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TREATMENT OF BREWERY WASTE WATER USING SAND AND CARBON FIXED BED

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Abstract: Reclamation of process wastewater is a key to water resources conservation and sustainability. Since brewery is inherently associated with the use of considerable amount of water, this study was undertaken to investigate the appropriate treatment of wastewater generated by Heineken (Wallia) brewery for the possibility of reuse. For this work, samples of wastewater were collected and characterized. Series of experiments were conducted to determine the amount of alum to use, the property of the sand and finally treatment of the wastewater was carried out using fixed bed filtration column consisting of granular activated carbon and sand. The physico-chemical parameter results obtained before application of the treatment for wastewater showed that 55.11NTU, 89.33 mg/l, 4.4 mg/l, 1.06 mg/l, 4.3mg/l and 1.92mS/cm for Turbidity, COD, TN, Ammonia, TP and EC respectively. Then Series of jar test experiments were conducted in which alum were used with in a coagulation/flocculation process at discharge pH with a concentration of 40mg/l. After wards fixed bed filtration column was constructed from Granular activated carbon which was obtained from Heineken brewery and sand from local market. The sand was characterized by using sieve analysis and its uniformity coefficient, density and effective size is found to be 5.67, 1.66 g/ml, 0.15 – 0.85 mm respectively. Sample results of the analysis after using the fixed bed filtration shows that overall concentration of turbidity and COD were reduced from 73 NTU to 28.92 NTU and 98 mg/l to

32.02mg/l, were as for the conventional filtration, it reduced to 3.22 NTU and 3mg/l, respectively. These results showed that coagulation/flocculation and sedimentation stage improve the subsequent filtration process. So a successive additional treatment of TN, Ammonia, TP and EC were done and resulted in reduction from 4.4 mg/l, 1.06 mg/l, 4.3mg/l and 1.92mS/cm to 0 mg/l, 0 mg/l, 0mg/l and 0.65mS/cm. These experimental results showed that it could be reused for boiler feed, cooling, rising and even for process water.

Keywords: Mojo sand, Carbon, Filtration

1. Introduction

In the food industry, the brewing sector holds a strategic economic position with the annual world beer production exceeding 1.34 billion hectoliters in 2002 (Au and Lechevallier, 2004). Beer is the fifth most consumed beverage in the world behind tea, carbonates, milk and coffee and it still continues to be a popular drink all over the world (Braeken, et al, 2004). This beverage is obtained through alcoholic fermentation, using selected yeast of genera Saccharomyces, malt cereals (mainly barley), and other sugar based raw material, to which hop, and adequate water is added. Brewers are very concerned that the techniques they use are the best in terms of product quality and cost effectiveness. During production, beer alternately goes through four chemical and biochemical reactions (mashing, boiling, fermentation and maturation) and three solid–liquid separations (wort separation, wort clarification and rough beer clarification) (Goldammer, 2008). Consequently water management and waste disposal have become a significant cost factors and an important aspect in the running of a brewery operation (Harrison, 2009).Every brewery tries to keep waste disposal costs as low as possible whereas the legislation imposed for waste disposal by the authorities becomes more and more stringent.

Though this brewing industry is faced by a number of problems, now a day’s their most critical concerns are water usage – its quality and scarcity - and the subsequent wastewater generated from its operations. The industry requires the use of large quantity of clean water in its beer production. The main water consuming areas of a typical brewery are brew house, cellars, packaging and general water use (van der Merwe, Friend, 2002). Specifically, of the water consumed, about two-thirds are used in the process and the rest in the cleaning operations (Fillaudeau et al, 2006). As revealed in literature survey by Simate (Simate et al, 2012), it is estimated that about 3-10 liters of water is required to produce 1 liter of beer. As a result, a large quantity of wastewater is produced. Consequently, water and wastewater management in breweries remains a critical practical problem.

Currently the ever increasing need for clean, but scarce water in the brewing industry has continued to motivate the need to find alternative sources of water. One alternative that requires attention is wastewater reclamation and reuse. Wastewater reclamation and reuse has been an important option since industrialization accelerated pollution in water environment, making it a limited resource for production activities (Seo et al, 1996). When properly treated and recycled, wastewater can be an alternative water source which can reduce the demand for fresh water. Recycled wastewater can reduce stress on the environment as well. However, the removal of contaminants from wastewater completely remains a big challenge.

There have shown that a good number of brewery wastewater treatment methods are either in operation, being piloted or under evaluation. These treatment processes are selective depending on the purpose of water and the water quality required, and wastewater characteristics (Chung et al, 1997). Furthermore, each method has its advantages and disadvantages, and the removal of contaminants using these technologies can be complex and costy. Breweries in Ethiopia mostly use groundwater as a raw material as seen in Heineken, Meta and also in other breweries in the country for their water production because of its constant and good quality. This exert a tremendous pressure on the ground water resource of the country and plus the high quantity of waste water they generate exert pollution load on the environment resulting in water pollution on nearby rivers and when released directly on the ground, the pollutant may percolate into the ground water resulting on ground water pollution. Due to this, we must start looking for alternative water resources and ways of wastewater treatment to prevent pollution. In this context, fixed bed filtration might be a solution to treat the waste water so that it could be reused. Brewery waste water usually contains a high concentration of biodegradable and non biodegradable organic compounds. Fixed bed filtration removes small organic compounds and used in a wide range of applications. It has already shown good results for the removal of organic pollutants compounds from surface water and waste waters for the purpose of drinking water (Fillaudeau et al, 2006).

This paper investigates the possibilities of fixed bed filtration to treat the waste water in view of recycling in order to decrease the amount of fresh water needed and wastewater generated. The quality standards for the regenerated waste water depend on the application.

This paper investigates the possibilities of fixed bed filtration to treat the brewery waste water in view of recycling in order to decrease the amount of fresh water needed and wastewater generated. The fixed bed is consist of naturally occurring sand which is profoundly found in mojo region in Ethiopia and activated carbon.

2. Methodology

2.1. Sieve Analysis

The standard procedure for conducting a sieve analysis of a filter medium was detailed in ASTM Standard Test C136-9 (ASTM, 1993).Since the activated carbon was obtained from factory, its properties were already known and there was no need to carry out sieve analysis to it. Whereas for the sand, the analysis was carried out since its natural sand (Mojo sand) and its main characteristics like usable portion, size distribution and density were not identified.

Sieving was carried out on 1000-g sample of hard materials (in this case sand), on 8-in sieves, and using a Ro-Tap type of sieving machine, it required three sieving periods of 5 min each to satisfy the 1 percent passing test. The Ro-Tap machine imparts both a rotary shaking and a vertical hammering motion to the nest of sieves.

Figure 2.1 Ro-Tap machine

2.1.1 Grain Size and Size Distribution

Grain size has an important effect on filtration efficiency and on backwashing requirements for a filter medium. It is determined by sieve analysis using ASTM Standard Test C136-92 (ASTM, 1993).Log-probability plot of the sieve analysis were drown to show the size gradation of the media constituents.

The size gradation of a filter medium was described by the effective size (ES) and the uniformity coefficient (UC).The ES was the size for which 10 percent of the grains were smaller by weight. It is read from the sieve analysis curve at the 10 percent passing point on the curve, and is often abbreviated by d_{10} .The UC was a measure of the size range of the media. It is the ratio of the 60% and 10% passing grain sizes that were read from the sieve analysis curve (ASTM, 1993). Values of d_{10} and d_{60} were read from an actual sieve analysis curve.

$$UC = \frac{d60}{d10}$$

$$d\ useable = 2(d60 - d10)$$

where d_{10} the size for which 10 percent passing point on the curve, d_{60} being the size for which 60 percent passing point on the curve and $d_{useable}$ usable portion of the sand.

2.2.2 Grain Density

Grain density is determined from the following ASTM Standard Test C128-93 (ASTM, 1993).This ASTM test uses a displacement technique to determine the density of sand. The procedure was an oven-dry sample were weighted and inserted into known volume of distilled water and then the density is calculated using the formula:

$$\rho s = \frac{Ms}{Vw}$$

Where Ms is mass of the sample,Vw the volume of the water displaced by the sample.

2.3. Fixed bed filtration media arrangement

This section discusses the construction, configuration and setup of the granular media filter. The filter column was made using a transparent PVC pipe with an internal diameter of 6cm and a total height of 12 cm.

The media was arranged as follows: The lighter activated carbon was placed on denser sand and sintered plastic beads under-drain supported the media from the bottom. The depth of the GAC bed was of the order of 6cm with sufficient sand to give a combined depth of 12 cm.

Figure 3.2 Arrangement of the filter media.

Then after the construction, conventional filtration ware carried out. But before that, the loading rate was determined. As can be seen from different literatures head loss development was observed earlier for higher initial flow rates: higher initial flow rates develop head lose more quickly than smaller initial flow rates (Aronino et al, 2009) (Crittenden & Harza, 2005). Furthermore, head losses increased proportionally with the square of the flow rate as was also observed by Farizoglu and his team (Farizoglu et al, 2003) in their studies. This is because of the progressive reduction in the filter effective surface area as the particulates are deposited onto the filter surface or lodged into the spaces between sand grains (filter pores).Because of this, the conventional filtration were operated at the smallest loading rate which is 0.5 l/h.

2.4. Batch laboratory scale water treatment plant

The treatment plant consists of the raw water tank, coagulant dosing tank, coagulation tank, flocculation and settling tank, rapid sand filter, and treated water tank.

Typical operations of the plant consisted of the followings: The raw water was collected from the treatment plant. Addition of a coagulant to coagulant tank will take place. In the coagulant tank, the wastewater mixed with the coagulant (alum) by mechanical agitation with a stirrer. Thereafter, the water undergoes flocculation by reducing the stirring speed and allowed to settle in by stopping the stirring completely. The sample from the flocculation and settling unit then goes to the fixed filter bed (mixture of GAC and sand).

Several criteria exist that necessitates backwashing of the sand filter, but for this study the need for backwashing will be determined by using a fixed time interval criteria, i.e., after 1 h of operation. The filter was backwashed for 15 min with water. The media then tapped down to the specified elevations after backwashing completed (APHA, 1995).

2.5. Data Analysis

Statistical analysis was performed with the help of Microsoft Excel program .Descriptive data analyses using graphs were made using Microsoft Excel program. Results obtained by experiment were compared with the specified industrial discharge limit values. The statistical significance of the experimental results was analyzed by the Student's *t*-test.

Removal efficiencies of treatment system were calculated based on the following formula (Boonsong and Chansiri, 2008).

$$\% \text{ Removal Efficiency} = \frac{Cinf - Ceff}{Cinf}$$

Where *Cinf* is initial parameter concentration, *Ceff* is final parameter concentration.

3. Result and Discussion

3.1. Origin of waste water

The brewery waste water was obtained from a Heineken brewery (Kilinto, Addis Ababa, Ethiopia).This brewery consumes 6 liters of water per liter of beer.Wastewater was originated at different places in the production process.In this factory three different types of wastewater: (the bottle rinsing water, the rinsing water of the bright beer reservoir and the rinsing water of the brewing room) were collected and treated by the biologically treatment(UASB) and released to the nearby river when the discharge limits are adhered. The wastewater which is treated by biological treatment and discharged has a low organic load, an intermediate conductivity, a more or less constant composition (in terms of e.g. COD and turbidity) and contains bacteria.

3.2. Characterization of the brewery wastewater

The table below illustrates physicochemical characteristics of Brewery wastewater from the discharge point of biological treatment plant in Heineken Brewery in Ethiopia.

Table 3.1 characterization of brewery wastewater

Parameters	Mean	Range	MoFE	EU
pH	7.70	7 - 8	6.0-9.0	6.0-9.0
COD(mg/l)	89.33	75 - 110	≤ 250	≤125
Turbidity(NTU)	55.11	47 - 75	------	50 – 100
Total nitrogen (mg/l)	4.4	4 - 5	≤ 40	≤5
Total ammonia(mg/l)	1.06	0.6 – 1.6	≤ 20	≤5
Total phosphorus(mg/l)	4.3	3 - 4	≤ 20	≤10
Conductivity(Sc m^{-1})	1.92	1.5 - 2	-----	-----

N.B. MoFE and EU are discharge limits set by the respective organizations and institutes.

The characterization result showed that the pH level range was 7 to 8. It was influenced by the amount and type of chemicals used in cleaning and sanitizing operations(e.g, caustic soda, phosphoric acid, nitric acid, sulphonic acid). The Nitrogen and phosphorus levels range from 4-5 mg/l and 3-4mg/l and their concentration mainly dependent on the handling of raw material and the amount of yeast present in the effluent .Whereas the ammonia level range from 0.6 – 1.6 which is generated mainly from the CO_2 room. The electrical conductivity was also in a range of 1.5 – 2 Scm^{-1} as can be seen from table 3.1.

In general, the results of these analyses indicated that the concentration of turbidity, COD, TN, TP and EC and the temperature were found to be in the range of their respective permissible values set by MoFA and EU but not in a range to be reused for any industrial purposes such as cooling, heating, rising etc.

Figure 3.1.Heineken brewery wastewater

3.3. Determinations of properties of the fixed bed filtration medium

3.3.1. Mojo sand

The sand used in this operation was obtained from local market which is widely used in our country as a construction sand . It is found in larger quantity in Mojo region and widely used for construction purpose only. The sieve opening for the sieve analysis range from 100µm - 2mm, the usable portion and other properties of the sand were determined from the graph below and by using the appropriate equations. Since the activated carbon was obtained from Heineken brewery factory, its properties ware already determined and there is no need to carry out sieve analysis to it.

For the discussion on Figure 4.9, reference should also be made to the experimental data in Appendix D.

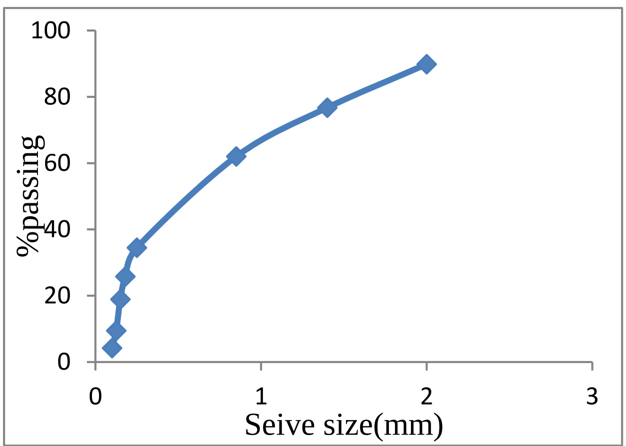

Figure 3.2. Size distribution of the Mojo sand

Since it was natural (not processed) sand, it has too fine and too coarse portion and this portion has to be removed in order for its filtering ability improved interims of uniformity. All sand between d_{10} and d_{60} (specified) was useable (this is 50% of specified sand).filtration process could only use the part that corresponds to the usable part of specific sand. From the above graph, the usable portion of the sand found between 125 - 850µm as can been seen. The ES (d_{10}) is approximately 125 µm and d_{60} is 850 µm. The density of the sand was found to be 1.66 g/ml (see appendix F2). The table below shows the characteristics of the sand from the above graph and the GAC which was going to be used in this research.

Table 3.2 Properties of the fixed bed media

Media	Diameter(mm)	ES(mm)	UC	density(g/ml)	Puseable (mm)
Sand	0.1 – 1.2	0.17	5.67	1.66	0.15 – 0.85
GAC	1 -2	---	1.45	0.53	--------

Table 4.2 shows the effective sizes which were the sieve size through which 10% of the filter media passes (d_{10}), uniformity coefficient which was ratio of sieve sizes through which 60% pass and through which 10% pass and usable portion of the sand which were determined from the graph. Note that the experiments were only conducted for the sand.

3.3. Comparison of modes of filtration

This section compares the performance of both modes of filtration (conventional filtration and direct filtration). Turbidity and COD removal were investigated and used to assess the performance of the filtration modes and aluminum sulfate dosage of 40 mg/l was used.

3.3.1. Turbidity removal

Turbidity was an important parameter in the water industry that was used in assessing the effectiveness of the filtration process and also the quality of drinking water and wastewater. It is also believed that turbidity serves as a carrier for nutrients and pathogens which could result in biological activity (Tyagi et al, 2009).

For both filtration modes, figure 3.3. Shows that there was low turbidity removal at the beginning of the filtration process. As the wastewater pass through the clean bed, its low capability at the start for capturing particles caused the turbidity to be around the initial value. This is because the maturation or 'ripening' period of the fixed bed filter is not reached. But after 15 minute the removal rate for both modes increased and finally achieved final residual turbidity of less than 3 NTU by conventional filtration and 28.92 NTU by direct filtration.

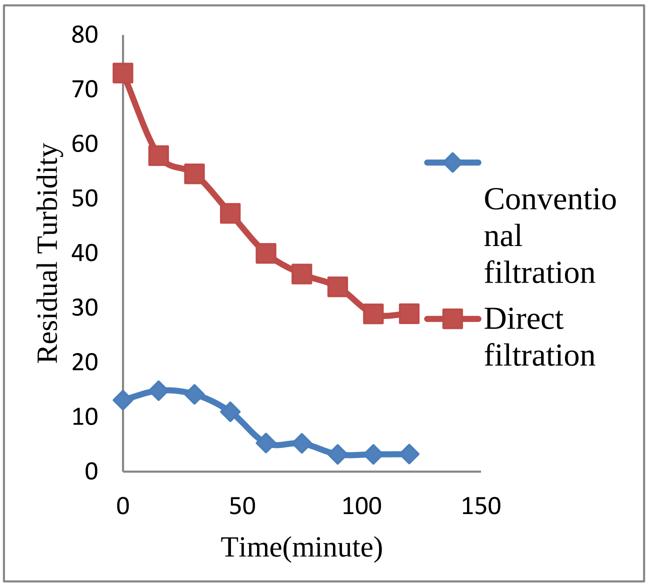

Figure 3.3. Effect of mode of filtrations on removal of turbidity

The role of coagulation/flocculation and sedimentation processes in the removal of turbidity may be explained as follows. During coagulation and flocculation, insoluble particles and/or dissolved organic matter interact to form larger and denser particles or flocs (orthokenetics). These larger and denser aggregates are then removed by allowing them to settle out of the water naturally under the force of gravity in the subsequent sedimentation stage by allowing them to settle for 50 minute.

Therefore, coagulation/flocculation step followed by sedimentation enhanced the removal of colloidal particulates and other suspensions that cause turbidity. In the fixed bed filter itself, the removal of particles occurs by two main processes. Firstly, physical straining (size exclusion) by trapping the particulate matter in between the grains of filters media. Secondly, adsorption, when particulates in the wastewater attach themselves to the filter media or to previously retained particles. The destabilization of particulates by coagulation and flocculation also enables particles to be attached to the filter media more readily.

The big difference in performance between the conventional and the direct filtration processes was due to the fact that the conventional filtration use the above processes for removal, whereas the direct filtration eliminates this steps and allows the filter material itself to do the work. However, in the direct filtration some sedimentation will take place on top of the filter, while the main reduction occurs within the filter, thus increasing the filter resistance or head loss. Therefore, because all the particles are removed by filtration, the direct filtration is not as efficient as the conventional filtration process.

In addition in this mode, the brewery wastewater was filtered with no coagulation/flocculation and sedimentation steps; the resulting filtrate had the highest turbidity compared to the conventional mode which provides evidence that without the coagulation/ flocculation and sedimentation stages, only little of the fine particles passing through the filter bed can be removed. In other words, because there is no coagulation/flocculation and/or sedimentation stage and that all the particles ware removed by filtration, the direct filtration is not as efficient as the conventional filtration method.

3.3.2 COD removal

Typically, the brewery wastewater has high COD values originating from organic components such as sugars, soluble starch, ethanol and volatile fatty acids (Braeken, et al, 2004)The disposal of such wastewater, if untreated (or partially treated), into water bodies can constitute potential or severe pollution problems to the water bodies since the effluents contain organic compounds that require oxygen for degradation. For example, water of high organic content value flows into a river, the bacteria in the river will oxidize the organic matter, thus consuming oxygen from the water faster than the oxygen dissolving back into the river from the air. Brewery wastewater must, therefore, be treated prior to disposal.

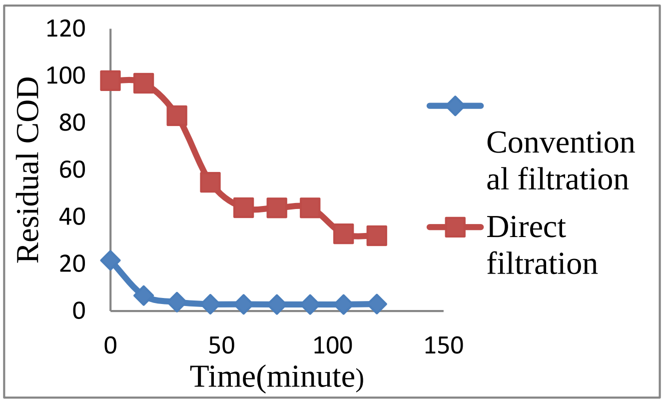

Figure 3.4. Effect of modes of filtration on removal of COD

The COD of the filtrate from both filtration modes as a function of operation time was also plotted above. A similar trend to turbidity removal (see Fig. 3.4) was also observed for the COD removal. Just like turbidity, which was also a physical-chemical parameter, the removal of COD in the filter-bed was believed to occur through the processes of straining (minor) and adsorption (major) to filter media and previously removed particulates. Conventional filtration was found to be the most effective (96.71%) as it removed most of the COD. The final COD achieved by conventional filtration was 3mg/l. This was attributed to both the coagulation/flocculation of COD and its subsequent removal in the sedimentation step. As for the direct filtration, both the coagulation/flocculation and sedimentation steps ware missing, therefore, the removal of the small-size particulates of COD only happens in the filter-bed; hence the least COD removal efficiency (47.95 %) observed in the direct filtration mode and final COD of 32.02mg/l was achieved.

3.4. Backwashing studies

Backwashing is an important process in the operation of a fixed bed filter; during which the unit was taken off-line, solids removed, and then returned to service. In other words, when the filter's pores become clogged such that there is an increase in pressure, they need to be cleaned. The need for backwashing may be determined using various criteria – a terminal head loss, a fixed time interval, or a breakthrough of solids (when solids begin to pass out with the effluent) (Au and Lechevallier, 2004). In this study, the filter was backwashed using a time interval of 1hrs of filter operation since it was conducted at laboratory scale and the minimum turbidity requirement for brewery process water was 5 NTU.

3.3.1 Removal of turbidity and COD after back washing relative to un backwashed

The turbidity and COD removed before and after backwashing were shown in Figure 3.5.- Figure 3.9, respectively. For the discussion of the Figures, reference should also be made to the experimental data in appendix E. The results in appendix E were runs conducted under similar experimental conditions.

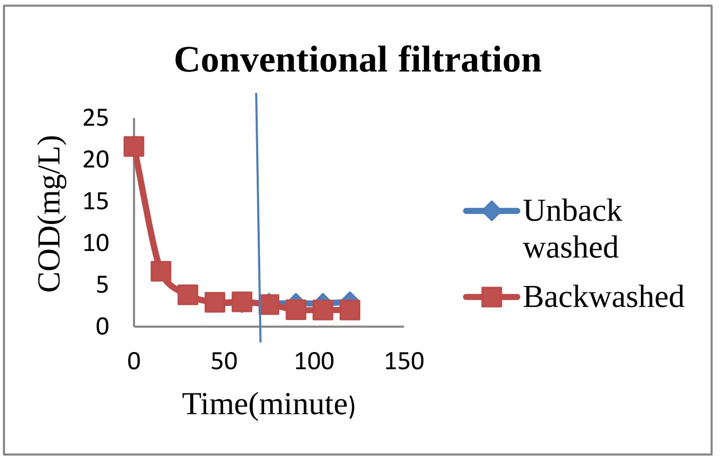

Figure 3.5. COD removals in backwashed and un-backwashed conventional filtration.

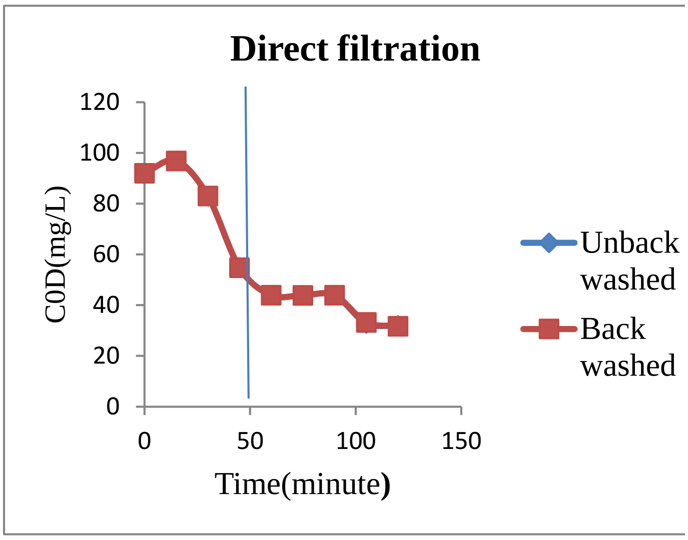

Figure 3.6. COD removals in backwashed and un-backwashed direct filtration.

Figures 3.5 and 3.6 shows that the removal trends before and after backwashing were similar. We could also see that, after backwashing the initial removal of COD for both cases (conventional and direct filtration) were similar with unbacks washed.

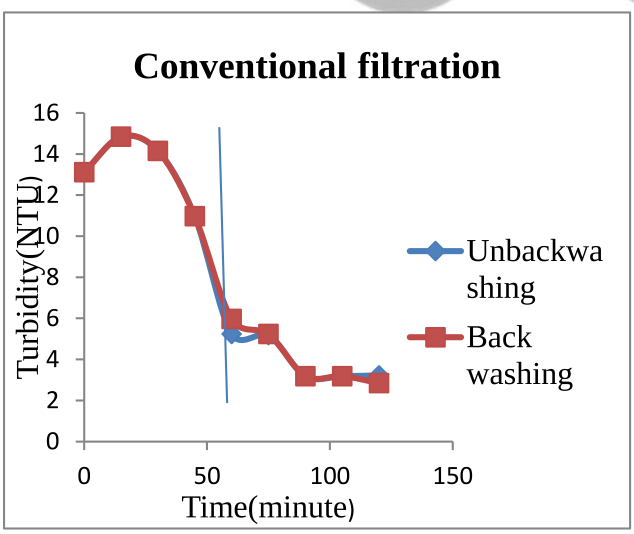

Figure 3.7 Turbidity removals in backwashed and un-backwashed conventional filtration.

Figure 3.7 showed that the turbidity removal trend before and after backwashing were a bit differs. After backwashing (after 60 minute), the initial removals for turbidity were not as high as that at the start of filtration. This was because the presence of some particulates that remained after backwashing reduced the maturation or 'ripening' period of the fixed bed filter. As can be seen from the figure the turbidity removal was seen to be a bit higher after back washing.

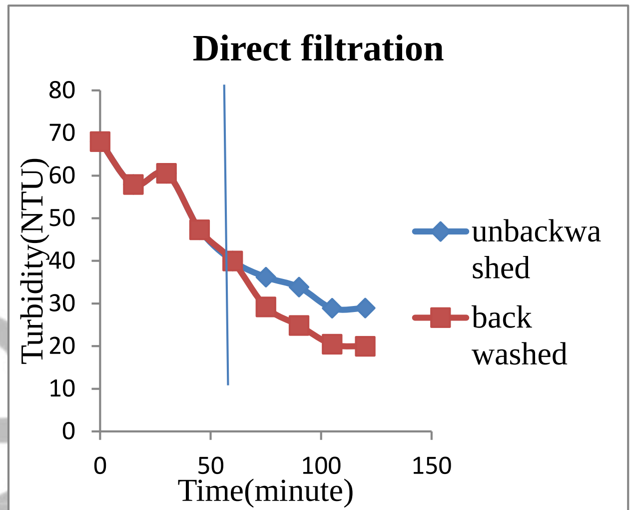

Figure 3.8 Turbidity removals in backwashed and un-backwashed direct filtration.

Figures 3.8 showed that the removal trends before and after backwashing were almost similar. However, after backwashing the removal for turbidity was becoming high and shows reduction of turbidity up to 15 NTU. This showed the significance of back washing while using this fixed bed in direct filtration, since there was no coagulation/flocculation and sedimentation process preceding the fixed bed filtration process.

These results also showed that it was not possible to use the water obtained by direct filtration for any industrial purpose even after undergoing backwashing whereas for conventional treatment, it was possible and also the backwashing period can be increased.

3.4. Additional characterizations of the conventionally treated wastewater

There has seemingly been little ammonium in the characterization of the wastewater, and the remaining was completely removed (100% removal rates).For detailed ammonium data, see appendix F. Total nitrogen was not detected in any of the effluent of the column. Total nitrogen concentrations were generally found to be in the range from 4-5 mg/L in the effluent wastewater and the remaining was completely removed (100% removal rates) after passing through the filter columns. For detailed total nitrogen data, see appendix F.

Total phosphorus was not detected in any of the effluent of the column. Total phosphorus concentrations were generally found to be in the range from 4-5 mg/L, effluent wastewater and the remaining was also completely removed (100% removal rates) after passing through the conventional filtration method. For detailed total phosphorus data, see appendix F.

Total conductivity was reduced from 1.88 – 2.11mScm^{-1} range to below 1mScm^{-1}after passing through the conventional filtration method. For detailed on total conductivity data, see appendix F.

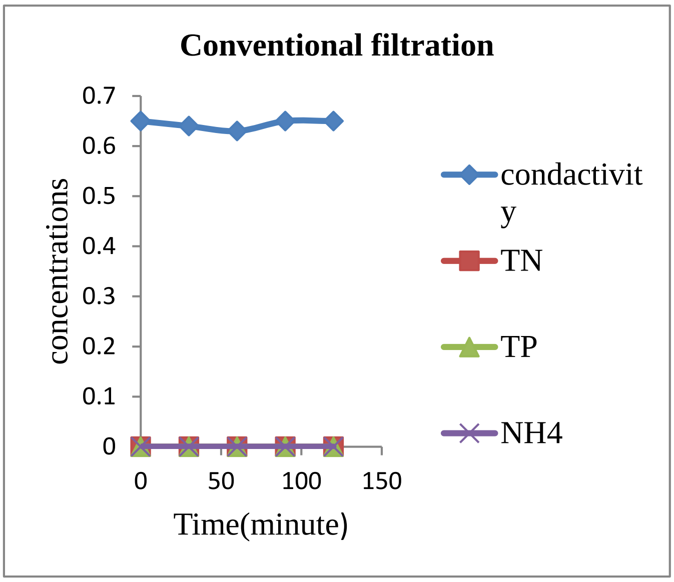

Figure 3.9 Conductivity, TN,TP and NH_4removals in conventional filtration.

The above figure illustrate that there was a complete removal of TN, TP and NH_4 after conventional filtration treatment and the conductivity was also reduced. This were major criterion for reusing the wastewater because they determines the slim formation, corrosively and scale formation nature of the wastewater which was going to be used either for cooling, heating or for boiler feed purpose.

3.5. The Evaluation of the conventionally treated wastewater for Industrial Reuse

Reclaimed water quality for industrial uses needs to be protective. Due to this, the effluent needs to be in the specified range.

Conductivity is the main determinative factor for the corrosion of pipes and machinery, scale formation, foaming etc. and physical quality of reclaimed water specifies the threat for solids deposition, fouling, blockages (EPA, 1992). The turbidity of the reclaimed water also found in the physical quality. Also, nutrients such as phosphorus and nitrogen may cause slime formation and microbial growth (EPA, 1992). Generally, industrial reuse of the reclaimed water in breweries was classified into three categories as cooling water, boiler-feed water, and process water. The compatibility of reuse options was discussed in the following topics, below.

3.5.1 Compatibility as Cooling Water

Cooling water recommended specifications specified by EPA of united state of America and conventional treatment plant effluent values were given in Table 4.2. So, a comparison was done below for these results. It's seen that the values of turbidity, COD, conductivity, ammonium, TN and TP parameters were below the limits.

Table 3.3 Comparison on the compatibility of treated effluent wastewater with Cooling Water standard set by EPA

Parameter	**Recommended Limit Value**	**Effluent**
COD	≤75	≤10
Conductivity	≤400mScm^{-1}	≤1mScm^{-1}
Ammonium	≤5.0	0
TP	≤4	0
TN	≤1	0
Turbidity	≤30	≤5
pH	6.9-9.0	7 – 8

3.5.2 Compatibility as Boiler-Feed Water

Boiler-Feed water recommended specifications and treatment plant effluent values specified by EPA of united state of America were given in Table 4.3. Also effluent values of the fixed bed treatment plant were given in Table 4.2. So, a comparison was done below for these results (Table 4.3).

Table 3.4. Boiler-Feed Water standard

Parameter	Low Pressure (<150 psig)	Intermediate Pressure (150-700 psig)	High Pressure (>700 psig)
COD, mg/L	5	5	1
Conductivity	-	-	-
Turbidity	10	5	0.5
Ammonia, mg/L	0.1	0.1	0.1
pH	7-10	8.2-10	8.2-9

The higher pressure of the boilers needs higher quality of feeding water, according to the Table 4.3.

Thus, the fixed bed filtration effluent was not good enough and the plant needs more additional treatment to reach the standard values for intermediate and high pressure boilers. But for the lower pressure boilers, all values were in the permitted range as can been seen from Table 4.2.

3.5.3 Compatibility as Process Water

The appropriateness of reclaimed water for industrial processes changes up to the usage. Quality and quantity of process water effluent entering the treatment plant could vary significantly, depending upon the different processes that were taking place within the brewery. In case of using the treated wastewater as process water, treatment should be done until very clean and fresh water quality is gained (Braeken, et al, 2004) (Crittenden & Harza, 2005).So here the comparisons were done with that of the drinking water qualities.

Table 3.4. Comparison of drinking water standards with the conventional filtration effluent

Parameter	WHO	EPA	Effluent
COD	≤5	≤10	≤3
Turbidity	≤10	0.5 – 1	≤3
pH	6.5-8.8	6.5-8,5	7 – 8
TN	≤1	≤1	0
Ammonia	≤1	≤1	0
TP	≤0.1	≤1	0
Conductivity	-	-	0.65

In summary, The Quality standards for rinse, boiler feed water (low pressure boilers), cooling water and drinking water were met as can be seen from EU standards and EPA standards which were listed above. Here these all tastes were not carried out for direct filtration since the turbidity and COD test which were carried out showed its well beyond the desired level. As a result the tests were carried for only to conventional filtration.

So this research showed that, fixed bed filtration of the brewery wastewater will not only make the environment safer but also make the brewing industry more productive interims of saving and properly utilizing the fresh water resources. For example Heineken (Wallia) brewery on average discharges 1900m^3 of wastewater daily. This wastewater which is discharge into nearby river annually exceeds 590,000m^3.So if this research became functional, it will provide an opportunity to reuse this much amount of wastewater for either of the above purposes and reduce the enormous burden on the ground water resources of klinto Area in Addis Ababa.

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Ethiopia.

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