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Exploration of the importance of tertiary treatment in domestic wastewater treatment

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Abstract. This thesis focuses on the essential role of tertiary treatment techniques. It delves into three specific tertiary treatments, which are named Membrane Filtration, Chlorination, and Photo-Fenton, and provides a detailed examination of each technique's process, advantages, and disadvantages. The study on Membrane Filtration outlines its effectiveness in eliminating pathogens and microorganisms and sheds light on cost and maintenance issues. Although chlorination is one of the most favored disinfection methods. It also has its disadvantages such as potential health risks and environmental impact. Considering Photo-Fenton as an environmentally favourable method, the study notes the dependence on sunlight availability and required optimization as limitations. This research heightens our understanding of these treatments, thus emphasizing their role in future water safety, provided advancements are made to enhance efficiency and mitigate limitations.

Keywords: tertiary treatment methods, membrane filtration, chlorination, photo-fenton

1. Introduction

Domestic wastewater treatments play an important role in the human society. Basically, water treatments can be separated into three levels of water processing. The first level is primary treatment, which is the process of solid removal; the second level is secondary treatment, which is the decomposition of bacteria; the third level is tertiary treatment, which is extra filtration of water. Therefore, Different levels of treatment get rid of certain matter inside the source water, from macro to micro matters. Through these levels of processing, the water would become safe for municipal use.

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To be specific, the primary treatment includes coagulation and sedimentation, the physical separation. With the method of primary sedimentation tank, which is gravity-fed, removes the suspended solids or organic matter such as grits and mud clot as they settle down and be filtrated by clarifier. Primary treatment could remove about 50% to 70% of suspended solids, and 25% to 40% of biological oxygen demand (BOD) [1]. The secondary treatment includes suspended-growth systems, the biological decomposition [2]. For example, the aerobic granular sludge (AGS) technology, which serves for dissolved matter removal, gets rid of chemical oxygen demand (COD), nitrogen (N), and phosphorus (P) inside the water through aerobic, anoxic anaerobic layers processes in a single granule with microorganisms [3]. Tertiary treatment is the process of the final purification of the water, which is also known as advanced treatment, includes further biological nutrient removal after secondary treatment.

To generalize the property of tertiary treatment, this treatment is the final disinfection process that is important to the ultimate water quality of water transmitted to domestic users, which is the main focus of this thesis: the authors made an effort in researching, summarizing, and comparing the advantages and disadvantages between various tertiary treatment techniques, therefore presenting the necessity of tertiary treatment in overall domestic wastewater treatment.

2. Three ways used in tertiary treatment

2.1. Membrane filtration

Membrance filtration has the pervasive and common method of pressure-driven. As the water solution is permeating through different membranes with different sizes of pores, thus achieving the physical filtration of the undesired matter. Here are some of the pressure-driven filtrations: micro filtration (MF), ultra filtration (UF), nano filtration (NF), and reverse osmosis (RO). Besides, there are also electrodialysis, gas separation, and pervaporation, which are not the most commonly used method that won’t be discussed in this passage.

Firstly, Pressures between 100 and 400 kPa are generally set for micro filtration modules to function at, which has a pore size on a scale of 1 μm [4]. These pressures enable the removal of bacteria, protozoa, and other debris like sand, clay, and cracks. Secondly, smaller pore sizes allow ultra filtration (UF) to reject bigger dissolved molecules. Thirdly, nano filtration (NF) group of membranes includes those that can reject tiny dissolved molecules and divalent ions. These membranes include pores that are 1 nm in size. Last but not least, reverse osmosis (RO) lacks holes and separates materials based on how quickly various solutes diffuse through the membrane’s polymer. Even monoval

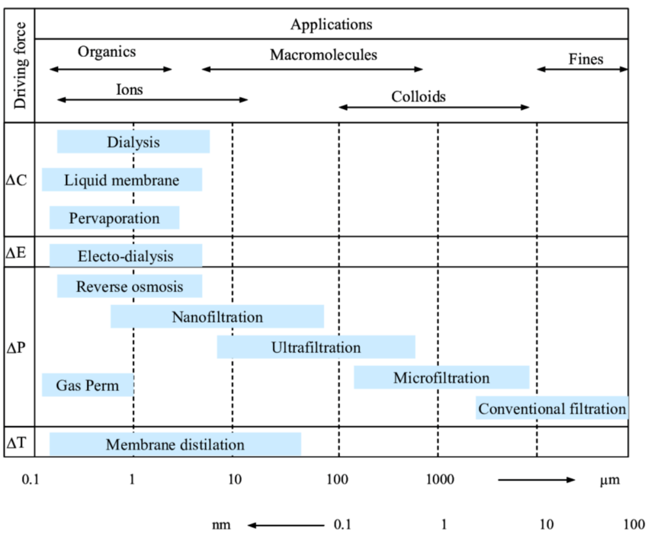

Figure 1. Range of membrane filtration [5].

There are both some advantages and disadvantages of membrane filtration. For advantages, firstly, membrane filtration is largely available from commercial manufacturers, and it has a number of applications: Diverse real-world uses include clarifying or sterile filtration (MF), polymer separation (UF), the removal of multivalent ions and nonionic solutes (ED), the desalination and generation of pure water (RO), and the extraction of salts from polymer solutions [6]. Secondly, it efficiently eliminates particles, suspended solids, and microorganisms by MF, UF, NF, and RO process. Volatile and nonvolatile organics are removed by NF and RO as well, thus the final effluent has high-quality of clearness. For Disadvantages, firstly, membrane filtration is costly for small industries to put into use, the design of membrane would be different according to environment, and energy consumed by constant pressure input is high. Finally, the membrane itself may face the problem of clogging as high concentration of water solution would generate bio-fouling onto the membrane [7].

2.2. Chlorination

2.2.1. Chlorination is extensively employed in tertiary treatment as one of the most favored disinfection methods. The rationale behind its widespread use lies not only in the ready availability of chlorine in gaseous, liquid, and solid forms but also in its ease of application owing to its high solubility in water. Among the three chlorine states, gaseous chlorine stands out as the most cost-effective approach in larger public water treatment facilities, offering economical disinfection. Additionally, when compared to chlorine solutions, gaseous chlorine demands less storage space.

2.2.2. A series of reactions occurs during the chlorination process with chlorides. Hydrolysis takes place when chlorine reacts with water, resulting in the formation of hypochlorous acid and hydrochloric acid.

$$Cl_2 + H_2O \rightarrow HOCl + HCl$$

Sodium hypochlorite reacts with water as follows:

$$NaOCl + H_2O \rightarrow NaOH + NaCl$$

Chlorine reacts with water, producing hypochlorous acid (HOCl), which dissociates to form the hypochlorite ion [8].

$$HOCl \rightarrow OCl^- + H^+$$

2.2.3. There are both advantages and disadvantages to using chlorination in tertiary treatment. Regarding the advantages, as previously mentioned, chlorine is readily available in all its forms and exhibits high solubility in water. Chlorine proves to be the most effective disinfectant for deactivating waterborne pathogens. Moreover, it’s essential to recognize that waterborne diseases were prevalent until the early 20th century. While earlier treatment methods eliminated many contaminants from drinking water, chlorine was the only solution that effectively reduced pathogens in the water supply. Since the widespread adoption of chlorination in the United States, waterborne illnesses such as typhoid, dysentery, and cholera have largely vanished [9]. As for the disadvantages, chlorine has a distinct odor. Furthermore, it can lead to skin irritation, as it opens up pores and strips the skin of its natural oils. This eventually results in dryness, irritation, and itchiness, with individuals with sensitive skin being particularly affected. This is due to excessive chlorine exposure, which can cause skin rashes, redness, and inflammation, potentially developing into blisters with continued chemical exposure [10].

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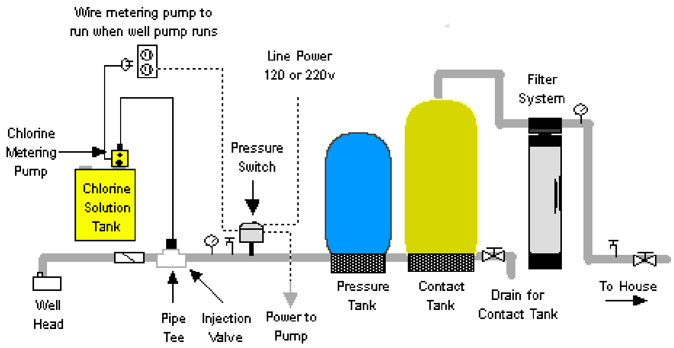

Figure 2. CHLORINATORS | Water Treatment | Waste Water Treatment | Water Treatment Process & Plant Design [1].

2.3. Photo-Fenton

Photo fenton is widely used among the advanced oxidation processes because of its low operational costs. In the study of removing sulfamethazine, the researchers found that this kind of antibiotics is totally degradated, but they also found that the TOC (total organic carbon) reduction reached to 56% [11]; on another study of photo-fenton directed by Trovo, when they use the photo-fenton process, the reduction of amoxicillin is perfect, and the TOC removal reached 81% [12].

It was quite effective of the photo-fenton (using sunlights) that they can easily remove the ARG (aquifer remediation goal) and ARB (anoxic recirculation basin)'s waste. As the research proposed by Miralles-Cuevas, when the combination of NF (nanofiltration) and solar photo-fenton is used, the various kinds of pH, like carbamazepine, flumequine, and so on, can be almost totally removed from the urban wastewater [13]. Moreover, when the process of solar photo-fenton is employed with SBR (sequencing batch reactor), this process can be used to address the concern of the antibiotic wastewater performance, and finally succeed in letting about 89% of the soluble COD decreasing [14].

Not Photo-fenton is more effective in removing the ARG and ARB, but solar photo-fenton is very kind to the environment impact. As the report directed by Rodriguez and co-workers, [15]. when they study the impact to the environment by proposing the LCA (life cycle assessment) into heterogeneous and homogeneous fenton process, they found that heterogeneous fenton emit lower GHG (green house gas) of 0.04 carbon dioxide (aquifer), and when Gallego- Schmid and his co-workers used this data to do further research, [16]. they found that in the acid pH condition, solar photo-fenton addressing the urban wastewater treatment can release about 554 carbon dioxide (aquifer)/1000m^3, which is lower than the operational system in the neutral pH condition.

In this way, considering all the research above, the specializer concludes that this process can be successfully used to make the environment continuous because of their improvement in degradation of recalcitrant pollutants.

2.4. Advantages and disadvantages Comparison

All three methods for water treatment have different advantages and disadvantages. Here is a comparison for those three methods.

First, For Membrane filtration, one of its major advantages is its ability to effectively remove various contaminants, including bacteria, viruses, suspended solids, and certain chemicals. This process ensures the production of clean and safe drinking water. Another advantage is the flexibility of the membrane filtration system, which can be easily scaled up or down according to the specific needs of the water treatment facility. In addition, membrane filtration provides a high level of automation, reducing the need for manual intervention and minimizing operational costs. However, there are some disadvantages to consider. Membrane filtration systems are relatively expensive to install and maintain, requiring regular cleaning and replacement of membranes. The pollution of organic matter or scale on the membrane will reduce the efficiency of the membrane and increase the operating cost. In addition, membrane filtration may not be effective in removing certain contaminants, such as dissolved salts or certain organic compounds. In such cases, additional treatment processes may be required, increasing the complexity and cost of the entire water treatment system.

Second, Chlorination is a commonly used method for water treatment. It is a powerful disinfectant that can kill a wide range of harmful microorganisms, including bacteria, viruses, and parasites. It helps to prevent the spread of waterborne diseases and can provide residual protection by remaining in the water distribution system, preventing the growth of microorganisms and ensuring the water remains safe during storage and distribution. Also, Chlorine is relatively inexpensive and widely available, making it a cost-effective option for large-scale water treatment which is still being commonly used.

However, Chlorine can react with organic matter in water to form disinfection byproducts, such as trihalomethanes (THMs) and haloacetic acids (HAAs). Some of these DBPs are known to be carcinogenic and can pose health risks. Then Chlorine can impart a noticeable taste and odor to the water, which some people find unpleasant. This can affect the overall acceptability of the treated water. Also, Environmental impact: Chlorine can have adverse effects on aquatic life and ecosystems when discharged into the environment. It can harm fish and other organisms in water bodies. And even though chlorine is effective against many microorganisms, it may not be as effective against certain pathogens which has a protective outer shell that can resist chlorine disinfection [17].

Furthermore, Photo-Fenton is also a good choice for domestic water treatment, it is a powerful oxidation process that can effectively degrade a wide range of organic pollutants in water. It can break down complex organic compounds into simpler and less harmful substances. This method can be applied to treat various types of water pollutants, including organic dyes, pesticides, pharmaceuticals, and industrial wastewater. It offers versatility in addressing different types of contaminants. The reaction rate of Photo-Fenton is relatively fast, allowing for efficient treatment of contaminated water within a shorter time frame compared to some other treatment methods. It utilizes natural sunlight or artificial UV light as the energy source, eliminating the need for additional chemicals in the treatment process. This can reduce the overall chemical usage and associated costs.

However, Photo-Fenton relies on the availability of light sources, whether natural sunlight or artificial ultraviolet light, to activate the process. This dependence may limit its applicability in areas where sunlight exposure is limited or artificial UV rays are not readily available. The efficiency of photofenton is affected by water quality parameters such as pH, temperature, and the presence of certain ions. In order for the process to work effectively, optimum conditions need to be maintained. The oxidation process in photofenton produces sludge, which requires proper treatment and disposal. Sludge management adds complexity and cost to the overall treatment process. If artificial ultraviolet light is used as a light source, it consumes a lot of energy, resulting in higher operating costs compared to natural sunlight.

When considering the use of photo-fenton for water treatment, it is important to evaluate these advantages and disadvantages in the context of specific water quality and treatment requirements. Proper optimization and monitoring are essential to ensure the effectiveness and efficiency of the process.

3. Conclusion

In our daily life, water is becoming more and more necessary for our daily life, and as the technological progress has greatly boosted, the tertiary treatment for the daily wastewater is becoming better and efficient. Although there might some advantages or disadvantages for different kinds of tertiary wastewater treatment, but we ultimately believe that as people can use them more and more proficient and effective, the wastewater treatment can be finally better and better, which will boost civilization for a future better life.

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