen and phosphorous takes place.



4 The anaerobic process – sludge digestion

In the sludge digesters anaerobic bacteria performs the treatment process, after which the water portion is returned to the inlet works, and the sludge proceed to the de-watering facility. In the secondary settling tanks the humus sludge (or waste activated sludge, depending on the type of reactor) is settled out of the water. Once again the process splits as the sludge is sent to a drying stage and the water through a maturation phase. The sludge de-watering phase removes water from the sludge to make the sludge easy to handle. This stable, odourless sludge is taken to a composting site to be used as a component in the composting of organic material, or to a landfill site to be co-disposed with household refuse on a landfill site.

Reasons for Primary Sedimentation

a) Separation of settle able and suspended solids from waste-water to treat solids separately

b) Reduction of the load imposed on the aerobic biological treatment section (40 – 60% of suspended solids removed and results in 30 – 40% reduction in O2 demand of effluent)

c) Could cause blockages of the stone media in biological filters resulting in ponding or filter failure.

d) Reduction in volume of aeration modules or biological filters is made possible by reduction in organic loading – savings in capital costs of construction

e) Resulting sludge can be anaerobically be digested and methane produced utilised – savings in electricity or fuel oil usage

f) Mass of Secondary sludge to be wasted is decreased

g) Fats, oils and grease which float on surface of PST can be easily removed

Reasons for Thickening Sludge before Anaerobic Digestion

a) Maximise the use of available digester capacity in digestion of solids, else excess water reduces retention time

b) Prevention of the dilution of feed material which would cause difficulty in the utilisation of the food by the bacteria

c) Reduces the amount of heat required in heated digester

d) Prevent the washout of solids and organisms from a hydraulically over-loaded digester

e) Prevention of dilution of alkaline buffer which would cause pH instability

f) Ideal range is 3 – 7%.

Microbiology of the Process

a) Bacteria, in absence of O_2, decompose organic matter to CO_2, CH_4 and H_2O

b) Two stage process:

   a. Stage 1: Organic material converted into organic acids by acid forming bacteria

   b. Stage 2: Organic acids serve as food for methane-producing bacteria, which converts acids into CO_2 and CH_4.

c) The end result of process is:

   a. A well stabilised sludge in which 40 – 60% of the volatile solids have been destroyed

   b. A combustible gas consisting of 60 – 75% methane with the remainder mainly CO_2.

Org matter + acid forming bacteria	Organic Acids
Organic acids + methane forming bacteria	CH_4 + CO_2

5 Aerobic treatment: Treating the liquid (water)

The predominantly water portion is brought in contact with air in order to dissolve oxygen for the treatment process. Various bacteria assist in the transformation of the organic compounds to gases and more bacteria. As the food volumes (COD) reduce, the bacteria die and thus form a stable sludge in the water. This sludge needs to be separated from the water before the final process steps.

In the secondary settling tanks the humus sludge (or waste activated sludge, depending on the type of reactor) is settled out of the water. Once again the process splits as the sludge is sent to a drying stage and the water through a maturation phase.

During the maturation phase the treated water flows into shallow maturation ponds where ultraviolet light kills the major part of the faecal coli and removal of some nitrogen and phosphorous takes place.

Disinfection of the treated effluent is usually done by dosing chlorine to the treated effluent. The chlorine kills the remaining harmful bacteria and other organisms that are still in the water.

Although the treatment process is complete, the water is usually not suitable for human consumption unless diluted in the potable water source and subsequently treated with the potable water before consumption. The reason for this is the high cost of increasing the effluent quality to the original state of the potable water, and therefore the water is purified to comply with standards that are legally imposed on wastewater treatment authorities. Frome here the effluent is discharged into the river or sea where the necessary dilution takes place.

As a means to conserve potable water and its scarce resources, this treated effluent is re-used for irrigation purposes in agriculture, sports fields and municipal parks. It is also used for industrial purposes and urban water features.