CHAPTER 15

AN OVERVIEW OF WASTEWATER TREATMENT IN DEVELOPING COUNTRIES

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An Overview of Wastewater Treatment in Developing Countries

Introduction

Basic requirements for lasting health improvements are *wholesome water supply*; appropriate *wastewater collection, treatment and disposal systems*; appropriate *excreta disposal systems*; and general understanding of public health programmes.

Every community produces both liquid and solid wastes. The liquid portion is essentially the water supply that has been fouled by a variety of uses. Wastewater may be of domestic and institutional or commercial and industry origin. In addition surface and storm water sources are included in the design of sewers and sewage treatment plants.

Water used in processes (industrial, domestic, etc) generates wastewater which has to be disposed of safely. If wastewater is not treated its accumulations will lead to *decomposition of organic matter* resulting in the release of offensive odours, will contain numerous *pathogens* which cause diseases, will contain nutrients which stimulate growth of aquatic plants, and may contain *toxic compounds.*

The above necessitates the immediate removal of wastewater from its sources of generation followed by treatment and disposal. The ultimate goal of wastewater management is the protection of the environment in a manner commensurate with public health, economic, social and political concerns.

Wastewater Quality

Suspended Soils (SS)

Suspended Solids (SS) give rise to the turbidity of a sewage and indicate the presence of various chemical and microbiological pollutants. SS are determined by filtering a measured volume of the wastewater and retaining the solids on a filter paper which is then oven dried and weighed.

Oxygen Demand (OD)

Oxygen Demand (OD) is the amount of oxygen required to oxidise the various organics within the sewage. OD is thus a gross and indirect measure of the total organic load contained in the sewage. OD is usually expressed as chemical oxygen demand (COD) or biochemical oxygen demand (BOD). COD provide a measure for all organics while BOD provide a measure for only the amount of biodegradable organic matter contained in the sewage.

Pathogenic Micro-organisms

Sewage will contain all types of **pathogens** being excreted by the contributing population. These constitute a health hazard and any consideration about the treatment and disposal of sewage must take this hazard into account. The need to remove pathogens should therefore be borne in mind when selecting a type of treatment works to be built.

Toxic Chemicals

Sewage with industrial component may contain *metals, phenols, and other substances toxic to human and animal and plant life.* Decisions about treatment and disposal of such wastewater must be based on careful consideration of these toxic effects.

Effluent Quality and Disposal

Sewage treatment works are designed to *reduce the concentration of suspended solids and oxygen demand, pathogens and toxic chemicals to produce an effluent of a given quality.* The desired quality of an effluent required will depend on the ratio of effluent flow to the receiving water flow (on the dilution available), on the quality of the receiving water, and on the use to which the receiving water is put.

Several common features of tropical rivers seriously affect their use as receiving waters for effluent discharges.

- *There is often a large difference between minimum and maximum flows.* At some times of the year heavy rains in the catchment will cause high flows whereas at other times flows will be low or non existent. At periods of low flow, the dilution provided by the river may be minimal and the flow may be nearly or completely undiluted effluent. In such cases high effluent quality is required.

- *At warmer temperatures water will contain less oxygen and in addition the rate at which bacteria use up available oxygen will be increased.* These factors reduce the oxygen available to meet the Oxygen Demand of the effluent.

- *Tropical rivers are often turbid, having high silt load, and slow flowing.* Both these features will further reduce the availability of oxygen. Turbid waters will inhibit photosynthesis and thus reduce the production of oxygen by algae. Sluggish flow will hinder the surface diffusion of oxygen into the water and the dispersal of the effluent.

In many cases in developing countries the microbiological quality of the effluent is more important where the inhabitants of downstream villages drink untreated river water.

Industrial Waste

Factories in developing countries are often located in areas such as the peripheries of large cities where the surrounding population uses untreated surface water for domestic purposes. Effluent discharge in the surface water then poses *a health risk to local communities.* Industrial wastes may also *endanger public health* by contaminating irrigated food crops, by contaminating or killing fish which are a source of protein, or by affecting bathing places.

The flow of effluent might be seasonal, particularly from the many industries which process agricultural products, and pollution problems will be increased if the peak discharge coincides with the season of low flows in the streams and rivers. Fish could be killed and populations depending on the river for water supply will lose their source of water supply.

Many different industries produce harmful wastes. Food and drink industries tend to discharge heavy organic pollution, rendering heavy Oxygen Demand in urban streams used as water sources by low income groups. Problems are caused by dyes from textile factories, plating wastes from metal-fining works, toxic effluents from chemical factories, heavy metal such as mercury and lead in waste from mines and factories.

Control

Most developing countries do not have adequate environmental control legislation, neither a body with clear responsibility, nor the means and authority to enforce it adequately. The cost of pollution control measures required for some industrial processes in the developed world may amount to 40% of the capital investment and 15% of operating costs. Clearly, because of this, there are savings, besides the reduction in its wage bill, which a corporation may make by moving a factory to a developing country, even if that means importing all the raw material and exporting the finished products. Politicians and administrators in developing countries are unwilling to deter the foreign investment they seek for their countries industrial development. Besides, large foreign companies have the resources and the expertise to evade the pollution control authority.

It is impossible to lay down standards in advance for all possible pollutants. The system should be in terms of guidelines rather than standards. The responsibility for treatment of polluting wastes must rest with the polluter, and it would normally be preferable to apply special treatment required as the waste leaves the factory, rather than combine it with other wastes.
Where toxic or hazardous substances are concerned, the legislation should be in such a form that the pollution control agency can define which substances are to be included, that prior consent can be conditional and can be revoked. Control can be assisted if a register is kept of all hazardous substances imported or manufactured, including what quantities and involved, and where.

Wastewater Management

Handling of Human Excreta

Collection and disposal of excreta is very important for control of infectious diseases. There is a direct relationship between water supply, wastewater, excreta disposal and health.

There are two ways of disposing of human excreta:

- ❑ **On site disposal** - waste material is disposed of into a latrine or septic tank within the residential plot. On-site disposal facilities include the conventional pit latrines, Ventilated Improved Pit latrine (VIP), septic tanks, aqua-privies, composting latrines, pour flush latrines etc.

- ❑ **Off site disposal** - involves immediate removal of waste material through a network of sewers to the treatment works.

Rural Sanitation

This is not primarily a technical problem. There is a variety of on site disposal systems which are appropriate and cheap. Examples of these are pit, latrines, composting latrines, reed odourless latrine, multrum, etc.

The main problem with rural sanitation is to encourage the population to use and maintain the facilities. There are several reasons contributing to non use of latrines and among them are the following: strong cultural preferences; people require a reason or motivation for using a latrine (e.g. privacy); any kind of latrine requires maintenance and will become fouled and offensive if not maintained.

Urban Sanitation

Around all major towns in developing countries the major problems are excreta and refuse disposal systems in low-income, high-density communities. The high density communities without adequate sanitation range from unplanned slums to planned high density housing areas where adequate sanitation has not been provided largely due to financial constraints. The most appropriate and convenient sanitation system under the circumstances is the conventional water borne sewage system but developing countries find the system inappropriate for several reasons, including the following:

Cost: High capital construction costs - laying sewers. Possible sources to finance the project if no donor; funds include borrowed money and repaid later, implying that the community must cover the repayment costs by sewerage charges or additional taxes, or the city must subsidise the sector at an opportunity cost to other sectors of public spending.

Water Use: Water borne systems use large amounts of drinking water (expensively treated) to merely transport wastes along pipes. In developing countries water is scarce and very expensive resource, frequently overloaded limited distribution systems, therefore water cannot be used extravagantly.

Water borne sewerage can be installed only in communities with individual house water connections; the majority of low income urban dwellers do not have this facility. Many of those with connections may have only intermittent supplies of water. Sewers can rapidly become blocked during the periods when the water is shut off.

Construction: Water borne sewerage is a complex system requiring careful and skilled construction if it is to operate smoothly. Such skills are generally in short supply in a developing country, forcing employment of expatriate companies, with subsequent loss of foreign exchange.

Sewer Laying: By and large, sewers must be laid in straight lines. To dig large trenches in straight lines through squatter settlements will necessitate the demolition of a substantial number of houses, which will often be socially and politically unacceptable.

Blockages: Conventional water borne systems are prone to blockages if large objects are fed into them. Materials used traditionally in certain areas for anal cleansing, such as sticks, stone, corn cobs, may also obstruct sewers.

Wastewater Treatment

On site Water borne Sewerage Systems

Septic Tank

A septic tank is an on site water borne sewage system suitable for areas with in-house water connections but without a network of sewers and a sewage treatment plant. All wastewater from the establishment is flushed into this system. The effluent overflows into a soak away or drain field while the solids settle at the bottom of the tank. It provides a high standard of hygiene and comfort; it needs little maintenance other than desludging at regular intervals.

The septic tank can be upgraded by connecting to a sewerage system using small bore sewers.

Aqua Privy

The system is based on the septic tank principle. In-house water connection is not a necessary criterion for its provision. It requires only sufficient water to clean the squatting plate and maintain a water seal to prevent fly breeding and odours. The system, like septic tank, can be upgraded by connecting to a sewerage system.

Sewerage Systems

Provision of water borne off site disposal system in a community is warranted when:

- ❑ there is sufficient water available and in-house connected;
- ❑ the population density is such that there is no room for on site disposal systems;
- ❑ the inhabitants can afford to install the required fixtures in the buildings; and
- ❑ existing water resources and the environment need protection against pollution.

Sewerage system if properly maintained, is the safest method of wastewater disposal as the waste is taken out of the premises to the treatment plant through a network of sewers. A sewerage system consists basically of a network of pipelines (called sewers) and manholes.

The sizes of sewer pipes depend on the amount of wastewater which is to flow through them. At the beginning of the sewer the flow may be minimal and this may result in deposition of particles in the sewer. These sewers therefore need periodic flushing to remove the accumulated particles.

Sewerage systems end at a treatment plant where wastewater is subjected to both physical and biological treatment. Some kind of industrial wastewater is sometimes subjected to chemical treatment. The end product of treatment is effluent which can be disposed of in different ways depending on its quality.
A by-product of wastewater treatment is sludge. Sludge requires to be stabilised for safe handling and disposal.

Biological Wastewater Treatment Processing

There are three basic types of aerobic units:

- Percolating filter or bacteria bed;
- Activated sludge; and
- Stabilisation pond.

The *biological filter* and *activated sludge* rely on similar principles. The *stabilisation pond* which is only suited to warm climates operates somewhat differently utilising bacteria and algae.

Percolating Filter

The **percolating filter** consists basically of a bed of stones, circular or rectangular in plan with intermittent or continuous addition of settled sewage to the surface. On a conventional filter the medium is 50 - 100 mm preferably hard angular stone grading dosed by a rotating distributor mechanism, the normal depth of the bed being 1.8 m.

Liquid trickles through the interstices in the medium where micro-organisms grow in the protected areas forming a slime or film, the liquid flowing over the film rather than through it. The film consists primarily of bacteria, protozoa, and fungi that feed on waste organics.

The organisms attached to the media in the upper layer of bed grow rapidly, feeding on the abundant food supply. As the wastewater trickles downward, the organic content decreases to the point where micro-organisms in the lower zone are in a state of starvation. Thus the larger proportion of BOD is extracted in upper 0.6 to 0.9m of a 1.8 m filter. Excess microbial growth sloughing off the media is removed from the filter effluent by a final clarifier.

Operational problems include the following:

- **Effluent quality and odours** both associated with organic loading, industrial wastes, and cold weather;
- **Filter flies**, which breed in sheltered zones of the media; and
- **Ponding**

Activated Sludge (Biological Aeration)

Activated sludge process depends on the use of high concentration of micro-organisms present as a floc kept suspended by agitation with either compressed air or mechanical agitation. In either case high rates of oxygen transfer are possible.

Raw wastewater flowing into the aeration basin contains organic matter (BOD) as food supply. Bacteria metabolise the waste solids, producing new growth while taking dissolved oxygen and releasing carbon dioxide. Protozoa graze on bacteria for energy to reproduce. Some of the microbial growths die, releasing cell contents to solution for synthesis. After addition of a large population of micro-organisms, aerating raw wastewater for a few hours removes organic matter from solution by synthesis into microbial cells. Mixed liquor is continuously transferred to a clarifier for gravity separation of the biological floc and discharge of the clarified effluent. Settled floc is returned continuously to the aeration basin for mixing with entering raw wastewater.

The activated sludge process though found in several developing countries has the following disadvantages:

- It is a highly technical system requiring highly trained technical staff which is relatively in short supply in a lot of developing countries;
- Complex design;
- High construction and maintenance costs;
- Complex electro-mechanical equipment for energy input; and
- Final effluent needs tertiary treatment in order to be safely re-used.

Stabilisation Ponds

Waste stabilisation ponds are large shallow man made lakes, usually

rectangular in plan and between 1 - 5 m deep, in which raw wastewater is treated through natural biological and physical processes. They require no mechanical equipment.
There are three types of ponds - *anaerobic, facultative and maturation.* Each type has a specific function. Anaerobic ponds are included when treating strong wastes. Facultative ponds used for treating normal domestic wastes. Maturation ponds are used for the reduction of faecal bacteria.

Anaerobic Ponds

Anaerobic ponds receive raw wastewater, with solids which settle down to undergo anaerobic digestion. By using anaerobic ponds total land requirement for the system could be reduced:

Depth:	3 - 5 m
Detention time :	5 days
BOD reduction:	60 - 70%
Desludging period:	Every 5 years

Facultative Ponds

Facultative ponds are commonly employed for stabilising municipal wastewater. The bacterial reactions include both anaerobic and aerobic decomposition of organic matter, and hence, the term facultative pond.

Waste organics in suspension are broken down by bacteria releasing nitrogen and phosphorus nutrients and carbon dioxide. Algae use these inorganic compounds for growth along with energy from sunlight, releasing oxygen to solution. Dissolved oxygen is in turn taken up by the bacteria, thus closing the symbiotic cycle. Oxygen is also introduced by re-aeration through wind action. Settleable solids decomposed under anaerobic conditions on the bottom yield inorganic nutrients and odourous compounds. The latter are generally oxidised in the aerobic surface water, thus preventing their emission to the atmosphere.

Depth:	1.5 - 2 m
Detention time :	20-40 days
BOD reduction:	60 - 99%
Desludging period:	Every 5 years

It follows that anaerobic pond desludging is not necessary.

Maturation Ponds

Maturation ponds follow the facultative pond principles. Wholly aerobic. May also serve as tertiary treatment for the effluent from a conventional treatment plant with primary and secondary treatment.

Depth:	1 m
Detention time:	7 days (usually the result of two ponds)
Pathogen removal:	99.999%

Appropriate Technology

Stabilisation ponds system is mostly effective in warmer climates. Most of the developing countries fall within this category. The following reasons make stabilisation ponds the most appropriate wastewater treatment system for developing countries.

- Does not require highly trained technical staff for its management;
- Low cost, simple operation, and easy maintenance;
- High pathogen removal, effluent can be re-used for unrestricted irrigation;
- Useful also for treating variety of industrial wastes; and
- Long detention time facilitates acceptance of shock loads.

The two main problems are as follows but are far outweighed by the advantages:

- Large land required; and
- Problems of smell and mosquitoes.

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