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Water Pollution: Source & Treatment

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Abstract Water covers about 70% of the Earth's surface whereas 0.002% of the water is available for human consumption. Contaminated water is the main source of infectious diseases (e.g. *Amoebiasis and Malaria,* Cholera, *Dysentery, Paratyphoid Fever, Typhoid, Jaundice*). The WHO reports that one sixth of the world's population (1.1 billion people) does not have access to safe water. Water pollutions that come from industry, agriculture or households, returns negatively back to the environment. Chemical wastes (e.g. Arsenic, Fluorides, Lead, Nitrates, Pesticides, Petro-chemicals) in the water have negative effect on living organism in water and subsequently on our health. The effects of water pollution are varied and depend on chemicals kinds that dumped and their locations (urban areas are highly polluted). Pollutants such as lead and cadmium are consumed by tiny animals. Later, the food chain continues to be disrupted at all higher levels. Several countries sought to regulate the discharges of pollutants in the water to minimize pollution and contamination through various treatments. In this review, we are going to explain the main source of water pollution to promote sustainable use of water. Moreover, ensuring the highest protection of water from all hazardous chemicals.

Keywords Source of pollution, Water pollutant, Hazardous chemicals, Infectious diseases

1. Introduction

Water pollution occurs when undesirable effluents disperse in a water system and so water quality change. Water pollution divided into three main sources, natural Sources: include thermal and acid effluents from volcanic areas and are not common on the earth, domestic sources that are primarily sewage and laundry wastes and generated in houses, apartments, and other dwellings. In rural and some suburban areas, domestic wastes are handled at the individual residence and enter the environment through the soil either in partially treated or untreated fashion. In urban areas, domestic wastes are collocated in sewage pipes and transmitted to control location either for treatment or discharge into a watercourse without treatment (This considered as the major potential source of water pollution). Urban sewage since they handled by established government agencies, they can usually be effectively controlled (Boyd and Tucker, 2012). Industrial wastes vary from industry to industry and from location to location. Some industries generate wastes high in organic matter, and these wastes can usually handled by methods similar to those used for domestic wastes, such industries include dairy and food-processing plants, meat-packing houses. Other industries, however, generate wastes that are low in organic matter but high in toxic chemicals such as metals, acids or alkalis. These include chemical plants, mining facilities, and textile mills (Nesaratnam, 2014, Williams et al., 2015).

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2. Type of Pollutants

There are many types of pollutants such as Oxygen demanding wastes; disease-causing agents; plant nutrients; organic chemicals; inorganic chemicals; sediments; radioactive substances and heat. In most situations, the waste treated is a mixture of the preceding types of pollutants, thus greatly complicating treatment and control procedures (Nesaratnam, 2014).

Algae and Water Pollution

A serious problem in many lakes and reservoirs used as sources of water is the growth of algae. Algae are undesirable because they cause bad odors and flavors in water and may produce toxic materials of potential danger to human. Algal growth favored by warm water temperatures, high sunlight, adequate a source of nutrients especially nitrates phosphates and carbon dioxide. Therefore, algal growth is most common in summer and is rare in winter. Occasionally, in late summer and early fall, algal growth may be so heavy that water resembles pea soup. This condition called an algal bloom (Palmer, 1980; Laliberte et al., 1994; Kamarudin et al., 2015). When algae float to the surface and drift into backwaters where they become concentrated. Bacteria attack and decompose them causing a reduction in oxygen, which in turn leads to the death of fish and other animals and the development of foul and putrefying odors (Glibert, 2014). Reservoirs for domestic water supplies are often good habitats for algal growth because they are relatively shallow and receive large amounts of algal nutrients from the watershed. In addition to the odor and flavor problems that may develop, heavy algal growth in reservoir makes filtration and disinfection of the water difficult, thus markedly increasing the coast of water purification. Algal growth in reservoirs controlled by the application of copper sulfate. In many water supplies, copper sulfate is applied routinely from two to four weeks. The exact amount of copper sulfate required depends on the alkalinity or acidity of the reservoir. Copper sulfate use in reservoirs must be carefully controlled because copper sulfate is toxic to fish and in high doses to humans (Paerl et al., 2001). Algal growth in swimming pools causes an unsightly slime on the walls of the pool and reduces water clarity. The best method of control is by chlorination, but if algal growth is heavy, copper sulfate treatment may be used (Hamilton, 1989; Spector, 2001; Hasskerl et al., 2015).

Eutrophication

Sewage not only contributes organic matter to the growth of bacteria but nutrients for the growth of algae. The enrichment of water courses with algal nutrients is called eutrophication and is a serious economic problem because algal growth adds organic matter back into the water, thus increasing the BOD that causing a deterioration of water quality. Nitrate and phosphate are especially important in water pollution because they are effective nutrient sources for algae (organic nitrogen converted to ammonia, then ammonia is oxidized to nitrate, and organic phosphorus converted to inorganic phosphate) (Boyd and Tucker, 2012). Since conventional sewage treatment does not eliminate algal nutrients, eutrophication can be prevented if advanced sewage treatment methods used. The elimination of nitrate is more complicated, as this anion is not perceptible by any of the agents used in advanced treatment systems (Craggs et al., 2012). One method for elimination of nitrate is de-nitrification using bacteria (Cheikh et al., 2013).

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand one of the most important factor that depleted the dissolved oxygen in the water. Because, water contains organic matter and bacteria that oxidize organic matter, in the process consuming oxygen (Baldry et al., 1991). The decrease in oxygen content has several important consequences: i. it makes the watercourse partially or completely anaerobic, and this lead to the development of odors, flavors, and toxic materials in the water. ii. When the water becomes anaerobic, many animals such as fish die, and their remains putrefy and add further foul odors and organic matter to the water. iii. Even if odors do not develop, water depleted of oxygen has a flat taste. iv. Decomposition of organic materials takes place much more slowly in the absence of oxygen; the purification process in the water course are therefore slow, and a thick, unsightly, organic-rich sediment may accumulate on the bottom of the watercourse. v. Certain undesirable animals, such as the red bloodworms (chironomid larvae), develop to very large numbers in waters depleted of oxygen. The consumption of oxygen by bacteria is called the biochemical oxygen demand, usually abbreviated BOD, the extent of oxygen consumption determined by the amount of oxidizable organic matter present in the water. The BOD commonly used as a measure of organic pollution degree in waters. The BOD evaluated by aerating the water sample well, then placing it in a sealed bottle, incubating for the standard period (usually five days at 20°C), and then determining the residual oxygen at the end of incubation. During the 5-day incubation period, microorganisms present in the water grow, oxidize the organic matter and consume oxygen (Fennel, 2014). The amount of oxygen consumed is roughly proportional to the amount of biodegradable organic matter.

Chemical Oxygen Demand (COD)

Chemical Oxygen Demand is another evaluation that used to measure the level of water contamination by organic matter. In this evaluation, the organic matter is oxidized via oxidizing agent (potassium dichromate). The COD is usually higher than the BOD because some organic materials in the water that are resistant to microbial oxidation and hence not involved in BOD will be easily chemically oxidized (Chen et al., 2014, Gattrell, 2014).

Self-Purification of Water

When sewage added to a river or other watercourse, pollution occurs. Pollution followed by purification, the process in which the quality of the water returned toward normal. When purification occurs without human intervention, it is called self-purification and occurs as a result of microbiological, chemical, and physical changes. Microbiological changes include the death of many intestinal microorganisms present in the sewage and growth of normal aquatic microorganisms able to oxidize organic matter entering the system. Chemical changes include oxidation of organic matter, the release of phosphate, nitrate and re-oxygenation of the water by the \ oxygen solution from the air. The most important physical changes involve sedimentation, in which particulate matter settles out of the water onto the bottom of the watercourse (Ostroumov, 2014, Drewniak et al., 2015).

Microbial Indicators of Sewage Pollution

Microbial indicators provide an excellent means of monitoring natural water for sewage pollution; because they easily detected. Any of the organisms used in evaluating drinking water for microbial purity can used as indicators of sewage pollution. The most frequently two indicators used are the coliform group and the subgroup of the coliforms (fecal coliforms). In general, any gram-negative, rod-shaped, facultative anaerobic bacterium is called coliform (*Escherichia coli* is typical coliform). The fecal coliform group defined as containing those coliforms can grow at an elevated temperature of 44.5°C. This elevated temperature is suitable for organisms associated with the intestinal tract and eliminates many of the no intestinal coliforms able to grow at the standard temperature of 35°C. The fecal coliforms are thus better indicators of recent sewage pollution (Kapoor et al., 2015, Sivaraja and Nagarajan, 2014). Furthermore, measuring enzymatic activities can provide information about the function and structure of microbial communities in contaminated media. These measures could use as rapid and cost-effective means for evaluating and monitoring remediation of contaminated media (Alrumman et al., 2015).

3. Water Treatment Methods

We will present only a brief, general account of typical four series steps.

Sedimentation

If the water source is highly turbid, the raw water is pumped into lagoons and allowed to stand for several hours. Silt and other materials sink to the bottom, and certain flocculating chemicals are added to contaminated water to precipitate and absorb finer particles (García et al., 2014).

Filtration

The water pumped from the settling areas into tanks that equipped with sand filters. The water is cleared from the most remaining impurities, including numerous bacteria and other microorganisms (Cui and Choo, 2014, Katsoyiannis et al., 2015).

Aeration

If the water contains large quantities of organic material, it may be sprayed into the air or allowed to flow over a series of shallow waterfalls to increase the availability of oxygen to microorganisms capable of oxidizing organic compounds (Hadad and Ghaderi, 2015, Shao et al., 2015).

Chlorination

Either chlorine gas or certain chlorine compounds are added to water to complete the purification process. Extremely small amounts of chlorine, about 0.3 parts per million, are usually adequate to kill almost all the microorganisms (certainly all the pathogens) remaining in the water. At the same time, chlorine neutralizes many odors and tastes in the water. The final product is then ready to be distributed to the public (Salgado et al., 2015, Speich et al., 2015). As we have indicated, there are many variations of these procedures. At one extreme water that are so pure that they require only chlorination or no treatment whatsoever. At the other extreme water that contain so many impurities that they must receive more elaborate treatment. For example, some waters contain large amounts of calcium, magnesium, or iron salts that must be removed by special chemical procedures to "soften" the water. Regardless of the initial quality of the water, fluorides may be added to reduce the incidence of dental caries (Pennel et al., 2015).

4. Sewage

Sewage is a mixture of natural organic and inorganic materials with a small ratio of man-made substances. The main source of sewage polluted is human excreta with food preparation from contributions and surface drainage. The physical and chemical nature of water wastes can be further complicated by industrial wastes that are composed of strong spent liquors from main industrials processes. Domestic wastewater comes mainly from the residence, commercial buildings, and institutions such as schools and hospitals, whereas, industrial wastewater comes from manufacturing plants. Inevitably, large towns and cities have a mixture of domestic and industrial wastewater, which is commonly referred to as municipal wastewater (de Mora and Harrison, 2013). The other wastewater that rich in organic materials and readily biodegraded are the agro industrial wastes, these wastes varied according to agricultural practice, manufacturing processes and from intensive animal rearing, silage production, food processing and the dairy industry (VikranthPridhvi and Musalaiah, 2015).

Physical Properties

The vast majority of the large solids, such as faces and paper have broken up into very small particles and made turbidity with visible particles of organic material. The water color become gray and change to yellow-brown, according to the time day. However, if all the oxygen has been consumed during transit in the sewer then the wastewater becomes anaerobic or septic. Thus water become much darker color and in extreme eases turns black (Sell, 1992, Olariu, 2015). So, the contaminated water problems are related to odors, corrosiveness (pH), and turbidity.

Odors

Phormidium, Actinomycetes and Streptomyces. Wastewater (becomes anaerobic) has a musty smell that is not at all offensive. Microorganisms that produce such odor are *Cyanobacteria, Oscillatoria,* Moreover, certain industrial wastes have distinctive odors that caused by gasses involved from decomposition of various fractions of the organic matter. The rotten eggs is the commonest odor that caused by hydrogen sulfide produced by anaerobic bacteria (reduction of sulfate to sulfide). On the other hand, volatile fatty acids odor produced during food processing treatment and storage (table 1). Where, carbohydrates wastewater undergoes partial anaerobic breakdown within the process and subsequently on storage in lagoons. For example, the volatile acids odor concentrations during sugar beet treatment are 24.3 ppm for acetic acid, 20.0 ppm for propionic acid, 0.05 ppm for iso-butyric acid and 0.24 ppm for butyric acid, 0.7 ppm for iso-valeric acid and 3.0 ppm for valeric acid. Other odors associated with sugar beet processing are the fishy odor come from trimethylamine and rotting cabbage produced from organic sulphides and the thiol compounds (table 1) (Dague, 1972, Muramoto et al., 1995, Loan et al., 2014). There are other odorous associated with chlorine and phenolic wastes as in the following table 1:

Table 1. The types of odors sources

Compounds	General Formulae	Odor Produced
Ammonia	NH_3	Ammoniacal, pungent
Amine	CH_3NH_2, $(CH_3)_3N$	Fishy
Diamines	$H_2N(CH_2)_4NH_2$, $H_2N(CH_2)_5NH_2$,	Rotten fish
Skatole	$C_8H_5NHCH_3$	Fecal, repulsive
Organic sulphides	$(CH_3)_3S$, CH_3SSCH_3	Strong delayed cabbage
Sulphur dioxide	SO_2	Pungent, acidic
Chlorophenol	ClPhOH	Medicinal, phenolic
Chlorine	Cl_2	Chlorine

Temperature

The temperature of the sewage is warmer than the normal water temperature, except during the warmest months and its rarely freezes owing to high conductivity. The temperature of raw sewage ranges from 8-12°C in winter to 17- 20°C in summer. (Boon, 1995; Domínguez et al., 2006; Sun et al., 2015). These variations in temperature can markedly influence the makeup of microbial communities. Optimum temperatures for bacterial activity are in the range from 25 to 35°C. Aerobic digestion inhibited if the temperature raised to 50°C. Whereas, methane-producing bacteria become quite inactive at 15°C. Moreover, at about 5°C the autotrophic-nitrifying bacteria pass away and at 2°C, the chemoheterotrophic bacteria acting on carbonaceous material turn into suspended. On the other hand, temperature affects the performance of activated sludge systems. Where the maximum acceptable temperature is limited to about 35° to 40°C that corresponds to the maximum temperature for the growth of mesophilic organisms.

Hydrogen Ion Concentration

The pH of sewage is usually above 7 depending mainly on the hardness of the waste water. Soft water catchments have a pH range of 6.7- 7.5 and hard water catchments have a range of 7.6 - 8.2. The most significant environmental impact of pH folds up synergistic effects. Synergy involves the combination of two or more substances that generate effects greater than their sum. This process is important in surface waters. In which, agricultural, domestic, and industrial areas may contain aluminum, ammonia iron, mercury or other elements. The pH of the water will determine the toxic effects, if any, of these substances. For example, 4 mg/l of iron would not present a toxic effect at a pH of 4.8. However, as little as 0.9 mg/l of iron at a pH of 5.5 can cause fish to die. Moreover, Synergy has significance when considering wastewater treatment. The steps involved wastewater treatment required specific pH levels for coagulation and alkalinity must fall within a limited range. (Van Haandel and Lettinga, 1994; Feigin et al., 2012; Liu et al., 2012; Wu et al., 2015).

Chemical Properties

Total solids (TSS)

TSS are the weight of matter remaining after wastewater evaporated at 105°C. TSS provide a simple characterization of the wastewater, it can be classified as either suspended or filterable depending on standard filter (Paredes et al., 2000; Maekawa, 2003). TSS are used to describe the strength of waste water, where more TSS in waste water, more polluted in waste water. TSS give the best indicator for the turbidity of the water, where suspended solids turn the water into milky or muddy looking owing to light scattering from very small particles (Paredes et al., 2000).

Organic Matters

Organic matter composed of carbon, hydrogen and oxygen with nitrogen. Sulfurs, phosphorous and iron are only frequently present. Three-quarters of the organic carbon can attribute to carbohydrates, fats, proteins, amino acids and volatile acids. The remainder comprises hormones, vitamins, surfactants, antibiotics, hormonal contraceptives, purines, pesticides, hydrocarbons, and pigments (Maekawa, 200). Many of the synthetic organic molecules are non-biodegradable whereas others are only biodegradable at very slow rates. The organic constituents of suspended solids and the filterable fraction of sewage are different (Maekawa, 2003, Gong et al., 2008, Jeswani and Mukherji, 2015). In sewage, carbohydrates comprise the largest group followed by non-volatile acids (Kekeç and Cosgun, 2015). Glucose, sucrose and xylose and arabinose represent 90 – 95 % of all the carbohydrates present, which is equivalent to 50 – 120 mg/l (Yuan et al., 2014, Barker and Stuckey, 1999, Lettinga, 1995). Protein is made up of long chains of amino acids connected via peptide bonds and is readily broken down by bacteria to form free amino acids, fatty acids, nitrogenous compounds, phosphates and sulfides (Dapena-Mora et al., 2007). Proteins are a comparatively important source of carbon in wastewater rather than soluble carbohydrate or fats in suspension. Protein is the principle constituent of all animal and to a lesser extent plant tissue (Pei et al., 2012). Fats are the major organic constituents in the suspended solids fractions and represent 60–80% of the organic carbon present. In wastewater terminology, fats are lipids or grease, to describe the whole range of fats, oil, and waxes discharged to the sewer. They are among the more stable organic compounds and not easily biodegradable. The major source of fats is food processing (butter, lard, margarine, vegetable fats and oil, meat, cereals, nuts and certain fruit). Fats are only sparingly soluble in water and important components of the suspended fraction in wastewater (50% of the total carbon present). Normal concentration ranges for fats in domestic wastewater are between 40–100 mg/l. Fats hydrolysis by hydrolytic action to produce fatty acids, and a wide variety of free fatty acids. The major acids include palmitic, stearic and oleic acids, which represent 75 - 90% of those present (Shon et al., 2006, Huang et al., 2010). Acetic acid is the major volatile acid found in sewage reported at concentrations between 6 –37 mg/l together with propionic, butyric and valeric acids those reprsent 90% of the total volatile acidity in wastewater. Non-volatile soluble acids are present at concentrations between 0.1–1.0 mg/l, the commonest being glutaric, glycolic, lactic, citric, benzoic and phenylacetic acids (Chen et al., 2004, Akunna et al., 1993). Not all biodegradable organic matter found in sewage can classify into one of the major categories (Stolte et al., 2008, Docherty et al., 2015).

Inorganic Matters

Sodium, calcium, potassium, magnesium, chlorine, sulfur (as sulfates and other forms), phosphates, bicarbonates, and ammonia are the main components in sewage. Domestic wastewater contains a very wide range of inorganic salts and trace elements (Heavy metals), including all those necessary for biological growth and activity. The inorganic content of domestic wastewater depends on the geology of the catchment from which the water supply originated (natural water dissolves minerals from the surrounding rocks and soil of the area), and on the nature of the polluting material itself (Kozai et al., 2014, Kahiluoto et al., 2015).

5. Sewage Treatment

Sewage treatment consists of a series of processes in which undesirable materials in the water are removed or rendered harmless. BOD destroyed, silt clay and other debris removed, pathogenic microorganisms killed, and the total number of microorganisms reduced. There are many designs for sewage-treatment systems; the best design to use for a specific system depends on local factors. Both biological and nonbiological treatments are used. The biological treatment process can be divided into two groups: digestion processes, which are anaerobic and oxidation processes, which are aerobic (Voulvoulis et al., 2015, Singh et al., 2016). In the following table 2, the end products of the aerobic and anaerobic microbial degradation of the major organic substrates found in sewage are listed:

Non-biological treatments include coarse and fine screening, sedimentation, sand filtration, chemical treatment to induce flocculation and incineration (Matter-Muller et al., 1980, Sutherland-Stacey et al., 2015). Suspended particulate materials tend to increase water turbidity (cloudiness) whereas, larger particles settle out when water is allowed to sit undisturbed in a holding reservoir. The colloidal solids, however, remain suspended in the water unless precipitated by a chemical, such as Alum (Aluminum potassium sulfate), that complexes the particle into floccules, large aggregates that quickly settle to the bottom of the tank. Flocculation also removes many viruses and bacteria. The clarified water is then filtered through sand or activated charcoal, a process that physically removes most bacteria, protozoa, and other cellular microbes, as well as many viruses (Fukuhara et al., 2006, Islam et al., 2015). Poliovirus and other small viruses may escape from filtration (Hejkal et al., 1979, Nenonen, 2015). The addition of chlorine is the final step in assuring a safe public water supply. Low concentrations of chlorine inactivate most of the pathogens in water. Although in higher concentrations of chlorine and its by-products are deleterious to people and the environment.

Table 2. The end products of the aerobic and anaerobic microbial degradation in sewage

Substrates	Anaerobic conditions	Aerobic conditions
Proteins and other organic nitrogen compounds	Amino acids Ammonia Hydrogen sulfide Methane Carbon dioxide Hydrogen Alcohols Organic acids Indol	Amino acids Ammonia → nitrites → nitrates Hydrogen sulfide → sulfuric acid Alcohols & Organic acids →.CO_2+ H_2O
Carbohydrates	Carbon dioxide Hydrogen Alcohols Fatty acid Neutral compounds	Alcohols & Fatty acid → CO_2 + H_2O
Fats and related substances	Fatty acids + glycerol Carbon dioxide Hydrogen Alcohols Lower fatty acids	Alcohols & Lower fatty acid → CO_2 + H_2O

Sewage treatment performed with four principle goals:

1. Elimination of any pathogens that might be present.
2. Decomposition of solid materials.
3. Alteration of the liquid fraction so that it will no longer support any microbial growth.
4. In large-scale systems, recovery of useful products to produce fertilizer and methane gas.

Sewage Disposal

There are several approaches to the disposal of domestic wastewater. One is to return the raw sewage directly to the environment, burying it or dumping it into oceans, lakes or rivers. Microorganisms, the decomposers, eventually digest the organic load and completely mineralize it, that converts it to the inorganic state (Almeida et al., 1999, Mara, 2013). This is the completion of the biogeochemical cycle. Decomposition also eliminates the pathogens in sewage by outcompeting them, rendering the material non-infective. After a period, the waste is safely free of pathogens, noxious chemicals and offensive odors (Kouloumpos, 2009). Unfortunately, this process requires so much time that sewage-contaminated water will likely use before the pathogens are eliminated, resulting in an epidemic of serious waterborne disease. The natural decomposition cycle is not rapid enough to keep up with the volumes of sewage generated by communities, especially large municipalities (Werther and Ogada, 199; Awwad et al., 2013).

Families may safely dispose of their sewage in septic tanks. These are containers for storing sewage while solids settle out, and decomposers break down organic compounds. Complete mineralization occurs only in the presence of molecular oxygen. The biological activity in the tank, however, quickly consumes oxygen and produces anaerobic conditions. Thus, decomposition is incomplete, and the liquid discharge from septic tanks contains solubilized organic compounds. In most systems, liquid leaving the tank trickles along pipes or troughs lined with gravel. The effluent (discharged liquid) aerated, and mineralization is completed by the decomposers attached to the surfaces over which the liquid flows. The treated effluent discharged into the surrounding soil. Large communities and cities in the United States rely on large-scale sewage treatment plants for disposal of wastewater (Garrec et al., 2003, Pisano et al., 1998).

Sewage first subjected to primary treatment, large solids (such as marbles, paper, rocks, dentures, and glasses) screened or skimmed off for burning and burying. The liquid then transferred to a sedimentation tank where more solids settle out to form sludge. Primary treatment is, therefore, more a process of physical separation than one of microbial decomposition. Both the effluents from the primary treatment and the sludge contain potentially dangerous pathogens and a high biochemical oxygen demand (BOD). The BOD is a way of expressing the amount of organic compounds in sewage as measured by the volume of oxygen required to bacteria metabolize. Digestion of these organic compounds in natural ecosystems, such as lakes, can deplete available oxygen and result in asphyxiation of fish. This type of environmental disruption minimized by treating sewage to reduce the BOD before its return to the environment. Primary treatment removes approximately one-fourth of the BOD from sewage. Primary treatment removes much of the organic material in the water (30-40%) but a significant amount remains (White and Sharma, 1978, Von Sperling, 1996). Secondary treatment is mostly a biological process that depends on complete aeration of the system. The BOD of sewage may be reduced by another 80 to 90 percent in oxygen excess during secondary treatment. One of two systems is usually employed to saturate the sewage with oxygen. The most common is called a trickle filter (although no filtering occurs). Slowly moving sprinkler arms trickle the effluent from the gravel. As the sewage seeps through the gravel, microbes attached to the rocks rapidly oxidize the dissolved organic compounds and much of the suspended solid material. The trickling action aerates the liquid and circulates the sewage. The effluent collected in a sedimentation tank for separation of remaining solids. The other one is the activated sludge system, which is slightly more efficient than the trickle filter system. In this system, the effluent from the primary system is held in the tank, and the air vigorously pumped through the liquid. Resident microbes in the sewage decompose much of the soluble organic material and suspended solids. The sewage then transferred to a settling tank for separation of liquid from the sludge. About a fifth of the sludge is recycled to the aeration tank as a starter inoculum for the incoming sewage (Kamiya and Hirotsuji, 1998, Xu et al., 2015). Sludge from both primary and secondary sedimentation tanks digested by anaerobic microorganisms. This process decomposes much of the organic material to methane, a flammable gas that is often recovered and used as fuel in the sewage facility. The remaining undigested (stabilized) sludge presents the most serious disposal problem. This material usually burned, but some are also dried and applied to soil as a fertilizer. The public safety of this practice evaluated since a few viruses may remain following anaerobic digestion (Stroot, 2015). By the end of secondary treatment, the infectious potential of sewage is virtually eliminated. Pathogens, indeed the majority of microorganisms from the human alimentary tract, are poorly adapted for growth outside the body, especially when confronted by a vast number of microbes that perfectly suited for exploiting the rich resources in sewage. These harmless microbes will quickly prevail at the expense of the pathogens. Before long the predominant organisms released in feces are completely replaced by the saprophytes favored by natural selection in sewage. Although the products of secondary treatment safely discarded, too much organic material remains in the effluent for its direct use by the people. Also, nitrogen and phosphorous are poorly removed by primary and secondary treatment, and elevated concentrations of these compounds can be detrimental to the environment. Secondary effluent used in some communities irrigates crops. The nitrogen and phosphorous compounds fertilize the plants while environmental microbes in the soil digest chemical contaminants. Some modern sewage facilities, however, further process wastewater by tertiary treatment to completely remove the BOD and all remaining nitrogen and phosphorous contaminants that they promote the growth of autotrophic microorganisms (e.g. cyanobacteria) leading to eutrophication. This stage of the process is a combination of physical and chemical treatments that yields water safe for drinking. After tertiary treatment, water may be pumped directly into the public reservoir for recycling or returned to the environment with no significant disturbance. The process is extremely expensive, however, and most often the effluent from secondary processing is returned to the environment, where natural process accomplish the equivalent of tertiary treatment (Xiao et al., 2015). The chemical and physical removal of sewage materials during tertiary treatment at Lake Tahoe, for example, involves some steps. Following secondary treatment by the activated sludge method, lime is added to the treated water to coagulate and precipitate phosphate-containing particles. The resulting precipitates are allowed to settle in a clarification tank. Gaseous ammonia in the water, derived from the mineralization of organic compounds, is removed by passing the water from the clarification tank through a stripping tower. In the tower, rough-textured hemlock slats break the falling water into droplets; NH_3 gas escapes and is dispersed by a fan. The water is then neutralized by adding CO_2 and passed through a series of temporary holding ponds before filtered through a sequence of cylinders. Some of the filters, made of coal, sand and garnet, remove remaining particles; others, made of activated charcoal, remove detergents, pesticides, and other toxic materials. Chlorine is added to the purified water as a final step in its treatment to kill or inhibit any remaining microorganisms and to oxidize any odor-producing substances that may remain (Stamm et al., 2015). In some designs for the tertiary treatment of sewage, chemical precipitation of phosphates has been combined with biological removal of nitrates. Certain bacteria (particularly species of Pseudomonas and Bacillus) can reduce nitrates (NO_3) completely to nitrogen (N_2) (denitrification). The N_2 gas that formed is inert, non-toxic and easily removed (Ebbers et al., 2015, Ryu et al., 2014).

Substances Resistant to Decomposition

Most organic substances in domestic sewage decompose readily during sewage treatment. In contrast, many chemicals present in industrial wastes are resistant to decomposition by the microorganisms present in normal sewage treatment systems. Some of these compounds are toxic if so, they can sometimes be effectively handled merely by diluting them to a point where they are no longer toxic. Other compounds are not toxic but are merely resistant to decomposition. Sometimes these materials cannot be treated biologically at all, and chemical means of treatment must use. In some cases, it may be possible to develop a microbial population that will degrade the compound (Li et al., 2013). If a compound can decompose by microorganisms, it is biodegradable; if it cannot decompose, even after attempts to obtain a population capable of degrading it, it is considered non-biodegradable. It often observed that when a new substance first introduced into a sewage-treatment system, it decomposes slowly, but after a period, decomposition is rapid as a result of the development of the suitable microbial population. Therefore, when beginning the treatment of a new material, it is important to ensure that the proper population is present before introducing material into the treatment plant (Hvitved-Jacobsen et al., 2013, Steele et al., 2012, Schaubroeck et al., 2015, Jurzik et al., 2015).

Nitrification & Denitrification

Nitrification: Ammonia can be a major problem in waste water due to its oxygen demand in the receiving water, its toxicity to fish or because it acts as the fertilizer and can alter the flora of receiving water. Its toxicity to fish or because it act as a fertilizer and can alter the flora of the receiving water. One method of treating ammonical wastewater is to oxidize it biologically to nitrate (nitrification). Bacteria such as *Nitrosomonas* or *Nitrobacter* are common nitrifying organisms that found in rivers, lakes or wastewater treatment plants. They use carbon dioxide as their source of carbon while the oxidation of ammonia gives them energy (Gong et al., 2012, Liang et al., 2015).

$$2NH_3 + 3O_2 \xrightarrow{\textit{nitrosomonas}} 2NO_2 + 2H + 2H_2O$$

$$2NO_2 + O_2 \xrightarrow{\textit{nitrobacter}} 2NO_3$$

There are numerous problems in trying to use nitrification to remove from wastewater, particularly in temperate or cold climates. The nitrifying bacteria are relatively slow growing and function best at temperatures of 20° – 25°. At temperatures of 5°, their metabolism may be almost dormant. Thus, although nitrification may achieve in a treatment plant in warmer weather, nitrification in cold climates may be very limited. The presence of organic matter in the wastewater is not necessary for these bacteria, but trace levels of nutrients such as phosphate, magnesium, copper, and iron are essential (Kadlec and Wallace, 2008, Kroiss et al., 1992, Ge et al., 2015).

Many heavy metals and some organic will inhibit nitrification. The optimum pH for nitrification is 7.5 to 8.5, and the process is very slow if the pH drops to 6.0. The addition of small quantities of alkali may be required to maintain a suitable pH because of the acidity formed in the nitrifying process. All of the aerobic biological treatment processes can be adapted to nitrify ammonia. The main operational problems are the inability to operate the nitrifying process at low ambient temperatures and sensitivity of nitrifying bacteria to low concentrations of toxic constituents (Benbi and Richter, 2012, Li et al., 2015).

Denitrification

De-nitrification, the opposite of nitrification in water, is the removal of oxygen from nitrates in anoxic or anaerobic conditions resulting eventually in gaseous nitrogen that bubbles off and thus removed. Many heterotrophic bacteria found in an aerobic biological process can adapt to using the oxygen that is combined in nitrates if the dissolved oxygen is very low or zero (respiration under anoxic conditions). The sludge in the bottom of a secondary sedimentation tank has little oxygen and with a nitrified effluent a problem may occur if the sludge rises to the surface because of denitrification, caused by the nitrogen bubbles lifting the sludge. This is unlikely if the sludge spends less than 2h in the settling tank. The major remedy is to increase the rates of sludge collection and return from the settling tank. Sludge collection can increase by having three or four scraper arms in the tank (Zhao et al., 1999, Qian et al., 2015). In activated sludge treatment, if the sludge well nitrified, some denitrification can be achieved by not fully aerating the return sludge in the first compartment of the aeration tank. The return sludge is then efficiently mixed with the incoming from the primary sedimentation tanks. Some 50% denitrification has thus regularly achieved. Alternatively a reduced number of air diffusers can be used instead (one –third of the number ordinarily used for aeration) with equally good results. Sewage may also denitrify by locating an anoxic activated sludge plant after secondary sedimentation. Methanol or settled sewage may add to the secondary effluent. As it enters the anoxic mixing tank, to act as organic carbons source for the denitrifying bacteria. There is a further stage of sedimentation, from which the sludge returned to the anoxic mixing tank. Other schemes exist to get denitrification in activated sludge plants. For example four zones alternating anoxic, aerobic, anoxic and aerobic followed by sedimentation. Alternatively an anaerobic filter may be used to denitrify the effluent from secondary sedimentation. The same process has been observed in polluted rivers when a batch of well-nitrified effluent meets some raw sewage. The nitrogen bubbles off. Appreciable losses of nitrate by denitrification have been noticed from effluent left for a few days in a lagoon for tertiary treatment (Chai et al., 2014, Ntougias et al., 2015, Lust, 2014).

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