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POLLUTANTS IN WASTEWATER EFFLUENTS: IMPACTS AND REMEDIATION PROCESSES

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Abstract

Due to extensive industrialization and increase in population density and urbanized societies, the world is faced with problems related to the management of wastewater. On a daily basis, the effluents generated from domestic and industrial activities constitute a main cause of pollution of receiving water bodies, which is a great burden on water quality management. Some of these pollutants are pathogenic microorganisms, phosphorus and nitrogen, hydrocarbons, heavy metals, endocrine disruptors and organic matter. The majority of water related infections, such as cholera, typhoid fever, diarrheoa and others are caused by the presence of pathogenic microorganisms in water. The diseases caused by bacteria, viruses and protozoa are the most common health hazards associated with untreated waters. The main sources of these microbial contaminants in wastewater are human and animal wastes Also, the presence of these phosphorus and nitrogen in excess amounts could lead to the eutrophication of water sources, which may also create environmental conditions that favour the growth of toxin-producing cyanobacteria. Chronic exposure to some of such toxins produced by these organisms can cause a host of other diseases. In addition, the danger of non-biodegradable and recalcitrant pollutants in water is their ability to persist in natural ecosystems for an extended period and have their ability to accumulate in successive levels of the biological food chain. As a result of these negative effects, a number of processes are in place for the treatment of wastewater effluents before discharge into receiving water bodies. This review was therefore aimed at providing an insight into the major pollutants in wastewater effluents and the various treatment processes.

Key words: Remediation, Pollution, Wastewater

INTRODUCTION

A variety of substances in untreated or improperly treated wastewater effluents are known to be toxic to plants and animals, including humans and pose negative impacts on the environment. The major contaminants in wastewater effluents are nutrients (nitrogen and phosphorus), heavy metals, hydrocarbons, organic matter, microbes and endocrine disruptors are the major contaminants in wastewater that leads to adverse effects to both human health and the environment (Davies, 2005). In wastewater, the organic matter and other forms of contaminants makes it a breeding ground for most pathogenic organisms, such as bacteria, fungi, protozoa and viruses. The presence of these organisms in wastewater is usually accountable for a host of water-related diseases; hence the need for treatment before discharging into receiving water bodies (Jegatheesan *et al*., 2008). The presence of nitrogenous compounds in wastewater effluents at concentrations above the required limit is known to be detrimental to receiving water bodies.

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Ammonia, which is usually present in wastewater in the main form of nitrogen, is known to be toxic to aquatic organisms when in excess concentration. The ingestion of nitrate containing water could lead to methemoglobinemia, also called blue babies syndrome in infants and other susceptible individuals. In addition, a number of endocrine disruptors, such as 17β-estradiol, estrone and testosterone have been reported to cause reproductive organ failure in humans and animals. Besides, heavy metals, such as zinc and mercury are reported to lead to protein conformation and causing cancer (EPA, 2007; Samir and Ibrahim, 2008).In addition, a variety of pathogenic microorganisms are known to possess the ability to thrive in wastewater. When such microbial- polluted wastewater into water bodies, they pose serious threat to the health of humans and animals (Surface Water Quality Bureau, 2008).

One of the major contributors to various cases of water pollution is wastewater effluents. Some of these problems include metal poisoning, irritations and pathogenic infections of humans and animals. Another major problem caused by untreated wastewater effluent is eutrophication, which excessive nutrient proliferation could lead to the stimulation of algae growth which can lead to increased cost in water purification. Other impacts of eutrophication are dissolved oxygen depletion, physical changes to receiving water bodies, bioaccumulation and biomagnification of contaminants, toxic substance release and nutrient enrichment effects (Akpor and Muchie, 2011). The awareness of most society towards the prevention of water borne diseases has brought more attention to the treatment of wastewater. This is because wastewater treatment is an important link in the prevention and transmission of water borne diseases (Davies, 2005). To avoid the negative impacts of untreated and improperly treated wastewater effluents, there is the need for effective and efficient treatment discharge into receiving water bodies. Wastewater treatment entails the ability to achieve improvements in the quality of wastewater. Several methods have been employed in the removal of pollutants from wastewater. These remediation processes include physical remediation, chemical remediation, phytoremediation and microbial remediation (Rubalcaba, 2007; Prescott, 2011). Although, these treatment processes play vital roles in wastewater remediation, they have their flaws, which necessitate in some cases the application of a combination of processes for remediation. This study was therefore aimed at reviewing the major pollutants in wastewater and their environmental and health impacts. Also reviewed were the various treatment processes for the treatment of wastewater.

Impacts of pollutants in wastewater effluents

One of the major threats to aquatic organisms is the presence of pollutants in wastewater effluents. The major contaminants in wastewater are nutrients (nitrogen and phosphorus), hydrocarbons, heavy metals and microbes.

Effects of nitrogen and phosphorus

The two major eutrophic nutrients in wastewater effluents are nitrogen and phosphorus. It is indicated that over 47% and 53% of streams have medium to high level of phosphorus and nitrogen, respectively (Watershed Academy Webcast, 2011). In untreated wastewater, nitrogen is primarily in the form of ammonia and organic nitrogen, while phosphorus may exist as soluble orthophosphate ion, organically-bound phosphate, or other phosphorus/oxygen forms (Akporand Muchie, 2010). The presence of algal blooms in water has been indicated to lead to non-linear decrease in water clarity level. The recognizable effect of eutrophication is the occurrence of algal blooms, which in turns leads to the depletion of dissolved oxygen concentration in receiving water bodies. A low DO in water bodies is known to the death of aquatic life, muddy water and drastic reduction of desirable flora and fauna. In addition, toxic algae, such as *Microsystis*, which is known to strongly inhibit large cladoceransmay also be noticeable in algae blooms (Jack *et al*., 2002). Another impact of eutrophication is an increase in the amount of chlorine required for the disinfection of water bodies, which could increase the increasing the risk of cancer (Fisher *et al*., 2004; Wang *et al*., 2007). Also, excessive nutrient proliferation in wastewater effluents may lead to the stimulation of harmful microbes like *Pfisteria* (Hasselgien *et al*., 2008). The presence of *Pfisteria* in a water body is identified to cause eye and respiratory irritation, headache, and gastrointestinal complaints (Morris, Jr, 2001; Watershed Academy Webcast, 2011). Additionally, the presence of remarkably high nitrate content above a maximum contaminant level of 1o mg/L in water is known to lead to methemoglobinemia (blue-baby disease) in infants and other susceptible individuals. During methemoglobinemia in infants, nitrate is reduced to nitrite in the digestive system, which attacks the hemoglobin. Some reports have suggested that the presence of nitrite could cause chemical or enzymatic reaction with amine, which to formsnitrosoamines, which are carinogens (EPA, 2002; WHO, 2006).

Effects of hydrocarbon

Although petroleum hydrocarbons are toxic to all forms of life, environmental contamination duetocrude oil is relatively common because of its widespread use and associated disposal operations and accidental spills (Lan *et al*., 2009; Abha and Singh, 2012).The presence of hydrocarbon pollutants in wastewater effluents is known to lead to several health and environmental impacts, which are of great concern. Although petroleumis an important energy resources and raw materials of chemical industry, when in contact with receiving water bodies could result in serious problems, such as threat to fishery, marine habitats of wildlife, human health, and the destruction of ecological balance which may take years or even decades to recover (Zhang *et al*., 2011).

Since petroleum consists of highly toxic chemicals, its presence in water can cause significant damage to body organs (liver and kidney) and systems, such as the nervous, respiratory, circulatory, immune, reproductive, sensory and endocrine systems (Costello, 1979; Obidike *et al*., 2007). Also, a host of other diseases and disorders could be caused to humans and animals by the presence hydrocarbons in water. The degeneration and necrosis of interstitial cell and exudation of the interstices in the testes of rats have been reported when exposed to petroleum. It has also been indicated that the exposure of rats to crude oil could induce reproductive cytotoxicity that is confined to the differentiating spermatogonia compartment (Obidike *et al*., 2007). Knox and Gilman (1997) have also stated that petroleum derivatives are associated with associated childhood cancers. The observation of aspiration pneumonia in sheep following exposure to gas condensate has also been indicated in the past (Adler et al., 1992).

A number of reports of petroleum hydrocarbon exposure in humans, primates, ruminants, horses, wildlife and dogs have been reported in literatures (Bamberger and Oswald, 2010). Although in a report by Waldner and co-workers (1998), no association between the productivity of cattle and exposure to sour gas pipeline leak was observed, a longer term study by the same authors in cattle reported an association between sour-gas flaring and increased risk of still birth, as well as increase drisk of calf mortality. Studies on habitat selections have observed that animals, such as mule deer have a tendency of moving away from areas of gas development. One such studies, indicated a drop in deer population dropped by45%within a year and decrease in their survival rates in area of gas development (Sawyer *et al*., 2006).

Effects of Heavy metals

The most anthropogenic sources of heavy metals found in wastewater are industrial, petroleum contamination and sewage disposal (Santos et al., 2005). Although, some heavy metals, such as zinc, copper and iron are described to be essential in aquatic environment because of their roles in several biochemical processes, when present in high concentrations, they become detrimental (Samir and Ibrahim, 2008). The incorporation of heavy metals into food chains could lead to their in aquatic organisms to a level that affects their physiological state. Because most heavy metals are known to be toxic and carcinogenic, they represent serious threat to human health and the fauna and flora of receiving water bodies. A number of heavy metals, such as zinc, copper, nickel and arsenic are reportedly are known for their toxicity, even at very low concentrations (Dhokpande and Kaware, 2013).

It is indicated that heavy metals have a propensity of binding with proteins, thereby changing their conformation and inactivating them, which typically results to health complications (Prescott, 2011). Some studies have indicated zinc poisoning to be a cause of stomach cramps, skin irritations, vomiting, nausea, anaemia, damaged pancreas, disturbed protein metabolism, arteriosclerosis, respiratory disorders, and metal fever (Galadima, 2012). In addition, the presence of zinc has been shown pose great danger to infants and unborn, especially when large concentrations of it is absorbed by their mothers during pregnancy (Aghahowa, 2012). In addition, the presence of zinc in wastewater is indicated to cause an increase in water acidity, which could affect the cultivation and yield of crops (Oyewale, 2000; Oladele *et al*., 2012).

Furthermore, apart from been known as one of the causes of kidney damage, the presence of lead in humans and animals is revealed to have effects on haemoglobin synthesis, which could lead to anaemia. Although some of the effects of lead are reported to be irreversible, chronic exposure may lead to sustained decrease in kidney function, which could lead to possible renal failure. It is hypothesized that one of the most important factors that influence the aquatic toxicity of lead is its free ionic concentration and availability to organisms; hence it is unlikely to affect aquatic plants at levels that might be found in the general environment (Baysal *et al*., 2013). In the case of mercury, its organic forms are known to be more toxic to aquatic organisms than the inorganic forms. Although aquatic plants are affected by mercury in water at concentrations approaching 1 mg/l for inorganic mercury, the effect is greater even at much lower concentrations of organic mercury (Kenawy, 2010). For cadmium, its acute toxicity to aquatic organisms is variable, even between closely related species. This variation is said to be related to its free ionic concentration of the metal. Cadmium is reported to interact with calcium metabolism in animals. In fish, cadmium is reported to cause a lack of calcium (hypocalcaemia). This is probably by the inhibition of calcium uptake from the water, with the long-time effects of exposure to cadmium being larval mortality and temporary reduction in growth (Jarup, 2003).

In addition, although, chromium is necessary for the metabolism of insulin and essential for animals, at high concentrations it is known to be toxic to organisms. In animals, chromium is known to cause skin irritation and cancer. It is generally indicated that hexavalent chromium, is more toxic to organisms in the environment than the trivalent chromium with its ability to cause irritation and cancer. Chromiumis also indicated to make fishes to be more susceptible to infection. A high concentration of chromium is also known to cause damage in the tissues of several invertebrates, such as snails and worms (Baysal *et al*., 2013).

Effects of Microbes

It is indicated that the majority of waterborne microorganisms that cause human disease are from fecal wastes that are released by humans or animals that contain these diseases (Kris, 2007). The most common health hazards that are associated with the consumption of untreated drinking and recreational waters are caused by bacteria, viruses and protozoa. Untreated water is vehicle for several water-related diseases, such as typhoid fever, cholera, shigellosis, salmonellosis, campylobacteriosis, giardiasis, cryptosporosis and Hepatitis A. The majority of pathogenic microorganisms have the capacity to cause acute and chronic diseases with short to long-term effects, such as degenerative heart diseases and stomach ulcers with intensity. Viruses are among the most important and potentially most hazardous pollutants in wastewater. They are more resistant to treatment, more infectious, more difficult to detect and require smaller doses to cause infections (Okoh *et al*., 2007). For bacteria, they are the most common microbial pollutants in wastewater. They cause a wide range of infections, such as diarrhea, dysentery, skin and tissue infections. The major pathogenic protozoans associated with wastewater are *Giardia* and *Cryptosporidium*. They are more prevalent in wastewater than in any other environmental source (Akpor and Muchie, 2011).

Effects of organic waste and endocrine disruptors

Organic wastes consist of carbon, hydrogen, oxygen, nitrogen and other elements; and could either be carbohydrate, protein or fat which are biodegradables.

The majority of organic materials in wastewater originate from plants, animals or synthetic sources. They enter wastewater in through human wastes, paper products, detergents, cosmetics, foods, and from agricultural, commercial, and industrial sources. The presence of organic matter in water lead to imposes an oxygen demand on the microorganisms that help in the degradation, hence depleting the level of dissolved oxygen that is available for other aquatic organisms. A decrease in dissolved oxygen below a certain point will have adverse effect on the physiology and metabolism of aquatic organisms, which lead to their death. The death of aquatic organisms, such as fish will deplete the recreational value of such waters due to the release of odours and the overall degradation of water quality (Davies, 2005)

Endocrine disruptors are said to be chemicals or natural by-products in the environment that mimic hormones in the body. They are also known as exogenous agents that interfere with the synthesis, secretion, transport, binding, action, or elimination of natural hormones in the body that are responsible for the maintenance of homeostasis, reproduction, development and behavior (EPA, 2012).They can be divided into two general classes: endocrine hormones and endocrine mimics, which include xenobiotics, such as xenoestrogens, xenoandrogens and phytoestrogens.

The presence of endocrine disruptors in receiving water bodies is indicated to threaten reproductive success and long-term survival of sensitive aquatic populations. Examples of reproductive hormones that are commonly detected in effluent-affected ecosystems are 17β-estradiol, estrone, testosterone, and the synthetic birth control compound, 17α-ethinylestradiol. There are also a number of other endocrine disrupting chemicals that share sufficient structural similarity with the endocrine hormones to interact with animal endocrine receptors sites and trigger negative effects. This group, referred to as endocrine mimics generally exhibit less endocrine reactivity, but are essentially ubiquitous in wastewater. The endocrine mimics are often reported at concentrations of 3-5 orders of magnitude higher than the endocrine hormones (Bradley and Kolpin, 2013).

Treatment processes for wastewater effluents

The proper treatment of wastewater effluents before discharging into receiving water bodies is vital to protect the environment and safeguard public health. The processes for wastewater treatment are grouped into the following categories: phytoremediation, chemical remediation, physical remediation and microbial remediation processes.

Phytoremediation processes

Phytoremediation is a treatment process that involves the use of plants. During phytoremediation, contaminants are either removed or transformed into harmless and sometimes valuable forms (Leather international, 2013). The process uses various plants to degrade, extract, contain, or immobilize contaminants from soil and water. Although phytoremediation has received attention over the years and is usually classified as a clean and cheap method, it has the following limitations:

- For the remediation to take place, the process involves contact between the root of plant and the contaminant, hence the plant must be able to extend its roots to the contaminant or the contaminated media must be moved into the range of the plant's reach (EPA, 2002).
- The process is dependent on the growth of a plant; this makes it to take longer time for remediation to take place. Because of the length of time that may be involved, for contaminants that pose acute risks for human and other ecological receptors, the process may not be the remediation technique of choice (EPA, 2002).
- Although the process easily be used in places where the concentration of contaminants at the root zone is low or at medium level, at high concentrations of contaminants, there could be inhibition of growth or death of the plant, hence limiting its effectiveness in environments where contaminant concentration is high. (EPA, 2002)

In the application of phytoremediation in the treatment of wastewater can be classified based on the contaminant fate and the mechanisms involved Although a variety of phytoremediation processes exists, the ones are applicable in wastewater treatment are phytodegradation, phytoextraction and phytoimmobilisation (Todd and Josephson, 1996; EPA, 2002).

Phytodegradation of wastewater pollutants

Phytodegradation, which is also referred to as phyto transformation entails the destruction of a contaminant through uptake by plants as nutrient. In some cases, certain plants that are used have the ability of taking up toxic compounds, detoxifying and metabolizing them as nutrients (Kidney, 1997). A typical application of phytodegradation in wastewater is the use of microalgae to reduce the nutrient content in wastewater. Microalgae have the ability to assimilate nutrients into their cells (Mamun et al., 2012). The wastewater pollutants that have reportedly been phytodegraded include chlorinated solvents, herbicides, and insecticides and inorganic nutrients. For phytodegradation to occur, the plant used must have the ability to take up the compound and metabolise it. In the case of a toxic compound, the detoxification is a three-phase (bioactivation, conjugation and compartmentalization) process that is characterised by the participation of different classes of enzymes, and by the properties and allocation of their reaction products (Newman *et al*., 1998). During bioactivation, the plant relies on the formation of reactive groups in the pollutant molecule. The aim of this phase is for the activation of the compound to the actual detoxification, which takes place in the next step.

This phase mainly involves enzymes, such as flavin and polysubstratemonooxygenase, which exhibit hydrolytic and redox activity (Zakrzewski, 2000; Walker *et al*., 2002). In conjugation, the activated pollutant binds to a sugar molecules, amino acids or SH-groups of glutathione to produce less toxic substances that have polar structures. Depending on whether it is a sugar, amino acid or glutathione, this reaction is catalysed by UDP-dependent glucosyl transferase, N-acetyl transferases and the family of glutathione transferases. During the last phase, which is known as compartmentalization, the inactivated pollutant is removed by conjugation from the cytosol to the vacuole or apoplast occurs that allows safe deposition of derived toxins (Spaczyński, 2012).

Phytoextraction of wastewater pollutants

Phytoextraction, which is also referred to as phytomininginvolves the planting of a crop species that possess the ability to accumulate contaminants (hyperaccumulator plants) in the shoots and leaves of the plants, after which they are harvested and the pollutant is removed from the site. It is reported that plants that possess hyper accumulation ability do not only accumulate high levels of essential micronutrients, but can also absorb significant amounts of nonessential metals, such as cadmium (EPA, 2002). For phytoextraction to occur, the pollutant must be able to be transported from the root to the shoot of the plant, through the process of translocation, which is primarily controlled by two the root pressure and leaf transpiration. It is only after translocation that the pollutant can be reabsorbed from the sap into leaf cells.

One of the most efficient metal hyper accumulator is *Thlaspicaerulescens* (alpine pennycress). It is indicated that while most plants show toxicity symptoms at metal accumulation of about 100 ppm, hyper accumulator plants, such as *T. caerulescens* can accumulate up to 26,000 ppm without showing any injury (Brown *et al*., 1995). Because hyper accumulator plants have higher requirement for metals, than non-accumulator species, they have be shown to colonize metal-rich environments ((Hajar, 1987; Baker and Proctor, 1990).Phytoextraction is said to be advantageous because of its environmental friendliness. Just as in all phytoremediation processes, because it is controlled by plants, it takes more time to achieve remediation than other traditional clean-up methods.

Phytoimmobilization of wastewater pollutants

Phytoimmobilization, also known as phytostabilisation involves the binding of pollutants in water and rendering them non-bioavailable or immobilized by removing the means of transport. This can take the form of binding the pollutant a humic molecule, physical sequestration of metals as occurs in some wetlands, or by root accumulation in non-harvestable plants (EPA, 2002; USDA, 2002). The transport of the pollutant can be reduced through absorption and accumulation by the plant roots, adsorption onto roots, precipitation, complexation, or metal valence reduction or by binding into humic matter through the process of humification (EPA, 1997). In some cases, phytoimmobilisation may occur in water into which plant roots release plant exudates, like phosphate, so as to generate insoluble precipitated forms of contaminants, such as lead phosphate, thus removing the contaminant from solution without having it taken up into the plant (Dushenkov *et al*., 1995).

Chemical remediation processes

Chemical remediation is the use of chemical compounds in the treatment of pollutants. It include selectron-beam irradiation, chemical extraction, radicolloid treatment, sorption to organo-oxide and wet air oxidation (Hamby, 2000; Rubalcaba, 2007).

Electron-beam irradiation

An electron-beam irradiation operates on the principle that when water is irradiated with electron beams it has the ability to produce free radicals (H^+ and OH^-). The free radicals can react with organic contaminants, such as trichloroethylene and carbon tetrachloride, which could result in the release of harmless chemical entities, such as CO_2, H_2O, salts, and other compounds. (Rosocha, 1994). The use of electron beam technology has been indicated to be efficient in the removal of up to 99.99% pollutants in wastewater, when in full-scale operation (Nyer, 1992). Although it is indicated that the use of high dose rates of electrons are less efficient than when low dose rates are used, reports have also shown that high energy electron-beam irradiation is an effective and economical means for the removal of hazardous organic pollutants in water (Hamby, 2000).

Chemical extraction

Chemical extraction, which is also known as solvent extraction, is the use of chemical compounds for the removal of pollutants. This technique is mostly employed in the removal of heavy metals. The technique involves the use of organic solutions that contain extractants to transport selected metals from one aqueous solution to another. When this happens, the metals are separated, purified and recovered (Zhang, 2010). Most common extractants are organic compounds with molecular mass 200–450. They are almost insoluble in water (5–50 ppm) and selectively extract metals from aqueous solutions. The efficiency of removal is dependent on the extraction conditions, such as the type of extractant, anions present in the aqueous phase, and pH. Chemical extraction is commonly used in combination with other technologies, such as solidification/stabilization, precipitation and electro winning. In water treatment, the process involves the mixing of wastewater with organic solvent that contains a reagent. The metal of interest present in the wastewater reacts with the reagent to form a chemical compound, which is more soluble in the organic than in the aqueous solution. As a consequence, the substance of interest is transferred to the organic solution (National Technical University of Athens, 2013).

Radiocolloid treatment

Radiocolloids are known as suspensions of tiny radioactive particles, which are located in media, such as water. The inorganic colloids are usually characterized by concentration, mineralogy, and radioactivity levels. There are certain radiocollloids, such as colloids of plutonium and americium whose presence in wastewater may lead to high level of radiation, which may be carcinogenic when in contact with human (Nuttall and Kale, 1994).

One process for the removal of radicolloids in water is polyelectrolyte capture. A polyelectrolyte capture process involves the addition of a polyelectrolytic solution to a medium containing the radiocolloid. The aim of adding the electrolyte solution is to attach to the negatively charged radicolloids, since they are positively charged (Nuttall *et al*., 1992). The polyelectrolyte polymer treatment of colloids is indicated to be successful in laboratory column tests (Hamby, 2000).

Removal by sorption to organo-oxides

An organo-oxide is a synthetic sorbents that provides an organic phase with the ability able to bind a non-ionic organic substance. Organo-oxide synthetic sorbents are formed when an anionic surfactant adsorbs onto oxides in an acidic environment. This occurs only when the oxide is positively charged. The positive charge is only attained at a pH that is less than the zero point of charge, i.e. the pH at which solid surface charges from all sources are zero (Hamby, 2000). According to Park and Jaffe (1994), the sorption of an anionic surfactant onto an oxide is inversely proportional to pH. With respect to the quantity of water treated, organo-oxide sorbents are said to be less efficient than other technologies. Despite their inefficiencies, when compared to other technologies, they have the advantages of in-situ generation, selective removal of specific contaminants through the use of a specific surfactant which can sorb a particular pollutant and the solute that is removed from the water can be recovered if so desired (Hamby, 2000).

Wet air oxidation

Wet air oxidation or hydrothermal treatment chemical treatment process that entails the oxidation of suspended or dissolved materials in water with dissolved oxygen at elevated temperatures (Clayton, 2013). The oxidation reaction is said to take place in the aqueous environment where the water is an integral part of the reaction. The water provides the medium for the dissolved oxygen to react with the organic compounds, which can also react in part with the organic compound. During wet oxidation, free radicals are formed with oxygen, which attack the organic compounds and results in the formation of organic radicals. A number of catalysts, such as homogeneous $Cu^{2+}$and $Fe^{3+}$with their heterogeneous counterparts, or precious metal catalysts are known to be effective in wet air oxidation reaction (Teletzke, 1966). A major characteristic of wet oxidation is the formation of carboxylic acids, in addition to carbon dioxide and water. The carboxylic acid yield is dependent on the design of the wet air oxidation system (Sadana, 1979).

Physical remediation processes

In modern wastewater treatment systems, physical remediation techniques are always used in combination with other treatment processes. Some physical remediation processes are screening, sedimentation, comminution, flow equalization and precipitation (Hamby, 2000).

Screening and Flow Equalization

Screening is the first operation in any wastewater treatment plant. During screening, large non-biodegradable and floating solids that frequently enter a wastewater treatment facility, such as rags, papers, plastics, tins, containers and wood are removed. The removal of these materials helps in protecting the treatment plant and equipment from any possible damage, unnecessary wear and tear, pipe blockages and the accumulation of unwanted material, which could interfere with the required wastewater treatment processes. Generally, screening is classified as coarse or fine. The coarse screens are typically used as primary protection devices and usually have openings of 10mm or larger. The fine screens are used for the removal of materials that may cause operational and maintenance problems in the treatment processes, particularly in systems that lack primary treatment. The fine screens have opening sizes of about 3 to 10 mm (GAH Global, 2013; Lenntech, 2013).

In wastewater treatment systems, flow equalization is the process of controlling hydraulic velocity or flow rate. In a short term, the process prevents high volumes of incoming flow (surges) from forcing solids and organic material out of the treatment process. It also controls the flow through each stage of the treatment system; thus allowing adequate time for the physical, biological and chemical processes to take place (Norweco, 2013). Typically, flow equalizations are used for the minimization of the variation of water and wastewater flow rates and composition. This is because the existence of wide variations in flow composition over time could degrade the process performance and efficiency of a treatment system (Goel, 2013).

Comminution and Sedimentation

A typical comminutor, which serves as both a cutter and a screen, is essentially aimed for the grinding and crushing of large solids of wastewater pollutants, such as organic matter. When in contatct with the comminutor, these large solids, such as rags and debris are shred into small particles. Communications do not remove the particles but only cuts them into smaller particles when the wastewater passes through (Herbert, 1998). Sedimentation or settling is the separation of suspended particles that are heavier than water. The process is based on the gravity force from the differences in density between particles and the fluid. During sedimentation, the settled solids are removed as sludge while the floating solids are removed as scum. The efficiency or performance of a sedimentation process is controlled by the detention time, temperature, tank design and condition of the equipment (Carlsson, 2001). In wastewater treatment, the most common form of sedimentation follows the coagulation and flocculation and precedes filtration. This type of sedimentation requires chemical addition in the coagulation or flocculation step thereby removing floc from the water. The sedimentation at this stage of a typical wastewater treatment system is said to remove up to 90% of the suspended particles from the water, including bacteria (Mountain Empire Community College, 2013).

Precipitation

Precipitation is the most common method for the removal of dissolved pollutants from wastewater. During precipitation, a reagent is added to the mixture in order to convert the dissolved metals into solid particle form. The presence of the reagent triggers a chemical reaction that causes the dissolved pollutants to form solid particles. The solid particles can then be removed by filtration. The efficiency of precipitation is dependent on the nature and concentration of pollutant to be removed and the kind of reagent used. In some case precipitation may involve chemical coagulation process. During chemical coagulation, there is the destabilization of wastewater particles so that they aggregate during chemical flocculation. The process destabilizes these particles by introducing positively charged coagulants that then reduce the negative particles' charge (Edwards, 1995; Thomasnet, 2013).

Microbial remediation processes

Microbial remediation entails the use of microorganism (bacteria, fungi, protozoa, rotifers and algae) for the breakdown of organic compounds and or pollutants (Wilson and Clarke, 1994). The process could be aspecific or a non-specific one. In a specific process, a microbe is used to target a single site of a molecule while in a non-specific process; a chain of microbial events is involved in the degradation process (Hamby, 2000; Jegatheesan, 2008; Davies, 2005).

All microbial remediation processes are dependent on environmental conditions, such as pH, molecular oxygen and nutrient conditions. As an example, the degradation of petroleum products requires the presence of oxygen while the degradation of halogenated compounds requires anaerobic conditions in order to remove the halogens. In addition, the bioremediation of a particular waste may require a series of different environmental conditions for a variety of microorganisms to cause a chute of reactions (Bellandi, 1988).

Bacteria

The primary microorganisms for biodegradation are the bacteria. They are known to have the ability to degrade a broad range of wastes. Based on oxygen requirement, the major groups of bacteria that are utilized in most treatment plants are the aerobes. These bacteria make use of the dissolved oxygen in the water. They use the free oxygen in the water to degrade the pollutants in the incoming wastewater into energy they can use for growth and reproduction. Although, oxygen in a conventional wastewater treatment system is usually added mechanically to the wastewater through the use of aerators in the aerated section of the treatment plant, with a normal influent load of pollutants, the dissolved oxygen content in the aerated section of most plants is reported to be 3- 5 mg/l (Cabridenc, 1985;Tong, 2013).

Many species of bacteria are reported to play a part in the removal of a number of pollutants, such as nitrate and phosphate, heavy metals and hydrocarbon pollutants from wastewater treatment systems. Some of these species *Escherichia coli, Acienetobacter, Aerobacter*, *Citrobacter*, *Proteus*, *Erwinia, Empedobacter*, *Achromobacter*, *Chromobacterium*, *Pseudomonas*, *Acinetobacter, Flavobacterium*, *Santhomonas, Streptococcus*, *Staphylococcus Micrococcus*, *Bacillus*, *Bacterium*, *Brevibacterium* and *Corynebacterium* (Cabridenc, 1985; Momba and Cloete, 1996; Akpor et al., 2013).

Fungi

Although little is known about fungal adaptations and processes in degrading anthropogenic substances, they possess the ability to remediate wastewater. They are said able to excrete enzymes that breakdown some exotic compounds, recalcitrant compounds and large organic molecules that are not readily degraded by most bacteria. They are also recognized for their superior aptitudes to produce a large variety of extracellular proteins, organic acids and other metabolites and for their capacities to adapt to severe environmental constraints (Coulibaly, 2003).

Essentially, it is reported that fungi remove metals by adsorption, chemisorptions (ion exchange), complexation, coordination, chelation, physical adsorption and micro precipitation. They are indicated to have advantages over bacteria in biological wastewater treatment by also producing valuable byproducts, such as amylase, chitin, chitosan, glucosamine, antimicrobials and lactic acids. Also, they fungi contain a group of extracellular enzymes that facilitate the biodegradation of recalcitrant compounds, such as phenolic compounds, dyes, and polyaromatic hydrocarbons (van-Leeuwen, 2013).

Aspergillu sniger, *Aspergillu sflavus*, *Aspergillu sversicolor, Aspergillu soryzae*, *Absidiafusca* and *Fusariumverticilliodes*, *Penicillium*or *Cephalosporium* and several other fungi species have been reported in the removal of eutrophication agents and bioremediation of metal contaminated waste streams. There is also a growing interest in the use of fungi for the removal of nitrogen, phosphorus and metals from commercial and municipal waste (Price et al., 2001; Vymazal, 2007; Akpor et al., 2013).

Protozoa and Rotifers

In wastewater systems, protozoa are associated with the ingestion of organic matter and other microbes. The ciliated protozoa are the major groups that are involved in wastewater treatment because of their ability to grow on water surfaces, feeding on decayed vegetation and microbes (Joanne et al., 2011). Protozoa play important ecological roles in the self-purification and matter cycling of natural ecosystems. It is generally accepted that their feeding on bacteria improve the treatment, thereby resulting in low organic load in treated wastes (Pauli et al., 2001). They are also reported to possess the ability to thrive in harsh environment, with temperature varying between 0°C and 50°C. It is however argued that their rates of population growth increase when food is not constrained and temperature is increased (Mountain Empire Community College, 2012). It is indicated that the excretions by protozoa contain many mineral nutrients, such as nitrogen and phosphorus, which help to recycle mineral nutrients in the activated sludge process. The presence of protozoa in the aeration tanks of an activated sludge system is said to be the hallmark of a well operated and efficient system. The main difficulty in their use in the treatment of wastewater is their segmentation since the majority of them are in contact with the sludge (Motta et al., 2001). A number of protozoa groups (ciliates and flagellates) have been implicated in the removal and mineralization of pollutants in wastewater treatment systems (Akpor *et al* 2008; Papadimitriou et al., 2010)

The rotifers are microscopic aquatic animals of the phylum Rotifera, which can be found in many freshwater environments and in moist soil. They inhabit the thin films of water that are formed around soil particles and are known to thrive mostly in still water environments, such as lake bottoms, as well as flowing water environments, such as rivers or streams (Orstan, 1999). In wastewater treatment systems, they are indicated to be beneficial in stabilizing organic wastes, stimulating microfloral activity, decomposition, enhancing oxygen penetration and recycling mineral nutrients. The presence of rotifers in activated sludge generally means a good, stable sludge with plenty of oxygen. Although little is known on their role in nutrient and heavy metal removal in wastewater treatment systems, it is reported that their principal role of rotifers in wastewater is the removal of bacteria and the development of floc. They are also said to contribute to the removal of effluent turbidity by removing non-flocculated bacteria (Mountain Empire Community College, 2013).

Algae

Microalgae have been reported to have application in the removal of nutrients, organic matter, xenobiotic compounds and metals in wastewater treatment systems. They are known to assimilate nitrogen in the form of nitrate, nitrite and ammonium and excess phosphorus from wastewater. The ability of microalgae to remove pollutants is dependent on the species that is used for remediation and the properties of the wastewater itself. The selection of an appropriate algal strain for wastewater treatment is therefore dependent on various factors like the characteristics of the wastewater, the original habitat of the strain and the climatic conditions in the treatment plant (Danilović *et al*., 2013; Oilgae, 2013). Microalgae are able to thrive in extreme growth conditions of pH and salt. They have the ability to remove heavy metals, produce oxygen with low energy input, fixcarbon dioxide and produces biomass. They are also reported to have greater feasibility than other organisms and are easy to handle. In addition, they low cost and easily cultured. A limiting factor in the use of microalgae is that a number of biotic factors, such as the presence of pathogenic bacteria or predatory zooplankton may have adverse impact on their. In addition, they can easily be out-competed by other microorganisms for essential nutrients. Another major practical limitation in algal treatment systems is harvesting or separation of algal biomass from the treated water discharge (Danilović *et al*., 2013; Oilgae, 2013).

Conclusion

One of the pollutants of receiving water bodies are untreated and inadequately treated wastewater effluents. When in contact with receiving water bodies, wastewater effluents possess the ability to deposit pollutants such as eutrophic nutrients, heavy metals, hydrocarbons, pathogenic microbes, endocrine disruptors and organic matter. The presence of these substances in water disrupts the eco-balance of aquatic life and pose as threat to human life. Some of these problems include eutrophication, metal poisoning, irritations and several water-related infections. To safeguards ecosystems and public health, there is the need to treat wastewater effluents before discharge. The remediation of wastewater can be achieved by various treatment processes, such as phytoremediation, chemical remediation, physical processes and microbial remediation processes. Although, these treatment processes play vital role in wastewater remediation, they have their flaws which make most wastewater treatment plant make use of a combination of these processes in their remediation processes.

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