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Aspects of Wastewater Collection, Treatment and Reuse: Review of Principles and Practices

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Abstract
Wastewater is defined as "spent" or "used" water of a community or industry which contains dissolved and suspended matter as pollutants. On the basis of sources, wastewater may be classified as domestic wastewater, industrial wastewater and stormwater, depending on whether its generated as a result of domestic and industrial activities or runoff due to rainfall in buildings and adjoining lands. The sources of wastewater also influence their composition and characteristics. Sewage is often used interchangeably with wastewater, although it often refers to liquid waste (mostly urine and faeces from residential, industrial, institutional and commercial establishments. The purpose of wastewater treatment is to improve its quality for various purposes including drinking, domestic, industrial and agricultural uses. Two common methods of wastewater treatment are: biological treatment method (where microorganisms are used to reduce the BOD level in the wastewater) and mechanical treatment method (where a combination of physical, biological and chemical processes are used to achieve a treatment objective, which are generally to reduce BOD, COD and TSS in the wastewater. Untreated wastewater in the environment before or after disposal maybe source of pollution of surface and groundwater in the area and contribute to spread of communicable diseases caused by pathogenic organisms present in the wastewater. In most rural areas and towns in Nigeria, there is no wastewater treatment system, collection and disposal are through pit latrines, water closet/septic tanks, soakaway pits and sometimes discharge into streams. Few wastewater collection and treatment plants, using biological and mechanical methods exist in urban areas/academic institutions including residential areas in Abuja, Lagos, Kaduna, Eungu and Port Harcourt; and academic institutions such as AfeBabaloa University Ado Ekiti, ObafemiAwolowo University He- Ife and IITA, Ibadan. Some industrial facilities including NNPC, SHELL Petroleum Office and Staff Quarters (Warri); CHEVRON and SHELL Petroleum Offices in Port Harcourt and Nigeria Brewery (Benin and Lagos). Some towns / Academic institutions such as Makurdi, Kano and UCH, University of Ibadan, have installed but non functional water treatment plants. In Nigeria and other countries of the world, treated wastewater may be used for groundwater recharge, as liquid in fire extinguishers and agricultural purposes (including irrigation).

***Keywords**: Wastewater, treatment, reuse, pollutants, mechanical, biological, irrigation and groundwater recharge.*

1.0. Introduction

Wastewater is defined as used water or spent water. And by this simple definition, it goes to say that wastewater is 'dirty water.' It is water generated after using freshwater, in various applications or processes, such asdomestic, commercial, industrial and agricultural purposes (Tchobanoglous *et al* 2003). A more comprehensive definition for wastewater is: "used water from any combination of domestic, industrial, commercial or agricultural activities, surface runoff/storm water, and any sewer inflow or sewer infiltration" (Tilley, E., *et al* 2014). Another word for Wastewater is SEWAGE. However, the word "SEWAGE" has a more exclusive usage for 'domestic' wastewater, which is, wastewater from toilets, bathrooms, kitchen and launderette (Davis and Cornwell, 1998). However, both "wastewater" and "sewage" could be used interchangeably except when particular emphasis is needed for categorization. The following definitions are important for proper understanding of the topic under consideration:

Wastewater is a generic term that includes all water containing contaminants and/or pollutants accumulated in them as a result of usage. Wastewater includes the following:

i. **Domestic wastewater**: This is water from human activities and containing human-waste such as faeces, urine, used water from bathroom, kitchen and laundry.

ii. **Industrial wastewater:** This wastewater from industrial processes, and operations e.g. manufacturing operations, mineral extraction, power generation, etc.

iii. **Leachate:** This water containing pollutants dissolved while percolating through municipal solid waste, ores, raw materials, industrial waste.

iv. **Cooling water:** This is water used to condense steam or reduce machinery temperatures with a resultant thermal pollution when introduced into freshwater streams or rivers.

v. **Return flow:** This is flowing water carrying suspended soil, pesticide residues, or dissolved minerals and nutrients from irrigated farmlands.

vi. **Surface runoff:** This is excess water from rainfall, ice melt, storm water, and river overflow, that could no long get absorbed by the soil.

vii. **Urban runoff:** This is wastewater from outdoor activities such as cleaning, landscape irrigation, etc.

viii. **Agricultural wastewater:** This is wastewater from various agricultural practices and operations such as animal husbandry, use of fertilizers, pesticides, composting etc.

Wastewater is one that can no longer be used for domestic and industrial activities due to its concentration of contaminants and pollutants which have the ability to cause wide-spread environmental health disaster or epidemic. Even when wastewater is collected and treated, it still cannot be used for certain domestic activities such as cooking, drinking, and bathing, which require premium purity and excellent Water Quality ranking.

2.0 **Sources, Classification and Composition/Characteristics of Wastewater**

2.1 **Sources and Classification of Waste water**

Wastewater is classified based on its source of origination or generation

Major sources of wastewater include:

i. Domestic sanitary activities (bathroom, kitchen, laundry, toilet);

ii. Industrial activities (used water from numerous industrial activities);

iii. Storm water/surface runoff (rain flood, runoff carrying agricultural waste, municipal run off)

Fig 1: Sources of waste water (Steel and McGhee 2007; Metchall and Eddy, 1972)

There are two broad categories of Wastewater:

i. Sewage wastewater

ii. Non-sewage wastewater

2.1.1. Sewage Wastewater

In simple and clear terms, sewage wastewater is wastewater that contains urine and faeces and is generated by everyday human activity and in any environment human is found. Sewage wastewater is basically domestic wastewater that comprise of wastewater from toilets, bathrooms, kitchen sink, and laundrette. This kind of wastewater is generated in homes, restaurants, schools, business premises, public toilets, hotels. It is an unsorted mix of used water from all domestic

human activities from individual residences or wherever inhabited by humans all channeled by pipes and collected by the sewerage system applicable or operational in such region.
Sewage wastewater can simply be referred to as DOMESTIC or SANITARY WASTEWATER. There are four major types of domestic wastewater we generate in the home. There are four colors by which each type of domestic wastewater is distinguished:

i. **Blackwater:** Blackwater refers to a combination of all wastewater generated from the toilet, kitchen sink and dishwasher which all move down the sewer through connecting pipes. Blackwater is the actual definition of sewage. Blackwater contains faeces, urine, food waste, FOG (fats, oils and grease), detergents, washing chemicals, and plastic waste (wet wipes, sanitary products, cotton buds, disposable contact lenses, teeth floss, condoms, etc.). So, you see, domestic wastewater or sewage is a combination of all the pollutants and contaminants we generate in our everyday lives, thus should be disposed thoughtfully. Blackwater can contain a critical quantity of microorganisms, bacteria and viruses that can cause wide range of diseases, impact water quality, harm plants and animals and present risks to human health. The bacteria, virus, and parasite content of blackwater makes it the most harmful to human life and the wider environment amongst all the types of wastewater. And this is why Blackwater collection, treatment and disposal is of great importance.

ii. **Greywater:** Greywater also known as sullage is water from baths, bathroom sinks and launderette. Greywater is wastewater generated by human domestic activities excluding faeces, urine and food waste. Greywater is also likely to have plastics in it, either as microfibres, particles from clothing made with man-made fibres or from products like make-up, toothpaste and body scrubs which is a threat to aquatic life, wildlife and the ecosystem should they drain into surface water bodies.Though greywater contains chemicals and cleaning fluids, it is more suitable for re-use considering the absence of the typical pathogens contains in human faeces, urine and decomposed food waste. Thus, systems could be installed in homes that could treat greywater and reuse it for flushing of toilets.

iii. **Yellow Water:** In the most practical form, yellow water is urine, pure urine without the other contaminants found in blackwater and greywater, such as faeces, toilet paper, food particles, FOG, or chemicals.

iv. **Brown Water:** Brown water is faeces. It is the sum total of the solid human waste that enters the wastewater system

2.1.2. Non-sewage wastewater

Non-sewage wastewater is composed of any wastewater that does not have in it human waste, that is basically, faeces, and urine.

The following types of wastewater are non-sewage wastewater:

i. Water generated from domestic washing machines, car washing (of home and commercial car), etc.

ii. Surface- and Storm Water runoff; these are rainfall runoffs that carry with it dissolved pollutants and contaminants as they flow through:

   a) car parks, containing pollutants such as fuel, oil, engine exhaust residues/sooth, tyre rubber, and petrochemicals.

   b) farmland containing dissolved agro-waste such as pesticides, fertilizer, etc.

   c) roads, footpaths, industrial premises etc. carrying every pollutant and contaminants on these ground surfaces all into the sewer system.

iii. Industrial wastewater, these are effluent from industrial activities such as manufacturing operations, mineral extraction, mines and quarries operations, power generation, and processes like food processing, beverage, cloth and shoe production, and other production activities. They are generally hazardous (Amadi et al, 2017)

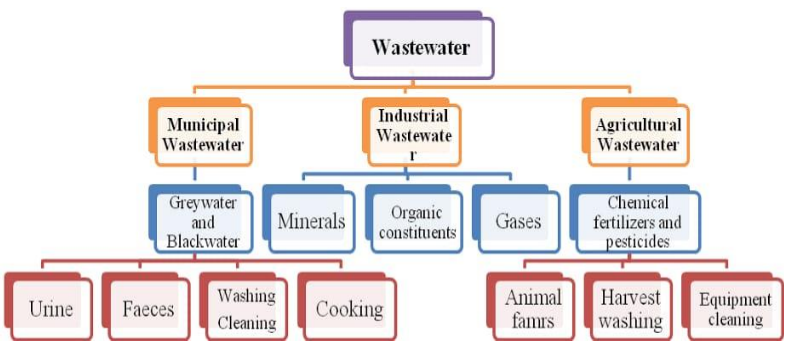


Fig. 2: Types of Waste Water (Steel and McGhee, 2007; Metcalf and Eddy, 1972)

2.2. Composition and characteristics of wastewater

2.2.1. Composition of wastewater

Wastewater has characteristic composition that makes it harmful to human, ecosystem and the environment. Wastewater from different sources or activities has varying characteristics and contaminant constituents which differentiate it from wastewater from other sources and activities. The characteristics of any wastewater is majorly based on the predominant contaminants or pollutants found in it. Tables 1,2,3 show composition of different types of wastewater.

Table 1: Typical composition of untreated domestic wastewater (mg/l) Davis and Cornwell, 1998)

Constituent (mg/l)	**Weak**	**Medium**	**Strong**
Alkalinity ($CaCO_3$)	50	00	200

BOD (as O_2)	100	200	300
Chloride	30	50	100
COD (as O_2)	250	500	1000
Suspended Solids (SS)	100	200	350
Total dissolved Solids (TDS)	200	500	1000
Total Nitrogen (N)	20	40	80
Total Organic Carbon (TOC)	75	150	300
Total Phosphorous (P)	5	10	20

Table 2: Examples of industrial wastewater concentration for conventional pollutants (Daris and Cornwell, 1998)

Industry	**BOD (mg/l)**	**Suspended Solids (mg/l)**
Ammunition	50-30	70 – 1,700
Fermentation	4,500	10,000
Slaughter House	400 – 2,500	400 – 1000
Pulp and Paper	100 – 350	75 – 300
Tannery	700 - 7000	40,000 – 20,000

Table 3: Examples of industrial wastewater concentration for unconventional pollutants (Davis and Cornwell, 1998)

Industry	**Pollutant**	**Concentration (mg/l)**
Coke by product (Steel mill)	Ammonia (as Organic Nitrogen (as phenol)	200 100 2000
Metal plating	Chromium	3 – 550
Nylon Polymer	COD TOC	23000 8,800
Plywood – Plant	COD Phenol Phosphorus (as PO_4)	2,000 200 – 2000 9 - 15

2.2.2. Characteristics of wastewater

2.2.2.1. Physical characteristics of wastewater

i. **Color:** Freshly generated wastewater is usually brownish or yellowish, but turns black with it.

ii. **Suspended Solids:** Wastewater has characteristic suspended solids which are insoluble solids suspended in a liquid and could be visibly seen.

iii. **Temperature:** Wastewater has temperature that is relatively warmer than room temperature.

iv. **Turbidity:** Turbidity is the degree of clearness or transparency of a liquid. Wastewater has a characteristic high turbidity because of the high presence of suspended solids in it

2.2.2.2. Chemical characteristics of wastewater

Wastewater contains different chemicals in various forms. They include:

i. **Chemical Oxygen Demand (COD):** This is a measure of the amount of organic matter in wastewater based on the oxygen required to oxidize it.

ii. **Nitrogen:** This is the amount of nitrogen present in organic compounds. Nitrogen in wastewater is measured in the following forms: nitrite, nitrate, ammonia, and organic nitrogen.

iii. **Phosphorus:** It is generally measured in its mineral and organic form, total phosphorus.

iv. Chlorine **(Cl^{-1})**

v. Sulfates **($SO4^{-2}$)**

vi. Heavy Metals

2.2.2.3. Biological parameters of wastewater

i. **Biochemical Oxygen Demand (BOD):** This is the amount of oxygen required to stabilize organic matter using micro-organisms.

ii. **Oil and grease:** Oil and grease are generated from food waste and petroleum products.

iii. **Microbial life in wastewater:** Wastewater contains the following microbes:

a) Bacteria

b) Protozoa

c) Mushrooms

d) Virus

e) Seaweed

f) Rotifers

g) Nematodes

3.0. Principles and Practices of Wastewater Collection and Treatment

3.1. **Overview**

Sewerage system is a system made up of components or aspects that work together in various stages/phases to achieve an end goal. Components of Sewerage System includes the following:

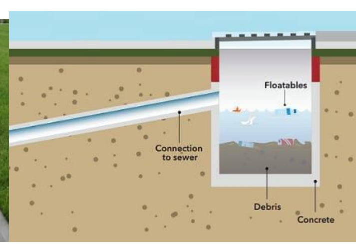
i. **Collection system**; that is, a network of sewer pipes;

ii. **Disposal Works**; that is, sewage pumping stations, outfalls, etc.;

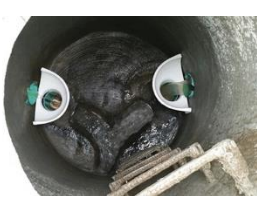
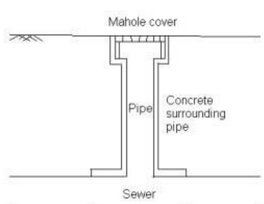
iii. **Treatment works**; that is the point where collected wastewater is treated to various degrees base on reuse needs, recycling, or final discharge and environmental sensitivities or peculiarities.

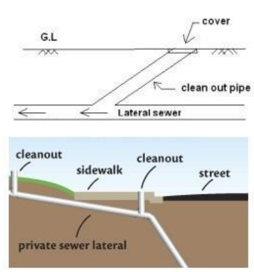
3.2. Wastewater Collection System
3.2.1. Components of Wastewater Collection System

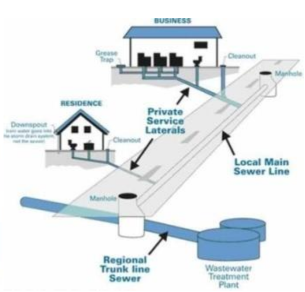
Wastewater collection is a very crucial aspect of environmental sanitation, management and community health. Wastewater collection is the process by which wastewater from different paths of certain municipal is collected, transported to either a treatment plant or a disposal site. Wastewater collection system is the first component of the sewerage system. Wastewater collection is made up a network of pipes, pumping stations, and appurtenances that convey sewage from its points of origin to a determined point of treatment and/or disposal. Sewerage system is comprised of all the facilities, equipment, and technologies employed in the collection, transportation, and disposal of sewage, such as inlets, catch basins, clean outs, manholes, lampholes, flushing tanks, grease and oil traps, inverted syphons, and storm These components play a crucial role in maintaining the functionality and efficiency of the sewerage system. The primary goal of the sewerage system is to ensure that the sewage discharged from the communities is appropriately collected, transported, and treated to the necessary degree before being finally disposed of so that it does not harm human health or the environment.



Street Inlets **Catch basin** **Manhole**





Drop manhole **Lamphole** **Clean-out** **Sewarage system**

Flushing tank/pump **Oil and grease tap** **Inverted siphon** **Storm regulator**

Fig. 3 Component of wastewater collection system (Chatterjee, 2005)

3.2.2. Types of Sewer and Classification of Sewerage System

Sewers are underground conduits for the transportation of sewage and wastewater. There are different types and classifications of sewer based on various parameters such as flow system, sewer material, sewer shape, etc. The following are types of sewers based on different parameters:

A. Classification of Sewerage System According to Flow

i. **Gravity Sewer Systems** are the traditional method of sewage disposal.

They are an effective method for collecting and disposing of sewage from houses in regions where there is a low water table, the terrain slopes gently, and flooding does not occur frequently. Gravity sewer systems use gradually sloping pipes to let sewage flow naturally away from your property and towards the collecting network. Ultimately, this network transports movements to a local or regional treatment facility. However, if the terrain surrounding your property is extremely hilly, does not slope in the direction necessary for sewage to flow naturally downward, or is prone to flooding, a pressure sewer system may be the best option.

ii. Pressure Sewer System

Pressure sewer systems are a cost-effective and environmentally favorable method for collecting, transporting, and disposing of household wastewater. They are often used in places where the land is either very hilly or very flat, where there is a lot of flooding or where the water table is high, or where other types of sewage systems are not practical. A pressure sewer system consists of a series of sealed pipes that are interconnected and fed by individual pumping units.

The wastewater from the household is processed by the pumping unit, and then it is transferred through a short pipeline on the property to the pressure sewer that is located on the street.

The pressure sewer is a component of the overall piping network that transports wastewater to the closest sewerage treatment facility, which could be in the immediate vicinity or many kilometers away. The only visible components of the pressure sewer system after installation are the storage tank lid, boundary valve kit, and control panel.

B. Classification of Sewerage System According to Shape

i. Circular Shape

It is the most popular. It is suitable for any type of waste.

ii. Standard Egg Shape

It is best suited for combined sewers. Its advantage over a circular shape is that it provides a greater flow velocity at a lower flow rate while maintaining the same capacity, however, its construction is harder, and it is less stable.

iii. New Egg Shaped Sewer

This is preferred for combined sewerage systems

iv. Horseshoe Shaped Sewer

This is appropriate for large sewers that have high discharges, such as trunk and outfall sewers. Horseshoe shaped sewer is appropriate when there is not enough headroom. Its height is greater than its breadth; its wall is most inclined with a semicircular arch at the top; and its invert may be flat, parabolic, or circular.

v. Parabolic Shaped Sewer

The upper arch of this type of sewer is shaped like a parabola and can be used to transport relatively small amounts of sewage. It is economical in to construct.

vi. Semi Elliptical Shaped Sewer

This type of sewer has a stability that makes it suitable for soft soil. It is only useful for transporting large quantities or numbers of effluent. It is used when pipes are bigger than 1.8m in diameter.

vii. Rectangular/Square Shaped Sewer

Rectangular shaped sewer is used typically for covered storm water drains. However, it also could be used as a storage tank because of its stability and simplicity of construction.

viii. U-Shaped Sewer

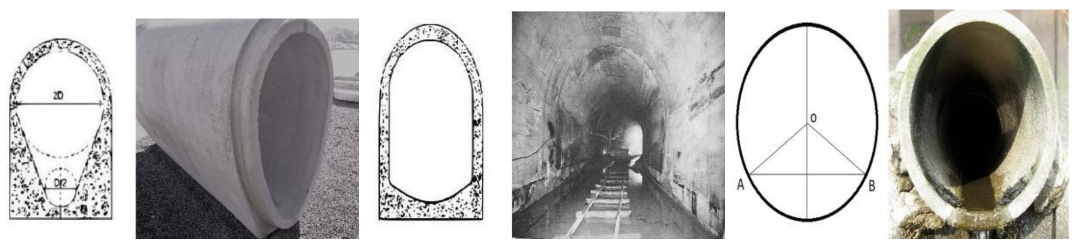
This type of sewer is used for combined sewers with maximal storm water flow. It is used for longer sewers and particularly in open cuts. The invert is formed in the shape of a semicircular arch.

ix. Semi Circular Shaped Sewer

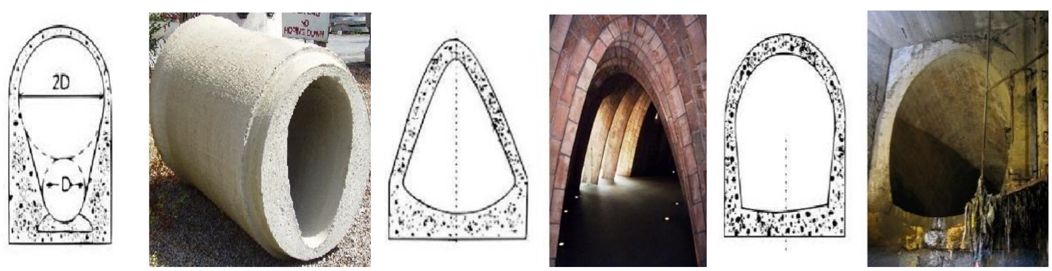
The bottom of this segment provides a wider base, making it suited for building huge sewers with less headroom, however, it has become obsolete.

x. Basket Handle Shaped Sewer

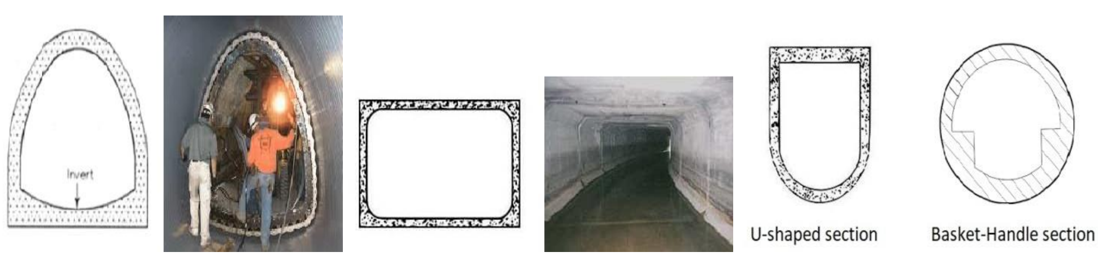
The upper portion of this type of sewer resembles a basket handle. In this case, the upper part is wider than the lower part. During the monsoon, it flows full through the narrow bottom portion, this too has become obsolete.



New void sewer *semi-circular shaped sewer* *circular shaped sewer*



Standard ovoid sewer *parabolic shaped sewer* *horse shoe shaped sewer*



Semi-elliptic shaped sewer *rectangular shaped sewer* *u-shaped sewer*

Fig. 4 Shapes of Sewers (Chatterjee, 2005)

C. Classification of Sewerage System According to Material

i. Asbestos Cement Sewer

They are made by combining cement and asbestos

ii. Brick Sewers

Brick sewers are constructed on-site and are used for large-scale sewer construction. Also, brick Sewers are extremely beneficial for the construction of storm sewers and combined sewers. However, brick sewers are susceptible to deformation, which can result in leaks. Recently, more sewers are made of concrete than brick

Brick Sewer *Asbestos Cement sewer* *Cast Iron sewer* *Cement Concrete sewer*

Fig. 5 Materials used as Sewers (Steel and McGhee, 2007)

iii. Cement Sewers

Cement sewers are suitable for small storm drains.

iv. Cast Iron Sewers

These types of sewer are watertight and of high strength and durability. Sewers made of cast iron are capable of withstanding high internal pressure and external loads.

v. Steel Sewers

Steel sewers are ideal when the sewage is transported under pressure, as they are impervious, lightweight, pressure-resistant, and flexible.

vi. Plastic Sewers

Sewage is now transported through industrial plastic, PVC sewers. Plastic pipelines are corrosion-resistant.

3.2.3. Types of Wastewater Collection System (Sewerage System)

There are a number of wastewater collection systems or sewerage systems in use but the choice of any sewerage systems depends on a lot of factors includes cost, availability of facilities, skill knowledge of sewerage technologies, Land use regulations, geologic condition of available land, technological know-how etc. The following are types of sewerage systems:

i. Separate systems

ii. Combined system

iii. Alternative system

3.2.3.1. Separate Systems

Separate wastewater collection system is sewerage facilities designed as separate sewerage systems that carry either of the following:

i. **Storm Sewers** usually carry surface runoff to a point of disposal in a stream or river. Small detention basins may be built as part of the system, storing storm water temporarily and reducing the magnitude of the peak flow rate. Storm sewers are usually built with sections of reinforced concrete pipe. Corrugated metal pipes (pipes with inner surface shaped into a series of parallel ridges and grooves so as to give added rigidity, and strength) may be used in some cases. Storm water inlets or catch basins are located at suitable intervals in a street right-of-way or in easements across private property. The pipelines are usually located to allow downhill gravity flow to a nearby stream or to a detention basin. Storm water pumping stations are avoided, if possible, because of the very large pump capacities that would be needed to handle the intermittent flows.

ii. **Domestic/Sanitary Sewers** on the other hand, carry domestic wastewater to a sewage treatment plant. Pretreated industrial wastewater may be allowed into municipal sanitary sewerage systems, but storm water is excluded. A sanitary sewerage system includes:

a) Laterals

b) Submains/collector

c) Interceptors/Trunk line

Except for individual house connections, LATERALS are the smallest sewers in the network, usually not less than 200 mm (8 inches) in diameter and carry sewage by gravity into larger SUBMAINS, or COLLECTOR sewers. The COLLECTOR sewers tie in to a main INTERCEPTOR, or TRUNK LINE, which carries the sewage to a treatment plant. Interceptors are usually built with precast sections of reinforced concrete pipe, up to 5 metres (15 feet) in diameter. Other materials used for sanitary sewers include vitrified clay, asbestos cement, plastic, steel, or ductile iron. The use of plastic for laterals is increasing because of its lightness and ease of installation. Iron and steel pipes are used for force mains or in pumping stations. Force mains are pipelines that carry sewage under pressure when it must be pumped.

iii. Combined Systems

Combined sewage collection sewerage systems carry a mixture of both domestic (sanitary) the sewage, industrial wastewater, storm sewage and run off. Combined sewers typically consist of large-diameter pipes or tunnels, because of the large volumes of storm water that must be carried during wet-weather periods. They are very common in older cities but are no longer designed and built as part of new sewerage facilities. Because wastewater treatment plants cannot handle large volumes of storm water, sewage must bypass the treatment plants during wet weather and be discharged directly into the receiving water. These combined sewer overflows, containing untreated domestic sewage, cause recurring water pollution problems and are very troublesome sources of pollution.

In some large cities the combined sewer overflow problem has been reduced by diverting the first flush of combined sewage into a large basin or underground tunnel. After temporary storage, it can be treated by settling and disinfection before being discharged into a receiving body of water, or it can be treated in a nearby wastewater treatment plant at a rate that will not overload the facility. Another method for controlling combined sewage involves the use of swirl concentrators. These direct sewage through cylindrically shaped devices that create a vortex, or whirlpool, effect. The vortex helps concentrate impurities in a much smaller volume of water for treatment.

iv. Alternative Systems

Alternative systems are used when the cost of conventional gravity sewers are unaffordable or site conditions are not favorable., high water table, at such, alternative sewerage systems could be employed. Basically, we have three alternative wastewater collection systems that may be used under these circumstances, but I added a fourth one; they are:

a. Small-diameter Gravity Sewer Systems

In small-diameter gravity systems, septic tanks are first used to remove settle able and floating solids from the wastewater from each house before it flows into a network of collector mains (typically 100 mm, or 4 inches, in diameter). These systems are most suitable for small rural communities. Small-diameter gravity sewers do not carry grease, grit and sewage solids, thus, the pipes can be of smaller diameter and placed at reduced slopes or gradients to minimize trench excavation costs.

b. Pressure Sewer Systems

Pressure sewers are best used in flat areas or where rock excavation would be very expensive. This system uses Grinder Pumps to discharge wastewater from each home into the main pressure sewer, which can follow the slope of the ground.

c. Vacuum Sewerage System

In a vacuum sewerage system, sewage from one or more buildings flows by gravity into a sump or tank from which it is pulled out by vacuum pumps located at a central vacuum station and then flows into a collection tank. From the vacuum collection tank the sewage is pumped to a treatment plant. This is a common sewerage system in most underdeveloped countries.

d. Septic Tank/Soak away Pit System

Septic Tank-Soak away Pit sewerage system is an alternative system. It is a sewage collection and treatment system commonly used by individual residential buildings in suburban, cities and towns that do not have a functional central municipal sewerage system.

The Septic Tank-Soakaway Pit system is built with two compartments commonly called chambers. In this sewerage system, one compartment is the Septic Tank section with concrete walls and floor while the other compartment is the Soakaway Pit. The soakaway pit only has its walls as concrete while the bottom is of natural earth, a mechanism that permits the wastewater drained in it to naturally drain down into the earth.

The Septic Tank chamber is responsible for treating the wastewater naturally by separating the solid waste from the liquids. Generally, solids are heavier than liquids, so, the solid waste settles down at the bottom of the septic tank concrete floor while the wastewater flows into the second compartment which is the Soakaway Pit through pipes that create opening between the two compartments or chambers. The wastewater draining into the soakaway compartment is naturally absorbed by the earth-bottom of the soakaway pit. This sewerage system is comprised of a network of plumbing pipes connecting the laundrette, kitchen sinks, bathroom and water closet (WC) toilet to the septic tank-soakaway pit, such that every liquid waste from all parts of the building all goes through the connected plumbing pipes into the septic tank first, where the solid waste settle down while the liquid waste flows into the chamber where it is absorbed by the earth.

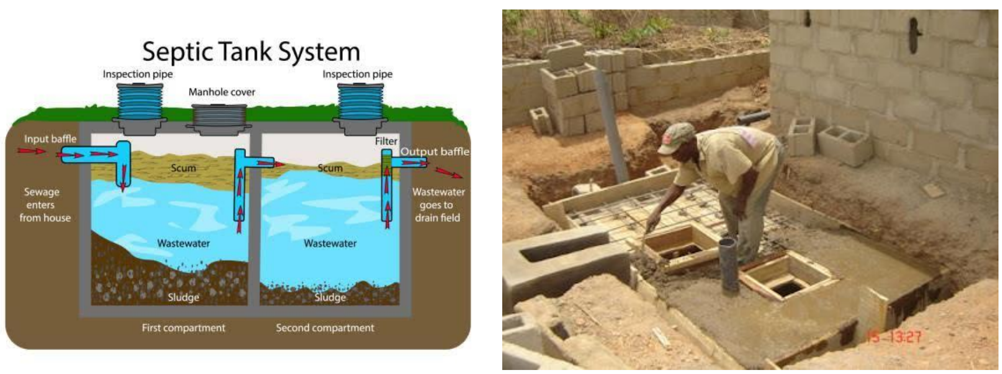


Fig 6: Typical Septic Tank-soakaway system (Davis and Cornwell, 1998).

3.2.2. Principles and Practices of Wastewater Treatment

3.2.2.1. Objectives and General Principles

Wastewater Treatment, also called Sewage Treatment is the removal of impurities from wastewater, or sewage for reuse or before it reaches aquifers or natural bodies of water such as rivers, lakes, estuaries, and oceans where it could be disposed for reuse or recycle or even on arid farm lands where it could be used for irrigation. Municipal wastewater is a mixture of all three types of wastewater. It consists of domestic/sanitary sewage, industrial wastewater and storm water runoff. This means that in a wastewater treatment plant, there is likelihood to have all the classes of water contaminants and/or pollutants (biological, chemical and physical) present.

Municipal wastewater contain varieties of inorganic substances from domestic and industrial sources including a number of potentially toxic elements such as arsenic, cadmium, chromium, copper, lead, mercury, zinc, etc., organic compounds and pathogenic viruses, bacteria, protozoa and helminths at the levels indicated in

Table 4.Possible levels of pathogen in wastewater (Chatterjee, 2005).

Type of pathogen		Possible concentration per litre in municipal wastewater[1]
Viruses:	*Enteroviruses*[2]	5000
Bacteria:	Pathogenic *E. coli*[3]	?
	Salmonella spp.	7000
	Shigella spp.	7000
	Vibrio cholerae	1000
Protozoa:	*Entamoeba histolytica*	4500
Helminths:	*Ascaris Lumbricoides*	600
	Hookworms[4]	32
	Schistosoma mansoni	1
	Taenia saginata	10
	Trichuris trichiura	120

Pathogenic bacteria will be present in wastewater at much lower levels than the coliform group of bacteria, which are much easier to identify and enumerate (as total coliforms/100ml). Escherichia coli are the most widely adopted indicator of faecal pollution and they can also be isolated and identified fairly simply, with their numbers usually being given in the form of faecal coliforms (FC)/100 ml of wastewater. There are basically three types of contaminants found in wastewater/sewage:

i. **Biological Contaminants:** These are basically bacteria, fungi, algae.
ii. **Chemical Contaminants:** These are contaminants consisting of organic impurities, mineral impurities or their mixture and heavy metals.
iii. **Physical Contaminants:** These are suspended solids, large mechanical impurities such as debris, and sand.

3.2.2.2. Wastewater Treatment Plant Parameters

The most commonly used parameters in wastewater treatment plants are BOD, COD and TSS. When degrading environments, it is common to analyze nitrogen (NGL, NH4, NO3) and phosphorus parameters in order to control the environmental risks caused by wastewater, an analysis is important. This analysis is intended to determine and quantify the substances and micro-organisms contained in a wastewater waters so as to ascertain better methods of removing them thereby reducing them to an acceptable level for the purpose of maintaining sound environment health.

i. Dissolved Oxygen (DO)

Dissolved oxygen is simply the oxygen readily available in and on surface water for respiratory use by microbes and phytoplankton in a water body. In general, it is the analysis of the dissolved oxygen concentration. It is measured with an oxymeter. To maintain life in an aquatic environment, it is essential to maintain a sufficient level of oxygen. It is essential for photosynthesis and the alteration of organic components. The surface area of a surface water body and wind velocity are factors that determine dissolved oxygen concentration of the water body. However, the presence of organic matters which function by the use of oxygen uses up the dissolved oxygen. This explains the lack of oxygen in the wastewater. Temperature also affects this parameter. The colder it is, the more oxygen is soluble in water

ii. Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) is a measure of all oxygen consuming substances. It is about the substances that can be eliminated by wastewater treatment using oxygen-centered technologies and those not for biological treatment. This measurement of the amount of oxygen consumed by a water sample is performed with strong oxidizing reagents. For example, potassium dichromate. Practically, the measurement of oxidation is done by a COD test to quantify the amount of oxidizable material. The amount of reagent consumed for the oxidation of the organic matter present, reported in mgO/L, corresponds to the COD. COD is useful in terms of water quality because it allows for the determination of the effect of an effluent on the receiving environment and to determine the biochemical oxygen demand (BOD).

iii. Biochemical Oxygen Demand (BOD)

BOD is a measure of the amount of oxygen required to remove or alter biologically degradable organic matter in wastewater. The water sample is stored for five days at 20°C, without light and covered tightly. We talk about BOD 5 because the analysis is done over 5 days. Some countries use other varieties such as BOD 7 or BOD 21, called ultimate BOD. However, BOD5 is mostly used around the world. The darkness prevents the risk of photosynthesis and the temperature of 20°c favors the propagation of micro-organisms fond of O_2. The degradation of organic pollutants by micro-organisms, or self-purification, consumes oxygen. It is this decrease in oxygen in the environment that is measured by the BOD5. Like the COD, the BOD 5 is also expressed in mg/l of oxygen (mgO_2/L). It allows determining the impact of an effluent on the receiving environment. Indeed, the BOD 5 represents the proportion of organic matter that is naturally biodegradable, and therefore mobilizes oxygen in the waterways. (https://www.1h2o3.com/en/learn/wastewater-parameters/effluent-standards/)

iv. Suspended Solids (SS)

Suspended solids (SS) are the materials in the transient phase in wastewater treatment plants. That is, they are not in colloidal or dissolved form. As the name suggests, these are particles suspended in the liquid. They can be filtered and are composed of organic and mineral particles. TSS is a commonly used term although it is actually Total Suspended Solids (TSS).TSS analysis consists of passing a volume of sample through a membrane filter. This membrane will then be placed in an oven at 105°C for at least one hour. The difference in weight before/after filtration is used to determine the amount of suspended solids. This is measured in mg/l. TSS is one of the parameters commonly used to determine the quality of a wastewater because it represents a danger to the receiving environment.

3.2.3. Wastewater Treatment Technologies/Methods

3.2.3.1. Overview 1

A number of sewage treatment technologies have been developed but the choice of a suitable technology for use in wastewater treatment must consider the availability of technical know-how, and the economic demands of using such a technology. Wastewater treatment would require the application of as many technologies as required to get the needed standard of treated water that could be certified good and usable for certain purposes based on standards set by World Health Organization (WHO), and necessary water quality standard organizations.

The main criteria for selecting a sewage treatment technology are thus:

- i. Type/source of sewage
- ii. Desired Effluent Quality
- iii. Expected Construction And Operating Costs
- iv. Availability Of Land and land use regulations
- v. Energy Requirements
- vi. Sustainability.

Wastewater treatment technologies are both scientific and natural systems/methods used in wastewater treatment to desired water quality standard for reuse. Wastewater treatment technologies could be summarily classified into three principal types:

- i. Mechanical treatment systems
- ii. Aquatic (lagoon) treatment systems
- iii. Terrestrial treatment systems

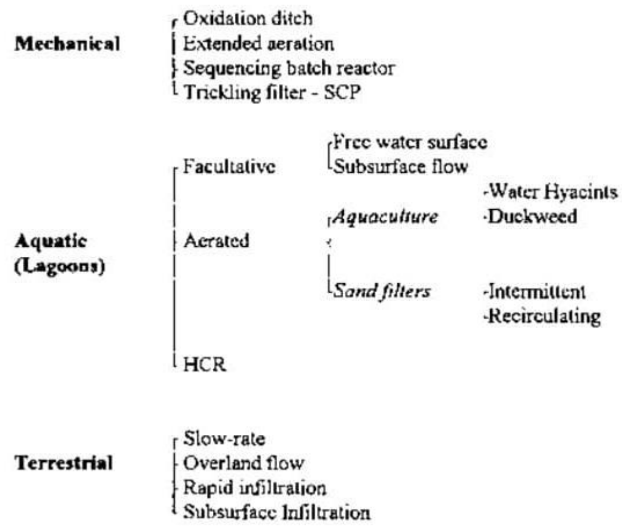


Fig. 7: Summary of Wastewater Treatment Technologies (USEPA, 1992)

3.2.3.2. Mechanical/Engineered Treatment Technologies

Mechanical treatment systems use natural processes within a constructed environment to achieve wastewater treatment goals. Mechanical systems combine physical, biological, and chemical processes in the treatment of wastewater to required standards. Mechanical systems replicate natural environment and process within an artificial environment, employing its mechanisms for wastewater treatment

It is a treatment option when suitable lands are unavailable for the implementation of natural system technologies (World News of Natural Sciences 4; 2016 33-43). Components of Mechanical treatment technologies include: tanks, pumps, blowers, screens, grinders, and other mechanical components. Examples of mechanical treatment technologies include:

i. **Oxidation Ponds:** This is used for reducing the biochemical oxygen demand (BOD) of wastewater. This is a very effective and simple technology, which consists of a ring-shaped channel equipped with mechanical aeration devices. The wastewater is screened and aerated through these devices which circulate at 0.25–0.35 m/s.

ii. **Aerobic Ponds:** In aerobic treatment of wastewater, bacteria and algae are used that maintain aerobic condition throughout its depth. The aerobic ponds may be shallow or aerated.

iii. **Anaerobic Ponds:** It is a biological treatment of wastewater in which naturally occurring bacteria are utilized for breaking the biodegradable compounds present in wastewater. These bacteria under anaerobic condition may remove high concentrations of BOD and chemical oxygen demand (COD). The presence of anaerobic bacteria in these ponds break the organic matter present in the effluents and thus release methane and CO2 whereby sludge is deposited at the bottom, while crust is formed on the surface.

iv. **Trickling Filter-SCP:** This technique is used to remove or reduce pathogen and level of nitrogen in the wastewater as pathogens present in wastewater may cause serious threats to humans mostly in developing countries of the world. This trickling filter is composed of some porous material like rocks, sledge, or plastic medium having large surface area and permeability. The microorganism in the wastewater gets attached with the filter media. The Tickling filter solids contact process (TF-SCP), is an "attached-growth" system.

v. **Activated Sludge System:** This is a biological wastewater treatment, which is mainly used for the removal of biodegradable compounds and pathogens present in wastewater. Its efficiency depends on retention time, temperature, pH, and the presence of other biological flora present in wastewater. Sequencing batch reactor (SBR), oxidation ditches, and extended aeration systems are all variations of the activated-sludge process, and employ the "suspended-growth" system.

3.2.3.3. Aquatic (Natural Ecological) Treatment Technologies

Aquatic systems are represented by lagoons. Aquatic treatment system are variations of the following technologies:

i. **FACULTATIVE LAGOONS** are the most common form of aquatic treatment-lagoon technology currently in use. The water layer near the surface is aerobic while the bottom layer, which includes sludge deposits, is anaerobic. The intermediate layer is aerobic near the top and anaerobic near the bottom, and constitutes the facultative zone (An L, Hu J, Yang M; 2008).

ii. **AERATED LAGOONS** are smaller and deeper than facultative lagoons. These systems evolved from stabilization ponds when aeration devices were added to counteract odors arising from septic conditions. The aeration devices can be mechanical or diffused air systems. The chief disadvantage of lagoons is high effluent solids content, which can exceed 100 mg/l.

HYDROGRAPH CONTROLLED RELEASE (HCR) LAGOONS are a recent innovation designed to counter the high solid effluent concerns in using aerated lagoons. In this system, wastewater is discharged only during periods when the stream flow is adequate to prevent water quality degradation. When stream conditions prohibit discharge, wastewater is accumulated in a storage lagoon.

Table 5. Typical Design Parameters for Aquatic Treatment Technologies (Reed et al, 1995).

Technology	Treatment goal	Detention Time (days)	Depth (feet)	Organic Loading (lb/ac/day)
Oxidation pond	Secondary	10-40	3-4.5	36-110
Facultative pond	Secondary	25-180	4.5-7.5	20-60
Aerated pond	Secondary, polishing	7-20	6-18	45-180
Storage pond, HCR pond	Secondary, storage, polishing	100-200	9-15	20-60
Root zone Treatment, Hyacinth pond	Secondary	30-50	<4.5	<45

Source: S.C. Reed, et al., *Natural Systems for Waste Management and Treatment*, New York, McGraw-Hill, 1988.

Aquatic treatment technologies can be used in treating a wide range of wastewaters. This system functions within the different range of weather conditions and can also be supplemented by additional pre- or post-treatments using the following:

a. Constructed wetlands,

b. Aqua cultural production systems,

c. Sand filtration.

Constructed wetlands, aqua cultural operations, and sand filters are generally the most successful methods of polishing the treated wastewater effluent from the lagoons (Daniszewski and Falkowski, 2001a and 2001b). These systems have also been used with more traditional, engineered primary treatment technologies such as Imhoff tanks, septic tanks(see section 3.4. for more on septic tank) and primary clarifiers. Their main advantage is to provide additional treatment beyond secondary treatment where required.

1. CONSTRUCTED WETLANDS

In recent years, constructed wetlands have been utilized in two designs:

i. systems using surface water flows

ii. Systems using subsurface flows.

Both systems utilize the roots of plants to provide substrate for the growth of attached bacteria which utilize the nutrients present in the effluents and for the transfer of oxygen (see section 3.4. for more on constructed wetlands).

Bacteria do the bulk of the work in these systems, although there is some nitrogen uptake by the plants.

The Surface Water System is a look-alike of natural wetland. They are basically systems with long, narrow basins, and depths of less than 2 feet, in which aquatic vegetation such as bulrush (Scirpus spp.) or cattails (Typha spp.) are planted for the sole purpose of water treatment/purification.

The Subsurface/shallow Groundwater Systems use a gravel or sand medium, approximately eighteen inches deep, which provides a rooting medium for the aquatic plants and through which the wastewater flows.

2. AQUACULTURE SYSTEMS

These are distinguished by the type of plants grown in the wastewater holding basins. These plants are commonly water hyacinth (Eichhorniacrassipes) or duckweed (Lemna spp.). These systems are basically shallow ponds covered with floating plants that detain wastewater at least one week. The main purpose of the plants in these systems is to provide a suitable habitat for bacteria which remove the vast majority of dissolved nutrients.

Table 6: The design features of Aquaculture System (USEPA, 1992)

Design Factor	Surface water flow	Subsurface water flow
Minimum surface area	23-115 ac/mgd	2.3-46 ac/mgd
Maximum water depth	Relatively shallow	Water level below ground surface
Bed depth	Not applicable	12.30 m
Minimum hydraulic residence time	7 days	7 days
Maximum hydraulic loading rate	0.2-1.0 gpd/sq ft	0.5-10 gpd/sq ft
Minimum pretreatment	Primary (secondar optional)	Primary
Range of organic loading as BOD	9-18 lb/ac/d	1.8-140 lb/ac/d

Heavy metals which are characteristic of industrial wastewater could be satisfactorily treated using aquatic technologies. Certain aquatic plants are known to remove certain heavy metals from wastewater, plants such as: Water Velvet, Duckweed, Sharp Dock, Water Hyacinth, Calamus, Water Dropwort, EiochhorniaCrassipes, Gladiolus, IsoetesTaiwanensis, EchinodorusAmazonicus, ElsholtziaArgyi, ElsholtziaSplendens, Pterisvitta (a species of fern). Detailed studies were done for each of the aquatic plants, below are the findings:

i. ***Duckweed***: Duckweed is found to have the potential of removing the following heavy metals: Cadimum, Cd, Chromium Cr, Copper, Cu, Nickel, Ni, Lead, Pb, and Se. (Zayed et al.)

ii. ***Water Hyacinth:*** Water hyacinth is reported to play dominant role in sewage treatment. Water hyacinth possesses a very good fibrous root system and a large biomass, thus is excellent in accumulation of organic and inorganic nutrients and trace elements including: Cadimum, Cd, Lead, Pb, and Gold, Ag. (Zhu et al.)

iii. ***Eiochhornia Crassipes***: according to Dos Santos and Lenzi experiments, aquatic Eiochhorniacrassipes is found to be useful in the removal of Lead (Pb) from contaminated water.

iv. ***Water Dropwort*** was found to have the capacity of accumulating Mercury, Hg.

v. ***Calamus*** was found as the best for the accumulation of Lead (Pb) thereby removing it from the wastewater as a kind of Wastewater treatment.

vi. ***Sharp Dock*** was found to be a good accumulator of Nitrogen, N and Phosphorus, P. (Wang et al., 2012).

A hydroponic experiment in order to investigate the role of three hydrophytes: Gladiolus, Isoetestaiwanensis, and Echinodorusamazonicus, for the accumulation of Cd from contaminated water was conducted by Li et al and it was found that Gladiolus was the best Cd accumulator as compared to the other two plants.

Mustatha 2013 examined the efficacy of Cu elimination from the contaminated water by Elsholtziaargyi and Elsholtziasplendens in hydroponics. The results show that Elsholtziaargyi showed better Cu phytofiltration than Elsholtziasplendens, which was associated with better ability to absorb higher Cu concentrations and translocation to shoots.

The role of different wetland plant species for the treatment of sewage water was done by Tangahu et al. And it was found that most of the wetland species were capable of accumulating N, P, Cd, Pb, and Hg.

Interestingly also, Pterisvitta, a species of fern has been identified as hyper accumulator of Arsenic, As-contaminated soils and waters. It can accumulate up to 7500 mg of As/kg on a contaminated site without showing toxicity symptoms. Trees have also been found to absorb large quantities of contaminants present in wastewater owing to their large biomass and it is also cost effective and ecologically sound means of contaminants displacement. Plant use various mechanisms in this purification process.

3. SAND FILTERS

These have been in use for wastewater treatment purposes. There are two commonly types of sand filters:

i. the intermittent filter

ii. the recirculating filter

Their difference is majorly in the method by which the wastewater is applied.

Intermittent Filters are flooded with wastewater and then allowed to drain completely before the next application of wastewater.

Recirculating Filters use a pump to recirculate the effluent to the filter in a ratio of 3 to 5 parts filter effluent to 1 part raw wastewater.

Both types of filters use a sand layer, 2-3ft thick, underlain by a collection system of perforated or open joint pipes enclosed within graded gravel. Water is treated biologically by the epiphytic flora associated with the sand and gravel particles (Bolong N. Ismail A, Salim MR, Matsuura T; 2009), although some physical filtration of suspended solids by the sand grains and some chemical adsorption onto the surface of the sand grains play a role in the treatment process.

3.2.3.4. Terrestrial/Land Treatment Technologies/Methods

Terrestrial treatment systems include the following;

i. Slow-rate overland flow,

ii. Slow-rate subsurface infiltration, and

iii. Rapid infiltration methods.

Overland Flow Systems are a land application treatment method in which treated effluents are eventually discharged to surface water. The main benefits of these systems are their low maintenance and low technical manpower requirements. Wastewater is applied intermittently across the tops of terraces constructed on soils of very low permeability and allowed to sheet-flow across the vegetated surface to the runoff collection channel. Treatment, including nitrogen removal, is achieved primarily through sedimentation, filtration, and biochemical activity as the wastewater flows across the vegetated surface of the terraced slope. Loading rates and application cycles are designed to maintain active microorganism growth in the soil. The rate and length of application are controlled to minimize the occurrence of severe anaerobic conditions, and a rest period between applications is scheduled. The rest period is usually long enough to prevent surface ponding, yet short enough to keep the microorganisms active. Site constraints for land technology application are given in table 5 below:

Table 7: Site Constraint for Land technology application of Waste treatment method (USEPA, 1992)

Feature	Slow Rate	Rapid Infiltration	Subsurface Infiltration	Overland Flow
Soil texture	Sandy loam to clay loam	Sand and sandy loam	Sand to clayey loam	Silty loam and clayey loam
Depth to groundwater	3 ft	3 ft	3 ft	Not critical
Vegetation	Required	Optional	Not applicable	Required
Climatic restrictions	Growing season	None	None	Growing season
Slope	<20%, cultivated land <40%, uncultivated land	Not critical	Not applicable	2%-8% finished slopes

a. **Slow-rate Overland Flow Systems** require vegetation, both to take up nutrients and other contaminants and to slow the passage of the effluent across the land surface to ensure maximum contact times between the effluents and the plants/soils.

b. **Slow-rate Subsurface Infiltration systems**are designed for municipalities of less than 2,500 people. They are usually designed for individual homes (septic tank systems), but they can be designed for clusters of homes. Although they do require specific site conditions, e.g., permeability, slope, etc., they can be low-cost methods of wastewater disposal. Subsurface Infiltration Systems are "zero discharge" systems that rarely discharge effluents directly to streams or other surface waters.

c. **Rapid Infiltration Systems;** in this system, most of the applied wastewater percolates through the soil, and the treated effluent drains naturally to surface waters or recharges the groundwater (Bjerregaard LB, Madsen AH. Korsgaard B, Bjerregaard P; 2006).Their cost and manpower requirements are low. Wastewater is applied to soils that are moderately or highly permeable by spreading in basins or by sprinkling. Vegetation is not necessary, but it does not cause a problem if present. The major treatment goal is to convert ammonia nitrogen in the water to nitrate nitrogen before discharging to the receiving water.

Terrestrial technologies treatment systemsdepend on physical, chemical, and biological reactions on the soil and within the soil. Terrestrial systems make use of the nutrients contained in wastewaters; plant growth and soil adsorption convert biologically available nutrients into less-available forms of biomass, which is then harvested for a variety of uses, including methane gas production, alcohol production, or cattle feed supplements. Additionally, terrestrial/land wastewater treatment have low maintenance costs, and may yield additional benefits by providing water for groundwater recharge, reforestation, agriculture, and/or livestock pasturage.

Table 8: Summary Of The Advantages And Disadvantages Of All The Various Treatment Technologies (USEPA, 1992).

Treatment Type	Advantages	Disadvantages
Aquatic Systems		
Stabilization lagoons	Low capital cost Low operation and maintenance costs Low technical manpower requirement	Requires a large area of land May produce undesirable odors
Aerated lagoons	Requires relatively little land area Produces few undesirable odors	Requires mechanical devices to aerate the basins Produces effluents with a high suspended solids concentration
Terrestrial Systems		
Septic tanks	Can be used by individual households Easy to operate and maintain Can be built in rural areas	Provides a low treatment efficiency Must be pumped occasionally Requires a landfill for periodic disposal of sludge and septage
Constructed wetlands	Removes up to 70% of solids and bacteria Minimal capital cost Low operation and maintenance requirements and costs	Remains largely experimental Requires periodic removal of excess plant material Best used in areas where suitable native plants are available
Mechanical Systems		
Filtration systems	Minimal land requirements; can be used for household-scale treatment Relatively low cost Easy to operate	Requires mechanical devices
Vertical biological reactors	Highly efficient treatment method Requires little land area Applicable to small communities for local-scale treatment and to big cities for regional-scale treatment	High cost Complex technology Requires technically skilled manpower for operation and maintenance Needs spare-parts-availability Has a high energy requirement
Activated sludge	Highly efficient treatment method Requires little land area Applicable to small communities for	High cost Requires sludge disposal area (sludge is usually land-spread)

3.2.3.5. Advanced Wastewater Treatment and Innovative Technologies

There has been current development in waste-water treatment technologies that could to a large extent, deal with the challenge of removal of heavy metal ions such as As, Cd, Cr, Cu, Pb, and Hg completely from wastewater treatment. Hence, we can as well refer to them as 'HEAVY METAL REMOVAL TECHNOLOGIES'. Population explosion and its consequent increase in anthropogenic activities has made sewage/wastewater management and treatment a growing concern. However, with the ever enhancing innovative trend in science and technology, more effective wastewater treatment technologies are being discovered to reduce the impact of rising water demand. These technologies are mostly applied in the tertiary stage of wastewater treatment for best results. These wastewater treatment and innovative technologies include the following:

a) **Advance Oxidation**

Advanced oxidation technology uses chemical reagents or free radicals to break down persistent organic contaminants in wastewater in an oxidation reaction. This technology is very effective especially for managing chemical compounds that are difficult to treat with conventional methods.

b) **Photo catalytic Oxidation** This technology uses catalyst such as titanium dioxide that is activated by ultraviolet (UV) light to break down organic contaminants and microorganisms in wastewater. The UV light triggers the catalyst, generating free radicals that oxidize and degrade the pollutants.

c) Anaerobic Membrane BioReactor (An-MBR)

An-MBR treatment combines anaerobic digestion with MBR technologies that concentrates the solid digestate using a micro- or ultrafiltration membrane with a suspended growth bioreactor instead of conventional centrifuges or dissolved air (flotation.https://www.fluencecorp.com/industrial-wastewater-treatment-methods/).

d) Membrane Technologies

Membrane-based technologies include the following:

i. Reverse osmosis (RO)

ii. Ultrafiltration (UF)

iii. Nanofiltration (NF).

They are vastly used to separate and concentrate dissolved solids, contaminants, and suspended particles. For Reverse Osmosis and Ultrafiltration methods, water is forced through membranes under high pressure, leaving contaminants behind and producing purified water that can be reused in a variety of applications.

Reverse Osmosis (RO) uses semipermeable membrane to remove salts and impurities, while **UF and NF membranes** effectively remove particles, bacteria, and macromolecules. Membrane technologies are particularly useful for treating wastewater for reuse and for the recovery of valuable resources from wastewater. Effluent treated with these steps can be safely reused for applications including irrigation, industrial processes, managed aquifer recharge, and even as drinking water.

Ultrasonic Reactors

Ultrasonic reactors use high-frequency ultrasonic waves. These high frequency ultrasonic waves have the capacity to create microbubbles that collapse violently thereby generating high temperatures and pressures that disintegrate contaminants and microorganisms, and effectively decontaminate water.

e) Naturally Or Genetically Enhanced Microorganisms

In this technique, naturally enhanced microorganisms are used to treat wastewater with refractory TOC/COD or specific contaminants. This process involves selecting of special breeds of microorganisms and generating improved variant breeds. These new breeds of microorganisms are then introduced into the treatment process for the treatment/ purification of the wastewater to the required standard.

f) Electrocoagulation And Electrooxidation

In this method, electric current is used to eliminate pollutants through coagulation and oxidation processes.

g) Automation

This is an advanced wastewater purification process whereby the treatment plant implements modern technologies with complex instrumentation and process control systems. Automation is a technology that allows and uses online/digital analytical instruments, programmable logic controllers (PLC), supervisory control and data acquisition (SCADA) systems, human machine interface (HMI), and various process control software that permits the automation and computerization of treatment processes with provision for remote operations. Such innovations improve system operations significantly, thus minimizing supervision needs.

3.2.4. Overview 2 (Alternative to Overview 1)

According to Dhameja (2005), the main aim of wastewater treatment is the removal of contaminants from water so that the treated water can be reused for beneficial purposes. The wastewater treatment is carried out in three stages namely: primary, secondary and tertiary or advanced wastewater treatment.

A. **Primary Treatment:** Wastewater contains a wide variety of solids of various shapes, sizes and diversities. The primary treatment is of general nature and is used for removing suspended solids, odour, colour and to neutralize suspended solids, odour, colour and to neutralize the high or low pH in the case of industrial effluents (industrial wastewater). The stage exploits the physical or chemical properties of the contaminants and removes the suspended and floating matter by screening, sedimentation, floatation filtration, precipitation, etc processes or activities that constitute primary treatment including.
   i. Screening
   ii. Commuting shredding of solid parties with smaller size pieces.
   iii. Grit removal
   iv. Skimming tanks
   v. Sedimentation
   vi. Floatation
   vii. Neutralization (pH correction)
   (use of limestone, treatment or caustic soda treatment to neutralize acidic effluent and use of carbondize treatment and surphaoric acid treatment to neutralize alkaline effluent.Only neutral effluent should be discharged into the drain or public sewer.

B. Secondary or Biological Treatment
The biological process technology of sewage treatment is a secondary treatment that is aimed at removing, stabilizing and rendering harmless very fine suspended matter in solids of the wastewater that remain even after the primary treatment has been done. Since much of the organic matter in wastewater may be colluded or dissolved, the primary treatment processes are largely ineffective in removing it. The organic matter still represent a high demand for oxygen which must be reduced further so that the effluent must be reduced further so that the effluent may be rendered suitable for discharge into the water bodies. In biological treatment oxygen supplied to the bacteria is conscience under controlled conditions so that most of the BOD is removed in the treatment plant rather than in the water course. Thus, the principal

requirements of a biological waste treatment process are an adequate amount of bacteria that feed on the organic material present in wastewater, oxygen and some means of achieving contact between the bacteria and the organics.

Two of the most commonly used systems for biological waste treatment are the activated sludge system and biological form system. In the activated sludge system, the wastewater is brought into contact with a diverse group of micro-organisms in the firm of flocculent suspension in an aerated tank, whereas in the biological film system also known as trickling filters, the wastewater is brought into contact with a mixed microbial population in the form of a film of slime attached to the surface of a solid support system. In both cases, the organic matter is metabolized to more stable inorganic forms.

C. **Tertiary or Advanced Wastewater Treatment:** Usually the primary and secondary treatments are sufficient to meet wastewater effluent standards. However, if water produced is required to be of higher quality standards (in case the water to be put to some direct reuse) then advanced wastewater treatment is carried.

A wide variety of methods are used in advanced waste treatment which include the removal of (a). suspended solids (b) BOD, (c). Plant nutrient (d).Dissolved solids and (e).toxic substances. These methods may be introduced at any stage of the total treatment process as in the case of industrial wastewater or may be used for complete removal of pollutants after the secondary treatment.

4.0. Reuse of Treated Wastewater and Case History

4.1. Reuse of Treated Wastewater

Treated Wastewater may be reused in various ways including (Jimenez, 2006; Jimenez and Asano, 2008);

i. Reuse of wastewater can improve the quality of streams and lakes by reducing the effluent discharges that they receive.

ii. Wastewater may be reclaimed and reused groundwater recharge, or recreational purposes.

iii. The use of grey-water recycling systems in new commercial buildings offers a method of saving water and reducing total sewage volumes. This is by filtering and chlorinating drainage from tubs and sinks, reusing the water for non-portable purposes like flushing toilets and urinals. Recycled water could be marked with any dye color to ensure that it is not used for potable purposes.

iv. Used for fire extinguisher

v. Wastewater can be a source for plant nutrient especially for soils with low fertility.

vi. A source of income; across Africa, Asia, and Latin America, the micro-economies of sewage water support a large number of low-income individuals, hence stoppage or overregulation of the use of sewage water could take away the only income source of numerous landless people.

vii. Urine can be turned into a good fertilizer because of its ammonium/ urea content. It contains nutrients that are readily taken up by plants. Urine also contains very low levels of heavy metals (much lower than chemical fertilizers) and pathogens. However in treatment plants, the potency of urine as a fertilizer gets lost or greatly watered down. This opens up the possibility of storing, collecting and recycling urine rather than sending it though the sewage treatment system.

viii. Wastewater can also be diverted to anaerobic digestion to create methane for generating energy; a process increasingly incorporated into sewage treatment plants.

ix. Use for agricultural purposes. Municipal wastewater could be used for crop and landscape irrigation in arid lands. In Katsina, a notable urban area in the semi arid region of Nigeria, wastewater reuse of for agricultural purposes is a major practice, in fact, it is more like an occupation, a business and a major source of income for the larger populace (Ruma and Sheikeh, 2010).

x. Artificial Groundwater Recharge, AGR, is one of the reuse of wastewater in Nigeria (Adewumi et al.), especially in arid and saharan regions of Nigeria where rainfall, water resources and supply are not in abundance. AGR is done both intentionally and unintentionally. When wastewater is disposed or disposal whether indiscriminately or appropriately on ground surface, it seeps through the soil into the subsurface and eventually reaches the aquifer in the area, thereby recharging the groundwater. This process also serves as a wastewater treatment method/process, whereby the soil filters off the waste contaminants and pollutants in the disposed wastewater.

4.2. Case History

Amaefule *al*, (2023) described the technologies advancement and socioeconomic impact of wastewater treatment in Nigeria.

4.2.1. Introduction

Wastewater in Nigeria comes from various sources such as households, markets, hospitals, agricultural and industrial activities and its mainly discharged into the environmental without treatment. Untreated wastewater entering the environment leads to degradation, transmission of illnesses, pollution of water resources and destruction of ecosystem (mainly aquatic habitat).Therefore, adequate wastewater treatment is vital for preserving and sustaining human life, health and environmental/socio-economic development.

American Society of Civil Engineers (1982) defined sewage wastewater and spent or used water of a community in industry which contains dissolved or suspended matter. The word wastewater and sewage are used interchangeable in this study. Although more often, sewage refer to used water of a community including specifically human excreta of faeces and urine, (Feachem *et al*, 1998; Adesogan, 2013; Adejuwon and Adeniyi, 2011).Sewage is created by residential, institutional and commercial establishments. Raw sewage includes household liquid wastes from toilets, baths, showers, kitchen sinks and so forth that is disposed of via sewers. Fig 1 show summary of Sewage Disposal Pattern in Urban Areas of Nigeria (Adesogan, 2013).Everybody knows that the site of sewage of a community is unbearable if proper disposal measures are not taken. Sewage should be treated before its disposal in order to prevent pollution of surface and underground water resources, and to reduce the spread of communicable diseases caused by pathogenic organisms present in sewage (Ogedemgbe, 2014).

Fig 8.

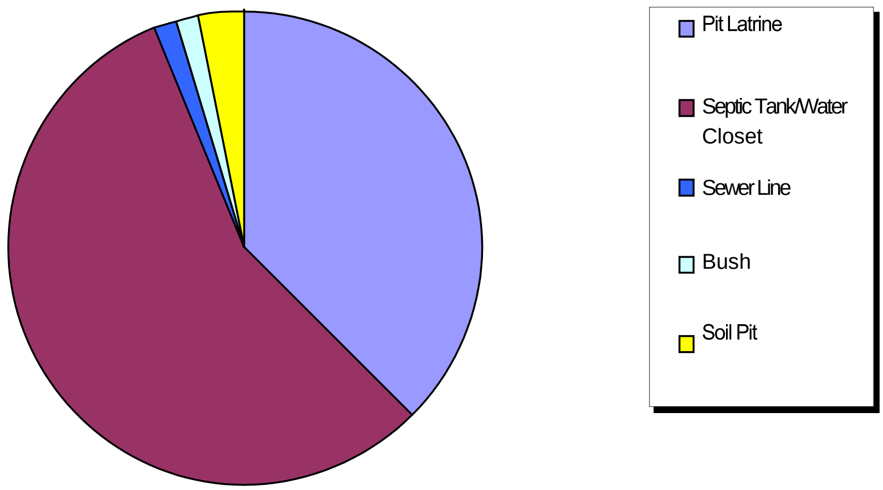


Fig. 8: Sewage Disposal Pattern in Urban Areas of Nigeria (Adesogan, 2013).

4.2 **Overview and Current States of Wastewater Treatment Technologies in Nigeria**
According to Yorkor and Memdi (2019), Nigeria'swastewater treatment focuses on removing Biological Oxygen Demand (BOD). It often gives minimal consideration for removing phosphorus and nitrogen which are also in high concentration. When these nutrient-packed wastewater effluentsare released into the environment, they often lead to eutrophication. According to Adesogan (2013), out of twenty six (26) wastewater plants in Nigeria listed in the study 22 were reported having functional and 4 non-functional systems (Table 1). These non-functional sewage plants are in Ifunga, Port Harcourt, Rivers State, Makurdi, Central, University College Hospital, Auchi, Ibadan and Kano central.

The treatment methods listed are:

1. **Biological treatment**: In this treatment, micro-organisms can feed on complex materials to reduce the BOD level and turn them into simpler forms for further treatment. Methods such as activated sludge, trickling filters and oxidation ponds are used
2. **Mechanical treatment**: Here, biological, physical and chemical procedures are engaged to achieve the desired treatment outcomes. A series of tanks, pumps, blower and grinders are used and equally regulatory and control steps are taken.

Table 9: Sewerage Technologies Practiced in the Urban Area of Nigeria (Adesogan, 2013)

STATE	LOCATIONS OF SEWER LINES	KIND OF TREATMENT	LEVEL OF TREATMENT	STATUS
F.C.T, Abuja	Wupa Central Plant	Mechanical	Complete	Functioning
Markurdi	Markurdi Central	Mechanical	Complete	Not Functioning
Kaduna	Nigerian Brewery, Kaduna	Mechanical	Complete	Functioning
Kano	Kano central	Mechanical	Complete	Not Functioning
Enugu	Abakpanike Estate	Biological	Partial	Functioning
Edo	Nigerian Brewery, Benin	Mechanical	Complete	Functioning
Delta	NNPC, Warri Shell Petroleum Main Office and Staff Quarters Warri	Mechanical Mechanical	Complete Complete	Functioning Functioning
Rivers	Ifruga Estate, Rivers Etope Estate , Rivers Chevron Office, Rivers Shell Petroleum office, Rivers	Mechanical Biological Mechanical Mechanical	Partial Partial Complete Complete	Not Functioning Functioning Functioning Functioning
Lagos	Abesan Oke Afa Alausa Olusosun Nigerian Brewery, Lagos	Biological Biological Mechanical Biological Mechanical Biological	Partial Partial Partial Partial Complete Partial	Functioning Functioning Functioning Functioning Functioning Functioning
Ekiti	University of Lagos ABUAD	Mechanical and Biological	Partial	Functioning
Oyo	UCH University of Ibadan I.I.T.A Ibadan Nigerian Brewery, Ibadan	Mechanical Biological Mechanical Mechanical	Partial Partial Complete Complete	Not Functioning Functioning Functioning Functioning
Osun	OAU, Ile-Ife Nigerian Brewery, Ilesha	Biological Mechanical	Partial Complete	Functioning Functioning
Ogun	Agbara Industrial Estate	Mechanical	Complete	Functioning

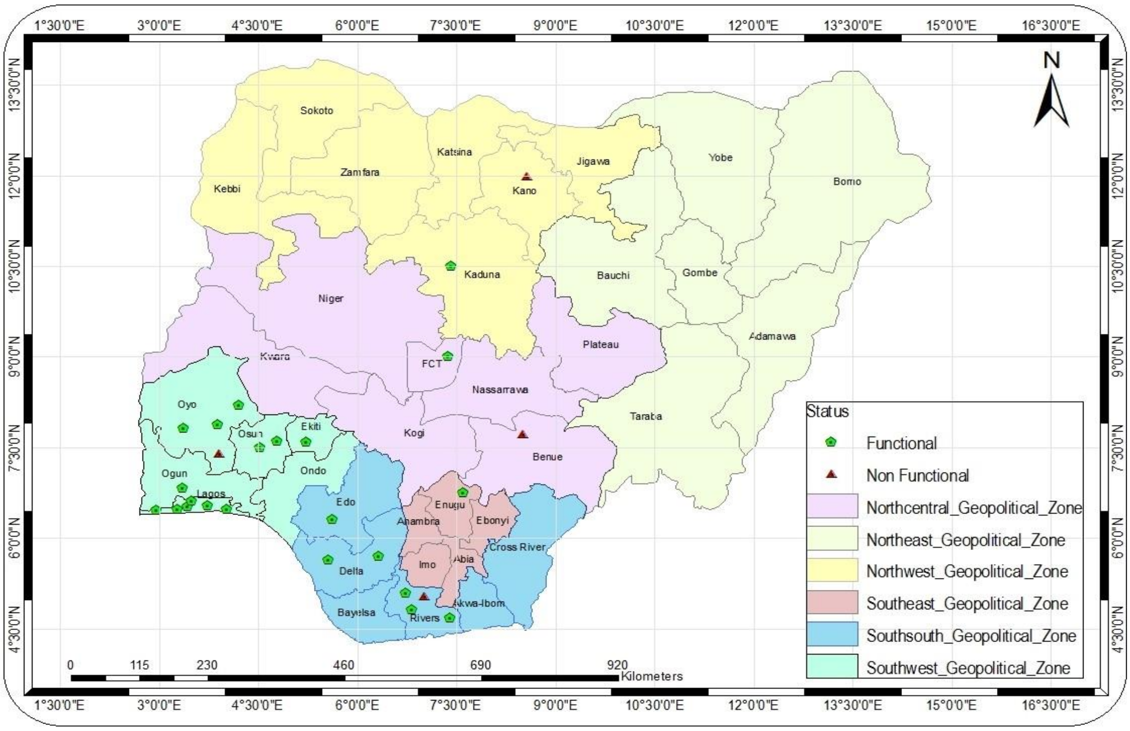


Fig 9: Geographical spread of 26 wastewater plants in Nigeria (Adesogan, 2013).

In summary, the paper/study revealed that virtually all urban sewages are not treated. The only places where sewage treatment technology is employed in the country are some selected institutions. These includes University of Ibadan, which employs biological treatment method, Obafemi Awolowo University, Ile Ife, International institute of Tropical Agriculture, Ibadan in Oyo State, Afe Babalola University, Ado Ekiti and Wupa Sewage treatment plant in Abuja, which uses mechanical treatment.

There are some other places like estates where sewage are being treated in the Urban Areas of Nigeria. Examples are Agbana Industrial Estate in Ogun State, Abakpa Nike Estate in Enugu, Ifruga and Etope Estates, both in Port Harcourt, Lagos State government have three functional plant built recently, industrial areas from the buck of the places where sewage technologies are located. These are places like Shell Office in Port Harcourt and Warri, Chevron Office in Port Harcourt, Nigeria National Petroleum Corporation (NNPC) in Warri, Nigeria Brewery at Kaduna, Benin, Ibadan, Lagos and Ilesa.

The majority of sewage disposal method with country is water closet and septic tank, functional pit laterines.

4.3. Recent Technological Advancements in Wastewater Treatment.

In Nigeria, the technologies used in wastewater treatment consist mainly of primary treatment like screening filtration, centrifugation, sedimentation, Coagulation and floatation. These old treatment method needed improvement because of flu recent increase in water quality standards.

There is need for modern technologies because they not only reduce energy consumption but are also eco-friendly, more reliable and increase sustainability (Nathanson and Ambubakar, 2023). The recent advancements in wastewater treatment points towards advanced biological and chemical treatment depending on sewage characteristics and contaminant. Only one or combination like aspects of the treatments may be applied. These are listed below

1. **Biological Treatment:**
   a. Reverse Osmosis (RO) and Nanofiltration (NF)
   b. Aeration processes
   This approach can be used to reduce up to 90-99% of biodegradable organics in the water including phosphates, nitrates, volatile organic compounds dissolved and suspended organics, hydrogen sulphide carbondioxide, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and other pollutants. Oxidation Ponds, aeration Legoons and activated sludge are the principal technologies used to carry out the aerobic process.
   c. Anaerobic process
   This treatment involves the degradation of organic pollutants in microorganism in the absence of air. Anaerobic, technologies are generally used as pretreatment in wastewater rich in high organic material (BOD, COD, TSS) before the aerobic process.
2. **Chemical Treatment**: These are efficient chemical methods that are used to remove organic contaminants that cannot degrade by use of biological process. They includes
   a. oxidation/reduction (Redox reactions)
   b. Electrodialysis

4.4 . Challenges Facing Wastewater Treatment Practices in Nigeria.

Some challenges that impact the effectiveness and efficiency of wastewater treatment in Nigeria includes:

i. None availability of can hinder or slow down wastewater collection, treatment and safe storage.
ii. Poor waste management can lead to contaminant settling into water bodies.
iii. Negligence: Poor monitoring and evaluation of wastewater treatment systems.
iv. Population growth industrialization and urbanization have exacerbated unstable and untreated wastewater discharge issues.
v. Lack of infrastructures or abandonment (make stagnant) of existing central sewage systems like in Abuja and Lagos.
vi. Policy issues, there is no review of current laws and lack of regulation compliance.

5.0. Conclusion

Wastewater is “used” or “spent” water generated as a result of human activities such as domestic, industrial, recreational and agricultural. Wastewater usually has many pollutants including dissolved solids, suspended solids micro-organisms and organic compounds that if not removed, may cause health problems to human beings. There are three classes of wastewater including domestic wastewater, industrial wastewater and stormwater wastewater. Their sources and composition influence their characteristics. Domestic wastewater (also called sanitary wastewater) is often used interchanged with sewage that is liquid waste associated with domestic activities in the toilets, kitchens, bathrooms and laundries. The industrial wastewater is associated with series of activities including steel, metals plating, paper and plywood manufacturing, and petrochemicals. Wastewater treatment refers to series of activities that are performed on wastewater to remove or reduce their pollutants, particularly TDS, TSS, COD, BOD, Total Hardness (calcium and magnesium carbonates), heavy metals, phosphorus and ammonia etc to make the wastewater fit for reuse in several areas including ground water recharge, irrigation and liquid for fire extinguishers, Mechanical, biological, chemical and sometimes combination of mechanical/biological treatment methods are often used in the treatment process.

In Nigeria, sewage is generated and disposed without treatment into pit latrines and septic tanks –soakaway pits in many communities. However, some industries (including Nigerian Breweries, SHELL Petroleum and CHEVRON Petroleum); some academic institution (includes Afe Babalola University, Ado Ekiti, IITA Ibadan, and Obafemi Awolowo University, Ile-Ife) and some Housing Estates (in Enugu, Abuja, Lagos and Port Harcourt) have functional wastewater treatment plants.

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