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Pollution indicators and pathogenic microorganisms in wastewater treatment: Implication on receiving water bodies

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Abstract: There is the indication that human deaths as a result of water-borne diseases exceed five million people per year, with over half of the diseases being microbial intestinal infections, especially cholera and diarrhea. A number of pathogenic microorganisms, regarded as water pollution indicators have been observed as the agents of such. These water pollution indicators are present in feces, sewage and can survive as long as pathogenic organisms. These pathogenic microorganisms cause several waterborne infections and diseases like bacterial (cholera, salmonellosis, shigellosis and several diseases associated with pathogenic strains of *E. coli*), viral (ranging from a mild febrile illness to myocarditis, meningoencephalitis, poliomyelitis, herpangina, hand-foot-and mouth disease and neonatal multi-organ failure), protozoan (cryptosporidiosis, diarrhea encaphilitis, giardiasis, amoebiasis) and fungal (candidiasis, blastomycosis, cryptococcusis, aspergilosis). These biological contaminants that cause several water-borne diseases can however be removed from water through physical (ultraviolet radiation, solar radiation and boiling) and chemical disinfection methods (chlorination, chloramination and ozonation). The aim of this paper was to review the microbial indicators and pathogenic microorganisms in water and wastewater. The paper also discussed the treatment strategies for microbial-contaminated water and wastewaters.

Keywords: Pollution, Wastewater, Pathogens, Microbial Indicators

1. Introduction

Untreated and improperly treated wastewater is known to contain pathogens which can cause disease outbreak, hence the need for adequate treatment before discharge into receiving water bodies. The treatment of wastewater is carried out to minimize and eliminate potential health risks. The major groups of pathogens that are of importance to wastewater are either bacteria, viruses, fungi or protozoa (FAO, 1993).

Bacteria, which are the most common pathogens in water, gain entrance into water mostly through fecal contamination (Sharma, 2013). Pathogenic or potentially pathogenic bacteria are normally absent from a healthy intestine unless infection occurs. In the case of an infection, large numbers of pathogenic bacteria will be passed in the faeces. Bacterial pathogens cause typhoid, paratyphoid and other *Salmonella* type diseases. Some of the bacteria pathogens that are found in wastewater include *Salmonella*, *Shigella*, pathogenic strain of *Escherichia coli*, *Yersinia, Campylobacter, Vibrio* (Bitton, 2005; Cabral, 2010). Viruses are reported to be the most hazardous pathogens found in wastewater. They are more resistant to treatment, more infectious and difficult to detect in wastewater. Their entrance into water is also through fecal contamination. The viral pathogens that are of importance in wastewater are enteroviruses (including polioviruses), hepatovirus, reoviruses and diarrhoea-causing viruses, especially rotavirus (Bosch, 1998). In the case of protozoa, their detection in wastewater is often as cysts and oocysts. Many species of protozoa can infect humans through ingestion, causing diarrhea and dysentery. The two major protozoan pathogens in water are *Cryptosporidium* and *Giardia* (FAO, 1993; Toze, 1997; Yates, 2013).

Since there is a wide range of pathogens that are present in wastewater and owing to the inherent difficulties of analysis, thus making the direct determination of the numbers impractical on a routine basis, the microbiological analysis of water depends majorly on detecting the presence of indicator organisms. Indicator organisms are present in large numbers in wastewater, although they may not necessarily be pathogenic. Their detection suggests that human contamination of the water has occurred and that more dangerous organisms could be present. An indicator organism should be applicable in all types of water, always be present or absent when pathogens are present or absent, respectively and should lend itself to routine quantitative testing procedures without interference from or confusion of results because of extraneous organisms. Most indicator organisms are are present in feces and sewage and can survive as long as pathogenic organisms. The major factors that are considered in classifying an organism as an indicator organism includes its association with fecal contamination, its relationship with the pathogen concerned and efficient and simple testing procedures. Indicator organisms are therefore referred to as basic tools for the measurement of water quality, they provide evidences for the presence or absence of pathogenic organisms in water (Plutzer and Torokne, 2012; Department of Health, 2013).

The aim of this paper was to review the major pathogenic and indicator organisms that are of importance in wastewater effluents. The paper also reviewed the various treatment methods for the removal of microbial pathogens from wastewater effluents with particular emphasis on the merits and demerits of each treatment method.

2. Microbial Pathogens in Wastewater

The major microbial pathogens in water are bacteria, viruses, fungi and protozoan parasites. Bacteria pathogens are mostly present in feces and a wide variety can be present in wastewater due to fecal contamination. The discharge of untreated or inadequately treated wastewater into the environment can have negative impact on human health due to the release of pathogenic microorganisms into water which could lead to serious health diseases (Rosario *et al*., 2009). Water that is contaminated with microbial pathogens is a medium for several waterborne diseases, such as cholera, typhoid fever, shigellosis, salmonellosis, campylobacteriosis, giardiasis, cryptosporidiosis and Hepatitis A (WHO, 2004). Several pathogenic organisms in contaminated water are the basic causes of gastrointestinal illnesses in human. Some of the pathogens are known to cause several outbreaks of diseases by releasing toxins in the human body (Krauss and Griebler, 2011). The major groups of water borne pathogens and the diseases they cause are shown in Table 1.

Bacterial pathogens

The major water related diseases caused by bacteria are cholera, salmonellosis and shigellosis. The majority of bacterial pathogens in wastewater are found in the gastrointestinal tract of humans and animals. They mostly belong to the following genera: Vibrio, Salmonella, Shigella, Leptospira and pathogenic strains of *Escherichia coli*, Yersinia and Campylobacter (Cabral, 2010; Yates, 2013). These pathogens cause diseases, such as cholera, salmonellosis, shigellosis/bacillary dysentery and diseases caused by pathogenic strains of E.coli.

Table 1. *Major Water Borne Pathogens and Diseases they Cause*

Microorganisms	Pathogenic organism	Diseases caused
Bacteria	*Salmonella*	Typhoid, bacillary dysentery
	E.coli (enterotoxigenic)	Gastroenteritis
	Yersinia	Gastroenteritis
	Campylobacter	Gastroenteritis
	Vibrio	Cholera
	Leptospira	Leptospirosis
Viruses	Polio virus	Paralysis
	Rota virus	Infantile gastroenteritis
	Hepatitis A virus	Infectious hepatitis
	Norwalk virus	Gastroenteritis
	Adenovirus	Conjunctivitis
	Reovirus	Respiratory disease
	Echovirus	Aseptic Meningitis
Protozoa, helminths and other parasites	*Giardia lamblia*	Diarrhea, malabsorption
	Entamoeba coli	Diarrhea, ulceration
	Entamoeba histolytica	Amoebic dysentery
	Cryposporidium parvum	Diarrhea
	Ascaris lumbricoides	Ascariasis
	Ancylostoma	Anemia
	Nectar	Anemia
	Trichuris	Diarrhea, anemia
	Tenia solium	Teniasis
	Trichuris trichuria	Trichuriasis

Source: (Yates, 2013)

Cholera, an infection of the small intestine caused by *Vibrio cholera* is primarily transmitted through the consumption of contaminated water (Cabral, 2010; Michelle, 2013). The incubation period of the disease ranges from 1–3 days. The disease is characterized by an acute and very intense diarrhea that can exceed one liter per hour. The bacteria secrets exotoxins that attach to the intestinal cells, causing loss of water, potassium, chloride and carbonate ions from the cells of the mucous membrane leading to diarrhea in patient (Farmer and Brenner, 2003; Cabral, 2010).

Salmonellosis is a disease caused by Salmonella species. The two types of salmonellosis caused by these pathogens are typhoid and paratyphoid fever, which are associated with ingestion of fecal-contaminated water and gastroenteritis (Le Minor, 2003; Michelle, 2013). Salmonellosis of newborns and infants presents diverse clinical symptoms, from grave typhoid-like illness with septicemia to mild or asymptomatic infection (Cabral, 2010).

The causative agent of shigellosis in human is Shigella species. The disease transmission through water is due to their high surviving nature. In the epithelial cell of the intestinal tract of humans, Shigella produces a high level of cytotoxic shiga toxin. The incubation period of the disease ranges from 1–4 days and usually begins with fever, anorexia, fatigue and malaise (Strockbine and Maurelli, 2005; Emch and Yunus, 2008; Cabral, 2010). .

The groups of pathogenic E. coli which cause diseases in human health include the enterotoxigenic E. coli (ETEC), enterohemorrhagic E. coli (EHEC) and enteroinvasive E. coli (EIEC). The ETEC strains are the common cause of infantile gastroenteritis, commonly associated with children below 5 years of age in developing countries and accounts for several million cases of diarrhea disease and several ten of thousand deaths each year (Bettelheim, 2003; Scheutz and Strockbine, 2005; WHO, 2006; Cabral, 2010). The EHEC strain (serotype O157:H7) has an incubation period of 3-4 days and symptoms occur for 7-10 days and 2 -7 % leads to renal failure. The EIEC strains are like the Shigella. They invade and replicate in the intestinal cells of humans. The disease symptom is characterized by diarrhea, abdominal cramps, vomiting, fever, chills, malaise and also appearance of blood and mucous in stools of patient. They are frequently associated with diseases such as gastroenteritis and enterocolitis dysentery (Bettelheim, 2003; Scheutz and Strockbine, 2005; WHO, 2010).

Viral pathogens

Viral pathogens, especially the human enteric viruses, which comprise of the highest number of water borne pathogens, have been found in water as a result of fecal contamination. The enteric viruses include the families Picornaviridae (poliovirus, enterovirus, coxsackievirus, hepatitis A virus and echovirus), Caliciviridae, Reoviridae, Adenoviridae, and Coronaviridae (Krauss and Griebler, 2011). Viruses are among the most important and potentially most hazardous pollutants in wastewater. Generally, viruses are indicated to be more resistant to treatment, more infectious, more difficult to detect and require smaller doses to cause infections. The presence of viruses in polluted waters could lead to a broad range of asymptomatic to severe gastrointestinal, respiratory, skin, eye, nose and ear infection. The enteroviruses and adenoviruses are the most common cause of symptoms of illness in healthy individuals and are often present in polluted water (Environmental News Network, 2007). The spectrum of diseases caused by enteroviruses is broad and ranges from a mild febrile illness to myocarditis, meningoencephalitis, poliomyelitis, herpangina, hand-foot-and mouth disease and neonatal multi-organ failure. Most infections, particularly in children, are asymptomatic, but still lead to the excretion of large numbers of the viruses, which may cause clinical disease in other individuals (WHO, 2006). The major disease caused by the enteric virus is acute gastroenteritis in both adult and adolescence. The hepatitis A virus is a very small enteric virus and is transmitted through fecally contaminated water by infected persons. The symptoms of disease include inflamed liver, followed by lassitude anorexia, weakness, fever, jaundice and nausea (Yates, 2013).

Protozoan pathogens

Protozoa are mostly associated with gastrointestinal disease, dysentery and ulceration of the liver and intestine. Protozoans can cause life threatening diseases in unborn children, immunocompressed individuals and even the elderly. They are also related to diseases, such as plasmodia, schistosomes, giardiasis, amoebiasis, cryptosporidiosis. The presence of free-living amoeba in water can cause severe diseases in man, for example the Naegleria fowleri, which is the primary cause of amoebic meningoencaphalitis (US National Library of Medicine National Institute of Health, 2003).

The most common protozoan pathogens that are reportedly present in wastewater treatment systems are classified into three groups, the flagellates (Peranema), the sarcodines (Arcella, Euglypha) and the ciliates (Trachelophyllum, Litonotus, Aspidisca, Euplotes, Carchesium, Epistylis, Opercularia). Others include the zoonotic Cryptosporidium pavum, Giardia lamblia, Toxoplasma gondiiis, Entamoeba histolystica, and also free-living amoeba species e.g. Acanthamoeba specie and Naegleria fowleri (Amaral et al, 2004; Krauss and Griebler, 2011).

The two most common parasitic protozoa that are found in wastewater are Giardia and Cryptosporidium. When Giardia cysts gain access to the stomach, they adhere to intestinal wall, leading to giardiasis, a disease, though not fatal but is characterized by diarrhea, abdominal cramps, weight loss, nausea and general gastrointestinal distress (Toze, 1997). Similarly, *Cryptosporidium parvum* is a parasitic protozoan which causes cryptosporidiosis in individuals who have ingested the oocyst in contaminated water (WHO, 2006). When cryptosporidiosis oocysts attach to the gastrointestinal tract of humans, they produce symptoms that include headache, abdominal cramps, nausea, vomiting, diarrhea and fever. Also, *Entamoeba hystolistica* can cause diarrhea encaphilitis and even dysentery to infected individuals (ExotoxNet, 1997).

Fungal pathogens

The most common pathogenic fungi that have been isolated from wastewater include species of Aspergillus, Candida, Rhizopus, Penicillium, Drechslera, and Rhodotorula. Several infections that are known to be caused by fungi are classified according to the site of initial infection, which are superficial mycoses, subcutaneous mycoses and systemic mycoses (Faryal and Hameed, 2005; Department of Environmental and Rural Affairs, 2011).

The majority of fungal diseases are mostly related to water used for recreational activities, such as bathing, swimming and washing. Some pathogenic fungal species could cause fatal nervous system infection through constant exposure to fungal spores can also cause respiratory allergies. They could also produce toxins which can be fatal to health when ingested. The diseases caused by fungi are known as mycosis. Most waterborne fungi remain in spore form and immunocompromised individuals are mostly at risk of infection. The major water-related fungal diseases are candidiasis, causeds by Candida albicans, blastomycosis, caused by Blastomyces dermatitidis, cryptococcusis, caused by Crptococcus neoforman, aspergilosis, caused by Aspergillus fumigatus, coccidiomycosis, caused by Coccidioides immitis and paracoccidioidomycoses, caused by Paracocciodoides brasiliensis (Warrington, 2011).

3. Microbial Indicators in Wastewater

Indicator organisms in wastewater are organisms whose presence suggests the presence of a pathogen in wastewater. The density of an indicator organism is always associated with health hazards and several sources of pollution. It is indicated that for an organism to qualify as an indicator organism of a particular pathogen, it must be continuously and totally related to the source of the pathogen and be abundant enough to provide appropriate and exact mass concentration of the level of pathogen in relation to high risk of illness. Also, an indicator organism should have resistant ability to disinfectants, environmental stress and toxic materials that may be present at the source of the pathogen (Berg, 1978; Galveston Bay Centre, 2002).

Bacteria indicators are the most important indicators of faecal contamination. These indicators include members of the Enterobacteriacea family, which the total and the fecal coliforms and *Escherichia coli*. Other bacterial indicators are the fecal streptococci (*Streptococcus* and *Enterocoocus*) and *Clostridium* (Krauss and Griebler, 2011). Generally, the coliforms are gram negative, non-spore forming, oxidase negative, rod shaped, and facultative anaerobic bacteria. They are lactose fermenters with gas production at 35 – 37 ^{o}C in a medium with bile salt (WHO, 2001). They can thrive at high temperatures, high pH (up to 9.6), and high salt concentration (up to 6.5% sodium chloride) and are considered as the most valuable indicator of fecal contamination. Although it is indicated that several species of the four *Enterobacteriaceae* genera *Escherichia* sp., *Klebsiella* sp., *Enterobacter* sp. and *Citrobacter* sp. have the ability of giving positive results to tests on environmental waters, the fecal coliform groups are the most widely used. The wide usage of the fecal coliforms is due to their continuous association in fecal waste of man and animals (Cabral, 2010).

In wastewaters, coliforms are seen in abundance, ranging from one to ten million colony forming units in every 100 mL of primary treated effluent (Galveston Bay Information Centre, 2002). Of the total coliform group, *E. coli* is the most numerous in mammalian feces, hence is considered the most specific indicator of fecal pollution (National Health and Medical Research Council, 2003). *Escherichia coli*, a member of the coliform bacteria population which could serve as an indication of fecal contamination, is a natural and essential part of the bacterial flora in the gut of humans and animals. Although some *E. coli* strains are pathogenic and play roles in intestinal and urinary tract infections, the majorities of *E. coli* strains are nonpathogenic and reside harmlessly in the colon (Scheutz and Strockbine, 2005).

Another group of indicators of bacterial pollution in water and wastewater are the fecal streptococci. The fecal streptococci are gram-positive, catalase-negative cocci. They consist of two main genera, *Enterococcus* and *Streptococcus*, with the *Enterococcus* indicated to be the preferred indicator of fecal pollution. These organisms are normally found in the gastro-intestinal tract of warm-blooded animals; hence their presence in water indicates fecal contamination. The fecal streptococci and fecal coliform are used to differentiate human fecal contamination from that of warm blooded animals (WHO, 2001). Some species of fecal streptococci include *Enterococcus faecalis*, *Enterococcus faecium*, *Enterococcus durams*, *Enterococcus hirae*, *Streptococcus bovis* and *Streptococcus equines* (Galveston Bay Information Centre, 2002).

Other indicators of bacterial pollution are *Clostridium perfringes* and *Bifidobacteria*. *Clostridium perfringens* is an anaerobic gram-positive, endospore-forming, rod-shaped, sulfite-reducing bacterium. It is found in the colon and represents approximately 0.5 % of the fecal microflora that is commonly found in human and animal feces (Bitton, 2005). The *Bifidobacteria* are gram positive rods, obligate anaerobes, non-spore formers and non-motile. They are all catalase negative, lactose fermenters and are numerous in feaces of warm-blooded animals. In addition, they are resistant to high temperature environment and can survive longer in an environment than enteric pathogens. Although they are indicated to be highly numbered in human feces, because of their sensitivity to oxygen, their role as useful indicators of fecal pollution in water is limited (Galveston Bay information Centre, 2002).

The major indicators of viral pollution in water and wastewaters are the phages, which are viruses that affect bacteria. The phages are used as models for human enteric viruses in water quality testing (Ashbolt *et al*., 2001). Generally, phages have been considered microbial indicators of viral pollution as they have similar characteristics with the human enteric virus. The coliphages are viruses that infect coliforms. They are also known as phages of coliforms and have been used to indicate human enteric viruses. The most used coliphages are the T-type (DNA that contains tailed phages) and F-RNA coliphages (RNA phages which can cause infection through the F-Pilli also known as sex factor). Because of their similar morphological structure and behaviour, they have been regarded as the best indicators for fecal pollution than fecal indicator.

Three groups of bacteriophages have been considered as indicators: somatic coliphages, male-specific RNA coliphages (FRNA phages/F+ coliphages) and phages infecting *Bacteroides fragilis* (Leclerc et al., 2000; Berger and Oshiro, 2002). The somatic coliphages infect mostly *E. coli*, although some can infect other enterobacteriaceae. They have been reportedly used as water quality indicators in estuaries, seawater, freshwater, potable water, wastewater and biosolids (Mocé-Llivina et al., 2003). The F+ coliphages include the families Inoviridae (FDNA) and leviviridae (FRNA). These coliphages are either single-stranded DNA or RNA and infect *E. coli* cells that contain the F plasmid, which is the plasmid that codes for the F or sex pilus to which the phage attach. Their consideration as indicators of wastewater pollution is due to their high numbers in wastewaters and their relatively high resistance to chlorination (Nasser et al., 1993; Yahya and Yanko, 1992).

Furthermore, diatoms are used to indicate the general quality of wastewater, with respect to nutrient enrichment. This is because they provide several valuable interpretations with respect to changes in water quality, such as turbidity, conductivity, chemical oxygen demand, biological oxygen demand, dissolved oxygen and chloride (Rey et al., 2002).

4. Treatment Strategies for Microbial-Contaminated Water and Wastewater

The two fundamental reasons for the treatment of water and wastewater are to safeguard public health and prevent the pollution of receiving water. The strategies for the treatment of microbial-contaminated water and wastewater are grouped into two: physical (solar radiation and ultraviolet radiation) and chemical disinfection (chlorination, chloramination, ozonation) processes. Each of these processes involves the destruction or inactivation of microorganisms. Although, no disinfection process is known to provide 100 % effectiveness, any good process should be characterized by the ability to penetrate and destroy pathogenic organisms during water treatment process and should be harmless to humans and the environment. Also, it must be cheap to acquire and maintain, easy and safe to handle, store and transport. In addition, during the disinfection process, toxic residuals, mutagens and carcinogens should not be produced (LeChevallier et al., 2004).

Physical disinfection processes

The two main physical disinfection processes are solar and ultraviolet (UV) radiations. Ultraviolet disinfection involves the exposure of contaminated water to UV light that has been generated by an electronic discharge through mercury vapour. The radiations from the UV light penetrates cells of pathogenic organisms in water and destroys their cell genetic material, thereby preventing reproduction (EPA, 1999; Tech Brief, 1999). Ultraviolet radiation is an effective method for the removal of microorganisms, such as *Cryptosporidium* and *Giardia*. Because UV radiation is not associated with the production of harmful by-products and known to improve the taste, colour and odour of wastewater, it is considered a safe method of primary disinfection (Trojan Technologies, 2013).

The advantage of a UV disinfection process is that it is an effective means of inactivating virus, spores and cysts. It does not produce toxic by-product and odour and does not also pose any danger of overdosing (Andrew, 2005). Despite the advantages, UV radiation is disadvantageous because it does not leave any residual behind after disinfection; hence there is the possibility of microbial regrowth. Another disadvantage is that because the method lacks any mechanism for determination of its effectiveness, it may not be effective in water that is highly turbid (Environmental Health Directorate, Department of Health, 2010). Generally, UV disinfection method is a recommended treatment method for several pathogenic organisms, such as *Burkholderia* sp., *Clostridium perfringens, Escherichia coli* 0157:H7, *Salmonella typhi, Shigella dysenteriaeI,* Calciviruses, Hepatitis A virus, Rotavirus, *Cryptosporidium* sp., *Giardia* sp.and *Toxoplasma gondii* (EPA, 2012).

A solar disinfection method is a thermal inactivation and photo-oxidation used to inactivate pathogenic organisms in contaminated water of low turbidity (CDC, 2012a). This method involves the use of the synergetic combination of optical and thermal processes for the treatment of contaminated water that is already contained in a transparent container for the inactivation of microorganisms such as bacteria, virus and protozoa. It is one of the simplest, inexpensive treatments available. It entails filling plastic containers with contaminated water and exposing to the sun for a whole day, thereby exposing microbial cells to ultraviolet radiation from sunlight, which leads to the destruction of their DNA (CDC, 2008; Dawney and Pearce, 2012).

The advantages of this method are its effectiveness against bacteria, protozoa and viruses, its proven reduction of diarrheal disease incidence in users, acceptability to users due to its simplicity and low cost. Also, the method causes minimal change in taste of the water and there is a reduced likelihood of recontamination since the water is served directly from the small, narrow-necked bottles with caps in which it was disinfected (CDC, 2008). The drawbacks of the method are that it requires pretreatment (filtration or flocculation) of waters of higher turbidity and the acceptability concerns because of the limited volume of water that can be treated at once. Also, the length of time required to treat water is long (CDC, 2012b).

Chemical disinfection processes

There are three commonly used chemical disinfection processes: chloramination, chlorination and ozonation. Chloramination, refers to the use of chlorine and ammonia to disinfect water and is considered one of the best technologies for water disinfection. Chloramines are formed from the combination of chlorine and ammonia. The disinfection method is by the frequent addition of ammonia to water that already contains free chlorine at pH 8.4. The method is effective and kills microbial cells by penetrating their cell walls, thereby obstructing their metabolism. It is documented that chloramination has served as an effective means for removing microbes such as coliform bacteria, heterotrophic bacteria as well as Legionella bacteria (San Fransisco Public Utilities Commission, 2013). The advantages of chloramination are its ability to improve the odour, taste, smell and flavour of water and it remains active for a very long period of time. The drawback of the use of chloramine for disinfection is it’s less effectiveness in killing some pathogenic microorganisms like E. coli, rotavirus and polio (Brockovich, 2010).

In the case of chlorination, the method involves the use of chlorine to disinfect water. The chlorine could either be in solid (calcium hypochlorite) or liquid (sodium hypochlorite) and gas. When added to water, chlorine helps in the reduction of pathogens by affecting the reproduction and metabolism of microorganisms present in the water (Michigan State University, 2010). This method involves introduction of chlorine, (about 0.2 – 0.4 mg/L) into contaminated water at pH of between 5.5–7.5 (Lenntech, 2013). Chlorination disinfection method is a well-established technology and leaves a residual behind, which can prolong disinfection after the treatment process, thereby preventing microbial regrowth. The disadvantages of chlorination are the high corrosiveness of chlorine and the production of harmful by-products (trihalomethanes) during disinfection process. Also, apart from the fact that some microorganisms are resistant to chlorine when in low dosage, the method is indicated to increase the chloride content of wastewater (EPA, 1999).

For ozonation, it involves the use of ozone for disinfection. Ozone is considered a very effective oxidizing agent for the treatment of water. The method is indicated to have good bactericidal and virucidal activities. It is considered the most effective disinfectant that can kill microorganisms including bacteria, viruses and protozoans (OzoneFac, 2013). Ozone is considered as the most powerful oxidant which can inactivate microorganisms in contaminated waters and it is more effective than chlorine (Promolife, 2011). The advantage of ozone is that, when compared to chlorination and chloramination, it is considered more effective in killing microorganisms and fast in activity. Also, it is not associated with the production of harmful by-products and helps in the removal of taste and odour from water. The disadvantage is that it that it is not effective in killing cysts and some other larger organisms. Besides, the cost of the equipment used for ozone generation is high and there is always the possibility of microbial re-growth. In addition, apart from the fact that ozone itself can be harmful to human health, the process requires electricity byproducts like bromate which can also cause harm to humans (Guides Network, 2013).

5. Conclusion

This paper which was aimed at reviewing the microbial pathogens, indicators of microbial pollutants and treatment strategies for microbial-contaminated water and wastewater has revealed the following:

- The presence of pathogenic organisms in water and wastewater has led to several water-related diseases.
- Because of the enormous time and cost involved in the detection of some of these microbial pollutants, indicator organisms are used.
- The advantages of these indicator organisms are that they are not pathogenic, and directly detect the presence of fecal contamination from warm-blooded animals.
- The various disinfection process enumerated above is beneficial not only to wastewater treatment but also drinking water.

This review was able to provide an insight to the major microbial pathogens and indicators of microbial pollution in water and wastewater. It has also shown the effectiveness of the various treatment processes for the elimination from and inactivation of microbial contaminants in water and wastewater.

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