USING SLOW SAND FILTRATION METHOD WITH DOMESTIC CHARCOAL TO TREAT DISTILLERY WASTEWATER IN AUNGLAN TOWNSHIP

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Abstract

Distilleries generate large volume of wastewater which poses a considerable environmental impact by polluting the natural environment. This study focused to evaluate the feasibility of slow sand filtration integrated with domestic charcoal layer as a promising treatment method for the distillery wastewater effluent. Distillery wastewater was collected from Aunglan Township, Thayet District in Magway Region. Before and after treatment for two weeks, selected parameters of effluent were analyzed. All of the effluent parameters (pH, conductivity, total alkalinity, COD, DO, BOD, and chloride, calcium, magnesium and bicarbonate) of treated distillery wastewater sample were within the allowable limits of USEPA standard except turbidity, total hardness, TDS, total phosphate, ammonia nitrogen. After treatment, pH value of the acidic wastewater changed from 3.67 to 6.10 and total alkalinity and total hardness values were found to be 70 ppm and 550 ppm, respectively. *E.coli* in the distillery wastewater was reduced significantly than the initial value but higher than USEPA limit. The slower sand filtration treatment can be taken as an alternative and economical method for treatment of wastewater.

Keywords: distillery wastewater, slow sand filtration method, charcoal,*E.coli*

Introduction

Water pollution occurs when unwanted materials enter in to water, changes the quality of water and harmful to environment and human health. Metal ions are often present in wastewater from industries, and sometimes there is the need to reduce their concentrations to certain minimum (Hassena *et al*., 2017**)**. Clean water is essential for health and the living in general for humans. For some people the access of clean and fresh water is a simplicity but for others, the lack of clean water, especially in rural areas creates one of the biggest humanitarian problems in the world today (Williams, 2015). Due to increased human population, industrialization, use of fertilizers and man-made activity water is highly polluted with different harmful contaminants. The use of current wastewater treatment technologies for such reclamation is progressively failing to meet required treatment levels. Industrial wastewater is one of the major sources of aquatic pollution which could significantly endanger surrounding environments and ecosystems (Agyemang *et al*., 2013).

Advanced wastewater treatment technologies are essential for the treatment of industrial wastewater to protect public health and to meet water quality criteria for the aquatic environment and for water recycling and reuse. The protection of receiving waters is essential to prevent eutrophication and oxygen depletion in order to sustain fish and other aquatic life (Agyemang *et al*., 2015).

The best approach to working out an effective and efficient method of industrial wastewater treatment is to understand how substances are dissolved or suspended in water and then to deduce plausible chemical or physical actions that would reverse those processes (Gutierrez, 2018). Slow sand filtration plays a key role in rural water treatment (Skat, 1996). Slow sand filtration is a type of centralized or semi-centralized water purification system (Bruni and Spuhler, 2020). Filter operation neither requires sophisticated mechanical parts nor the use of chemicals. Since slow sand filters reduce the number of microorganisms present in the water, they improve the bacteriological

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water quality. In addition, fine organic and inorganic matter is separated, and the organic compounds dissolved in the water are oxidized (Skat, 1996). A well-designed and properly maintained slow sand filter (SFF) effectively removes turbidity and pathogenic organisms through various biological, physical and chemical process in a single treatment step (Bruni and Spuhler, 2020). Good quality of water resources depends on a large number of physico-chemical parameters and biological characteristics (Sharma *et al*., 2016). In this study, some physicochemical parameters such as pH, turbidity, conductivity, total alkalinity, total hardness, total dissolved solids, chloride, DO, BOD and COD, etc. were analyzed for testing water quality, after treatment of distillery wastewater by slow sand filtration method.

Material and Methods

Sample Collection

A total of about 40 L of wastewater was collected from Aunglan Township, Thayet District in Magway Region (Figure 1). Aunglan Township is far away 81.39 miles from Magway Township. The collection was carried out the periods of January in 2019. The distillery wastewater was stored in 20 L sterilized prewashed polyethylene containers, rinsing each container three times with the wastewater sample before collection. The sampling containers were sealed and stored in clean, dry and dust free environment at room temperature until further analysis in the laboratory.

Figure 1 Location map of study area

Treatment of Distillery Wastewater by Slow Sand Filtration System

The design of slow sand filtration system was applied for the distillery wastewater treatment (Bryant *et al*., 2015).

Preparation of sand, gravel and charcoal

The collected sand was sieved through a 100 mesh sieve to get coarse sand and fine sand. Then, the different size gravels, coarse sand, fine sand and charcoal (domestic charcoal) were washed with pure water and dried in an air at room temperature for 72 h. After that, they were washed with 0.01 M HCl and once again with distilled water. Then, they were also washed with ammonia solution 0.1 M and once again with distilled water.

Pre-treatment tank

The slow sand filtration system was designed, using a 100 L plastic container. A green thread socket covered with a mesh was fitted through a hole created at the base of the container. The mesh was used to prevent particles (e.g., fine sand) from clogging the effluent outlet. Connected to the socket was a PVC tube which served as effluent outlet. The plastic lid was used to cover the set-up during treatment to prevent foreign particles from dropping into the treatment system. It was used as filter for treatment. Another container was prepared in the same way. Design of pre-treatment tank was shown in Figure 2.


Figure 2 The overall set-up of the slow-sand filtration system used for the treatment

Treatment of distillery wastewater with pre-treatment tank

Firstly, the filter bed was made of a bottom layer of stones (average of 5 mm in diameter) to a depth of 10 cm. The strata were covered with a mesh to prevent mixing of the gravels and the coarse sand. The coarse sand with depth of 12 cm occupied the second layer. The final layer of the filter bed was activated charcoal (from domestic charcoal) of a depth of about 8 cm. The whole filter high occupied 60 cm of the plastic container. Then, another filter bed was also made up of bottom layer of 10 cm depth of gravels (average of 2 mm in diameter). After that, second layer was followed by fine sand of about a depth of 15 cm. The high depth of fine sand was so to increase retention time in order to ensure efficient treatment. The final layer of the filter bed was also domestic charcoal of a depth of about 8 cm. Then 20 L of distillery wastewater sample was added into the first treatment tank. After one week treatment, this sample was also added to another treatment tank for one week. The components of the slow sand filtration bed used in this study are shown in the Figures 3, 4, 5 and 6. After two weeks treatment, some physicochemical parameters of distillery wastewater were measured.


Figure 3 Different size gravel (average 5 mm and 2 mm in diameter) used in slow sand filtration system

Figure 4 Fine sand and coarse sand used in slow sand filtration system

Figure 5 Charcoal used in slow sand filtration system

Figure 6 Mesh to prevent mixing of the gravels and the coarse sand

Analysis of Distillery Wastewater Quality

Some physicochemical parameters and *E .coli* count of distillery wastewater before and after treatment were analysed by the methods and instruments as listed in Table 1.

Table 1 Methods and Instruments Used for Wastewater Quality Analysis

Parameters	Method used	Instrument used
pH	ISO 10523:2008	Robot Mentech
Turbidity	ISO 7027:1999	Robot Mentech
Conductivity	NS-ISO 7888:1993	Robot Mentech
Total alkalinity	ISO 9963:1996	Robot Mentech
Total hardness	Titrimetric Method	Titrator
TDS	Gravimetric Method	HANNA (HI-9145), Italy
COD	Titrimetric Method	-
DO, BOD	Manual Method	DO Probe
Cl, Ca, Mg,	ISO 14911:1998, ISO 10304 1:2009	Ion Chromatography (IC)
Bicarbonate	Titrimetric Method	Continuous Flow Analyzer (Skalar)
Total phosphate	Spectrophotometric Method	UV-1800 Spectrophotometer
Ammonia-Nitrogen	Titrimetric method	Micro Kjeldhal method
Fe, Cu	Spectrophotometric Method	Atomic Absorption Spectrophotometer, nov AA 400, Analytikjena,
E.coli	Plate Count Method	Gram staining and UV detection with UV Lamp

Determination of Some Physicochemical Parameters of Distillery Wastewater

In this experiment, some physicochemical parameters such as pH, turbidity, conductivity, total alkalinity, total hardness, total dissolved solids, chemical oxygen demand, dissolved oxygen, biochemical oxygen demand, chloride, calcium, magnesium, bicarbonate, total phosphate, ammonia-nitrogen, Fe, Cu and *E.coli* of distillery wastewater sample before and after treatment using slow sand filtration method were analyzed.

Determination of pH in the distillery wastewater sample

The pH value of wastewater sample was measured with ISO 10523:2008 method by Robot Mentech machine at Ministry of Agricultural Research (MAR), Yezin, Naypyitaw.

Determination of turbidity in the distillery wastewater sample

The turbidity value of wastewater sample was also measured with ISO 7027:1999 method by Robot Mentech machine at Ministry of Agricultural Research (MAR), Yezin, Naypyitaw.

Determination of conductivity in the distillery wastewater sample

The conductivity value of wastewater sample was also measured with NS-ISO 7888:1993 method by Robot Mentech machine at Ministry of Agricultural Research (MAR), Yezin, Naypyitaw.

Determination of total alkalinity in the distillery wastewater sample

The total alkalinity value of wastewater sample was determined by ISO 9963:1996 method using Robot Mentech machine at Ministry of Agricultural Research (MAR), Yezin, Naypyitaw.

Determination of total hardness in the distillery wastewater sample

The distillery wastewater (50 mL) was poured into the beaker and total hardness value was recorded directly from Titrator display at Ministry of Agricultural Research (MAR), Yezin, Naypyitaw.

Determination of total dissolved solids in the distillery wastewater sample

Distillery wastewater (100 mL) was accurately measured and filtered with the preweighed filter paper. The filtrate was evaporated to dryness in a preweighed porcelain crucible on oven. Then the crucible with residue was cooled in a desiccator for half an hour and weighed. The process of heating in the oven and cooling in the desiccator until a constant weight was obtained (Vogel, 1968).

Determination of chemical oxygen demand in the distillery wastewater sample

COD was measured by the permanganate oxidation method. 25 mL of wastewater sample was placed in a conical flask. A 2.5 mL of potassium permanganate solution was added to the sample and the flask was placed on a boiling water bath for 1 hour. After that, the sample was cooled for 10 minutes. Then, 2.5 mL of potassium iodide was added to the sample and followed by 5 mL of sulphuric acid solution. The solution was titrated with standard sodium thiosulphate solution until a pale yellow color was obtained. The starch solution (1 mL) was added to the above solution to get a blue color. The titration was continued until the blue color disappeared completely. The whole above procedure was repeated for another two times. A blank test in the manner using distilled water instead of the sample was also carried out (Government of India and Government of the Netherlands, 1999).

Determination of dissolved oxygen in the distillery wastewater sample

Distillery wastewater was filled into the glass bottle so that bubbling did not occur and initially dissolved oxygen content was determined by manual method. Dissolved oxygen contents was recorded directly from DO probe display at Ministry of Agricultural Research (MAR), Yezin, Naypyitaw.

Determination of biochemical oxygen demand in the distillery wastewater sample

The distillery wastewater was filled in the glass bottle without bubbling. The initially dissolved oxygen (DO) content was determined by a dissolved oxygen meter at Ministry of Agricultural Research (MAR), Yezin, Naypyitaw. Solutions of 1 mL of 0.05 % urea and 1 mL of phosphate buffer was added to the bottle. The bottle was incubated at 20 ºC for 5 days. After incubation, the concentration of oxygen was determined by the dissolved oxygen meter. The difference between the initial DO content and DO content after 5 days incubation was the 5 days biochemical oxygen demand (BOD) in ppm.

Determination of chloride content in the distillery wastewater sample

The chloride value of wastewater sample was measured with ISO 14911:1998 method by Ion Chromatography (IC) machine at Ministry of Agricultural Research (MAR), Yezin, Naypyitaw.

Determination of calcium and magnesium contents in the distillery wastewater sample

The metal ions content (Ca , Mg) of distillery wastewater sample were determined with ISO 14911:1998 and ISO 10304 1:2009 methods by Ion Chromatography (IC) mechine at Ministry of Agricultural Research (MAR), Yezin, Naypyitaw.

Determination of bicarbonate in the distillery wastewater sample

Bicarbonate was measured by Titrimetric Method using Continuous Flow Analyzer (Skalar) at Ministry of Agricultural Research (MAR), Yezin, Naypyitaw. It was also measured by titration with standardized hydrochloric acid using methyl orange as indicator. Methyl orange turns yellow below pH 4.0. At this pH, the carbonic acid decomposes to give carbon dioxide and water.

Determination of total phosphate in the distillery wastewater sample

The content of total phosphate in the distillery wastewater was determined by the colorimetric molybdenum blue method. The 25 mL of wastewater was placed in a conical flask. A 1 mL of ammonium molybdate solution and 3 drops of chlorostannous acid solution were added and allowed to stand for 15 min. The solution was placed in a glass cell and the absorbance was measured in a UV-visible double-beam spectrophotometer at 690 nm. Prior to this, a standard calibration curve (absorbance vs. concentration) was made with phosphate concentration of 0.0, 0.2, 0.4, 0.6, 0.8, 1.0 and 1.2 ppm, and the absorbance were measured by spectrophotometric method using UV-1800 Spectrophotometer. It was measured at Ministry of Agricultural Research (MAR), Yezin, Naypyitaw.

Determination of ammonia nitrogen content in the distillery wastewater sample

The wastewater sample (5 mL) was introduced into a dried Pyrex Kjeldahl flask. The catalyst mixture composed of (3.5 g) anhydrous potassium sulphate, (0.4 g) copper sulphate and concentrated sulphuric acid (15 mL) were added. The flask was partially closed by means of a funnel and the contents were digested by heating the flask in an inclined position in the digestor. The mixture was heated gently for about 30 minutes and heating was continued vigorously for about 1 h until the solution become clear. Then the flask was allowed to cool and about 10 mL of distilled water and a few sodium thiosulphates were added and Kjeldahl distillation apparatus was set up. Sodium hydroxide 30 % solution (80 mL) was poured through the side arm into the flask together with 100 mL of distilled water. The contents were distilled by direct heating. The ammonia evolved was allowed to absorb in 100 mL of 4 % boric acid solution contained in the receiver flask.

The ammonia distillate was titrated with 0.1 M hydrochloric acid, using the mixed indicator solution until the color changed from green to pinkish. Blank and standard determinations were also carried out as described above except that distilled water and standard ammonia solution were used in lieu of the sample solution. The amounts of total nitrogen and subsequently protein content in the sample was calculated as described in general formula (Government of India and Government of the Netherlands, 1999).

$$\text{Total protein} = (\text{total N} - \text{non-protein N}) \times 6.25$$

Determination of iron and copper contents in the distillery wastewater sample

The contents of Fe and Cu were determined by spectrophotometric method using atomic absorption spectrophotometer (Nov AA 400) at Ministry of Agricultural Research (MAR), Yezin, Naypyitaw.

Determination of *E. coli* in the Distillery Wastewater by Plate Count Method

Resolic acid 0.1 g, sodium hydroxide 0.7998 g and distilled water 10 mL were mixed into the reagent bottle. Then, the solution was stored in the refrigerator for one week. After cooling the refrigerator, resolic acid solution 0.1 mL, Defco agar 5.2 g and distilled water 250 mL were boiled on the stove for 15 min. Then, the mixture solution 6 mL was poured into the petri dish. It was shaken on the shaker for 18 h. It was used for control to compare with *E.coli* counting in wastewater. Moreover, wastewater sample 1 mL and the mixture solution 5 mL were added into another petri dish. The petri dish was also shaken on the shaker for 18 h. And then, wastewater containing petri dish was compared with the control using UV detection method to count *E.coli* bacteria. *E.coli* count in the distillery wastewater sample was measured at Ministry of Agricultural Research (MAR), Yezin, Naypyitaw.

Results and Discussion

Some Physicochemical Parameters of Untreated and Treated of Distillery Wastewater Sample

Some physico-chemical parameters such as pH, turbidity, conductivity, total alkalinity, total hardness, total dissolved solids (TDS), chemical oxygen demand (COD), dissolved oxygen (DO) and biochemical oxygen demand (BOD), chloride, calcium, magnesium, bicarbonate, total phosphate, ammonia nitrogen, iron, copper and *E.coli* of distillery wastewater sample before and after treatment by using slow sand filtration technique were determined and the results are comparatively shown in Table 2.

pH

The pH values of water are very important in determination of water quality since it effects other chemical reactions such as solubility and metal toxicity. In this study, the pH value of untreated wastewater sample was 3.67. Lower the pH value higher is the corrosive nature of water. After treatment with slow sand filter, the pH value of wastewater sample was increased to 6.10. The value of treated wastewater was within the range of USEPA standard value 6-9.

Biochemical oxygen demand

Before treatment, the biochemical oxygen demand value of wastewater sample was 71.70 ppm. The biochemical oxygen demand value of treated wastewater sample was found to be 30.50 ppm. The value of treated wastewater sample was within the permissible level of USEPA standard 50 ppm. If the BOD concentration is higher, the water is polluted. According to the results of BOD, the wastewater was none polluted.

Chloride content

Before treatment, the chloride value of wastewater sample was 3.38 ppm. After treatment, the chloride value was reduced to 2.02 ppm. USEPA standard value of chloride is 142 ppm. Therefore, the chloride value of treated wastewater sample was satisfied with the USEPA value 142 ppm. The presence of a low salt content may render the wastewater suitable for domestic, agricultural and industrial uses.

Calcium and magnesium contents

The content of calcium and magnesium value of untreated wastewater sample were 20 ppm and 16.25 ppm. After treatment, the content of calcium and magnesium values of treated wastewater sample were found to reduced 7.75 ppm and 7.26 ppm. USEPA standard of calcium and magnesium values were 230 ppm and 100 ppm. These values were satisfied the USEPA standard.

Bicarbonate

The bicarbonate value of untreated wastewater sample was 5.45 ppm. After treatment, the dissolved oxygen value of wastewater sample was increased to 6.5 ppm. Therefore, the resulted value of treated wastewater was within the permissible level of USEPA standard (6.5-8.4 ppm) and they were suitable for domestic purposes.

Total phosphate

Before treatment, the total phosphate value of wastewater sample was 2598 ppm. After treatment, the phosphate value was reduced to 198.40 ppm. USEPA standard value of phosphate is 30 ppm. Phosphate is an essential nutrient for living organisms in water bodies. The total phosphate value was not satisfied USEPA standard. High concentrations of phosphate can indicate the presence of pollution due to decomposition of organic matters.

Ammonia nitrogen

Ammonia nitrogen value of untreated wastewater sample was 8.60 ppm. After treatment, ammonia nitrogen value decreased to 3.10 ppm. From result obtained, the treated ammonia nitrogen value of wastewater sample was deviated from the USEPA standard 2 ppm and the analyzed wastewater was not suitable for domestic purposes.

Iron and copper contents

Before treatment, the values of iron and copper concentrations in the wastewater sample were 10.46 ppm and 1.99 ppm respectively. After treatment, the value of iron and copper concentrations in the wastewater sample were 4.45 ppm and 0.45 ppm respectively. Therefore, the values of iron and copper in the treated wastewater sample were not consistent with the USEPA standard value 0.3 ppm and 0.2 ppm. The contents of iron and copper in the wastewater were not suitable for domestic, agricultural and industrial uses.

E. coli count

Before treatment, the number of *E. coli* in the wastewater sample was 2500 CFU/100 mL. After treatment, the number of *E. coli* in the wastewater sample was reduced to 300 CFU/100 mL. USEPA standard value of *E. coli* is 100 CFU/100 mL. Therefore, the treated value of wastewater sample was not consistent with the USEPA standard. But, *E. coli* in the distillery wastewater was reduced significantly than initial wastewater.

Table 2 Comparative Data of some Physicochemical Parameters in Distillery Wastewater before Treatment and after Treatment with Slow Sand Filter

Parameters	Unit	Before treatment	After treatment	USPA Standard
pH	-	3.67	6.10	6-9
Turbidity	NTU	459	44.50	10
Conductivity	μScm^{-1}	5059.25	1619.25	2000
Total alkalinity	ppm	120	70	500
Total hardness	ppm	1240	550	500
Total dissolved solids	ppm	3500	1250	1200
Chemical oxygen demand	Ppm	171.40	75.20	100
Dissolved oxygen	ppm	3.70	5.55	4-6
Biochemical oxygen demand	ppm	71.70	30.50	50
Chloride	ppm	3.38	2.02	142
Calcium	ppm	20	7.75	230
Magnesium	ppm	16.25	7.26	100
Bicarbonate	ppm	5.45	6.50	6.5–8.4
Total phosphate	ppm	2598	198.40	30
Ammonia - nitrogen	ppm	8.60	2.56	2
Iron	ppm	10.46	4.45	0.50
Copper	ppm	1.99	0.45	0.20
E. coli	CFU/100 mL	2500	300	100

Conclusion

Distillery effluent released to the environment prior to any treatment poses a threat to the natural environment. Many advanced technologies are developed for wastewater treatment but most of them are not cost effective. In this study, slow sand filtration treatment technique was used as filter using locally available materials such as coarse sand, find sand, gravels and domestic charcoal. The results of current study show that it is possible to reduce pollution from distillery wastewater. The application of slow sand filtration method can also be considered as an alternative and economical method for reducing water pollution in rural areas. This research using slower sand filtration method was found to be handy to prepare, beneficial and cost effective for reducing water contamination in rural areas.

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