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Wastewater Effluent Discharge: Effects and Treatment Processes

Akpor O. B.[+]

Institute for Economic Research on Innovation, Tshwane University of Technology, 159 Skinner Street, Pretoria, South Africa,

Abstract. Wastewater treatment is a vital component in any community without which water-borne pathogens can spread resulting in diseases and degradation of receiving water bodies. This paper was aimed at reviewing the ecological and health impacts of untreated wastewater effluents and current advances in wastewater treatment. The pollutants in wastewater can be divided into two broad categories: biological and chemical, with the major chemical pollutants being nitrogen, phosphorus, heavy metals, detergents, pesticides and hydrocarbons. The majority of waterborne microorganisms that cause human disease come from animal and human fecal wastes. These contain a wide variety of viruses, bacteria, and protozoa that may get washed into drinking water supplies or receiving water bodies. Also, the processes for the removal of impurities in wastewater can be divided into two: chemical and biological. All biological-treatment processes take advantage of the ability of microorganisms to use diverse wastewater constituents to provide the energy for microbial metabolism and the building blocks for cell synthesis. Although biological processes have been extensively investigated in wastewater treatment over the past decades, most investigations have been concentrated on bacteria. More recently, it is now known that a significant fraction of nutrient mineralization taking place in nutrient removal systems may be a result of protozoan activity. Since the performance and evaluation of a country's wastewater management system cannot be simply attributed to the presence of Acts, policies and guidelines, there is the need for appropriate implementation strategies. This can be enhanced through the utilization of technologies that are most economically useful efficient.

Keywords: wastewater treatment, chemical, biological

1. Introduction

Globally, the effluents that are discharged from wastewater treatment systems represent one of the largest sources of pollution. The negative impacts of these effluents to aquatic ecosystems and to humans, from harmful substances found in them have been documented both at national and international levels Some of these impacts can include death of aquatic life, algal blooms, habitat destruction from sedimentation, debris, and increased water flow and other short and long term toxicity from chemical contaminants; in combination with chemical accumulation and magnification at higher levels of the food chain (Canada Gazzette, 2010).

The United Nations General Assembly in the year 2000 adopted the millennium Development Goals (MDGs). The MDG that is most directly related to the safe use and discharge of wastewater is Goals 8-ensure environmental sustainability. In order to maximize the health and environmental benefits associated with the use and discharge of wastewater, several legislations and guidelines have been developed, both at international and national levels. The World Health Organisation (WHO) Guidelines for the reuse of effluents were developed in 1973, with revised editions in 1989 and 2006 (WHO, 2006).

Previously, many treatment plants were designed to remove nutrients by the addition of chemicals. Since chemical treatment is known to increase sludge volume and often results in sludge with poor settling and dewatering characteristics and the depression of the pH, biological treatment is advocated in recent years. Since large amounts of waste products are passed through sewage treatment systems on a daily basis, appropriate nutrient removal strategy is critical for the preservation of our lakes, streams, rivers and other receiving water bodies (vander Post & Schutte, 2003). This paper was therefore aimed at reviewing the

[+] Phone: +27-12-382-3073, Fax +27-12-382-3071
Email: AkporBO@tut.ac.za,

ecological and health impacts of untreated wastewater effluents and current advances in nutrient removal from wastewater.

2. Ecological and Health Impacts of Pollutants in Wastewater

Wastewater pollution has always been a major problem throughout the world. These pollutants can be divided into two broad categories: biological and chemical (Kris, 2007).

2.1. Ecological impacts

The major chemical pollutants in wastewater are nitrogen, phosphorus, heavy metals, detergents, pesticides and hydrocarbons. Of these chemicals, the two commonest nutrient limiting ones are nitrogen and phosphorus (Larsdotter, 2006). The presence of nitrogen in wastewater discharge can be undesirable because it has ecological impacts and also affect public health. The principal forms of nitrogen are organic nitrogen, ammonium ($NH4^+$ or NH3), nitrite ($NO2^-$) and nitrate ($NO3^-$) (Hurse & Connor, 1999). These occurrences are generally associated with disposal of municipal sewage and fertilizer application to agricultural crops. The dangers that all these incidents have posed are a clear indication that nitrogen must be removed from wastewater before discharge (Kurosu, 2001). Nitrogen in untreated wastewaters is primarily in the form of ammonia and organic nitrogen, both soluble and particulate (Sabalowsky, 1999).

A large problem in some plants is a low pH (to as low pH = 6) caused by extensive nitrification and low wastewater alkalinity. This often causes pin floc and high effluent turbidity. Some plants reduce aeration to reduce nitrification or add soda ash, lime or magnesium hydroxide as a source of alkalinity if this becomes a problem. The use of lower dissolved oxygen concentration (1.0 mg/l or less) to control nitrification is not without the risk of inducing filamentous bulking by low dissolved oxygen filaments (Jenkins, et al., 2003). During nitrification process, there is always a consumption of alkalinity and a production of alkalinity during denitrification process. In practice, 7.14 kg of alkalinity of $CaCO_3$ are consumed for every gram of NH_3–N oxidized. The hydroxide ions produced during denitrification process result in the replacement of 5 0 % of the alkalinity consumed during nitrification 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 (Jenkins, et al*.,* 2003). .

Surface waters can also contain levels of phosphorus in various compounds, which is an essential constituent of living organisms. In natural conditions, phosphorus concentration in waters is balanced; however when phosphorus input to waters is higher than it can be assimilated by a population of living organisms, the problem of excess phosphorus content occurs (Rybicki, 1997). Since phosphate is the limiting component for growth in most ecosystems and emission of phosphate in surface waters leads to eutrophication and algae bloom, thus having negative impacts on nature conservation, recreation and drinking water production, it is necessary to control the emission of phosphates from discharges of wastewater (van Larsdrecht, 2005). The 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 general purpose of phosphorus removal from wastewater is to eliminate excess phosphorus content discharge to receiving waters and then utilize this excluded phosphorus load in the way which is the most proper for the natural phosphorus cycle in nature. Usually, phosphorus is present in wastewater in soluble form. Only about 15 % of total phosphorus contained in settleable particles may be removed by primary sedimentation with no metal salt addition .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 (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). 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). Algal blooms can also be aesthetically undesirable, alter the native composition and species diversity of aquatic communities, impair recreational values of surface waters, impede commercial fishing and pose problems for water treatment. When deprived of oxygen, fishes and other aquatic organisms die, emitting foul odours.

2.2. Health Impacts

The majority of waterborne microorganisms that cause human disease come from animal and human fecal wastes. 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. Diseases caused by bacteria, viruses and protozoa are the most common health hazards associated with untreated drinking and recreational waters Contaminated water is a vehicle for several waterborne diseases, such as cholera, typhoid fever, shigellosis, salmonellosis, campylobacteriosis, giardiasis, cryptosporidiosis and Hepatitis A (WHO, 2004). Also, many microbial pathogens in wastewater can also cause chronic diseases with costly long-term effects, such as degenerative heart disease and stomach ulcer.

The density and diversity of these pollutants can vary depending on the intensity and prevalence of infection in the sewered community. 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 (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 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*, etc. The major pathogenic protozoans associated with wastewater are *Giardia* and *Cryptosporidium*. They are more prevalent in wastewater than in any other environmental source.

Drinking water with high nitrate content often causes methemoglobinemia (blue-baby disease) in infants. When this happens, nitrate is reduced to nitrite in the digestive system, which in turn attacks the hemoglobin in infants resulting in methemoglobinea. Methemoglobinemia is associated with nitrates in drinking water above the maximum contaminant level (10 mg/l) as set by the US Environmental protection Agency (EPA, 2002). Nitrite can also interact with amine chemically or enzymatically to form nitrosoamines which are carcinogens. Also, the presence of nitrogen and phosphorus in fresh water can also create environmental conditions that favour the growth of toxin-producing cyanobacteria and algae. 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, the United Kingdom, the United States of America and Zimbabwe. In some cases, liver cancer in humans is thought to be associated with exposure to cyanobacterial toxins through drinking water line and exposure to these toxins has usually been through contaminated drinking-water or recreational water contact (WHO, 2006).

In addition, eutrophication also leads to the production of algal blooms and plant growth in streams, ponds, lakes, reservoirs and estuaries and along shoreline. Algal blooms are responsible for depletion of dissolved oxygen and contribute to serious water quality problems (EPA, 2000). 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 (WHO, 2006). In extension, recreational water users and anyone else coming into contact with the infected water is at risk (Resource Quality Services, 2004).

3. Advances in Nutrient Removal from wastewater

The processes for the removal of impurities in wastewater can be divided into two: chemical and biological.

3.1. Chemical nutrient removal processes

Chemical removal is a method of wastewater treatment in which chemicals are added to form particles which settle and remove contaminants. Chemical treatment is still an essential component in many wastewater treatment schemes. The general purposes of the chemical treatment are: removal of suspended solids (turbidity) from the water; pH adjustment; removal dissolved material in the water; improve water quality. The most common methods in chemical treatment are coagulation/flocculation, chlorination, chloramination, ozonation and ultraviolet light (UV) (Gray, 2002).

Although flocculation doesn't kill pathogens, it reduces their levels along with removing particles that could shield the pathogens from chemical or thermal destruction, and organic matter that could tie up chlorine added for purification. Along with organic matter and heavy metals, 60-98 5 of coliform bacteria, 65-99 % of viruses and 60-90 % of *Giardia* could be removed through this process (Tchobanoglous et al., 2003). Some of the advantages of coagulation/flocculation can be obtained by allowing the particles to settle out of the water with time (sedimentation). Adding coagulation chemicals such as alum will then increase the rate at which the suspended particles settle out by combining many smaller particles into larger floc which will settle out faster. In bulk water treatment, the alum dose is varied until the required dose is found (Gomez et al., 2006).

Chlorination is the most prevalent practice of disinfection. Although it requires a relatively long contact time, because of its high oxidation potential, it is still a disinfectant of choice. However, chlorine does not only disinfect, but also rapidly reacts with contaminants such as NH_4^+, NO_2^-, H_2S, Fe^{2+} and other organic compounds, thus leading to the formation of compound called trihalomethanes, which are considered health hazards Chloramination (use of chloramines as disinfectant) has the benefit of reduction of formation of trihomethanes but because of their relatively longtime after discharge to receiving water environment, always lead to toxicity problems. It is mostly used in treatment of wastewater with high organic compounds (Tchobanoglous et al., 2003).

Ozonation is used mainly in secondary wastewater treatment. It has good bactericidal and virucidal activities with have no problem with suspended solids, colour and lacks toxic by-products. Its disadvantages include its expensiveness and lack of maintenance a residual in the water after treatment, there is always the possibility of microbial re-growth. The efficacy of UV and chlorine has been found to produce good disinfection in wastewater. Ultraviolet light has no problem of formation of toxic by-products and is faecal indicators are very sensitive. Its disadvantages are that it is expensive, increases volume of sludge produced and usually results in sludge with poor dewatering and settling characteristics. The main advantages of chemical treatment over biological processes are: mineralization of non-biodegradable compounds and smaller reactor volume (Tchobanoglous et al., 2003).

3.2. Biological Processes

Biological wastewater treatment can be divided into two treatment groups: on-site and off-site treatment systems. Both require proper maintenance and the demand for each varies, as do their public health and environmental impacts. All biological-treatment processes take advantage of the ability of microorganisms to use diverse wastewater constituents to provide the energy for microbial metabolism and the building blocks for cell synthesis. It is important for any biological wastewater treatment process to aim at achieving maximal reduction of biological oxygen demand of wastewater with a minimal reduction of biological solids. This is accomplished by removing substances that have a high demand for oxygen from the system through the metabolic reactions of the microorganisms, the separation and settling of activated sludge 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). This metabolic activity can remove contaminants that are as varied as raw materials and by-products. Biological wastewater treatment can be divided into two treatment groups: on-site and off-site treatment systems. Both require proper maintenance and the demand for each varies, as do their public health and environmental impacts. In the past decades biological removal processes has gained attention over chemical processes.

Enhanced biological phosphate removal has always been considered to depend on polyphosphate bacteria that are able to accumulate polyphosphate by storing more phosphorus than they need for growth (Mbewele, 2006). Although bacteria are known to oxidize ammonia nitrogen to nitrate nitrogen in a two-stage conversion process known as nitrification, very little energy is derived from this oxidation reaction. Since energy is required to convert CO_2 to cellular carbon, nitrifying bacteria are considered to represent only a small percentage of the total population of microorganisms in activated sludge (Choubert et al., 2005). However, the roles protozoa play in nutrient removal in aquatic systems have also evolved in recent years. It is now known that a significant fraction of nutrient mineralization taking place in nutrient removal systems may be a result of protozoan activity (Caron & Goldman, 1993; Coleman, 1994; Akpor et al., 2007).

The effectiveness of protozoa in the purifying process is due to the fact that they feed off dispersed bacteria, thus eliminating them. The presence of ciliate protozoa reflects an increase in effluent quality and can also be taken as bio-indicators of the health of the activated sludge process (Gerardi, 2007). They are also useful indicators of parameters (BOD, COD and DO) other than effluent quality in the purifying process. The type of structure of the ciliate protozoan community can characterize various types of biological quality of the sludge (Madoni et al., 1996). It is also important to note that protozoa release excretions to the bulk solution. These excretions contain many mineral nutrients, including nitrogen and phosphorus, and help to recycle mineral nutrients in the activated sludge process. These nutrients are then available for bacterial activity in degrading wastes (Johannes, 1965). Some speculations in the past have also shown that microzooplankton, specifically heterotrophic protozoa, is similarly important for *in situ* nitrogen remineralization Studies by several workers have shown that protozoa accelerate the mineralization of carbon due to nutrient excretion (phosphate, ammonium, nitrate), thus playing an extremely important role in nutrient regeneration in aquatic ecosystems (Johannes, 1965; Sherr et al., 1998; Anderson & Griffic, 2001).

4. Conclusions

Globally, because of rapid industrialization and increasing population density, domestic and industrial wastewaters are large sources of effluents that are discharged into receiving water bodies daily. The quality of wastewater effluents is responsible for the degradation of the receiving water bodies with the impacts of such degradation resulting in the spread of various waterborne diseases, decreased levels of dissolved oxygen, physical changes to receiving waters, release of toxic substances, bioaccumulation or biomagnification in aquatic life, and increased nutrient loads. To therefore safeguard public health and prevent negative environmental impacts, guidelines and policies aimed at treating wastewater before discharging into receiving water bodies are being adopted at both national and international levels.

For the assurance of an effective water quality management, appropriate wastewater treatment strategies are vital. Previously, most wastewater treatment plants were designed to remove nutrients by the addition of chemicals. However, because chemical processes have several drawback, such as, increased volume of sludge, production of sludge with poor settling and dewatering characteristics and the depression of the pH, biological treatment is being advocated in recent years. Since the performance and evaluation of a country's wastewater management system cannot be simply attributed to the presence of Acts, policies and guidelines, there is the need for appropriate implementation strategies. This can be enhanced through the utilization of technologies that are most economically useful efficient.

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