Water treatment plants essay sample

Environment, Water

Surface waters necessitate water treatment before consumption to guarantee no health risk is present to the user. Poor quality water which consists of dissolved and suspended particles, can impact and cause health risks to consumers. The most important contamination is the microbiological contamination as it leads to infectious diseases (Water Treatment, 1994). Chemicals such as nitrates and cyanide when contaminate the water cause long-term health risk such as cancer, kidney and liver damages. Physical contamination may also cause a health risk such as eczema as it extends microbial survival (Drinking Water Treatment Chemicals, 2001). The water treatment system is designed to remove the contamination, which includes the suspensions of solids from the water.

During the treatment the final process used is disinfection where many types of disinfectants are used, however ultraviolet radiation and chlorination are the most common types used. Chlorination is believed to be a more suitable process compared to ultraviolet radiation. However, ultraviolet radiation also has many positive processes to produce germ-free water. The treatment process involves the removal of contaminants through a number of stages which include: pre- water treatment, suspension, coagulation and flocculation, sedimentation, filtration, and disinfection which include either chlorination or ultraviolet radiation.

This is called the multiple barrier principle (Water Treatment, 1994). Figure 1: This shows large objects in the surface water being removed as it is passing through the screen. The flow of water is indicated by the direction of the black arrows.

http://www. chemistry. wustl. edu/~edudev/LabTutorials/Water/PublicWaterSupply/PublicWaterSupply. html Figure 1: This shows large objects in the surface water being removed as it is passing through the screen.

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The pre-water treatment begins with the process of screening, in which the site of the water intake is covered by large screens (Casiday, RC 1999). The heavier solid particles move slower than the lighter particles which allow the lighter particles to pass through the screen with the force of the water. However, the larger and heavier particles that move slowly are stopped by the screen as they can't filter through. This leads onto suspension where the small particles that passed through the screen are removed. The water collected is allowed to sit steadily, as the heavy particles settle to the bottom of the tank because they are denser than the water so they sink, while the lighter particles float on top. After the settling is completed the water on top is collected through the outlet on the side of the tank without disturbing the layer of sediment (Casiday, RC 1999).

Figure 3: The structure of a guar gum polymer. http://en. wikipedia. org/wiki/Guar_gum Figure 3: The structure of a guar gum polymer. http://en. wikipedia. org/wiki/Guar_gum The finely dispersed solids that do not settle

are known as colloids which are suspended in the water. Colloids dispersed in water are known as hydrocolloids, which take different states such as gel and sol. Hydrocolloids are irreversible or reversible, meaning they can interchange between states or stay in a single state (About Coagulation and Flocculation , 2009). Most hydrocolloids in the water going through treatment are results of natural sources. Main hydrocolloids include: agar-agar, carrageenan, alginate and guar gum. Figure 2: The structure of an algarose polymer. http://en. wikipedia. org/wiki/Agar-agar

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Figure 4: Negatively charged particles repel each other due to charges on their surface. http://water. me. vccs. edu/courses/env211/lesson9. htm

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The solid particles repel each other, as they are stabilized by negative electric charges on their surfaces, preventing the particles from colliding and producing a larger mass, called flocs, and therefore does not settle. The removal of the colloidal particle from the suspension can be assisted by chemical coagulation and flocculation.

In the coagulation process, the destabilization of colloids occurs by neutralizing the force that separates them. Iron salts and aluminum sulfate ($Al_2(SO_4)_3$) are the commonly used coagulants in water treatment facilities. However, aluminum sulfate ($Al_2(SO_4)_3$) is used more often the reaction can be seen: Aluminum sulfate + Calcium Bicarbonate (already in water)Aluminum Hydroxide + Calcium sulfate + Carbon Dioxide $Al_2(SO_4)_3$ (s) + 3 $Ca(HCO_3)_2$ (aq) 2 $Al(OH)_3$ (s) + 3 $CaSO_4$ (s) + 6 CO_2 (g) (Coagulation and Flocculation Process Fundamentals, 1998) Aluminum sulfate + Calcium Bicarbonate (already in water)Aluminum Hydroxide + Calcium sulfate + Carbon Dioxide $Al_2(SO_4)_3$ (s) + 3 $Ca(HCO_3)_2$ (aq) 2 $Al(OH)_3$ (s) + 3 $CaSO_4$ (s) + 6 CO_2 (g) (Coagulation and Flocculation Process Fundamentals, 1998)

Coagulants neutralize the negative charges of the colloidal particles, preventing them from repelling against each other. This force that attracts the particles is known as the Van der Waal’s force. When the particles stop repelling each other they come closer and due to their motion in water, they collide, so the strength of attraction allows the particles bond together. After, enough particles have combined together, a floc is formed and it settles to the bottom of the tank through sedimentation. The contact time in the rapid mix chamber is typically 1 to 3 minutes (Coagulation and Flocculation Process, n. d). Figure 5: Coagulants are added to water and they form a precipitate. This mass then settles to the bottom by sedimentation. http://www. chemistry. wustl. edu/~edudev/LabTutorials/Water/PublicWaterSupply/PublicWaterSupply. html Figure 5: Coagulants are added to water and they form a precipitate. This mass then settles to the bottom by sedimentation.

Figure 6: Process of Coagulation, flocculation and sedimentation. igure 6: Process of Coagulation, flocculation and sedimentation.

http://www. safewater. org/PDFS/knowthefacts/conventionalwaterfiltration. pdf Flocculation occurs after coagulation when bridges are formed between the flocs and bind the particles into large agglomerates through higher molecular weight polymeric material (About Coagulation and Flocculation, 2009). When bridging occurs the particles combine as different particles are absorbed by segments of the polymer chain. Destabilisation either by bridging or charge neutralisation is caused by anionic flocculants reacting against the positively charged suspension (About Coagulation and Flocculation, 2009). Anionic polymers are mostly used with metal coagulants and salts. Anionic flocculants have a molecular weight which tends to be very high (Coagulation and Flocculation Process Fundamentals, 1998). However, with aluminium and iron type coagulants, low to medium weight cationic polymers are used alone or in combination (Coagulation and Flocculation Process, n. d,).

These usually include inorganic flocculants as alum and also iron compounds that affect the pH coagulation ranges and floc characteristics, similar to alum. Cationic polymers also interact with negatively charged particles or oil. Similarly, cationic flocculants often have high charge density, with molecular weight playing a minor role (Tripathy, TT, 2006). Other types of polymers and flocculants include non-ionic polymers, synthetic flocculants, and natural flocculants. Polymers are several times more expensive than inorganic coagulants but result in cleaner water (Tripathy, TT 2006).

The flocculating agent must be added slowly and gentle mixing should occur. Small flocs allow contact with each other through slow and gentle mixing, which clusters them into large particles. The agglomerate particles can be easily broken apart during the mixing as they are fragile. An overdose of polymers can result the tendency of the floc to float instead of settle as polymers are lighter than water. The flocculated particles are removed through sedimentation, if there is only sufficient density between the liquid and the suspended matter (About Coagulation and Flocculation, 2009).

The process of flocculation ranges from 15 minutes to an hour (Coagulation and Flocculation Process Fundamentals, 1998). Figure 7: Insoluble particles which are suspended in water are left to settle. The heavier particles sink to the bottom and are allowed to sit over time.

Figure 7: Insoluble particles which are suspended in water are left to settle. The heavier particles sink to the bottom and are allowed to sit over time. Sedimentation occurs when water is sent to a settling basin where they let the water sit around and allow the flocculated and coagulated particles to settle to the bottom of the tank. These particles are heavy suspended particles and settle as it is denser than the water (Casiday, RC, 1999). The water is then slowly released into long channels without disturbing the layer of sediment at the bottom. The process usually takes four hours; the larger particles settle faster than the smaller particles, therefore both the large and small particles collide as they settle (Casiday, RC, 1999).

Figure 8: Water containing solid impurities enters through the sand filter which is forced by gravity through the layers of sand and gravel. http://www. technologystudent. com/energy1/watr2. htm Figure 8: Water containing solid impurities enters through the sand filter which is forced by gravity through

the layers of sand and gravel. http://www. technologystudent. com/energy1/watr2. htm Filtration removes particulate matter from water by forcing the water to go through porous media. The filtration used to remove the contaminants and precipitations from the reactions is gravity filtration (Convential Water Treatment, n. d).

The filtration system consists of filters with varying of pores, made up of graded layers of sand with the finest sand at the top, gravel and charcoal at the bottom. Water molecules are pushed through the medium passing through holes and spaces between the sand, gravel and charcoal pieces by gravitational force. Thus, as the water passes through the bottom of the filter it no longer consists of those solid impurities which are stuck in the holes (Water Treatment, 1994). The water is passes into the under drain free of all solids exiting the filter. The filter bed is cleaned through a process called back washing where the flow of water is reversed and solids are removed (Convential Water Treatment, n. d).

Last process that is involved in producing drinking water is disinfection. Disinfection prevents bacteria, protozoa and some viruses into the distribution system. The two most common methods to kill microorganisms in the water supply are chlorination or ultra-violet radiation. Chlorine can be added in three different forms: Chlorine gas, Chloramination, Chlorine-dioxide (Chlorination Chemistry, n. d). All Chlorine processes kill pathogens by breaking the chemical bond in their molecules. The chlorine compounds exchange atoms with other compounds such as enzymes in bacteria and other cells (Disinfectants, 2003).

As the chlorine and enzyme make contact, the hydrogen atoms in the molecule will be exchanged by chlorine causing the enzyme to not function properly and die (Disinfectants, 2003). Chlorine gas is the most pure form of chlorine, consisting of two atoms bonded together. When chlorine gas is added to water these reactions occur: Chlorine + Water Hypochlorous Acid + Hydrochloric Acid (Dr. Houston, 2010) Cl_2 (g) + H_2O(l) HOCl(aq) + HCl (aq)|

The chlorine reacts with water and forms hypochlorous acid which is a weak acid, therefore is dissociates into hypochlorite ions depending upon its pH: Hypochlorous AcidHydrogen Ion + Hypochlorite Ion (Dr. Houston, 2010)HOCl (aq) H^+ (aq) + OCL^- (aq)|

The concentration of HOCI and OCI- are dependent on the water's pH and temperature. They are referred to as free chlorine and at 25°C and a pH of 7. 5, half of the chlorine is HOCI and the second half is OCI-. The formation of extra hypochlorite ions is more efficient at a low pH as hypochlorous acid is more efficient in its free chlorine form (Dr. Houston, 2010). This is because disinfection at a low pH with more hypochlorous acid is efficient rather than a high pH with more hypochlorite ions in water.

Hypochlorite ions are not as pure as chorine gas, therefore more dangerous. Their strength decomposes over time when kept in storage and become ineffective before reacting with bacteria (Chlorination Chemistry, n. d). The free chlorine residual is important as there is chlorine available to kill bacteria as it forms during the storage (Chlorination Chemistry, n. d).

Figure 10: The diagram shows the function of chlorine demand and residual and where each comes into use during the disinfection process. Figure 10: The diagram shows the function of chlorine demand and residual and where each comes into use during the disinfection process.

Chloramination is used when the water contains ammonia or certain amino compounds. The free chlorine reacts with these compounds to form chloramines which are – monochloramine, dichloramine, and trichloramine (Disinfectants, 2003). However, chloramines are hundred times less effective than free chlorine (Disinfectants, 2003).

A chlorine ion replaces a hydrogen ion on the ammonia molecule, which results in a monochloramine Hypochlorous Acid + Ammonia Monochloramine + Water (Dr. Houston, 2010)HOCl (aq) + NH_3 (g) NH_2Cl (g) + H_2O (l)|

Monochloramine than reacts with more hypochlorous acid to form a dichloramine: Monochloramine + Hypochlorous Acid Dichloramine + Water (Dr. Houston, 2010) NH_2Cl(g) + HOCl (aq) $NHCl_2$ (aq) + H_2O(l)|

Lastly, trichloramine is formed when dichloramine reacts with more hypochlorous acid: Dichloramine + Hypochlorous Acid Trichloramine + Water (Dr. Houston, 2010) $NHCl_2$ (aq)+ HOCl (aq) NCl_3 (l) + H_2O (l)|

These disinfecting agents are known as combined chlorine residual as the chlorine is combined with nitrogen. Chloramines have weaker bonds than chlorine, and the ammonia and chlorine bond can be broken down by bacteria, heat and light.

The breakpoint is when the chlorine demand has been satisfied and the chlorine reacts with all the bacteria and ammonia in the water (Chlorination Chemistry, n. d). If extra chlorine is added after the breakpoint it is referred to as breakpoint chlorination as the chlorine and water react to form hypochlorous acid in a direct proportion to the amount of chlorine placed. It is common to add chlorine as it creates some free chlorine residual (Chlorination Chemistry, n. d). The efficiency of the free chlorine decreases over time as ultraviolet rays from the sun are exposed to the water (Pickard, BP, 2006).

Figure 11: The graph shows what happens when chlorine as it is added to water. http://water. me. vccs. edu/concepts/chlorchemistry. html

Figure 11: The graph shows what happens when chlorine as it is added to water. http://water. me. vccs. edu/concepts/chlorchemistry. html

Ultraviolet disinfection is when ultraviolet light is bounded in a transparent protection sleeve and is mounted in a chamber where the water passes through and the ultraviolet rays are projected and absorbed by the stream of water (Disinfection with ultraviolet light, n. d). The ultraviolet light is an energy-rich electromagnetic ray with a wavelength of 200-400 nanometers. The UV light is absorbed by the bacteria and viruses reproductive mechanisms, which reconstructs the DNA of that organism- interrupting the cell division and so it can’t reproduce as it has lost its pathogenic effect. Therefore, the microorganism is dead and the risk of disease is eliminated (Ultraviolet Disinfection, 2000).

Figure 13: DNA strand being rearranged as it absorbs UV light. http://www. wedeco. com/us/expertise/uv-technology/uv-disinfection. html

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Figure 12: The ultraviolet radiation spectrum- displays the range of the wavelength used. http://www. wedeco. com/us/expertise/uv-technology/uv-disinfection. html

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The two disinfection processes both have advantages and disadvantages, but through comparison chlorination appears to be a more suitable process. Chlorination is a disinfectant which is cheap as the installing costs of a chlorination units are $400-500 including material costing $800-1200 (Effluent Disinfection Processes, 2012). Maintenance and labor of the tablet would cost $105-150 per year (Effluent Disinfection Processes, 2012).

Similarly, chlorination is also more efficient and easy to handle. The level of microorganisms in drinking water can be reduced by chlorination. This process eliminates unwanted odors and tastes, also helping removing iron and manganese from raw water. Chlorine not only produces residual between to remove bacteria which grows in storage tanks but is also highly soluble in water (Convential Water Treatment, n. d). Chlorine is easily stored for long periods of times without the risk of getting deterioration.

Measuring the dosage of chlorine that should be added can be easily controlled, minimizing the chance for over or under dosing (Water Treatment in Disinfection, 2008). Likewise, disadvantages of chlorine include the careful handling and storage. Similarly, the explosive nature of chlorine can be hazardous and extra care needs to be taken during storage and handling. An overdose of chlorine may cause a larger residual resulting in bad taste and odour (Water Treatment in Disinfection, 2008). However, these problems are easily controllable and resolved before causing any major problems.

On the other hand ultraviolet disinfection has only a few advantages which include: removing some organic contaminants such as bacteria and viruses but not cysts, leaving no smell or taste in the water and no toxic byproducts are introduced (Ultraviolet Disinfection, 2000). This process also requires little contact time ranging from 10- 60 minutes and allows the microorganisms to become inactive although does not remove them completely (UV water treatment, n. d). Disadvantages are that with high levels of suspended solids, turbidity colour or organic matter-UV radiations are not suitable as it becomes difficult for the radiation to penetrate water (Ultraviolet Disinfection, 2000).

Likewise, non-living contaminants such as lead, asbestos and chemicals are ineffective with UV light. UV radiation is extremely resistant to tough cryptosporidium cysts (Comparison of Treatments and Options for Drinking Water, n. d). During power outages the process of disinfection can be stopped as electricity in needed. The re-growth of microorganisms is considered a risk as it forms during storage and the water is contaminated again (Disinfection of Treated Wastewater, 2002). Ultraviolet disinfection is not as cost effective as chlorination as the installation of UV units and associated facilities are $1000-2000, labor and lamp replacements cost around $120-180, with the addition an electricity bill (Effluent Disinfection Processes, 2012).

The best method of disinfection would be chlorination, to supply suitable drinking water to a large city. Chlorine is very cost effective and doesn't need much handling, Chlorination completes the process of disinfecting till it is clean and continues the cleaning process throughout its storage period to ensure people get hygienic and uncontaminated water to drink. Ultraviolet radiation may also be effective if some areas of disinfecting, but this process has too many needs and doesn't give full satisfaction as bacteria may from during storage. Thus, it can be concluded that chlorination is the most effective way of disinfection.

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