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Wastewater Quality- It's Impact on the Environment and Human Physiology: A Review

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ABSTRACT

Wastewater is a major contributor to a variety of water pollution problems. They are generated continuously without adequate treatment. Poor wastewater treatment facilities result in inadequate treatment of this wastewater that is discharged into receiving water sources, resulting in pollution. The poor quality of discharged wastewater is responsible for the degradation of the receiving water body. Microorganisms associated with wastewater play many beneficial roles in the systems, a great number of them are considered to be critical factors in contributing to numerous waterborne diseases. Also, wastewater has been shown to contain a variety of anthropogenic compounds, many of which have endocrine-disrupting properties. Wastewater should be treated efficiently before discharge to avert pathophysiological risk to the user of these water resources and the aquatic ecosystem. The release of raw and improperly treated wastewater onto watercourses has both short-and long-term effects on the environment and physiology of the people. The only way to reduce the impact of wastewater on the environment, human physiology, and public health is proper enforcement of water and environmental laws to protect both rural and urban communities and also the adequate treatment of wastewater before discharge. To achieve unpolluted wastewater discharge into receiving water bodies, careful planning, adequate treatment, regular monitoring, and appropriate legislation are necessary.

Keywords: *Human Physiology; Wastewater quality; anthropogenic compounds.*

1.0 Introduction

The world is confronted with issues identified with the administration of wastewater. This is because of high industrialization, expansion in populace thickness, and high urbanized social orders (McCasland et al., 2008). The effluents created from homegrown and modern exercises comprise the significant wellsprings of the regular water contamination load. This is an incredible weight as far as wastewater the board and can thus prompt a point source contamination issue, which builds treatment cost extensively, yet additionally presents a wide scope of synthetic poisons and microbial foreign substances to water sources (Amir et al., 2004). The counteraction of contamination of water sources and assurance of general wellbeing by defending water supplies against the spread of sicknesses are the two crucial purposes behind treating wastewater. This is refined by eliminating substances that have a popularity for oxygen from the framework through the metabolic responses of microorganisms, the partition and settling of solids to make a satisfactory nature of wastewater effluents, and the assortment and reusing of microorganisms back into the framework, or expulsion of overabundance microorganisms from the framework (Abraham et al., 1997). In civil wastewater treatment frameworks, the normal water quality factors of concern are organic oxygen interest (BOD), substance oxygen interest (COD), disintegrated oxygen (DO), suspended solids, nitrate, nitrite and alkali nitrogen, phosphate, saltiness, and a scope of different supplements and follow metals (Brooks, 1996). The presence of high convergences of these contaminations over the basic qualities specified by public and worldwide administrative bodies is considered inadmissible in getting water bodies. This is because, aside from causing a significant disadvantage in wastewater treatment frameworks, they likewise lead to eutrophication and different

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physiological effects in people and creatures (EPA, 2000; CDC, 2002; Runion, 2008). As of late, the reuse of treated profluent that is typically released to the climate from city wastewater treatment plants is getting an expanding consideration as a solid water asset. In numerous nations, wastewater treatment for reuse is a significant element of water assets arranging and execution. This is pointed toward delivering excellent water supplies for consumable use. A few nations, for example, Jordan and Saudi Arabia have public arrangements to reuse all treated wastewater effluents, accordingly have gained extensive headway towards this end. In China, sewage use in horticulture has grown quickly quite a few years prior and a large number of hectares are inundated with sewage emanating. The overall acknowledgment is that wastewater use in farming is supported on agronomic and monetary grounds, although care should be taken to limit unfriendly wellbeing and ecological effects (Sowers, 2009). Besides, wastewater reuse is progressively becoming significant for enhancing drinking water needs in certain nations throughout the planet. The choice of reuse of wastewater is becoming vital and conceivable because of expanded environmental change, accordingly prompting dry spells and water shortage, and the way that wastewater profluent release guidelines have become stricter prompting a superior water quality (Rietveld et al., 2009). The target of this paper is to audit the characteristics of wastewater released into getting water bodies and their effects on the environment, human physiology, and general wellbeing.

2.0 Wastewater

Wastewater is defined as the polluted form of water generated from rainwater runoff and human activities that have been affected by domestic, industrial, and commercial use (Britannica, 2005). The composition of all wastewaters is thus constantly changing and highly variable, which is why it is so difficult to pinpoint a singular definition of the word itself. The composition of wastewater is 99.9% water and the remaining 0.1% is what is removed. This 0.1% contains organic matter, microorganisms, and inorganic compounds. The wastewater is released to a variety of environments, such as lakes, ponds, streams, rivers, estuaries, and oceans. Wastewater also includes storm runoff, as harmful substances wash off roads, parking lots, and rooftops.

2.1 Types of wastewaters

Wastewater is often used interchangeably with the term sewage, "sewage" technically denotes any wastewaters which pass through a sewer. Before entering a wastewater treatment plant, wastewater is sometimes called Raw wastewater or Raw sewage. It comprises all used water in homes and industries including stormwater and runoffs from lands, which must be treated before it is released into the environment to prevent any harm or risk it may have on the environment and human health.

- Domestic wastewater originates from activities such as restroom usage, bathing, food preparation, and laundry.
- Stormwater also spelled stormwater, is water that originates from rain, including snow and ice melt. Stormwater can soak into the soil (infiltrate), be stored on the land surface in ponds and puddles, evaporate, or contribute to surface runoff. Most runoff is conveyed directly to nearby streams, rivers, or other water bodies (surface water) without treatment.
- Industrial wastewater originates from industrial or commercial manufacturing processes, such as agriculture, and is usually more difficult to treat than domestic wastes. Industrial wastewater’s composition varies on an industry-by-industry basis.

2.2 Sources of wastewater

Sources of wastewater include; Domestic sewage carries used water from houses and apartments; it is also called sanitary sewage. Industrial sewage is used water from manufacturing or chemical processes and Storm sewage, or stormwater is runoff from precipitation that is collected in a system of pipes or open channels.

Domestic wastewater is slightly more than 99.9 percent water by weight. The rest, less than 0.1 percent, contains a wide variety of dissolved and suspended impurities. Although amounting to a very small fraction of the sewage by weight, the nature of these impurities and the large volumes of sewage in which they are carried make disposal of domestic wastewater a significant technical problem. The principal impurities are putrescible organic materials and plant nutrients, but domestic sewage is also very likely to contain disease-causing microbes. Industrial wastewater usually contains specific and readily identifiable chemical compounds, depending on the nature of the industrial process. Storm sewage carries organic materials, suspended and dissolved solids, and picks up debris, grit, nutrients, and various chemicals. as it travels over the ground.

2.3 Organic content of wastewater

The organic content of wastewater is made up of human faeces, protein, fat, vegetable, and sugar material from food preparation, as well as soaps. Some of this organic content is dissolved into the water and some exist as separate particles. The portion of organic material that does not dissolve but remains suspended in the water is known as suspended solids. Wastewater is treated to remove as much organic material as possible.

2.4 Characteristics of wastewater

The characteristics of wastewater vary from industry to industry and therefore would have different treatment processes. In general, the contaminants in wastewater are categorized into physicochemical and microbiological. Some indicators measured to ascertain these contaminants include (Peavy *et al*.,1985; Obuobie *et al*., 2006).

2.5 Physicochemical characteristics

The physicochemical characteristics of wastewater that are of special concern are pH, dissolved oxygen (DO), oxygen demand (chemical and biological), solids (suspended and dissolved), nitrogen (nitrite, nitrate, and ammonia), phosphate, and metals (Larsdotter, 2006).

The hydrogen-ion concentration is an important quality parameter of both natural and wastewaters. It is used to describe the acid or base properties of wastewater. A pH less than 7 in wastewater influent is an indication of septic conditions while values less than 5 and greater than 10 indicate the presence of industrial wastes and non-compatibility with biological operations. The pH concentration range for the existence of biological life is quite narrow (typically 6-9). An indication of extreme pH is known to damage biological processes in biological treatment units (Gray, 2002). Another parameter that has a significant effect on the characteristics of water is dissolved oxygen. It is required for the respiration of aerobic microorganisms as well as all other aerobic life forms. The actual quantity of oxygen that can be present in the solution is governed by the solubility, temperature, partial pressure of the atmosphere, and the concentration of impurities such as salinity and suspended solids in the water (EPA 1996; Metcalf and Eddy, 2003). Oxygen demand, which may be in the form of BOD or COD, is the amount of oxygen used by microorganisms as they feed upon the organic solids in wastewater (Gray, 2002; FAO, 2007).

The 5- day BOD (BOD5) is the most widely organic pollution parameter applied to wastewater. It involves the measurements of dissolved oxygen used by microorganisms in the biochemical oxidation of organic matter. The presence of sufficient oxygen promotes the aerobic biological decomposition of organic waste (Metcalf and Eddy, 2003). Although the BOD test is widely used, it has several limitations, which include the requirement of a high concentration of active acclimated microorganisms and the need for treatment when dealing with toxic wastes, thus reducing the effects of nitrifying organisms. The BOD measures only the biodegradable organics and requires a relatively long time to obtain test results (Gray, 2002; Metcalf and Eddy, 2003). Similarly, the COD test measures the oxygen equivalent of the organic material in wastewater that can be oxidized chemically.

The COD will always be higher than the BOD. This is because the COD measures substances that are both chemically and biologically oxidized. The ratio of COD: BOD provides a useful guide to the proportion of organic material present in wastewaters, although some polysaccharides, such as cellulose, can only be degraded anaerobically and so will not be included in the BOD estimation. One of the main advantages of the COD test is that it can be completed in about 2.5 h, compared to the 5-day BOD test (Gray, 2002; Metcalf and Eddy, 2003). The amount of solids in drinking water systems has significant effects on the total solids concentration in the raw sewage. Although wastewater is normally 99.9 % water, 0.1 % of it comprises solids. Discharges from industrial and domestic sources also add solids to the plant influent. Although there are different ways of classifying solids in wastewater, the most common types are total dissolved solids (TDS), total suspended solids (TSS), settleable, floatable, and colloid- dal solids, and organic and inorganic solids (EPA, 1996). Normally, wastewater processes using settling or flotation are designed to remove solids but cannot remove dissolved solids.

Biological treatment units such as trickling filters and activated sludge plants convert some of these dissolved solids into settleable solids that are removed by sedimentation tanks (Eckenfelder and Grau, 1992).

Heavy and trace metals are also of importance in water. The metals of importance in wastewater treatment are As, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Mo, Ni, K, Se, Na, V, and Zn. Living organisms require varying amounts of some of these metals (Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, and Zn) as nutrients (macro or micro) for proper growth. Other metals (Ag, Al, Cd, Au, Pb, and Hg) have no biological role and hence are non-essential (Metcalf and Eddy, 2003; Hussein *et al.,* 2005). Heavy metals are one of the most persistent pollutants in wastewater. Unlike organic pollutants, they cannot be degraded, but accumulate throughout the food chain, producing potential human health risks and ecological disturbances. Their presence in wastewater is due to discharges from residential dwellings, groundwater infiltration, and industrial discharges. The accumulation of these metals in wastewater depends on many local factors, such as the type of industries in the region, way of life, and awareness of the impact on the environment through the careless disposal of wastes (Hussein *et al.,* 2005; Silvia *et al.,* 2006).

The danger of heavy and trace metal pollutants in water lies in two aspects of their impact. Firstly, heavy metals can persist in natural ecosystems for an extended period, and, secondly, they can accumulate in successive levels of the biological food chain (Fuggle, 1983). Although heavy metals are naturally present in small quantities in all aquatic environments, it is almost exclusively through human activities that these levels are increased to toxic levels (Nelson and Campbell, 1991). The methods for determining the concentrations of these metals vary in complexity according to the interfering substances that may be present. Typical methods of determining their concentrations include flame atomic absorption, electrothermal atomic absorption, inductively coupled plasma, and inductively coupled plasma (ICP)/ mass spectrometry (APHA, 2001).

Surface waters contain levels of phosphorus in various compounds, which are essential constituents of living organisms. In natural conditions, the phosphorus concentration in waters is balanced. However, when phosphorus input to waters is higher than that which a population of living organisms can assimilate, the problem of excess phosphorus content occurs (Rybicki, 1997). An excess content of phosphorus in receiving waters usually leads to extensive algal growth (eutrophication). Controlling phosphorus discharge from municipal and industrial wastewater treatment plants is a key factor in preventing the eutrophication of surface waters (Department of Natural Science, 2006). The following groups of phosphorus compounds are of great importance in wastewater: organic phosphates, condensed phosphates, and inorganic phosphates. Although phosphate itself does not have notable adverse pathophysiological effects, phosphate levels greater than 1.0 mg/L may interfere with coagulation in water treatment plants (Ganczarczyk, 1983; McCasland *et al.,* 2008). On the other hand, nitrogen is important in wastewater management. It can have adverse effects on the environment since its discharge above the required limit of 10 mg/l can be undesirable due to its ecological and health impacts (Kurosu, 2001; Amir *et al.,* 2004). Nitrogen is required by all organisms for the basic processes of life to make proteins, grow and reproduce. It is recycled continually by plants and animals. Most organisms cannot use nitrogen in the gaseous form (N_2) for their nutrition, so they are dependent on other organisms to convert it into other forms (Jenkins *et al.*, 2003).

The principal forms of nitrogen are organic nitrogen, ammonia, nitrate, and nitrite. Ammonia, nitrate, and nitrite make up the inorganic forms (Hurse and Connor, 1999). Organic and inorganic forms of nitrogen may cause eutrophication problems in nitrogen-limited freshwater lakes and estuarine and coastal waters. In the environment, ammonia is oxidized to nitrate, creating an oxygen demand and low dissolved oxygen in surface waters (Kurosu, 2001; Sabalowsky, 1999). Although nitrate levels that affect infants do not pose a direct threat to older children and adults, they indicate the presence of other serious residential or agricultural contaminants, such as bacteria and pesticides (McCasland *et al.,* 2008). Methemoglobinemia is the most significant health problem associated with nitrate in water. Usually, blood contains an iron-based compound (hemoglobin) that carries oxygen, but when nitrate is present, hemoglobin can be converted to methemoglobin, which cannot carry oxygen.

Similarly, nitrogen in the form of ammonia is toxic to fish and exerts an oxygen demand on receiving water by nitrifiers (CDC, 2002).

2.6 Microbiological characteristics

The major microorganisms found in wastewater influents are viruses, bacteria, fungi, protozoa, and helminths. Although various microorganisms in the water are considered to be critical factors in contributing to numerous water-borne outbreaks, they play many beneficial roles in wastewater influents (Kris, 2007). Traditionally, microorganisms are used in the secondary treatment of wastewater to remove dissolved organic matter.

The microbes are used in fixed-film systems, suspended film systems, or lagoon systems, depending on the preference of the treatment plant. Their presence during the different treatment phases can enhance the degradation of solids, resulting in less sludge production (Ward-Paige *et al.,* 2005a).

Apart from solid reduction, wastewater microbes are also involved in nutrient recycling, such as phosphate, nitrogen, and heavy metals. If nutrients that are trapped in dead materials are not broken down by microbes, they will never become available to help sustain the life of other organisms. Microorganisms are also responsible for the detoxification of acid mine drainage and other toxins in wastewater (Ward-Paige et al., 2005b).

Microbial pollutants can also serve as indicators of water quality. The detection, isolation, and identification of the different types of microbial pollutants in wastewater are always difficult, expensive, and time-consuming. To avoid this, indicator organisms are always used to determine the relative risk of the possible presence of a particular pathogen in wastewater (Paillard *et al.*, 2005). For instance, enteric bacteria, such as coliforms, Escherichia coli, and faecal streptococci are used as indicators of faecal contamination in water sources (DWAF 1996; Momba and Mfenyana, 2005).

To indicate viral contamination, bacteriophages (somatic and F-RNA coliphages) are used. Also, Clostridium perfringens, a faecal spore-forming bacterium, which is known to live longer in the environment and reported to be resistant to chlorine, is used as an indicator for the presence of viruses, protozoa, or even helminths eggs (Payment and Franco, 1993; Grabow *et al.*, 1997). Furthermore, diatoms are used to indicate the general quality of water for nutrient enrichment, and they provide valuable interpretations for changes in water quality, such as turbidity, conductivity, COD, BOD, and chloride (Dela *et al.*, 2002).

2.7 Wastewater treatment

Wastewater treatment is the process and technology that is used to remove most of the contaminants that are found in wastewater to ensure a sound environment and good public health. Wastewater Management, therefore, means handling wastewater to protect the environment to ensure public health, economic, social, and political soundness (Metcalf and Eddy, 1991).

3.0 Objectives of Wastewater Treatment

Wastewater treatment is very necessary and it is more vital for the following:

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

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

Elimination of pathogens: Organisms that cause disease in plants, animals, and humans are called pathogens. They are also known as micro-organisms because they are very small to be seen with the naked eye. Examples of micro-organisms include bacteria (e.g. *Vibro cholerae*), viruses (e.g. *enterovirus*, *hepatitis A & E virus*), fungi (e.g. *Candida albicans*), protozoa (e.g E*ntamoeba hystolitica, Giardia lamblia*), and helminths (e.g. *Schistosoma mansoni, Ascaris lumbricoides*). These micro-organisms are excreted in large quantities in faeces of infected animals and humans (Awuah and Amankwaa-Kuffuor, 2002).

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

4.0 Process of Wastewater Treatment

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

4.1 Physicochemical unit operations

- Screening
- Comminution
- Flow equalization
- Sedimentation
- Flotation
- Granular-medium filtration
- Chemical precipitation
- Adsorption
- Disinfection
- Dechlorination
- Other chemical applications

4.2 Biological unit operations

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

4.3 Levels of Wastewater Treatment

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

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

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

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

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

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

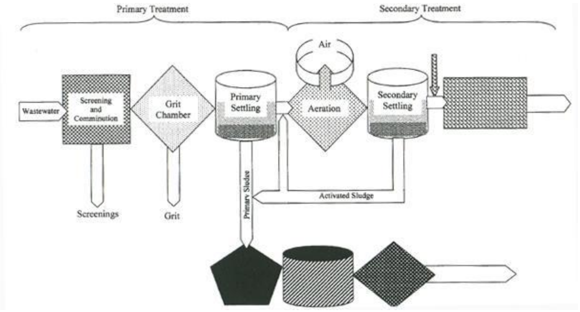
4.4 Methods of wastewater treatment

There are conventional and non-conventional wastewater treatment methods that have been proven and found to be efficient in the treatment of wastewater. Conventional methods compared to non-conventional wastewater treatment methods has a relatively high level of automation. Usually, have pumping and power requirements. They require skilled labour for the operation and maintenance of the system.

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

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

Figure 1: Typical Wastewater Treatment Plant



Source: NPTEL(accessed 2010)

4.5 Discharge of wastewater

The discharge of wastewater is the process of disposing of or reintroducing wastewater into the environment. The commonest methods of discharge are surface dispersal (such as irrigation), subsurface discharge, and dilution (disposal of wastewater into surface waters e.g. seas, lakes, estuaries, and rivers). When untreated wastewater is discharged into the environment, it poses environmental, aesthetic, and physiological problems. To safeguard public health and sustain the environment, there are several regulations and effluent discharge guidelines that stipulate the minimum treatment levels and maximum limits of pollutants in wastewater before it is discharged into receiving water bodies (Jegatheesan *et al.,* 2008).

Discharged wastewater is a major source of irrigation water in dry and semi-dry countries. During the 19th century, the release of wastewater into surface water bodies has led to the indirect use of wastewater and sewage into potable water supplies. For recreational purposes, sewage wastewater with high quality is needed through the use of improved treatment steps, such as disinfection and ultrafiltration processes. Some of the important factors that encourage recycling and reuse of wastewaters are the prevention of diversion of water from alternative uses, management of entering water resources, and reduction in structural costs (Abdel *et al.,* 1999). Another factor that encourages reuse is preventing the release of untreated wastewater to the environment. It also helps in giving nutrients to assist the growth of plants for irrigation which is harmful to the ecosystem (Mori, 1993).

4.6 Impacts of wastewater quality

The quality of wastewater is responsible for the degradation of the receiving water bodies, such as lakes, rivers, streams, etc. The potentially deleterious effects of polluted wastewater effluents on the quality of receiving water bodies are manifold and depend on the volume of the discharge, the chemical and microbiological concentration/ composition of the effluents. It also depends on the type of the discharge for example whether it is the number of suspended solids or organic matter or hazardous pollutants like heavy metals and organochlorines, and the characteristics of the receiving waters (Owili, 2003). Eutrophication of water sources may also create environmental conditions that favour the growth of toxin-producing cyanobacteria. Chronic exposure to such toxins produced by these organisms can cause gastroenteritis, liver damage, nervous system impairment, skin irritation, and liver cancer in animals (EPA, 2000; Eynard *et al.,* 2000; WHO, 2006). In extension, recreational water users and anyone else coming into contact with the infected water are at risk (Resource Quality Services, 2004). The potentially deleterious effects of pollutants from sewage effluents on the receiving water quality of the coastal environment are manifold and depend on the volume of the discharge, the chemical composition, and concentrations in the effluent (Owili, 2003).

4.7 Implications for microorganisms

Naturally occurring soil and water bacteria eat the organic waste in wastewater and use it as a food and energy source to grow rapidly. In a natural water environment where there is plenty of oxygen dissolved in the water, aerobic bacteria eat the organic material and form a slime of new bacterial cells and dissolved salt waste products. If undiluted wastewater is left on its own, anaerobic bacteria decompose the waste organic material and release odorous gases such as hydrogen sulphide. Odour-free gases such as methane and carbon dioxide can also be released. Where there is an overwhelming amount of wastewater, all the oxygen will be used up and the anaerobic bacteria will take over, making the water go septic. This is ultimately harmful to fish and other forms of life dependent on oxygen, on occasion creating dead zones.

4.8 Environmental impacts

The impacts of such degradation may result in decreased levels of dissolved oxygen, physical changes to receiving waters, the release of toxic substances, bioaccumulation or biomagnification in aquatic life, and increased nutrient loads (Environmental Canada, 1997). Wastewater is a complex resource, with both advantages and inconveniences for its use. Wastewater and its nutrient contents can be used for crop production, thus providing significant benefits to the farming communities and society in general. However, wastewater use can also impose negative impacts on communities and ecosystems. The widespread use of wastewater containing toxic wastes and the lack of adequate finances for treatment is likely to cause an increase in the incidence of wastewater-borne diseases as well as more rapid degradation of the environment. Although the harmful effects of using contaminated wastewater effluents could be delayed for several years using intensive and heavy irrigations, it adversely affects groundwater quality when nutrients leach down the soil (Mahmood and Maqbool, 2006). Eutrophication due to excessive amounts of nutrients contributes to the depletion of dissolved oxygen. It is important to note that other constituents of wastewater effluents also play an important role in the depletion of DO. The bacterial breakdown of organic solids present in wastewater and the oxidation of chemicals in it can consume much of the dissolved oxygen in the receiving water bodies (Borchardt and Statzner, 1990). These effects may be immediate and short-term or may extend over months or years as a result of the build-up of oxygen-consuming material in the bottom sediments (Environmental Canada, 1999).

The impacts of low dissolved oxygen levels include an effect on the survival of fish by increasing their susceptibility to diseases, retardation in growth, hampered swimming ability, alteration in feeding and migration, and, when extreme, lead to rapid death. Long-term reductions in dissolved oxygen concentrations can result in changes in species composition (Welch, 1992; Chambers and Mills, 1996; Environmental Canada, 1997). Poorly treated wastewater effluent can also lead to physical changes to receiving water bodies. All aquatic life forms have characteristic temperature preferences and tolerance limits. Any increase in the average temperature of a water body can have ecological impacts. Because municipal wastewater effluents are warmer than receiving water bodies, they are a source of thermal enhancement (Welch, 1992; Horner *et al.*, 1994). Also, the release of suspended solids into receiving waters can have several direct and indirect environmental effects, including reduced sunlight penetration (reduced photosynthesis), physical harm to fish, and toxic effects from contaminants attached to suspended particles (Horner *et al.*, 1994).

Another environmental impact of untreated wastewater, which at times can be linked to health, is the phenomenon of bioaccumulation and biomagnifications of contaminants. Due to the phenomenon of bioaccumulation, certain substances which are in low concentrations or barely measurable in water can sometimes be found in high concentrations in the tissues of plants and animals. These substances tend to be stable, live long chemically, and are not easily broken down by digestive processes (Environmental Canada, 1997; 1999). In some cases, through the process of biomagnification, the concentrations of some of the contaminants may be increased dramatically through a passage in the food chain that is prey to predators

(Chambers and Mills, 1996). Because of the processes of bioaccumulation and biomagnification, very low concentrations of certain substances in wastewater are of concern. Examples of such substances include organochlorine pesticides, mercury, and heavy metals. Although there are several other sources of persistent bioaccumulative (such as toxic substances in the environment), including industrial discharges and deposition of atmospheric contaminants, municipal wastewater remains one of the most significant (Environmental Canada, 1997). Also, the release of toxic substances from wastewater into receiving water bodies has direct toxic impacts on terrestrial plants and animals.

The toxic impacts may be acute or cumulative. Acute impacts from wastewater effluents are generally due to high levels of ammonia and chlorine, high loads of oxygen demanding materials, or toxic concentrations of heavy metals and organic contaminants. Cumulative impacts are due to the gradual buildup of pollutants in receiving water, which only becomes apparent when a certain threshold is exceeded (Welch, 1992; Chambers *et al.*, 1997).

In addition, eutrophication of water sources can lead to nutrient enrichment effects. Nutrient induced production of aquatic plants in receiving water bodies has the following detrimental consequences:

- Algal clumps, odours, and decolouration of the water, thus interfering with recreational and aesthetic water use.
- Extensive growth of rooted aquatic life interferes with navigation, aeration, and channel capacity.
- Dead macrophytes and phytoplankton settle to the bottom of a water body, stimulating microbial breakdown processes that require oxygen, thus causing oxygen depletion.
- Extreme oxygen depletion can lead to the death of desirable aquatic life.
- Siliceous diatoms and filamentous algae may clog water treatment plant filters and result in reduced backwashing.
- Algal blooms may shade and submerged aquatic vegetation, thus reducing or eliminating photosynthesis and productivity (McCasland *et al.*, 2008).

Although nitrogen and phosphorus are beneficial to aquatic life in small amounts when in excess they contribute to eutrophication. Eutrophication leads to algal blooms and plant growth in streams, ponds, lakes, reservoirs, and estuaries, and along shorelines (Eynard *et al.*, 2000). In lakes, rivers, streams, and coastal waters where large algal blooms are present, the death of the vast numbers of phytoplankton that make up the blooms may smother the lake bottom with organic material.

The decay of this material can consume most or all of the dissolved oxygen in the surrounding water, thus threatening the survival of many species of fish and other aquatic life (Environmental Canada, 2003; Eynard *et al.*, 2000). The net effect of eutrophication on an ecosystem is usually an increase of a few plant types and a decline in the number and variety of other plant and animal species in the system (Environmental Canada, 2003). In most surface waters, total ammonia concentrations greater than 2 mg/L are toxic to aquatic life, although this varies between species and life stages. Studies that have been carried out on the toxicity of ammonia to freshwater vegetation have shown that concentrations greater than 2.4 mg/L inhibit photosynthesis (Chambers *et al.*, 1997; WHO, 1997). Nitrate is believed to cause a reduction in amphibian populations. Adverse effects are reported to be poor larval growth, reduced body size, and impaired swimming ability (Environmental Canada, 1999).

4.9 Physiological and public health impacts

Diseases caused by bacteria, viruses, and protozoa are the most common health hazards associated with untreated drinking and recreational waters. The main sources of these microbial contaminants in wastewater are human and animal wastes (Environmental Canada; 2003 EPA, 2000; WHO, 2006). These contain a wide variety of viruses, bacteria, and protozoa that may get washed into drinking water supplies or receiving water bodies (Kris, 2007). Microbial pathogens are considered to be critical factors contributing to numerous waterborne outbreaks. Many microbial pathogens in wastewater can cause chronic diseases with costly long-term physiological effects, such as degenerative cardiovascular (heart) disease and gastrointestinal tract (GIT) such as stomach ulcers. The density and diversity of these pollutants can vary depending on the intensity and prevalence of infection.

The detection, isolation, and identification of the different types of microbial pollutants in wastewater are always difficult, expensive, and time-consuming. To avoid this, indicator organisms are always used to determine the relative risk of the possible presence of a particular pathogen in wastewater (Paillard *et al.,* 2005). Viruses are among the most important and potentially most hazardous pollutants in wastewater. They are generally more resistant to treatment, more infectious, more difficult to detect, and require smaller doses to cause infections (Toze, 1997; Okoh, *et al.,* 2007). Because of the difficulty in detecting viruses, due to their low numbers, bacterial viruses (bacteriophages) have been examined for use in fecal pollution and the effectiveness of treatment processes to remove enteric viruses (Okoh, *et al.,* 2007). Bacteria are the most common microbial pollutants in wastewater. They cause a wide range of infections, such as diarrhea, dysentery, skin and tissue infections, etc. Disease-causing bacteria found in water include different types of bacteria, such as *E. coli O157:H7; Listeria, Salmonella, Leptospirosis, Vibrio, Campylobacter,* etc (CDC, 1997; Absar, 2005). Wastewater consists of vast quantities of bacteria, most of which are harmless to man. However, pathogenic forms that cause pathology (disease) of the human body, such as typhoid, dysentery, and other pathophysiological condition such as gastrointestinal disorders may be present in wastewater. The tests for total coliform and faecal coliform non-pathogenic bacteria are used to indicate the presence of pathogenic bacteria (EPA, 1996; APHA, 2001).

Because it is easier to test for coliforms, faecal coliform testing has been accepted as the best indicator of faecal contamination. Faecal coliform counts of 100 million per 100 milliliters may be found in raw domestic sewage. Detectable health effects have been found at levels of 2300 to 2400 total coliforms per 100 milliliters in recreational waters. Disinfection, usual chlorination, is generally used to reduce these pathogens (EPA, 1996; Absar, 2005).

Waterborne gastroenteritis of unknown cause is frequently reported, with the susceptible agent being bacterial. Some potential sources of this disease are *E. coli* and certain strains of Pseudomonas, which may affect the newborn and have also been implicated in gastrointestinal disease outbreaks (Metcalf and Eddy, 2003). Also, highly adaptable, protozoa, are widely distributed in natural waters, although only a few aquatic protozoa are pathogenic. Protozoa infections are usually characterized by gastrointestinal disorders of a milder order than those from bacterial infections (Ingraham and Ingraham, 1995). Of the disease-causing organisms, the protozoans Cryptosporidium parvum, Cyclospora, and Giardia lamblia are of great concern because of their significant impact on individuals with compromised immune systems, including young children and the elderly.

Table 1: Pathophysiology (Acute and Chronic) and Health Effects Associated with Microbial Pathogens in Water

Pathogen	Agent	Acute effect	Chronic or ultimate effect
Bacteria	E. coli O157:H7 Legionella Pneumonia Helicobacter pylori Vibrio cholera Campylobacter Yersinia Salmonella Cyanobacteria Leptospirosis	Diarrhea Pneumonia Gastritis Diarrhea Diarrhea Diarrhea Diarrhea Diarrhea Fever, Chills	Adults: death (thrombocytopenia) Children: death (kidney failure). Elderly, death Ulcers and stomach cancer Death Death: Guillain-Barre syndrome Reactive fever Reactive fever Potential fever Well's Disease
Parasite	Giardia lamblia Cryptosporidium Acanthamoeba	Diarrhea Diarrhea Eye infections	Lactose intolerance, Failure to thrive, severe hypothyroidism Death in an immunocompromised host.
Viruses	Hepatitis viruses Adenoviruses Encho viruses	Liver infection Eye infections Meningitis	Liver failure

Numerous Crptospridium and Giardia oocysts are present in raw sewage, although not all are viable in terms of their ability to cause disease (Ingraham and Ingraham, 1995; Metcalf and Eddy, 2003). Cryptosporidium parvum and Giardia lamblia oocysts are the most resistant oocysts form in wastewater. They are of particular concern because they are found in almost all wastewaters and because conventional disinfection techniques using chlorine have not proved to be effective in their inactivation or destruction. In recent years, however, UV disinfection has been known to be effective in the inactivation of C. parvum and Giardia lamblia cysts (Metcalf and Eddy, 2003; Absar, 2005).

In addition, some human infections are associated with nematodes and flatworms, while the segmented worms are primarily ectoparasites, such as leaches (Metcalf and Eddy, 2003). Most of the helminths fall into three phyla: Nematoda (roundworms), Platyhelminthes (flatworms), and Annelida (segmented worms). The life cycles of helminths often involve two or more animal hosts, one of which can be human or animal waste that contains helminths. Contamination may also be via aquatic species of other hosts, such as snails or insects. Aquatic systems can be the vehicle for transmitting helminth pathogens, however modern water treatment methods (chlorination, chemical precipitation, sedimentation, sand filtration) are very effective in destroying these organisms (EPA, 1996; Absar, 2005).

Humans excrete more than 100 different types of enteric viruses capable of producing infection or disease. These enteric viruses multiply in the gastrointestinal tract (GIT) and are released in the faecal matter of infected persons. From the standpoint of health, the most important human enteric viruses are the enteroviruses, Norwalk viruses, rotaviruses, reoviruses, caliciviruses, adenoviruses, and hepatitis A virus (Rose and Gerba, 1991; Absar, 2005). Sedimentation, filtration, and disinfection, if used efficiently, usually provide acceptable virus removal (EPA, 1996). As previously stated, nutrients, especially nitrogen and phosphorus, stimulate the growth of toxic species of phytoplankton in both fresh and marine waters. Consumption of toxic algae or organisms that feed on them can cause serious harm to humans and other terrestrial animals. The resulting toxins can cause a lot of physiological disorders such as gastroenteritis, liver damage, nervous system impairment, and skin irritation. Health problems associated with cyanotoxins have been documented in several countries, including Australia, Brazil, Canada, China, the United Kingdom, the United States of America and Zimbabwe (Department of Natural Science, 2006; WHO, 2006). In some cases, liver cancer in humans is thought to be associated with exposure to cyanobacterial toxins through the drinking water line and exposure to these toxins has usually been through contaminated drinking water or recreational water contact (Chorus and Bartram, 1999; WHO, 2006; Runion, 2008).

The toxins produced by microscopic algae can reach undesirable concentrations during eutrophication. These toxins are concentrated further in the food chain when shellfish and other aquatic life consume the algae. Paralytic shellfish poisoning, diarrheal shellfish poisoning, and amnesic shellfish poisoning are examples of infections caused by toxic algae (Chrous and Bartram, 1999; EPA, 2000; WHO, 2006). In addition to the health risks associated with untreated wastewater, communities and individuals may have to deal with taste and odour problems caused by large accumulations of algae. Although additional filtration may provide a remedy, this is not without additional cost (Health Canada, 1997; 1998; WHO, 2006).

Even though nitrate itself is not harmful, about a quarter of ingested nitrate is converted to nitrite by microorganisms in the saliva. Once in the bloodstream, nitrites impair the blood's ability to carry oxygen by converting hemoglobin into methemoglobin. Ingestion of large amounts of nitrate or nitrite can result in methemoglobinemia in infants and susceptible individuals (WHO, 1997; Wigle 1998). Nitrates and nitrites are also of concern because nitrites react with amino acids in the stomach to form nitrosamines, which are powerful carcinogens in animals and humans (Runion, 2008). Another potential health risk associated with wastewater effluents results from the use of chlorine as a disinfectant in treatment. Although chlorination is effective in the elimination of typhoid fever, cholera, and other waterborne diseases, the potent oxidizing power of chlorine can react with naturally occurring organic material in raw wastewater effluent to produce hundreds of chlorinated compounds, such as trihalomethanes, chloroform, bromodichloromethane, etc. (Wigle, 1998).

Wastewater effluents have been shown to contain a variety of anthropogenic compounds, many of which have physiological malfunction such as endocrine-disrupting properties. Reports have shown that exposure to wastewater treatment effluents containing estrogenic chemicals can disrupt the endocrine functioning of aquatic life, this can cause permanent alterations in the structure and function of the reproductive system (Liney *et al*, 2006).

Evidence obtained from laboratory studies has revealed the potential of several environmental chemicals to cause endocrine disruption at environmentally realistic exposure levels. In an aquatic environment, such effects have reportedly been observed in mammals, birds, reptiles, fish, and mollusks from Europe, North America, and other areas. The observed abnormalities in these groups of animals vary from subtle changes to permanent alterations, including disturbed sex differentiation with feminized or masculinized sex organs, changed sexual behaviour, and altered immune function (Vos *et al.,* 2000). While multiple laboratory studies have shown the effects of such compounds on an individual basis at elevated concentrations, little research has attempted to characterize the effects of exposure to environmentally relevant mixtures of endocrine disruptors (Vos *et al.,* 2000; Sower, 2009).

Individuals can be exposed to chemicals in wastewater in various ways. They may ingest small amounts of pollutants in their drinking water or absorb contaminants through their skin while bathing or swimming, or through inhalation of airborne droplets while showering. They may also ingest food, such as fish that has been contaminated by water-borne pollutants (EPA 2000; Vos *et al.,* 2000). Although ammonia is not a hazard to human health at levels that ordinarily occur in the environment, exposure to it, especially in aquatic environments, can have several human physiological and health impacts. The most dangerous consequence of exposure to ammonia is respiratory physiology such as pulmonary edema, followed by severe irritation to moist tissue surfaces (WHO, 1997; Health Canada, 1998; WHO, 2006).

5.0 Conclusion

Wastewater should be treated to ensure a safe environment and foster robust physiological and public health. The presence of high concentrations of physicochemical parameters in wastewater above permissible limits stipulated by regulatory bodies indicates that they are not properly treated. There are conventional and non-conventional methods of wastewater treatment and the choice of a particular method should be based on factors such as characteristics of wastewater whether it from a municipality or industry (chemical, textile, pharmaceutical, etc.), technical expertise for operation and maintenance, cost implications, power requirements among others. Monitoring of these treatment facilities and enforcement of laws to ensure proper treatment of wastewater before discharge into receiving water bodies will reduce the environmental, physiological, and public health implications associated with wastewater.

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