Treatment and Recycling of Wastewater From Food Industry using Fixed-Bed Adsorption Treatment on the Tertiary Stage

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Abstract. Water pollution occurs when toxic pollutants of varying kinds (organic and inorganic) are directly or indirectly discharged into water bodies without adequate treatment to remove such potential pollutants. Today’s sources of these potential pollutants, which cause high deterioration of freshwater quality, are industrial waste discharge, and industrial waste disposal practices. Therefore, the development of wastewater treatment processes to alleviate water pollution has been challenging and demanding. Food wastewater was characterized using COD, DO, Turbidity, pH, TS, TDS, and TSS. Comprising a mixture of areas including physical, and chemical methods to remove various potential pollutants. In this study, coagulation, sedimentation, and adsorption treatment were used to remove the pollutants contained in wastewater and also the treated water recycled back to the food processing industry. In addition, Superpro Designer Software was used to design a water recycling system that successfully meets the requirements of the standard A Regulation on Malaysia Environmental Quality.

1. Introduction

The consumption of water is very important to all organisms living on this planet including human beings. Water covers about 71% of the earth’s surface and the 97% of that 71 % is dominated by the ocean, 2.4% by glaciers and polar ice caps, and finally 0.6% by lakes, rivers, and ponds. Since water covers most parts of the earth it does comes with a great disadvantage which is the turning of pure water into wastewater. Human’s daily activities have affected water’s quality since previous decades. Wastewater discharged from residential areas where the main source involved are the people living in the area, food industry which comes under certain companies, and agriculture which can be related to a private or government organization, possibly contains contaminants with higher concentrations. This what makes the issue of wastewater even worst.

Wastewater should be treated properly because it has the capability to contaminate the environment. This point should be stressed especially for certain industrial activities where their production of wastewater is very high and sometimes uncontrolled. Industries which directly contributes to wastewater issue are food processing, pulp and paper, wool processing textile dyeing, dairies and farms, and breweries [1]. Wastewaters which are released from the industry are totally different in chemical and physical properties, treatment method, level of toxicity, and mostly must undergo a process called pretreatment before being released to the environment. Based on this research, food processing wastewater was chosen and it is very much different from all other wastewater from different industries. It is different especially degradability and toxicity, basically, food processing wastewater will have zero toxicity and it can be degraded easily. But, a high concentration of biochemical oxygen demand (BOD) and total suspended solids (TSS) gives a disadvantage to the food processing type wastewater [2]. The main objective is to generate profit and to recycle the water of the wastewater stream. According to recycle and reuse theme, water will be recovered, recycled, and reused back within the food manufacturing system.

2. Experimental Materials and Methods
2.1. Coagulation Treatment
400 mL of the wastewater sample was poured into a 600 mL glass beaker. Then, the pH meter electrode was placed in the aqueous Al\(_2\)(SO\(_4\))\(_3\) (1M) solution and mix using jar test until it undergoes dispersion. The wastewater was mixed for 5 minutes rapidly at 150 rpm, afterward, slowed down for 30 minutes at 80 rpm and kept for 5 hours. The supernatant liquor was collected and analyzed for the COD value. The steps were repeated for different dosages of the coagulant. Settling and filtration characteristics of the slurry were analyzed to correct the sample turbidity.

2.2. Sedimentation Treatment
The simplest form of sedimentation treatment proceeds after the coagulation treatment which the beaker was left for one or two days for particles to settle down and then the resulting wastewater was collected without the sediment. Finally, the parameters in the wastewater were analysed.

2.3. Column Adsorption Treatment
The cotton fiber was placed at the end of the clean and dry adsorption column. Activated carbon was used as the adsorbent and the column bedheight was fixed to 4cm. Then the food wastewater sample was slowly poured through the filter funnel. The column effluent was collected at different intervals to determine the COD.

3. Results and Discussion

3.1. Raw Wastewater and Treated Wastewater
The criteria that characterized food wastewater were physical, biological and chemical compositions. The result of raw wastewater and the treated wastewater was measured and demonstrated in Table 1.

| Parameter          | Raw Wastewater | Primary (Coagulation) | Secondary (Sedimentation) | Tertiary (Adsorption) |
|--------------------|----------------|-----------------------|---------------------------|-----------------------|
| pH                 | 6.83           | 6.85                  | 6.81                      | 7.03                  |
| Turbidity (NTU)    | 515            | 480                   | 133.67                    | 66.6                  |
| DO (mg/L)          | 14.8           | 8.40                  | 5.20                      | 1.83                  |
| COD (mg/L)         | 1412           | 1695                  | 1583                      | 1125                  |
| TS (mg/L)          | 1              | 39                    | 38                        | 46                    |
| TDS (mg/L)         | 5              | 31                    | 27                        | 53                    |
| TSS (mg/L)         | 2.14           | 2.00                  | 1.37                      | 0.67                  |

The summary of the wastewater presented in figures 1 and 2 is based on the data calculated from each treatment. It clearly shows that the waste removal from wastewater was higher in every treatment. Based on figure 1, the reading of raw wastewater showed the pH value was 6.83, slightly acidic. A pH scale technically measures the logarithmic concentration hydrogen (H\(^+\)) and hydroxide (OH\(^-\)) ions which are water composite H\(^+\) + OH\(^-\) = H\(_2\)O [3]. In the coagulation treatment, pH control is important for flocculation generation [4] and affects the coagulation performance [5]. It is frequently effective at pH 5–7, but the nature of the wastewater can lead to certain differences in the pH level [6]. Sometimes it depends on the coagulant type; for example, alum can be efficient to reduce wastewater pollutants over a relatively broad pH range of 6–8 [7]. The pH conditions for alum coagulation are generally favorable between pH 6–7 [8]. It showed pH 7.03 during adsorption treatment due to removal of the suspended solids in wastewater and the water become clearer.
From the result table 1, it shows that dissolve oxygen value is 14.8 mg/L which higher than the National Water Quality Standard for Malaysia. Conversely, as the wastewater becomes fresher lower salinity, more oxygen can dissolve into the water [9]. Based on figure 1, it clearly shows that dissolved oxygen removal happens when increasing the alum coagulant. As increase the amount of alum coagulant dose, the higher the dissolved oxygen removal occurred. The process uses dissolved oxygen when the algae die and decompose [10]. During the sedimentation experiment, the alum coagulant keeps too longer, so the flocs settled down at the bottom of the beaker and then filter the sample measured again the DO reading it shows higher DO removal occur. However, few data on the dissolved oxygen kinetics of adsorption are available. The dissolved oxygen adsorption to activated carbon has been studied [11].

The results had shown that 10 mL of wastewater contains 1 mg/L of total solids. The main reason for lower total solids concentration because of others open and close the oven all the time might affect the result. After the coagulation, the total solids increase to 39 mg/L. When more alum coagulant added, the amount of total solids increased in wastewater. The total solid concentrations are conventionally divided into suspended solids and dissolved solids. A 0.45 mm filter has historically been used to differentiate between dissolved and suspended solids [12]. A slow mixing process called flocculation is preceded by plain sedimentation. The objective of flocculating is to help coagulate particles to collide and adhere in order to become larger, settle down the particles and to reduce the distribution of particle size as much as possible. The highest value of total solids shown in adsorption treatment because first few samples collected to check for COD analysis, after that only collect wastewater for testing TS, TDS, and TSS. So, the contaminants inside the adsorption column increasing, the amount of total solids also higher.

The sum of the cations (positively charged) and the anions (negatively charged) in wastewater is the total concentration of dissolved solids [13]. The results showed a 5 mg/L total of dissolved solids for the 10mL wastewater. Wastewater with very low TDS can be corrosive and corrosive wastewater can leak toxic metals like copper and lead from industrial. This also indicates the presence of trace metals at levels which could pose health risks [14]. In chemical coagulants, the TDS value increase as the dose of the coagulant increased. The total dissolved solids showed lower reading because the activated carbon efficiency becomes low not enough energy to reduce containments in wastewater. Heavy metals and other toxicants enter the soil which is irrigated with polluted waters and show toxic effects on plants and animals [15].

Suspended solids consist mainly of sand and grit approximately 70% of organic solids and 30% of inorganic solids [16]. Based on the results, the measurements show 2.14 mg/L suspended solids present in 100mL of wastewater. In coagulation treatment, total suspended solids are particles found in wastewater that are greater than 2 microns larger. Anything less than 2 microns average size of a filter is considered a solid dissolved. The most suspended solids, though bacteria and algae, consist of inorganic materials. Used aluminium sulphate to achieve TSS removal efficiencies of 65% and 32% respectively [17]. As a result, the sedimentation rate focuses on the surface of the deposition basin. Suspended particles are eliminated through sedimentation depending on size and specific gravity. If its specific gravity is similar to the water, suspended solids held in a filter could remain in suspension, while very dense particles passing through the filter may settle. The high capacity to adsorb such compounds resulting from wide surface area and porosity has led to the use of activated carbon to remove contaminants from wastewater. These contaminants produce bad tastes and odors and can also cause infection. Activated carbon can effectively remove over 99% of total suspended solids.
The COD reading of raw wastewater is 1412 mg/L. The higher levels of COD mean more organic oxidants in wastewater that reduce the dissolved concentrations of oxygen. After the coagulation treatment, the COD reading increased compared to raw wastewater. This is because effect of the coagulant, each coagulant has different behaviour from other coagulants. In this case, used aluminium sulphate coagulant, but the PAC was good in COD reduction and colour reduction. During the sedimentation treatment, most of the bacteria and other suspended solids have been removed from the wastewater so the amount COD is reduced. The removal of pollutants from wastewater by using adsorption granular activated carbon (GAC) in fixed beds is an important industrial wastewater treatment process [18]. This is the reason the amount of COD reduced in adsorption treatment better than other treatments. Activated carbon was used to remove highly odorous dissolved organic compounds from industrial wastewater [19]. It actually changed the colour of the wastewater and completely removed the odor of wastewater after adsorption treatment.

Based on the figure 2, it clearly shows that the turbidity of raw wastewater was higher before the treatment. After undergoes several treatments, the turbidity of wastewater started to reduced. The most effective turbidity removal occurred in sedimentation and adsorption treatment. However found low alum dose in virus removal not effective [20]. Similarly, sedimentation may lead to several removals of bacteria. The greatest protection against virus or bacterial pollution is adequate disinfection. The removal of particles makes sure the process of disinfection is adequate. In some cases such as Giardia lamblia, microbial organisms can be relatively resistant to chlorine. The transport of these species through the treatment of wastewater is prevented by adequate sedimentation. Not only increases the alum coagulant dosage can remove the turbidity but when using granular activated carbon also can achieved a minimum of 80% turbidity removal [21].
3.2. Design of Wastewater Recycling System

There are many software to design a wastewater recycle system. The SuperPro Designer has been selected as the best designer in this case because it allows modelling, assessing and optimizing every type of treatment of wastewater and water purification. But it is also a tool for evaluating pollution prevention and control options, and for sustainable development, and is also the SuperPro Designer that handles a wide range of chemical production processes.

First, new components must be registered in the system before the design is carried out. All parameters used in the laboratory experiments such as pH, DO, COD, turbidity, TS, TDS or TSS are the component chosen for this case. In the Figure 3, it clearly shows the overall design of wastewater treatment and recycling system.

At first, the raw wastewater and aluminium sulphate enter the coagulation treatment tank. Then, included all the operation data information in the system. It calculated and started to remove the waste from the coagulation tank and clean water passed to the sedimentation treatment tank. In sedimentation tank, there only two operations available either clarify and hold. The clarify operation has been chosen and starts to remove the unnecessary particles in the sedimentation tank. Then, it separated the sediment waste and clean water passed to adsorption treatment 1. In the first adsorption column, the operation sequences added such as transfer in, charge in, split, and transfer out. Then, updated the information in operation data. Data is calculated and started to remove the waste from adsorption column 1. Another
adsorption column added in this system because COD reading is higher. After adding the adsorption column 2, the COD reading started to reduce. It separated the waste from adsorption and clean water (which can be recycled to the food industry). The recycled water fulfilled the requirement in Environmental Quality Industrial Effluents Regulation 2009 which meet standard A.

In the figure 4, it shows that the raw wastewater data from superpro designer and experiment result is similar. The results for COD is 1412.5 mg/L, DO is 14.8 mg/L, pH is 6.83, TS is 1 mg/L, TDS is 5 mg/L, TSS is 2.14 mg/L, and water inlet is 993.09 g/L. For the turbidity, the experiment result is 515 NTU and for superpro, it has to convert the unit so it calculated 1 mg/L is 3 NTU, 515 NTU is 171.67 mg/L, then it covert to 0.17167 g/L.

![Fig.4: Raw Wastewater Concentration]

In the figure 5, it shows that the treated wastewater data from superpro designer and experiment result is different. This is because added two adsorption column in superpro software but in experiment only use once. According to the superpro data analysis, the COD is 70.5 mg/L, DO is 1.67 mg/L, pH have been removed because effect other values, turbidity is 41.52 NTU, TS is 53270 mg/L, TDS is 51240 mg/L, TSS is 3.34 mg/L, and water outlet is 890.11 g/L. For the experiment result, the COD is 1125 mg/L, DO is 1.83 mg/L, pH is 7.03, turbidity is 66.6 NTU, TS is 46 mg/L, TDS is 53 mg/L, and TSS is 0.67 mg/L. According to the overall analysis, only the amount of TS and TDS are at high level in water recycle stream. However, TS and TDS amount can be reduced through another treatment option which known as reverse osmosis, carbon filter membrane or deionization process. This equipment was not recommended for this wastewater treatment process due to high equipment and maintenance cost as well as time consuming. Since the TS and TDS was not listed in Malaysia Standard Requirement, so it can be disregard as it does not harm and affect recycle water in final treatment process.

![Fig.5: Treated Wastewater Concentration]

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Conclusion

The study has successfully treated the wastewater from the food industry and also have designed the water recycle system to the food industry. The food wastewater was characteristics using COD, DO, pH, turbidity, TDS, and TSS. There are many treatment available such as chemical, physical and biological treatment but only certain treatment have been selected to treat the wastewater. Superpro designer software is the best choice used to design a wastewater recycling system. The first adsorption column showed a very high amount of COD. Additional adsorption column added to the design then the COD amount reduced to 95% which achieved the Environmental Quality Industrial Effluents Regulation of standard A.

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