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Evaluation of Kitchen Wastewater with Additives

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Abstract. Kitchen sinks generate wastewater containing several pollutions including detergents, food particles, microorganisms, etc. When the possibility of reuse, environmental and health issues are concerned; the characteristics of this portion of sewage are considered important. In several municipal organizations, the wastewater produced in kitchen sinks is simply released into the environment which can cause several health and environmental issues and thus the effluent is required to be treated. Additives are able to improve the wastewater quality during treatment processes. This study is devoted to identify suitable additives for kitchen wastewater treatment. For this purpose, two types of additives have been selected: Baking soda which plays an important role in pH adjustment and Kombucha fungi which can be applied as a biological additive. The laboratory experiments have been conducted to measure indicator parameters including BOD_5, COD, Solids and Hardness. Based on Malaysian effluent standards, the level of BOD_5 and COD in UCSI cafeteria wastewater exceeds the limitations and thus it is required to be treated before releasing to the environment. Kombucha fungi and baking soda can be both effective for BOD5 and COD removal. However, baking soda is more efficient to treat the sewage with respect to BOD pollution.

Keywords: additive, BOD, cafeteria wastewater, COD, Total Solids

1. Introduction

Nowadays, wastewater is of great concern in modern societies and since our food, environment and health are greatly affected by the soil and water quality, the final disposal of wastewater calls for the integrated understanding of the possible consequences to the environment, public health and also the direct or indirect use for agricultural practices and other domestic uses. For this reason, the treatment processes are designed to achieve wastewater quality improvements based on national standards and expectations. Additives are able to enhance the improvement of wastewater quality during treatment processes. The influence of many types of additives is demonstrated by several studies. However, the selection of suitable additive for wastewater quality improvement depends on the wastewater source of generation and characteristics. In this study, the effect of two different low cost additives on cafeteria wastewater quality is investigated and the most appropriate additive is selected [1], [2].

The wastewater with no input from toilets is called grey wastewater which is related to wastewater generated in showers, hand basins, bathtubs, laundry machines and kitchen sinks in household, schools, office buildings, etc. The composition of grey wastewater depends on some factors including the installations and sources from where the water is drawn. The origins of chemical compounds in grey wastewater include washing, household chemicals, cooking and the piping. Generally, lower levels of organic matters and nutrients are existed in greywater compared to ordinary wastewater when there are no faeces, toilet papers and urine. Dishwashing detergents and other household chemicals contribute to the highest Chemical Oxygen Demand (COD). Each type of grey wastewater is suitable for specific type of reuse. Therefore, based on the types of grey wastewater and the intended use of the water, different types of pretreatment may be required [3]. The grey wastewater from kitchen sinks could include clay and sand from the rinsing of

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vegetables, etc. The concentration of total solids has large variations and ranged between 113 to 2410 mg/l where the origins for the highest values are the sink and an automatic dishwasher machine in the kitchen. Kitchen generates grey wastewater with the highest levels of nitrogen [3].

Suitability of wastewater for re-use or disposal is assessed by laboratory test methodologies called wastewater quality indicators. These tests are selected to be implemented based on the source of wastewater generation and the purpose of re-use. Biochemical Oxygen Demand (BOD) measures the readily biodegradable fraction of the organic load in water and hence, it is one of the most widely used criteria to assess water quality [4]. Chemical Oxygen Demand (COD) is also one of the most commonly utilized parameters for controlling water quality which represents the organic pollution. Using additives, enhancers, or simulators for a septic system is developed due to the recent interests in wastewater treatment and disposal. Based on Presley, D. and Powell, M. (2009), additives can be used in a septic system to accelerate digestion of organic solids; prevent system failure; break up scum; improve settling through coagulation; liquefy or gasify the solids in a septic tank; rejuvenate stressed bacterial populations in the septic tank and increase settleability of solids in the septic tank [5]. Generally, septic system additives are performing either a chemical or biological function. Sodium hydrogen carbonate (NaHCO3), which is known as sodium bicarbonate or baking soda, is a white color crystalline solid that often appears as a fine powder.

Baking soda keeps the pH of water near neutral pH level, which is considered as an ideal condition for the beneficial bacteria to break down and digest the organic wastes in domestic wastewater. PH adjustment together with chemical and physical processes causes the pollutants to form flocs and subsequently be removed [6]. Sodium bicarbonate also affects denitrification process. Since pH has a significant effect on the efficiency of denitrification process, controlling pH can improve the performance of denitrification process. Besides, different species of bacteria have different optimum pH values at which they function to their best, and there is no certain effective range of pH for all the strains [6].

The by-product obtained during tea fermentation by Kombucha culture is called tea fungus which represents a microbial symbiosis of aerobic bacteria and yeasts in floating cellulose mat produced during microbial growth. Bacteria and yeasts of the tea fungus (Kombucha) colony are arranged within the cellulose network in bands and layers. Tea fungus contains 17.9% of crude protein, 12% of crude fiber, 4.4% of crude lipid and 2.6% of ash, calculated on dry matter [7]. Waste tea fungal biomass is a potential bio-sorbent for chromium (Cr) and copper (Cu) ions in aqueous solutions. This study is aimed to investigate the effect of Kombucha mat on domestic wastewater quality indicators.

2. Materials and Methods

The study on wastewater quality and characteristics is based on experimental methodology which uses the manipulation and controlled testing to collect the research designs. In this project laboratory or controlled experiments was conducted in a well-controlled environment to guarantee accurate measurement. These experiments were applied for measuring UCSI cafeteria wastewater quality before and after remedies. The term” remedy” in this study is the addition of common consumer products for improvement of wastewater quality.

In order to evaluate the need for treatment, laboratory experiments were conducted to measure cafeteria wastewater quality parameters including Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), total solids, total dissolved solids and total suspended solids and the results were compared with Malaysian Effluent Standards (Malaysian Act 1974). After that, the effluent was divided into smaller groups and each group was tested with one type of additives in various doses and contact hours. The quality of these samples was compared to the quality of raw effluent and finally the most suitable additive and its most efficient dosage were recommended.

2.1. Preparation of Additives

100 ml of sample was poured into a beaker and 1 g of sodium bicarbonate was solved into 50ml distilled water to provide 20 g/l sodium bicarbonate solution. This solution was added to the samples in different quantities to provide the intended doses. In the other hand side, small part of Kombucha fungi was cut and

rinsed thoroughly with adequate amount of distilled water to make the culture free of media components. The fresh mat was cut into smaller pieces and the weights were recorded.

2.2. Evaluation of Major Parameters

UCSI university cafeteria located at Cheras, Kuala Lumpur, was selected as the source of wastewater generation for this study. Samples were collected from well-mixed areas of the sink and the containers made of materials which are resistant to rusting and corrosion were used for collecting the samples. To prevent built up such as grease and scum from contaminating samples, the sample containers were cleaned thoroughly on a regular basis and the leak-proof tops were used for storage containers. All the samples were kept at or below 40C. However, the freezing was avoided.

Wastewater quality measurements were started as soon as possible since biological activities will continue after a sample has been taken and during handling and storage some changes may happen. After collecting raw samples, the quality of each sample was determined by measuring the major parameters. Biochemical Oxygen Demand (BOD) was evaluated by using DO meter and pH was recorded at each interval. 5 days incubation was required for determination of final oxygen content. Although, the experiment was time consuming, it was considered more economic. Evaluation of chemical Oxygen Demand (COD) was implemented by colorimetric method using COD digester and colorimeter. Consuming COD reagent was expensive. However, faster results were achieved. Same method was applied for measuring hardness. Calcium and magnesium indicator, alkali and one drop of EDTA (Ethylenediaminetetraacetic acid) and EGTA (Aminopolycarboxylic acid) were used as the reagent and carbonate hardness were determined using colorimeter. Gravimetric method was selected for determination of solid contents. Filtration of the samples was the base of this experiment. 50 mm circular filter paper and evaporating dishes are the examples of the relevant equipment in this test.

3. Results and Discussions

3.1. Biochemical Oxygen Demand (BOD)

Table 1 indicates the effect of baking soda on BOD removal. Among the samples represented below, sample 3 was more affected by baking soda. The results obtained for sample 3 were similar with the other samples regarding to some aspects. For instance, although the highest removal percentage was achieved by the addition of 0.8 g/l sodium bicarbonate in 30 minutes, another high rate of BOD_5 removal was related to 0.8 g/l baking soda which has been reacted with the sample for 50 minutes. This dosage with similar contact time can be also considered effective for Sample 1 and 2. The next high BOD removal rates were 81.62%, 80% and 76.22% which were respectively related to 0.6 g/l (50 minutes), 0.6 g/l (40 minutes), and 0.8 g/l (40 minutes) of sodium bicarbonate. Fig. 1 displays the effect of sodium carbonate dosage and contact hours on BOD_5 respectively.

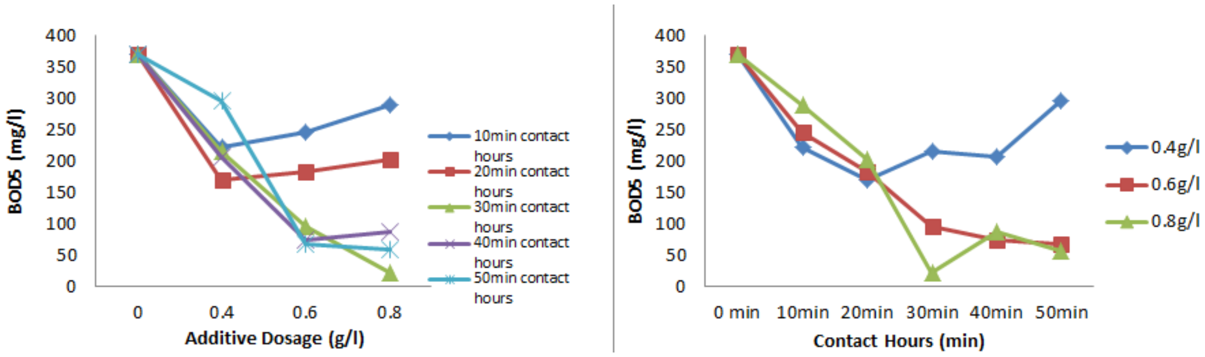

Fig. 1: The effect of sodium bicarbonate on BOD_5 (Sample 3)

Baking soda or sodium bicarbonate is able to neutralize the acidity of water, increase its alkalinity and finally keep the pH of water near neutral. Alkalinity can improve flocculation. This is because when the coagulants react with bicarbonates which bond with colloidal particles, the flocs can be formed and the suspended matters will be trapped. Wastewater treatment need to be operated in optimal pH range (near neutral) to increase the removal efficiency of COD, BOD_5, total solids and color and thus adding sodium bicarbonate for neutralization can be effective [8]-[10].

Table 1: The effect of baking soda on BOD removal

Additive Dosage (g/l)	Contact Hours (min)	pH			Removal Percentage (%)		
		Sample1	Sample2	Sample3	Sample1	Sample2	Sample3
0	-	7.5	7.4	6.6	-	-	0
0.4	10	7.2	7.5	7.6	31.58	28.80	40.00
0.6	10	7.3	7.8	7.8	-	68.00	33.51
0.8	10	7.4	8.1	8.1	45.03	12.00	21.62
0.4	20	7.4	8.0	8.1	16.37	55.60	54.05
0.6	20	7.4	8.2	8.2	43.86	62.40	50.27
0.8	20	7.5	8.3	8.3	35.09	87.20	45.41
0.4	30	7.5	8.1	8.3	60.23	44.80	41.62
0.6	30	7.6	8.2	8.3	38.01	61.60	74.05
0.8	30	7.7	8.3	8.4	35.67	53.60	94.05
0.4	40	7.6	8.2	8.4	40.94	50.40	43.78
0.6	40	7.7	8.2	8.4	47.37	62.40	80
0.8	40	7.8	8.3	8.4	56.14	59.20	76.22
0.4	50	7.7	8.2	8.4	25.73	48.40	20
0.6	50	7.7	8.2	8.5	35.67	48.40	81.62
0.8	50	7.8	8.3	8.5	59.06	52.00	84.32

Table 2: The effect of Kombucha on BOD removal

Additive	Kombucha						
Sample No.	Contact Hours (min)	pH	Additive Dosage (g/l)	DO Reading (mg/l)	5 Days Do Reading (mg/l)	BOD_5 (mg/l)	Removal Percentage (%)
1	-	6.3	0	6.31	5.18	113	-
2	60	7.0	2	6.31	4.73	158	-
3	60	7.9	4	5.59	5.05	54	52.21
4	60	7.2	6	5.98	4.23	175	-
5	60	8.6	8	6.28	5.35	93	17.70
6	120	6.2	2	5.71	4.71	100	11.50
7	120	6.2	4	5.59	4.49	119	-
8	120	6.4	6	5.57	4.52	105	7.08
9	120	6.7	8	5.57	4.24	171	-

Fungi are able to adapt to severe environmental constraints and to produce a large variety of organic acids, extracellular proteins and other metabolites. Destruction or removal of effluent ingredients including inorganic nutrients, metals and organic compounds is the other capability of fungi. The nutrient and carbon sources inside domestic wastewater can be removed by fungi biomass. Based on Thanh and Simard (1973), fungi biomasses can remove ammonia, phosphate, Chemical Oxygen Demand and total nitrogen at a rate of 73.3%, 84.1%, 39.3% and 68.1% respectively [11]. During the late 1950s to the middle 1960s, fungi were recognized effective for bio-purification of wastewaters. Since the fungi has the ability of degrading complex polymers including lignin materials, cellulose, hemi- cellulose and produce high value fungal biomass, it is considered efficient for treating food-processing wastewater. Enhancing Settlement and dewatering of domestic wastewater sludge due to the filamentous nature of fungi, is one of the effects of fungal treatment. Furthermore, the fungi would not act as an opportunistic pathogen. This is because of the obligatory acidophilic property of fungi [12]. Fungi produce protein, enzymes and other bio-chemicals which a wide range of bio-chemicals and enzymes are able to metabolize complex carbohydrates including starch more effective than bacteria. Fungi are able to grow at low pH. Therefore, the need for increasing the pH of many acidic food-processing effluents can be eliminated during treatment. Besides, the bacterial contamination can be minimized [12].

Based on table 2, and fig. 2, few concentrations of Kombucha could remove BOD_5 within certain contact hours. One of these concentrations was 4 g/l which decreased BOD_5 from 113 mg/l to 54 mg/l and removed BOD_5 up to 52.21% within one hour contact time. 8 g/l of Kombucha within one hour, 2 g/l and 6 g/l in two hours contact time were also able to decrease BOD_5 to 93 mg/l, 100 mg/l and 105 mg/l respectively. The removal percentage of BOD_5 for 8 g/l, 2 g/l and 6 g/l of Kombucha fungi were 17.70%, 11.50% and 7.08% respectively. However, it seems that the trend of BOD changes is regardless of additive dosage and contact hours.

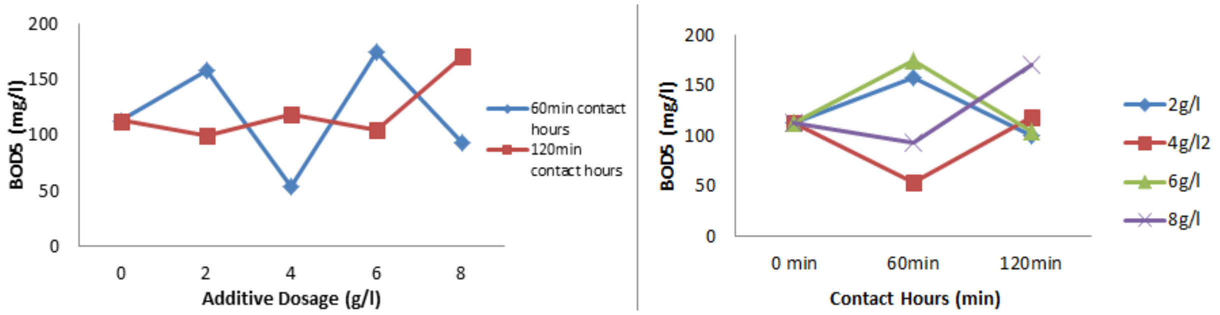

Fig. 2: The effect of Kombucha on BOD_5 (Sample 3)

3.2. Chemical Oxygen Demand (COD)

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are both a measure of dissolved oxygen in wastewater. Although, COD measurement is faster, BOD is considered more economical. The reason is COD measurement requires COD reagent and the reagent is considered expensive, while BOD test is cheap and does not require any chemical reagent and special facility. Thus in this study the effect of additives on dissolved oxygen were tested using BOD method for several additive concentrations and contact hours. COD test was only conducted for the most effective concentrations of additive and the most suitable contact time. Based on the BOD test results, 0.8 g/l of baking soda can give the best removal results in 30 minutes contact time. Besides, 4 g/l can be considered the most effective Kombucha dosage which is able to improve sample quality with respect to dissolved oxygen in 60 minutes period. Based on the results, both additives were able to decrease COD from 404 mg/l to a low concentration which was over range. This issue proves that selected concentrations of baking soda and Kombucha are able to remove COD pollution with a high percentage.

3.3. Solids

Fig. 3 shows that 0.4 g/l and 0.6 g/l of sodium bicarbonate are able to remove Total Solids (TS) and Total Dissolved Solids (TDS). 0.4 g/l and 0.6 g/l of baking soda decreased TDS level from 1.8 mg/l to 1.5 g/l and 1.2 g/l respectively. The removal rates were 16.67 % for 0.4 g/l and 33.33% (0.6 g/l). By the addition of 0.4 g/l, the value of TS remained constant. However, 0.6 g/l of baking soda could decrease this value from 1.6 mg/l to 1.1 mg/l (31.25% removal).

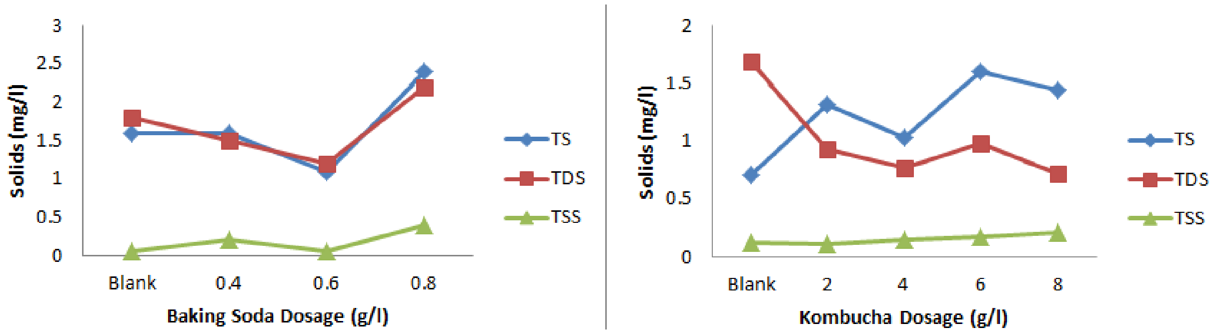

Fig. 3: The effect of additive dosage on solids

The level of Total Suspended Solids (TSS) is too low for this sample. TSS for blank sample is 0.05 mg/l. This value increased to 0.2 mg/l by the addition of 0.4 g/l of baking soda. Addition of 0.6 mg/l sodium bicarbonate could not change the level of TSS for this sample and the concentration of 0.8 g/l even added TSS level to 0.4 mg/l. Based on figure 3, it can be concluded that Kombucha is able to remove Total Dissolved Solids. 2 g/l, 4 g/l, 6 g/l and 8 g/l of Kombucha removed 44.38%, 54.44%, 42.01% and 57.40% of Total Dissolved Solids respectively. This can be caused by the ability of Kombucha culture in adsorption of dissolved solids. Higher concentrations of Kombucha fungi resulted in higher level of separated suspended solids. Total Solid level changed from 0.105 mg/l to 0.21 mg/l by the addition of 8 g/l Kombucha culture which means an upward trend in TS value. However, it seems that the level of Total Solids (TS) has no significant relationship with the additive dosage.

3.4. Hardness

The results and the related graphs (Fig. 4) indicate that hardness can be removed by the addition of sodium bicarbonate. 0.8 g/l of additive within 40 minutes can remove hardness completely up to 100%. The results show that hardness changed from 2.705 mg/l to zero by the addition of 0.8 g/l baking soda. The other conditions also can remove hardness. 0.8 g/l of sodium bicarbonate is able to remove hardness up to 5.73% when the contact time is 20 minutes. However, it can be concluded that 0.8 g/l is the most effective concentration in hardness removal and 40 minutes is the most effective contact time.

The results show that Kombucha culture is not able to remove hardness (Fig. 5). The initial hardness was 9.12 mg/l which this value was increased up to 11.85 mg/l by the addition of 4 g/l additive. For the concentrations of 2 g/l (120 minutes), 6 g/l (120 minutes and 60 minutes) and 8 g/l (60 minutes), over range results were produced. Production of over- range results means that the concentration of calcium or magnesium is above the upper limit specified for the test.

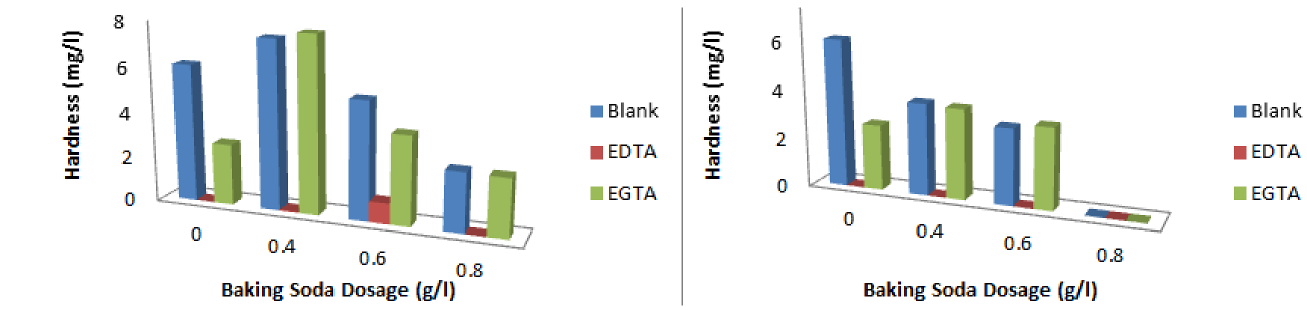

Fig. 4: The effect of baking soda dosage on hardness

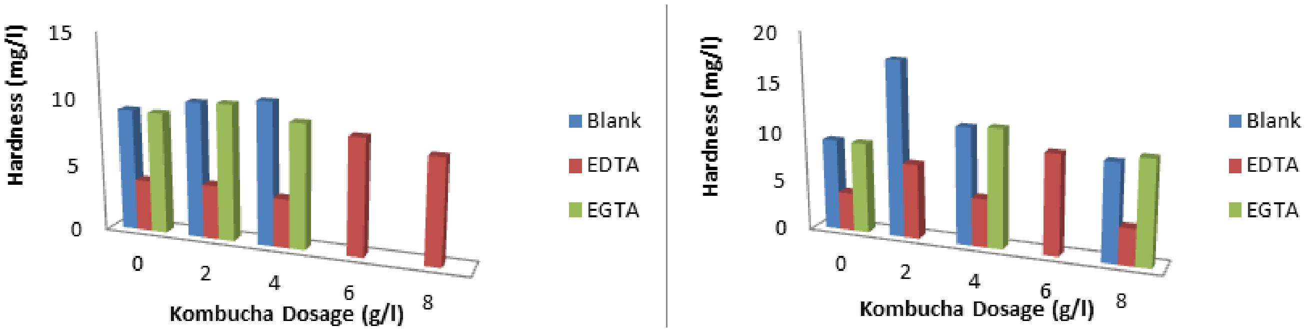

Fig. 5: The effect of Kombucha dosage on hardness

Based on Dey, D. et al. 2007, increasing pH value by the addition of hydroxide ions can remove carbonate hardness. The concentration of the presented carbonic acid and the pH play an important role in precipitation calcium carbonate [13]. When the bicarbonate ions are converted to carbonate form, the pH rises and the precipitates of calcium carbonate are formed. Therefore, the addition of sodium bicarbonate can adjust pH value and enhance carbonate hardness removal. Based on the obtained results, Kombucha culture is able to lower pH of wastewater and thus it is not considered effective in hardness removal.

EDTA (Ethylenediaminetetraacetic acid) and EGTA (Aminopolycarboxylic acid) are both the chelating agents which are used to evaluate hardness and thus there are two methods for measuring water hardness. EGTA method is specific for calcium hardness and gives a larger value in compared to EDTA method. However, EDTA can bind to both magnesium and calcium and thus it has no particular preference. In this study, both methods were investigated to evaluate the wastewater hardness. However, EGTA method is only used for comparison purpose.

The acceptable upper limits of several wastewater contaminants are known as standards which had been issued by the Department of Environment (DOE). In order to investigate the influence of treated and untreated wastewater on the environment and to design an efficient treatment system, the measurement of pollutants or in the other words wastewater quality indicators are required. Table 3 indicates the effluent standards from environment quality act 1974 [14]. It also shows the characteristics of UCSI cafeteria raw wastewater. UCSI cafeteria is located at zone "A" and thus the range of BOD_5 and COD for UCSI cafeteria wastewater exceeds the standard limitations. Therefore, this effluent is required to be treated before releasing to the environment. However, since the level of all types of solids together with hardness is within the permitted range, further treatment is not necessary. BOD_5 and COD are the parameters which are able most often to judge the strength of wastewater. High consumption of water will result in weak wastewater and due to this reason the sewage produced in USA has lower strength. Although, the tropical countries include Malaysia consume less water and thus the wastewater is stronger.

Table 3: UCSI wastewater characteristics

Parameter	Experimental Results (mg/l)	Standard		
		A	B	Other
PH Value	5.6-7.5	6.0-9.0	5.5-9.0	5.0-9.0
BOD_5 at 20°C	113-500	20	50	400
COD	139-629	50	100	1000
Total Solids	0.02-13.4	50	100	400
Total Dissolve Solids	0.01-9	-	-	-
Total Suspended Solids	0-4.8	-	-	-
Hardness	2.705-9.12	-	-	-

4. Conclusion

Out of 134 samples which had been conducted for this study, 29 measurements were related to the influence of Kombucha fungi and the rest were implemented to investigate the effect of baking soda on sample quality together with the preliminary studies. Kombucha fungi and baking soda can be both effective for BOD_5 removal. Baking soda has the ability to decrease BOD_5 level up to 94%. However, in this study 52%was the highest removal rate which achieved by the addition of Kombucha fungi. The concentration of additive, contact hours and the initial characteristics of wastewater sample are the parameters which can affect the function of additives and the removal percentage. 0.8 g/l of baking soda in 50 minutes and 4 g/l of Kombucha fungi within 60 minutes can be considered the effective concentrations for BOD_5 removal in this study. However, the results indicate that baking soda is more efficient to treat the sewage with respect to BOD pollution.

The most effective concentrations of additives which have successfully removed BOD_5 were only used to run COD analysis. These concentrations resulted in effective COD removal. However, the readings were over- range and thus the rate of removal could not be calculated. The samples were considered weak in terms of solids and due to this issue, the measurement of solids faced some difficulties during the study. Baking soda is able to remove Total Solids (TS) and Total Dissolved Solids (TDS) up to 31% and 33% respectively. However, this removal is regardless of additive dosage. Same conditions can be concluded for Kombucha fungi since the concentration is not effective for solids removal. Kombucha culture is able to decrease TDS only and 57% is the highest rate of removal.

If the additive concentrations which tested for this study only be considered, it can be concluded that baking soda can successfully remove hardness up to 100% while Kombucha culture increases the hardness value and no removal will be resulted. Based on the standard limitations established by the Ministry of Natural Resources and Environment of Malaysia for the discharge of sewage, UCSI cafeteria wastewater is extremely high in BOD_5 and COD and the values related to these parameters exceed the standards and limitations. Therefore, UCSI cafeteria sewage is required to be treated before releasing.

5. Acknowledgement

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