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Wastewater Management

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1. Introduction

Wastewater is water whose physical, chemical or biological properties have been changed as a result of the introduction of certain substances which render it unsafe for some purposes such as drinking. The day to day activities of man is mainly water dependent and therefore discharge 'waste' into water. Some of the substances include body wastes (faeces and urine), hair shampoo, hair, food scraps, fat, laundry powder, fabric conditioners, toilet paper, chemicals, detergent, household cleaners, dirt, micro-organisms (germs) which can make people ill and damage the environment. It is known that much of water supplied ends up as wastewater which makes its treatment very important. Wastewater treatment is the process and technology that is used to remove most of the contaminants that are found in wastewater to ensure a sound environment and good public health. Wastewater Management therefore means handling wastewater to protect the environment to ensure public health, economic, social and political soundness (Metcalf and Eddy, 1991).

1.1 History of wastewater treatment

Wastewater treatment is a fairly new practice although drainage systems were built long before the nineteenth century. Before this time, "night soil" was placed in buckets along streets and workers emptied them into "honeywagon" tanks. This was sent to rural areas and disposed off over agricultural lands. In the nineteenth century, flush toilets led to an increase in the volume of waste for these agricultural lands. Due to this transporting challenge, cities began to use drainage and storm sewers to convey wastewater into waterbodies against the recommendation of Edwin Chadwick in 1842 that "rain to the river and sewage to the soil". The discharge of waste into water courses led to gross pollution and health problems for downstream users.

In 1842, an English engineer named Lindley built the first "modern" sewerage system for wastewater carriage in Hamburg, Germany. The improvement of the Lindley system is basically in improved materials and the inclusion of manholes and sewer appurtenances— the Lindley principles are still upheld today. Treatment of wastewater became apparent only after the assimilative capacity of the waterbodies was exceeded and health problems became intolerable. Between the late 1800s and early 1900s, various options were tried until in 1920, the processes we have today were tried. Its design was however empirical until midcentury. Centralized wastewater systems were designed and encouraged. The cost of wastewater treatment is borne by communities discharging into the plant.

Today there have been great advances to make portable water from wastewater. In recent times, regardless of the capacity of the receiving stream, a minimum treatment level is required before discharge permits are granted (Peavy, Rowe and Tchobanoglous, 1985). Also presently, the focus is shifting from centralized systems to more sustainable decentralized wastewater treatment (DEWATS) especially for developing countries like Ghana where wastewater infrastructure is poor and conventional methods are difficult to manage (Adu-Ahyia and Anku, 2010).

1.2 Objectives of wastewater treatment

Wastewater treatment is very necessary for the above-mentioned reasons. It is more vital for the:

Reduction of biodegradable organic substances in the environment: organic substances such as carbon, nitrogen, phosphorus, sulphur in organic matter needs to be broken down by oxidation into gases which is either released or remains in solution.

Reduction of nutrient concentration in the environment: nutrients such as nitrogen and phosphorous from wastewater in the environment enrich water bodies or render it eutrophic leading to the growth of algae and other aquatic plants. These plants deplete oxygen in water bodies and this hampers aquatic life.

Elimination of pathogens: organisms that cause disease in plants, animals and humans are called pathogens. They are also known as micro-organisms because they are very small to be seen with the naked eye. Examples of micro-organisms include bacteria (e.g. *vibro cholerae*), viruses (e.g. enterovirus, hepatits A & E virus), fungi (e.g. *candida albicans*), protozoa (e.g *entamoeba hystolitica, giardia lamblia*) and helminthes (e.g. *schistosoma mansoni, asaris lumbricoides*). These micro-organisms are excreted in large quantities in faeces of infected animals and humans (Awuah and Amankwaa-Kuffuor, 2002).

Recycling and Reuse of water: Water is a scarce and finite resource which is often taken for granted. In the last half of the 20th century, population has increased resulting in pressure on the already scarce water resources. Urbanization has also changed the agrarian nature of many areas. Population increase means more food has to be cultivated for the growing population and agriculture as we know is by far the largest user of available water which means that economic growth is placing new demands on available water supplies. The temporal and spatial distribution of water is also a major challenge with groundwater resources being overdrawn (National Academy, 2005). It is for these reasons that recycling and reuse is crucial for sustainability.

1.3 Types of wastewater

Wastewater can be described as in the figure below.

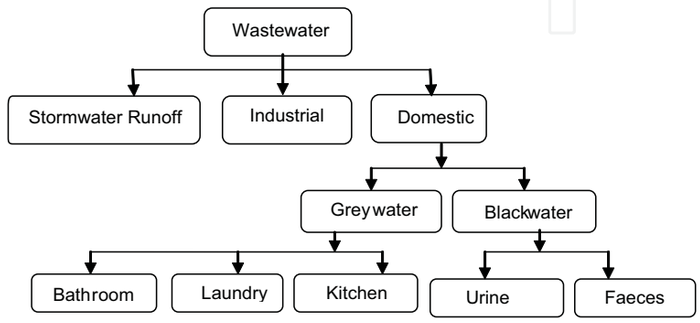


Fig. 1. Types of Wastewater

2. Definition of concepts and terminology

Stormwater Runoff is water from streets, open yard etc after a rainfall event which run through drains or sewers.

Industrial wastewater is liquid waste from industrial establishments such as factories, production units etc.

Domestic wastewater also known as municipal wastewater is basically wastewater from residences (homes), business buildings (e.g. hotels) and institutions (e.g. university). It can be categorized into greywater and blackwater.

Greywater also known as sullage is liquid waste from washrooms, laundries, kitchens which does not contain human or animal excreta.

Blackwater is wastewater generated in toilets. Blackwater may also contain some flush water besides urine and faeces (excreta). Urine and faeces together is sometimes referred to as night soil.

Sewage is the term used for blackwater if it ends up in a sewerage system.

Septage is the term used for blackwater if it ends up in a septic tank.

Sewerage system is the arrangement of pipes laid for conveying sewage.

Influent is wastewater which is yet to enter in a wastewater treatment plant or liquid waste that is yet to undergo a unit process or operation.

Effluent is the liquid stream which is discharged from a wastewater treatment plant or discharge from a unit process or operation.

Sludge is the semi-solid slurry from a wastewater treatment plant.

On-Site System: this is wastewater disposal method which takes place at the point of waste production like within individual houses without transportation. On- site methods include dry methods (pit latrines, composting toilets), water saving methods (pour-flush latrine and aqua privy with soakage pits and methods with high water rise (flush toilet with septic tanks and soakage pit, which are not emptied).

Off-Site System: in this system, wastewater is transported to a place either than the point of production. Off- site methods are bucket latrines, pour-flush toilets with vault and tanker removal and conventional sewerage system.

Conventional sewerage systems can be combined sewers (where wastewater is carried with storm water) or separated sewers.

Septic Tank is an on-site system designed to hold blackwater for sufficiently long period to allow sedimentation. It is usually a water tight single storey tank.

Faecal sludge refers to all sludge collected and transported from on-site sanitation systems by vacuum trucks for disposal or treatment.

Unit Operation: this involves removal of contaminants by physical forces.

Unit Process: this involves biological and/or chemical removal of contaminants.

Wastewater Treatment Plant is a plant with a series of designed unit operations and processes that aims at reducing certain constituents of wastewater to acceptable levels.

3. Characteristics of wastewater

Depending on its source, wastewater has peculiar characteristics. Industrial wastewater with characteristics of municipal or domestic wastewater can be discharged together. Industrial wastewater may require some pretreatment if it has to be discharged with domestic wastewater. The characteristics of wastewater vary from industry to industry and

therefore would have different treatment processes—for example a cocoa processing company may have a skimming tank in its preliminary treatment stage to handle for instance spilt cocoa butter while a beverage plant may skip this in the design. In general, the contaminants in wastewater are categorized into physical, chemical and biological. Some indicator measured to ascertain these contaminants include (Peavy, Rowe and Tchobanoglous, 1985 & Obuobie et al., 2006):

Physical

- **Electrical Conductivity** (EC) indicates the salt content
- **Total Dissolved Solids** (TDS) comprise inorganic salts and small amounts of organic matter dissolved in water
- **Suspended solids** (SS) comprises solid particles suspended (but not dissolved)in water

Chemical

- **Dissolved Oxygen** (DO) indicates the amount of oxygen in water
- **Biochemical oxygen demand** (BOD) indicates the amount of oxygen required by aerobic microorganisms to decompose the organic matter in a sample of water in a defined time period.
- **Chemical oxygen demand** (COD) indicates the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant
- **Total Organic Compound** (TOC)
- **NH4-N** and **NO3-N** show dissolved nitrogen (Ammonium and Nitrate, respectively).
- **Total Kjeldhal Nitrogen** is a measurement of organically-bound ammonia nitrogen.
- **Total-P** reflects the amount of all forms of phosphorous in a sample.

Biological

- **Total coliforms** (TC) is encompassing faecal coliforms as well as common soil microorganisms, and is a broad indicator of possible water contamination.
- **Faecal coliforms** (FC) is an indicator of water contamination with faecal matter. The common lead indicator is the bacteria *Escherichia coli* or *E. coli.*
- **Helminth** analysis looks for worm eggs in the water

3.1 Process of wastewater treatment

Due to the nature of contaminants in wastewater—physical, chemical and biological, the unit operations and processes in wastewater treatment can also be categorized as such. The units operations and processes in Waste-water treatment are summarized as follows (Economic and Social Commission for Western Asia (ESCWA), 2003):

Physical unit operations

- Screening
- Comminution
- Flow equalization
- Sedimentation
- Flotation
- Granular-medium filtration

Chemical unit operations

- Chemical precipitation
- Adsorption
- Disinfection
- Dechlorination

- Other chemical applications

Biological unit operations

- Activated sludge process
- Aerated lagoon
- Trickling filters
- Rotating biological contactors
- Pond stabilization
- Anaerobic digestion

3.2 Levels of wastewater treatment

There are three broad levels of treatment: primary, secondary and tertiary. Sometimes, preliminary treatment precedes primary treatment.

Preliminary treatment: removes coarse suspended and grits. These can be removed by screening, and grit chambers respectively. This enhances the operation and maintenance of subsequent treatment units. Flow measurement devices, often standing-wave flumes, are necessary at this treatment stage (FAO, 2006).

Primary treatment removes settleable organic and inorganic solids by sedimentation and floating materials (scum) by skimming. Up to 50% of BOD5, 70% of suspended solids and 65% of grease and oil can be removed at this stage. Some organic nitrogen, organic phosphorus, and heavy metals are also removed. Colloidal and dissolved constituents are however not removed at this stage. The effluent from primary sedimentation units is referred to as primary effluent (FAO, 2006).

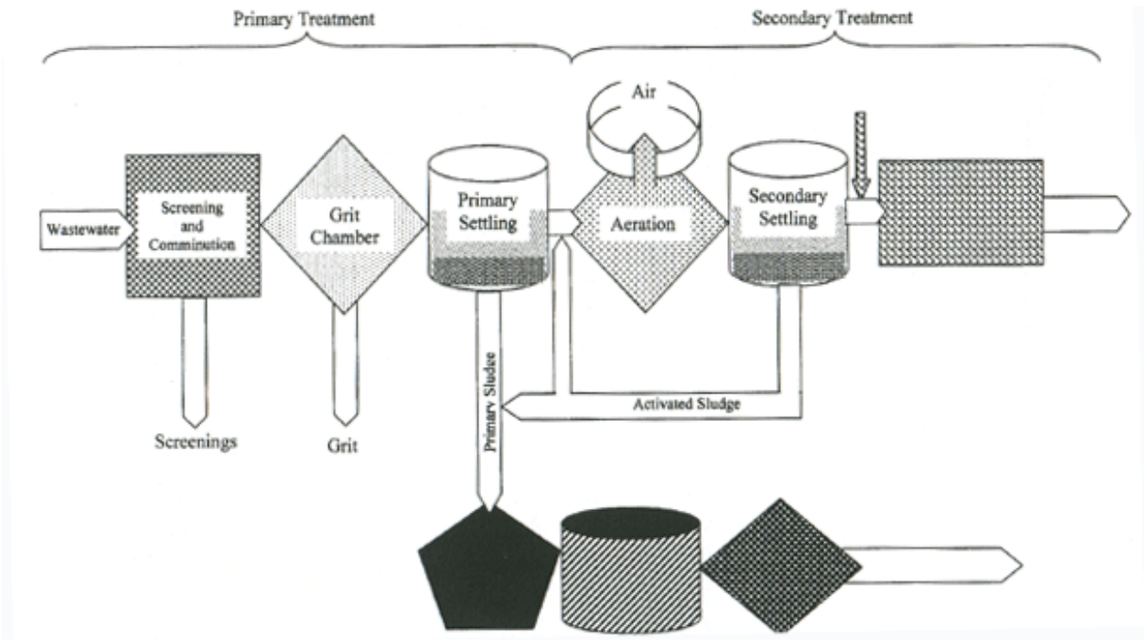
Secondary treatment is the further treatment of primary effluent to remove residual organics and suspended solids. Also biodegradable dissolved and colloidal organic matter is removed using aerobic biological treatment processes. The removal of organic matter is when nitrogen compounds and phosphorus compounds and pathogenic microorganisms are removed. The treatment can be done mechanically like in trickling filters, activated sludge methods rotating biological contactors (RBC) or non-mechanically like in anaerobic treatment, oxidation ditches, stabilization ponds etc.

Tertiary treatment or advance treatment is employed when specific wastewater constituents which cannot be removed by secondary treatment must be removed. Advance treatment removes significant amounts of nitrogen, phosphorus, heavy metals, biodegradable organics, bacteria and viruses. Two methods can be used effectively to filter secondary effluent—traditional sand (or similar media) filter and the newer membrane materials. Some filters have been improved, and both filters and membranes also remove helminths. The latest method is disk filtration which utilizes large disks of cloth media attached to rotating drums for filtration (FAO, 2006).

At this stage, disinfection by the injection of Chlorine, Ozone and Ultra Violet (UV) irradiation can be done to make water meet current international standards for agricultural and urban re-use.

4. Methods of wastewater treatment

There are conventional and non-conventional wastewater treatment methods which have been proven and found to be efficient in the treatment of wastewater. Conventional methods compared to non-conventional wastewater treatment methods has a relatively high



Source: NPTEL (accessed 2010)

Fig. 2. Typical Wastewater Treatment Plant

level of automation. Usually have pumping and power requirements. They require skilled labour for operation and maintenance of the system

4.1 Conventional methods

Examples of conventional wastewater treatment methods include activated sludge, trickling filter, rotating biological contactor methods. Trickling filters and Rotating Biological Contactors are temperature sensitive, remove less BOD, and trickling filters cost more to build than activated sludge systems. Activated sludge systems are much more expensive to operate because energy is needed to run pumps and blowers (National Programme on Technology Enhanced Learning (NPTEL), 2010).

These methods are discussed in detail in the subsequent sections.

4.1.1 Activated sludge

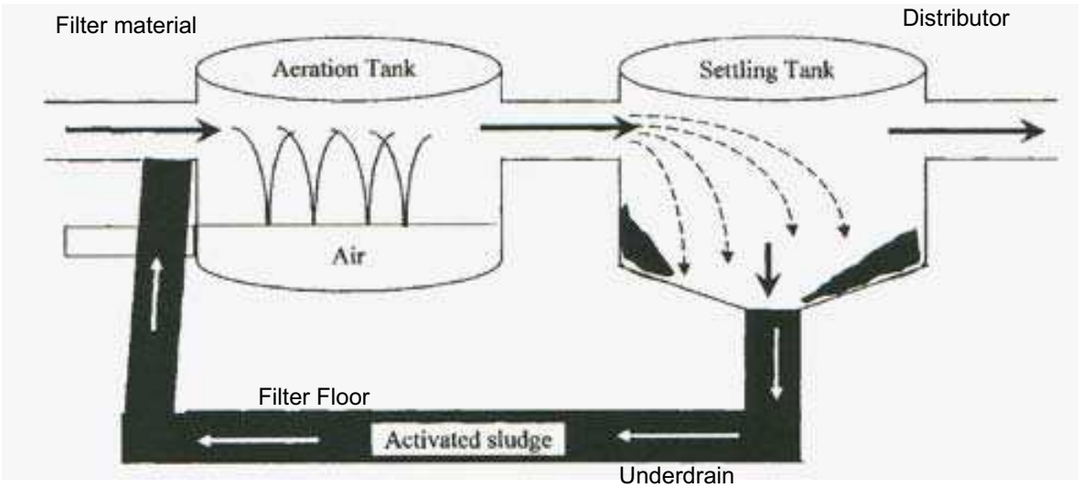
Activated sludge refers to biological treatment processes that use a suspended growth of organisms to remove BOD and suspended solids. It is based on the principle that intense wastewater aeration to forms flocs of bacteria (activated sludge), which degrade organic matter and be separated by sedimentation. The system consists of aeration and settling tanks with other appurtenances such as return and waste pumps, mixers and blowers for aeration and a flow measurement device. To maintain the concentration of active bacteria in the tank, part of the activated sludge is recycled.

Primary effluent (or plant influent) is mixed with return activated sludge to form mixed liquor which is aerated for a specified length of time. By aerating the system, activated sludge organisms use the available organic matter as food, thereby, producing stable solids and more organisms. The suspended solids produced by the process and the additional organisms become part of the activated sludge. The solids are then separated from the

wastewater in the settling tank and are returned to the influent of the aeration tank (return activated sludge). Periodically the excess solids and organisms are removed from the system (waste activated sludge) to enhance the performance of the system.

Factors such as temperature, return rates, amount of oxygen available, amount of organic matter available, pH, waste rates, aeration time, and wastewater toxicity affect the performance of an activated sludge treatment system. A balance therefore must be maintained between the amount of food (organic matter), organisms (activated sludge) and dissolved oxygen (NPTEL, 2010).

Activated Sludge systems are requires less space compared to trickling filter and has high effluent quality. The disadvantage is that BOD is higher at one end of the tank than the other the microorganisms will be physiologically more active at that end than the other unless a complet mixing activated sludge system process is used. Presently there are 11 activated sludge plants in Ghana, mainly installed by the large hotels (Obuobie, et al., 2006).



Source: Mountain Empire College, 2010

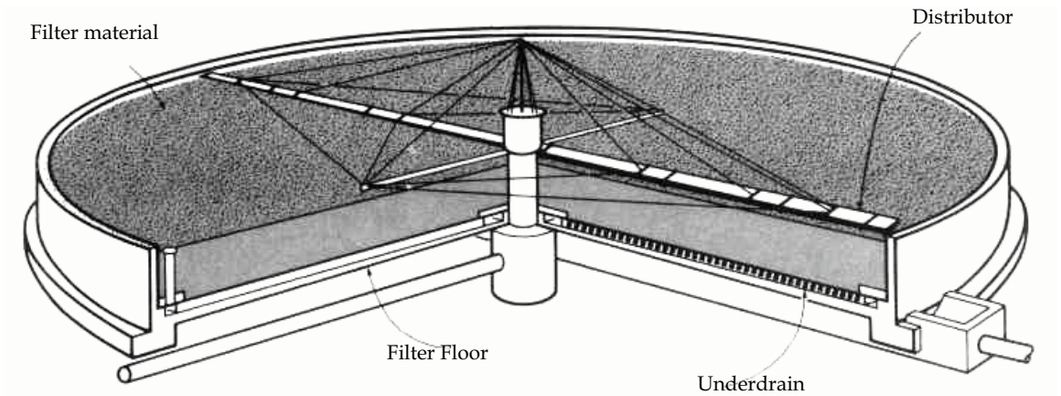
Fig. 3. An activated Sludge System

4.1.2 Trickling filter:

It is a growth process in which microorganisms responsible for treatment are attached to an inert packing material. It is made up of a round tank filled with a carrier material (volcanic rock, gravel or synthetic material). Wastewater is supplied from above and trickles through filter media allowing organic material in the wastewater to be adsorbed by a population of microorganisms (aerobic, anaerobic, and facultative bacteria; fungi; algae; and protozoa) attached to the medium as a biological film or slime layer (approximately 0.1 to 0.2 mm thick).

Degradation of organic material by the aerobic microorganisms in the outer part of the slime layer occurs. As the layer thickens through microbial growth, oxygen cannot penetrate the medium face, and anaerobic organisms develop. The biological film continues to grow to such a point that microorganisms near the surface cannot cling to the medium, and a portion of the slime layer falls off the filter. This process is known as sloughing. The sloughed solids are picked up by the underdrain system and transported to a clarifier for removal from the wastewater (US EPA, 2000).

Trickling filters are efficient in that effluent quality in terms of BOD and suspended solids removal is high. Its operational costs are relatively low due to low electricity requirements. The process is simpler compared to activated sludge process or some package treatment plants. Its operation and maintenance requirements is however high due to the use of electrical power. Skilled labour is required to keep the trickling filter running trouble-free: e.g. prevent clogging, ensure adequate flushing, control filter flies. It is suitable for some relatively wealthy, densely populated areas which have a sewerage system and centralized wastewater treatment; also suitable for greywater treatment.
It also requires more space compared to some other technologies and has potential for odour and filter flies (NPTEL, 2010).
This method has been widely used in Ghana. There are 14 trickling filter plants in Accra though they have broken down.

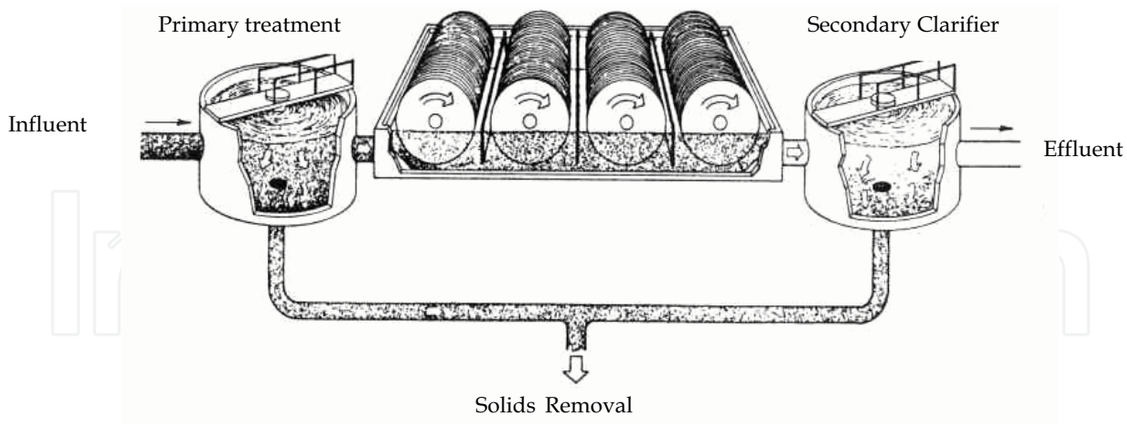


Source: ESCWA, 2003

Fig. 4. Cross section of a trickling filter

4.1.3 Rotating biological contactors

Rotating biological contactors (RBCs) consist of vertically arranged, plastic media on a horizontal, rotating shaft. The plastics range from 2 – 4 m in diameter and up to 10 mm thick (Peavy, Rowe ad Tchobanoglous, 1985). The biomass-coated media are alternately exposed to wastewater and atmospheric oxygen as the shaft slowly rotates at 1–1.5 rpm (necessary to provide hydraulic shear for sloughing and to maintain turbulence to keep solid in suspension), with about 40% of the media submerged. High surface area allows a large, stable biomass population to develop, with excess growth continuously and automatically shed and removed in a downstream clarifier. Thichness of biofilm may reach 2 – 4 mm depending on the strength of wastewater and the rotational speed of the disk.
RBC systems are relatively new, though it appeared to be best suited to treat municipal wastewater (Peavy, Rowe ad Tchobanoglous, 1985), they have been installed in many petroleum facilities because of their ability to quickly recover from upset conditions (Schultz, 2005). The RBC system is easily expandable should the need arise, and RBCs are also very easy to enclose should volatile organic content containment become necessary. RBCs have relatively low power requirements and can even be powered by compressed air which can also aerate the system. They follow simple operating procedures and thus require a moderately skilled labour. RBCs are however capital intensive to install and sensitive to temperature.

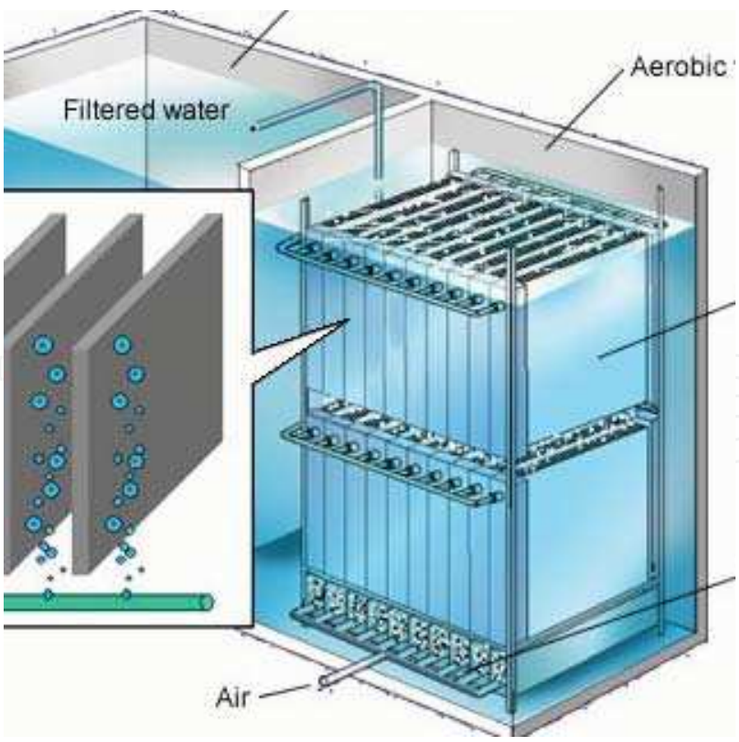


Source: ESCWA, 2003

Fig. 5. Rotating Biological Contactors

4.1.4 Membrane bioreactors

This method performs more than just one treatment step. Membrane bioreactor (MBR) systems are unique processes, which combine anoxic- and aerobic-biological treatment with an integrated membrane system that can be used with most suspended-growth, biological wastewater-treatment systems.



Source: Google Images

Fig. 6. Membrane Bioreator

Wastewater is screened before entering the biological treatment tank. Aeration within the aerobic-reactor zone provides oxygen for biological respiration and maintains solids in suspension. MBR relies on submerged membranes to retain active biomass in the process. This allows the biological process to operate at longer than normal sludge ages (typically 20-100 days for a MBR) and to increase mixed-liquor, suspended-solids (MLSS) concentrations (typically 8,000-15,000 mg/l) for more effective removal of pollutants. High MLSS concentrations reduce biological-volume requirements and the associated space needed to only 20–30% of conventional biological processes.

MBRs cover a small land area as it eliminates the need for secondary clarifiers, which equates to a huge savings in both footprint and concrete costs. They can operate at higher biomass concentrations (MLSS) than conventional treatment processes. Facility can be expanded by simply adding more membranes to existing basins without expanding land cover. For reuse quality, it does not require tertiary treatment, polymer addition, or any further treatment processes to meet standards. This reduction in the number of unit processes further improves system reliability and reduces operation activities (TEC, 2010). The generally high effluent quality reduces the burden on disinfection in the treatment process.

4.2 Non-conventional methods

These are low-cost, low-technology, less sophisticated in operation and maintenance biological treatment systems for municipal wastewater. Although these systems are land intensive by comparison with the conventional high-rate biological processes, they are often more effective in removing pathogens and do so reliably and continuously if system is properly designed and not overloaded (FAO, 2006). Some of the non-conventional methods include stabilization ponds, constructed wetlands, oxidation ditch, soil aquifer treatment.

4.2.1 Waste stabilization ponds

Waste Stabilization Ponds are man-made, shallow basins which comprise of a single series or several series of anaerobic, facultative or maturation ponds. This is a low-technology treatment process with 4 or 5 ponds of different depths with different biological activities. Treatment of the wastewater occurs as constituents are removed by sedimentation or transformed by biological and chemical processes (National Academy, 2005).The anaerobic ponds are mainly designed for the settling and removal of suspended solids as well as the breakdown of some organic matter (BOD_5). In facultative ponds, organic matter is further broken down to carbon dioxide, nitrogen and phosphorous by using oxygen produced by algae in the pond. Maturation ponds usually remove nutrients and pathogenic micro-organisms, thus primary treatment occurs in anaerobic ponds while secondary and tertiary treatment occurs in facultative and maturation ponds respectively (Awuah, 2002).

Anaerobic ponds are usually between 2-5 m deep and receive high organic loads equivalent to 100g BOD_5 and m^3/d leading to anaerobic conditions throughout the pond (Mara *et al.*, 1992). If properly designed, anaerobic ponds can remove 60% of BOD_5 at 200 C.

Facultative ponds are 1-2 m deep and usually receive the effluent from an anaerobic pond. In some designs, they receive raw wastewater acting as primary facultative pond. In facultative ponds organic loads are lower and allows for algal growth which accounts for the dark green colour of wastewater. Algae and aerobic bacteria generate oxygen which breaks down BOD_5. Good wind velocity generates mixing of wastewater in ponds thus leading to uniform mixing of BOD_5, oxygen, bacteria and algae which better stabilizes waste.

Maturation ponds are usually shallow ponds of about 1.0-1.5 m deep allowing aerobic conditions in for the treatment of facultative pond effluents. Further reduction of organic matter, nutrients and pathogenic microorganisms occurs here. Algal population in maturation ponds is more diverse and removal of nitrogen and ammonia is more prominent.

In Ghana so far, stabilization ponds have worked very well due to the convenient climatic conditions. It usually flows under gravity from one pond to the other and mostly does not require any pumping. It is less energy dependent thus plant activities cannot be interrupted due to power cuts. Its disadvantages however include odour problems and it requires a large area of land to function properly. Presently there are 21 stabilisation ponds in Ghana mainly in Accra and Kumasi. Some of them like the Tema Community 3, Achimota, have been closed Various combinations and arrangement of ponds are possible. The figure below shows some possible combinations.

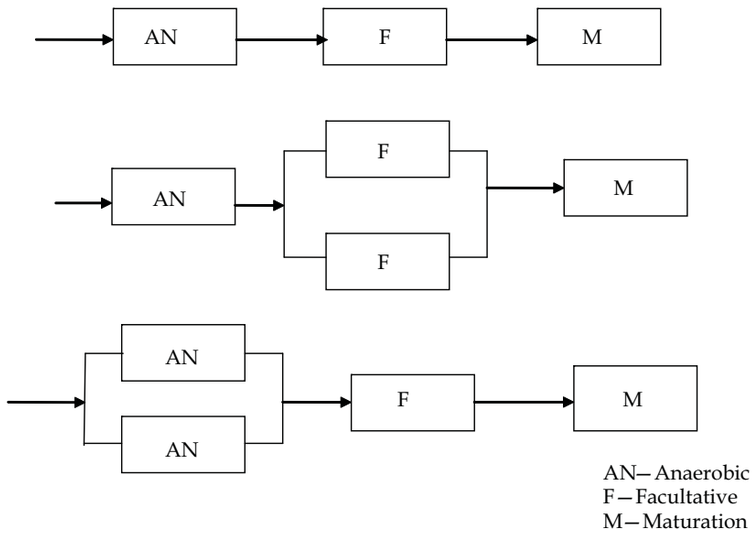
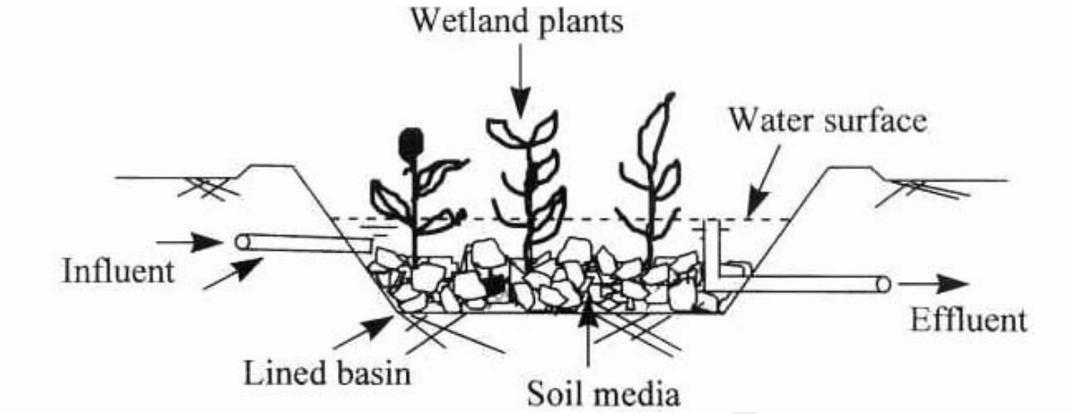


Fig. 7. Various Arrangement of Waste Stabilisation Ponds

4.2.2 Constructed wetlands

Constructed Wetlands (CW's) are planned systems which are designed and constructed to employ wetland vegetation to assist in treating wastewater in a more controlled environment than occurs in natural wetlands (Kayombo et al., 2000). They are an eco-friendly and a suitable alternative for secondary and tertiary treatment of municipal and industrial wastewater. They are suitable for the removal of organic materials, suspended solids, nutrients, pathogens, heavy metals and toxic pollutants. They are not ideal for the treatment of raw sewage, pre-treatment of industrial wastewater to maintain the biological balance of the wetland ecosystem.

There are two types of CW's namely Free Water Surface (FWS) and Subsurface Flow (SSF) systems. As the name suggests, with FWS, water flows above the ground and plants are rooted in the sediment layer below the water column. With SSF, water flows through a porous media such as gravels in which the plants are rooted. From a public health perspective, SSF should be used in primary treatment of wastewater because there is no direct contact of wastewater with atmosphere.

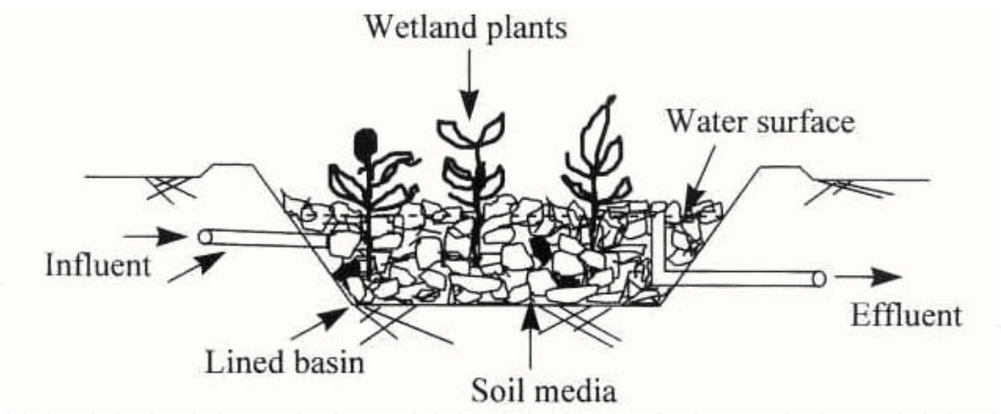


Source: ESCWA, 2003

Fig. 8. Free Water Surface System

The SSF is mostly anoxic or anaerobic as oxygen supplied by the roots of plants is used up in biofilm growth and as such does not reach the water colomn. The flow of water in SSF can be horizontal or vertical (Kayombo *et al.,* 2000*)*. FWS are suitable for treating secondary and tertiary effluents and also providing habitat due to aerobic conditions at and near the surface of the water. There condition at the bottom sediment is however anoxic.

Wetlands plants or macrophytes utilized in CW's include Cattails (*Typha latifolia sp), Scirpus* (Bulrus), *Lemna* (duckweed), *Eichornia crassipes* (water hyacinth), *Pistia stratiotes* (water lettuce) *Hydrocotyle* spp. (pennywort), *Phragmites* (reed) have been known and used in constructed wetlands.



Source: ESCWA, 2003

Fig. 9. Sub-surface flow system

CW's are relatively cheaper to construct operate and easy to maintain. This is an important decision variable for developing countries. In Egypt, according to Hendy (2006), between 2000 and 2004, a 60 acre artificial wetland constructed cost 25% the cost of conventional sewage treatment plant.

They provide effective and reliable treatment of wastewater and are tolerant to fluctuating hydrologic and contaminant loading rates. With the example in Egypt, $9 million (US) was spent to treat an initial volume of 25,000 metric tons per day. After a year of use, it was determined that the wetland was capable of treating 40,000 metric tons per day (Hendy,

2006). Also a study conducted by Ratnapriya *et al.,* (2009) revealed over 60% removal of BOD5, COD, nitrogen among others.
CW's also provide indirect benefits such as enjoying the scenic views of green spaces, encouraging wildlife habitats and providing recreational and educational centres. Again, in Egypt, the fishing industry is expanding since the wastewater was no longer being discharged directly into the waterways, the local fisheries improved. According to Hendy (2006), nitrates and heavy metals were filtered out, leaving the fish healthier, larger and in abundant quantity. This indirectly led to poverty reduction.
They however have some disadvantages such as land requirements, its design and operation criteria is presently imprecise. CW's are biologically and hydrologically complex and its process dynamics are not completely understood. Sometimes there are cost implications of gravels fills and site grading during construction (Kayombo *et al.,* 2000). It must be emphasized that if properly designed, constructed wetlands should not breed pests and mosquitoes.
In Ghana, there are not many CW's. There is presently a pilot SSF donor CW in Tema. This plant is not entirely low-cost as it was designed with some energy dependent units.

4.2.3 Oxidation ditches

An oxidation ditch is a modified activated sludge biological treatment process that utilizes hydraulic retention time of 24 - 48 hours, and a sludge age of 12 - 20 days. to remove biodegradable organics. Oxidation ditches are typically complete mix systems, but can be modified. Typical oxidation ditch treatment systems consist of a single or multichannel configuration within a ring, or oval. Preliminary treatment, such as bar screens and grit removal, normally precedes the oxidation ditch. Primary settling prior to an oxidation ditch is sometimes practiced and tertiary filters may be required after clarification, depending on the effluent requirements. Disinfection is required and reaeration may be necessary prior to final discharge. Horizontally or vertically mounted aerators provide circulation, oxygen transfer, and aeration in the ditch. Flow to the oxidation ditch is aerated and mixed with return sludge from a secondary clarifier. The mixing process entrains oxygen into the mixed liquor to foster microbial growth and the motive velocity ensures contact of microorganisms with the influent. Aeration increases dissolved oxygen concentration but decreases as biomass takes up oxygen during mixing in the ditch. Solids also remain in suspension during circulation (USEPA, 2000).
They require more power than waste stabilization ponds less land, and are easier to control than processes such as activated sludge process. A typical process flow diagram of treatment plant using an oxidation ditch is shown in Figure 10.

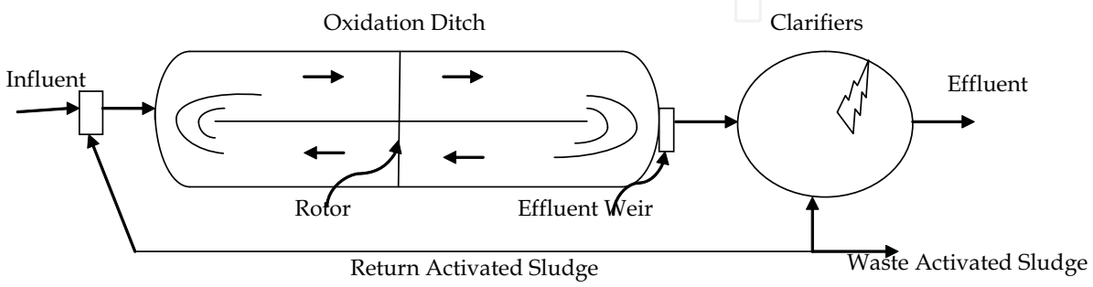
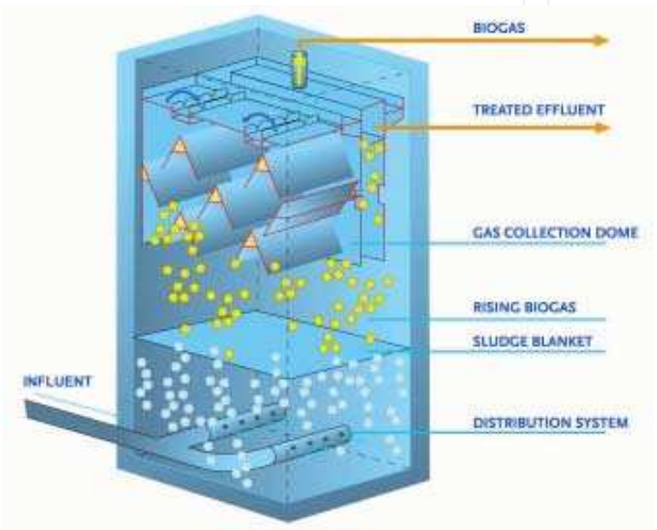
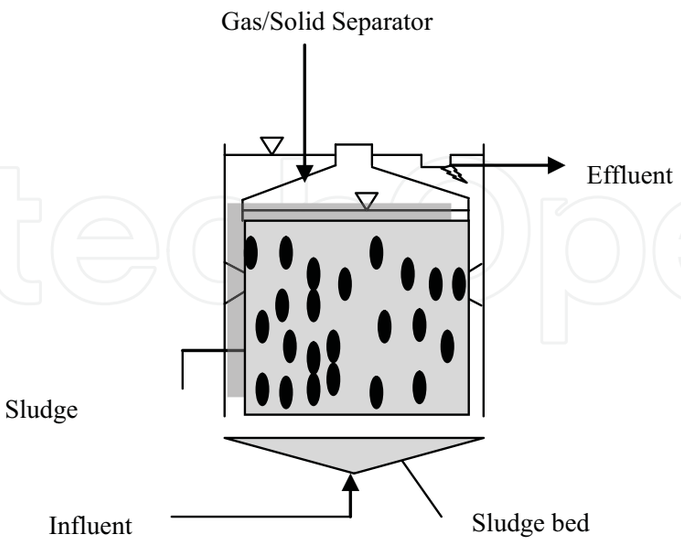


Fig. 10. Oxidation Ditch

4.2.4 Upflow anaerobic sludge blanket (UASB)

Upflow anaerobic sludge blanket is an anaerobic process using blanket of bacteria (see Figure 11) to absorb polluting load. It is a form of anaerobic digester which forms a blanket of granular sludge which suspends in the tank. Wastewater flows upwards through the blanket and is processed (degraded) by the anaerobic microorganisms. The upward flow combined with the settling action of gravity suspends the blanket with the aid of flocculants. Small sludge granules begin to form whose surface area is covered in agregations of bacteria. In the absence of any support matrix, the flow conditions create a selective environment in which only those microorganisms, capable of attaching to each other, survive and proliferate.





Source: Google Images

Fig. 11. Upflow Anaerobic Sludge Blanket

Eventually the aggregates form into dense compact biofilms referred to as granules. The UASB reactor works best when desirable micro-organisms are retained as highly active and fast settling granules. In the UASB reactor, when high solids retention time is met, separation of gas, sludge solids from the liquid occurs. The special Gas-Solid-Liquid Separators in the reactor enable collection of biogas and recycle of anaerobic biomass. Biogas contains 50 to 80% methane.

UASB is suitable for the primary treatment of high-COD mainly soluble industrial effluents. It can also be used for the treatment of wastewater effluents of low and medium strength. It is suited to hot climates Low energy requirement, less operation and maintenance, lower skill requirement for operation, less sludge production, resource recovery through biogas generation and stabilized waste as manure. UASBs however have relatively poor effluent quality than processes such as activated sludge process (Tare and Nema, 2010).

The technology however, needs constant monitoring to ensure that the sludge blanket is maintained, and not washed out. The heat produced as a by-product of electricity generation can be reused to heat the digestion tanks.

4.2.5 Soil aquifer treatment

Soil matrix has quite a high capacity for treatment of normal domestic sewage, as long as capacity is not exceeded. Partially-treated sewage effluent is allowed to infiltrate in controlled conditions to the soil. The unsaturated or "vadose" zone then acts as a natural filter and can remove essentially all suspended solids, biodegradable materials, bacteria, viruses, and other microorganisms. Significant reductions in nitrogen, phosphorus, and heavy metals concentrations can also be achieved. After the sewage, treated in passage through the vadose zone, has reached the groundwater it is usually allowed to flow some distance through the aquifer for further purification before it is collected through the aquifer.

Soil-aquifer treatment is a low-technology, advanced wastewater treatment system. It also has an aesthetic advantage over conventionally treated sewage since effluent from an SAT systems is clear and odour-free and it is viewed as groundwater either than effluent. Discharge effluent should travel sufficient distance through the system and residence times should be long enough, to produce effluent of desired quality (FAO, 2006).

4.3 Faecal sludge treatment and disposal

Sewage sludge contains organic and inorganic solids that were found in the raw wastewater. Sludge from primary and secondary clarifier as well as from secondary biological treatment need to be treated. The generated sludge is usually in the form of a liquid or semisolid, containing 0.25 to 12 per cent solids by weight, depending on the treatment operations and processes used. Sludge is treated by means of a variety of processes that can be used in various combinations. Thickening, conditioning, dewatering and drying are primarily used to remove moisture from sludge, while digestion, composting, incineration, wet-air oxidation and vertical tube reactors are used to treat or stabilize the organic material in the sludge (ESCWA, 2003).

Thickening: Thickening is done to increase the solids content of sludge by the reduction of the liquid content. An increase in solids content from 3 to about 6 per cent can decrease total sludge volume significantly by 50 per cent. Sludge thickening methods are usually physical in nature: they include gravity settling, flotation, centrifugation and gravity belts.

Stabilization: Sludge stabilization is aimed at reducing the pathogen content, eliminate offensive odours, and reduce or eliminate the potential for putrefaction. Some methods used for sludge stabilization include lime stabilization, heat treatment, anaerobic digestion, aerobic digestion and composting (ESCWA, 2003).

5. Wastewater reuse in agriculture

Irrigation with wastewater is both disposal and utilization and indeed is an effective form of wastewater disposal (as in slow-rate land treatment). However, some degree of treatment must normally be provided to raw municipal wastewater before it can be used for agricultural or landscape irrigation or for aquaculture.

In many industrialized countries, primary treatment is the minimum level of preapplication treatment required for wastewater irrigation. It may be considered sufficient treatment if the wastewater is used to irrigate crops that are not consumed by humans or to irrigate orchards, vineyards, and some processed food crops (FAO, 2006).

Nutrients in municipal wastewater and treated effluents are a particular advantage as supplemental fertilizers. Success in using treated wastewater for crop production will largely depend on adopting appropriate strategies aimed at optimizing crop yields and quality, maintaining soil productivity and safeguarding the environment. Several alternatives are available and a combination of these alternatives will offer an optimum solution for a given set of conditions. The user should have prior information on effluent supply and its quality. Wastewater effluent can be blended with conventional water or solely used. Heavy metal concentrations in streams used for irrigation in and around urban centres such as Accra and Kumasi have been sometimes found to be beyond recommended levels for irrigation purposed and should therefore may pose a health concern.

Countries must develop standards in congruence with the WHO guidelines and enforce it.

6. Industrial wastewater treatment

In general, the type of plant to be installed depends on the characteristics of the wastewater produced from that industry. The basic principle according to Kamala and Kanth Rao (1989) however is waste prevention by good housekeeping practices that will ultimately result in volume reduction and strength reduction. Industrial wastewater is treated the same way as domestic or municipal sewage—preliminary, primary, secondary and advanced treatment levels. Most of the treatment methods discussed is also applicable. There could however be peculiarities with different industrial depending on their major contaminant e.g. heavy metals, dye, etc.

Industrial wastewater in Ghana is generated from breweries, distilleries, textile, chemical & pharmaceuticals and institutions and hotels which are mainly situated in Accra and Tema. In the Western and middle belt of Ghana, mining activities are predominant and the major polluter of our rivers. EPA-Ghana grants permits to industries and requires industries to install or build an in-house waste treatment plant. EPA-Ghana takes samples quarterly from these industrial wastewater plants for testing in their own laboratories for monitoring purposes. Most of those who have permit have treatment plants though not all of them are functioning properly.

In recent years, there has been a growth of small-scale industries in the fruits and food processing industries in the Tema, light industrial area which do not have the resources to build treatment plant. Most of these small-scale industries empty their wastewater into nearby drains without treatment. In Kumasi, the principal generators of industrial wastewater in Kumasi are the two breweries, a soft drink bottling plant and an Abattoir.

7. Status of wastewater treatment plants in Ghana

The use of on-site treatment systems is quite extensive. Individual and community/residential based septic tanks are the most preferred. Septic tanks only partially treat sewage, and the effluent is still rich in organic material. The septic tank has to be emptied from time to time and the disposal of the septic sludge causes severe public health and environmental particularly in urban areas.

Major wastewater treatment methods found in Ghana includes stabilisation ponds, trickling filters and activated sludge plants. According to a recent survey, there are 46 wastewater treatment plants in Ghana. More than half of all treatment plants in Ghana are in the Greater Accra region, mainly in the capital city of Accra and port city of Tema. Brong Ahafo and Upper West regions have no treatment plants at all. The stabilization pond method is the most extensively used with almost all faecal sludge and large-capacity sewage treatment plants using the method. Most trickling filters and activated sludge plants recorded have a low capacity and belong to private enterprises like larger hotels.

Only about 10 of the treatment plants are operational (Obuobie *et al.*, 2006) and it is not clear if these plants meet the EPA effluent guidelines. This can be attributed to the fact that the conventional methods are energy dependent and also when the mechanical parts become faulty, the part has to be imported making it too expensive to maintain. Low-cost, low-technology methods are however manageable.

8. Challenges of wastewater management

Wastewater management though not technically difficult can sometimes be faced with socio-economic challenges. A few of the challenges are discussed below.

8.1 Infrastructure

Most often than not, wastewater infrastructure are not the priority of most politicians and therefore very little investment are made. It is however important to consider wastewater infrastructure as equally important as water treatment plant because almost all the water produced ends up as wastewater.

8.2 Pollution of water sources

Effects of wastewater effluent on receiving water quality is enormous, it changes the aquatic environment thus interrupts with the aquatic ecosystem. The food we eat contains carbonaceous matter, nutrients, trace elements and salts and are contained in urine and faeces (black water).

Medications (drugs), chemicals and in recent times hormones (contraceptives) are also discharged into the wastewater treatment plant. Discharge guidelines must be strictly adhered to. This will ensure sustainability of water sources for posterity.

The precautionary and the polluter-pays principles which prevent or reduce pollution to the wastewater have proven to be very efficient in the industrialized countries and should be adapted in developing countries as well.

8.3 Choice of appropriate technology

Because the economy of most developing countries is donor driven, funds for wastewater plants are mainly from donors. For this reason, they tend to propose the technology which should be adopted. For this reason, when the beneficiaries, take over the facility, its management of the operations and maintenance of parts become quite challenging as the technical expertise, power requirements etc are not sustainable.

8.4 Sludge production

Treatment of wastewater results in the production of sewage sludge. There must be a reliable disposal method. If it must be used in agriculture, then the risks involved must be taken into consideration. Due to the presence of heavy metals in wastewater, it is sometimes feared that agricultural use may lead to accumulation of heavy metals in soils thereby contaminating of yields.

8.5 Reuse

Effluents which meet discharge standards could be used for agricultural purposes such as aquaculture or for irrigation of farmlands. The challenge however is that if wastewater treatment plants are not managed and continuously monitored to ensure good effluent quality, reuse becomes risky.

9. Conclusion

Wastewater is and will always be with us because we cannot survive without water. When water supplied is used for the numerous human activities, it becomes contaminated or its characteristics is changed and therefore become wastewater. Wastewater can and must be treated to ensure a safe environment and foster public health. There are conventional and non-conventional methods of wastewater treatment and the choice of a particular method should be based on factors such as characteristics of wastewater whether it from a municipality or industry (chemical, textile, pharmaceutical etc.), technical expertise for operation and maintenance, cost implications, power requirements among others.
In most developing countries like Ghana, low-cost, low-technology methods such as waste stabilization ponds have been successful whilst conventional methods like trickling filters and activated sludge systems have broken down. Effluent which meets set discharge standards can be appropriately used for aquaculture and also irrigation. Though there are a few challenges in waste water management, they can be surmounted if attention and the necessary financial support is given to it.

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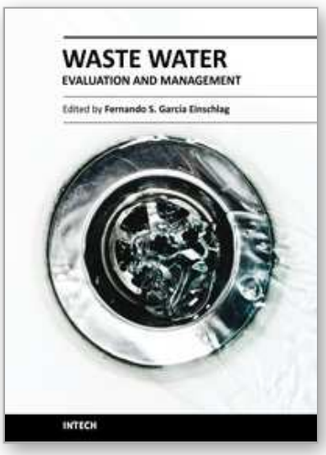
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Fresh water resources are under serious stress throughout the globe. Water supply and water quality degradation are global concerns. Many natural water bodies receive a varied range of waste water from point and/or non point sources. Hence, there is an increasing need for better tools to asses the effects of pollution sources and prevent the contamination of aquatic ecosystems. The book covers a wide spectrum of issues related to waste water monitoring, the evaluation of waste water effect on different natural environments and the management of water resources.

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