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Review

Environmental and public health implications of wastewater quality

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The reuse of treated effluent (for agriculture and as supplement for drinking water needs) is currently receiving attention as a reliable water source. This paper is aimed at reviewing the environmental and health impacts of untreated or inadequately treated wastewater effluents. The quality of wastewater effluents is responsible for the degradation of the receiving water bodies. This is because untreated or inadequately treated wastewater effluent may lead to eutrophication in receiving water bodies and also create environmental conditions that favour proliferation of waterborne pathogens of toxin-producing cyanobacteria. In extension, recreational water users and anyone else coming into contact with the infected water is at risk. Although various microorganisms play many beneficial roles in wastewater systems, a great number of them are considered to be critical factors in contributing to numerous waterborne outbreaks. Also, wastewater effluents have been shown to contain a variety of anthropogenic compounds, many of which have endocrine-disrupting properties. Since large amounts of wastewater effluents are passed through sewage treatment systems on a daily basis, there is a need to remedy and diminish the overall impacts of these effluents in receiving water bodies. In order to comply with wastewater legislations and guidelines, there is a need for adequate treatment before discharge. This can be achieved through the application of appropriate treatment processes, which will help to minimize the risks to public health and the environment. To achieve unpolluted wastewater discharge into receiving water bodies, careful planning, adequate and suitable treatment, regular monitoring and appropriate legislations are necessary.

Key words: Wastewater, discharge, treatment, health, environment, impacts, effluents

INTRODUCTION

The world is faced with problems related to the management of wastewater. This is due to extensive industrialization, increasing population density and high urbanized societies (EPA, 1993; McCasland et al., 2008). The effluents generated from domestic and industrial activities constitute the major sources of the natural water pollution load. This is a great burden in terms of wastewater management and can consequently lead to a point-source pollution problem, which not only increases treatment cost considerably, but also introduces a wide range of chemical pollutants and microbial contaminants to water sources (EPA, 1993, 1996; Eikelboom and Draaijer, 1999; Amir et al., 2004).

The prevention of pollution of water sources and protection of public health by safeguarding water supplies against the spread of diseases, are the two fundamental reasons for treating wastewater. This is accomplished by removing substances that have a high demand for oxygen from the system through the metabolic reactions of micro organisms, the separation and settling of solids to create an acceptable quality of wastewater effluents, and the collection and recycling of microorganisms back into the system, or removal of excess microorganisms from the system (Abraham et al., 1997). In municipal wastewater treatment systems, the common water quality

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Abbreviations: BOD, Biological oxygen demand; **COD,** chemical oxygen demand; **DO,** dissolved oxygen; **TDS,** total dissolved solids; **TSS,** total suspended solids; **ICP,** inductively coupled plasma.

variables of concern are biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), suspended solids, nitrate, nitrite and ammonia nitrogen, phosphate, salinity and a range of other nutrients and trace metals (DeCico, 1979; Brooks, 1996). The presence of high concentrations of these pollutants above the critical values stipulated by national and international regulatory bodies is considered unacceptable in receiving water bodies. This is because, apart from causing a major drawback in wastewater treatment systems, they also lead to eutrophication and various health impacts in humans and animals (EPA, 2000; CDC, 2002; Runion, 2008). In recent years, the reuse of treated effluent that is normally discharged to the environment from municipal wastewater treatment plants is receiving an increasing attention as a reliable water resource. In many countries, wastewater treatment for reuse is an important dimension of water resources planning and implementation. This is aimed at releasing high quality water supplies for potable use. Some countries, such as Jordan and Saudi Arabia have national policies to reuse all treated wastewater effluents, thus have made considerable progress towards this end. In China, sewage use in agriculture has developed rapidly several decades ago and millions of hectares are irrigated with sewage effluent. The general acceptance is that wastewater use in agriculture is justified on agronomic and economic grounds, although care must be taken to minimize adverse health and environmental impacts (FAO, 1992; Metcalf and Eddy, 2003; Rietveld et al., 2009; Sowers, 2009). Furthermore, wastewater reuse is increasingly becoming important for supplementing drinking water needs in some countries around the world. The option of reuse of wastewater is becoming necessary and possible as a result of increased climate change, thus leading to droughts and water scarcity, and the fact that wastewater effluent discharge regulations have become stricter leading to a better water quality (Rietveld et al., 2009). The objective of this paper is to discuss the characteristics of wastewater effluents and the impacts of wastewater quality on health and the environment.

CHARACTERISTICS OF WASTEWATER EFFLUENTS

Physico-chemical characteristics

The physic-chemical 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 (DeCicco, 1979; Larsdotter, 2006).

The hydrogen-ion concentration is an important quality parameter of both natural and waste waters. 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 (EPA, 1996; Gray, 2002). Another parameter that has 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 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 (Water Environmental Federation, 1996; Gray, 2002; FAO, 2007). The 5-day BOD (BOD_5) is the most widely organic pollution parameter applied to wastewater. It involves the measurement of dissolved oxygen used by microorganisms in the biochemical oxidation of organic matter. The presence of sufficient oxygen promotes the aerobic biological decomposition of an organic waste (Metcalf and Eddy, 2003). Although BOD test is widely used, it has a number of 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 (Eckenfelder and Grau, 1992; 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 of 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 colloiddal 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 have the ability to persist in natural ecosystems for an extended period, and, secondly, they have the ability to 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 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 health 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 (Maynard et al., 1999; 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 in 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). Despite the fact that 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 nitrite 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).

Microbiological characteristics

The major microorganisms found in wastewater influents are viruses, bacteria, fungi, protozoa and helminthes. Although various microorganisms in water are considered to be critical factors in contributing to numerous waterborne 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 helminthes eggs (Payment and Franco, 1993; Grabow et al., 1997). Furthermore, diatoms are used to indicate the general quality of water with respect to nutrient enrichment, and they provide valuable interpretations with respect to changes in water quality, such as turbidity, conductivity, COD, BOD and chloride (Dela et al., 2002).

IMPACTS OF WASTEWATER EFFLUENTS

The quality of wastewater effluents is responsible for the degradation of the receiving water bodies, such as lakes, rivers, streams, etc. The potential deleterious effects of polluted wastewater effluents on the quality of receiving water bodies are manifold and depend on volume of the discharge, the chemical and microbiological concentration/ composition of the effluents. It also depends on type of the discharge for example whether it is amount 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 is at risk (Resource Quality Services, 2004). The potential deleterious effects of pollutants from sewage effluents on the receiving water quality of the coastal environment are manifold and depend on volume of the discharge, the chemical composition and concentrations in the effluent (Owili, 2003).

Environmental impacts

The impacts of such degradation may result in decreased levels of dissolved oxygen, physical changes to receiving waters, release of toxic substances, bioaccumulation or biomagnifications 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 on 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 affect 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 buildup 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 preference 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 a number of 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 effluent, 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 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 bioaccumulatives (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 become 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: (i) Algal clumps, odours and decolouration of the water, thus interfering with recreational and aesthetic water use; (ii) extensive growth of rooted aquatic life interferes with navigation, aeration and channel capacity; (iii) dead macrophytes and phytoplankton settle to the bottom of a water body, stimulating microbial breakdown processes that require oxygen, thus causing oxygen depletion; (iv) extreme oxygen depletion can lead to the death of desirable aquatic life; (v) siliceous diatoms and filamentous algae may clog water treatment plant filters and result in reduced backwashing, and (vi) algal blooms may shade and submerge aquatic vegetation, thus reducing or eliminating photosynthesis and productivity (Atlas and Batha, 1987; Ratsak et al., 1996; Kurosu, 2001; Alm, 2003; Mbewele, 2006; 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 (EPA, 2000; 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, 1997; 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, 1999; 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).

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 (WHO, 1997; Environmental Canada, 1998; 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 effects, such as degenerative heart disease and stomach ulcer (Table 1). 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

Table 1. Acute and chronic health effects associated with microbial pathogens in water.

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

Source: CDC, 1997.

faecal 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, Leptosporosis*, *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 diseases, such as typhoid, dysentery, and other intestinal disorders may be present in wastewater. The tests for total coliform and faecal coliform nonpathogenic 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 millilitres 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, usually 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. Protozoal 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. 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). *Crptosporidium 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 disnfection 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 helminthal 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 intestinal tract 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 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, United Kingdom, 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). Despite the fact that 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 haemoglobin 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 have been found to be powerful carcinogens in animals and humans (Fraser, 1995; El-Bahri et al., 1997; 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 endocrine-disrupting properties. Reports have shown that exposure to wastewater treatment effluents containing estrogenic chemicals can disrupt the endocrine functioning of aquatic life, thus 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 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 behavior, 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 waterborne pollutants (Health Canada, 1997; Wigle, 1998; 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 health impacts. The most dangerous consequence of exposure to ammonia is pulmonary edema, followed by severe irritation to moist tissue surfaces (WHO, 1997; Health Canada, 1998; WHO, 2006).

CONCLUSIONS

Wastewater effluents are major contributors to a variety of water pollution problems. Some of these problems include eutrophication, which can stimulate the growth of algae, increased water purification cost, interference with the recreational value of water, health risks to humans and livestock, excessive loss of oxygen and undesirable changes in aquatic populations. Since large amounts of wastewater effluents are passed through sewage treatment systems on a daily basis, there is a need to remedy and diminish the overall impacts of these effluents in receiving water bodies. In order to comply with wastewater legislations and guidelines, wastewater must be treated before discharge.

This can be achieved through the application of appropriate treatment processes, which will help to minimize the risks to public health and the environment. To achieve unpolluted wastewater discharge into receiving water bodies, there is the need for careful planning, adequate and suitable treatment, regular monitoring and appropriate legislation. This is will enhance science-based decisions and ensure the sustainability of the environment and the health of plants and animals. There is also a need to ensure that effluents standards and limitations, as set by regulatory bodies are not compromised.

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