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Research Article

Impact of Dashen Brewery Effluent on Irrigation Water Quality of Shinta River in Gondar, Ethiopia

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Abstract

The main objective of this study is to assess the quality of water released from Dashen brewery and used for irrigation to grow vegetables in Gondar city of Ethiopia. Water samples from the upper part of Shinta river (which is above the point of effluent of waste water to the river), at the point of brewery waste water effluent, and other four sampling points (100 m, 200 m, 300 m and 400 m) down the stream from the point of waste water effluent were taken to determine the pollution level of Shinta river by the waste water exposed by the Dashen brewery. The water samples were taken to the laboratory and analyzed by standard analysis methods. The result of the laboratory analysis of the water samples show that most of the physico-chemical properties of the waste water (Electrical Conductivity, Total Suspended Solids, Total Dissolved Solids, Dissolved Oxygen, Biological Oxygen Demand, Chemical Oxygen Demand, nitrate and phosphate) were above the standard set by USEPA limit for irrigation water. pH, temperature and trace elements (As, Cd, Pb, Hg, Ni and Zn) were within the permissible limit of USEPA for irrigation water. Therefore the water released from Dashen Brewery in to the Shinta River should be released to the river after treated with standard waste treatment plant and the responsible bodies should have regulatory mechanisms in order to protect the river water from pollution.

Keywords: Water quality, Dashen brewery, Shinta river, physico-chemical properties, permissible limit.

Introduction

The water resources of our planet, a basic resource for our existence, are the most threatened aspect in life existence. In the food industry, the brewing sector has a strategic economic position with the annual world beer production exceeding 1.34 billion hectoliters (FAO, 2002). According to FAO (2002) beer is the fifth most consumed beverage in the world following tea, carbonates, milk and coffee and it is the most popular drink with an average consumption of 23 L/person per year. The brewing industry has an ancient tradition and is still a dynamic sector open to new developments in technology and scientific progress (Malone *et al.,* 2010). Brewers are very concerned in that they use techniques which are best in terms of product quality and cost effectiveness. During production, beer alternately passes through three chemical and biochemical reactions (mashing, boiling, fermentation and maturation) and three solid liquid separations (wort separation, wort clarification and rough beer clarification) (Verstl, 1999). A significant cost factor and an important aspect in the running of a brewery operation are water management and waste disposal (Unterstein, 2000).

Every brewery tries to minimize waste disposal costs whereas the legislation imposed more stringent cost for waste disposal by the authorities (Knirsch *et al.*, 1999). Water consumption in a brewery is not only an economic parameter but also a tool to determine its process performance in comparison with other breweries (Perry and De Villiers, 2003). The food and beverage industries including brewing are water consuming in the production process, the consumption of water ranging from 4 to 11 hl water/hl beer (Unterstein, 2000). In the production of beer, the average water consumption of around 5-6 hL/hL beer is correlated to beer production for industrial breweries (Perry and De Villiers, 2003). According to Perry and De Villiers (2003), water consumption is divided into 2/3 of it and is used in the process and 1/3 is used in the cleaning operations and the effluent load is very similar to the water load since none of this water is used to brew beer and most of it is exposed as effluent. Diatomaceous earth has various important mechanisms for filtration in the production process brewing as reported by Baimel *et al.* (2004).

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The conventional dead-end filtration with filter-aids (Kieselguhr) has been the standard industrial practice for more than 100 years and will be increasingly scrutinized from economic, environmental and technical standpoints in the coming century (Baimel *et al.*, 2004). About two thirds of the diatomaceous earth production is used in the beverage industry (beer, wine, fruit juice and liqueurs), the conventional dead-end filtration with filter-aids consumes a huge amount of diatomaceous environmental, sanitary and economic implications (Baimel *et al.*, 2004). Therefore, the main objective of this study is to assess the quality of water released from Dashen brewery and used for irrigation to grow vegetables.

Materials and methods

Sampling and data collection methods: Water samples from 100 m above the point of discharge (sample point 1), at the point of effluent discharge (sample point 2), 100 m (sample point 3), 200 m (sample point 4), 300 m (sample point 5), 400 m (sample point 6) and 500 m (sample point 7) from the point of effluent respectively were taken and analyzed. Water sample 100 m above the point of the effluent was analyzed to compare it with the brewery effluent and water samples down the stream in order to check whether the pollution is from the brewery or from any other source. All the samples were analyzed for pH, temperature, EC, TSS, TDS, DO, BOD, COD, nitrate, phosphate and trace elements (Pb, Ar, Zn, Cd, Hg and Ni). The results of brewery effluent water and the samples taken down the stream were compared to the water sample taken from the Shinta River above the point of effluent of Dashen brewery and the water quality standard for irrigation water set by USEPA guidelines.

Sample analysis methods

pH: pH of samples was noted using potentiometric method using pH meter already standardized by using buffer solutions of known value before analysis.

Temperature: Temperature was measured using the thermometric method at the site of sampling using portable calibrated mercury thermometer (EPA, 2003).

Electrical conductivity (EC): EC is the measure of the ability of an aqueous solution to convey an electric current. This ability depends upon the presence of ions, their total concentration, mobility, valence and temperature. EC was determined by conductivity meter.

Total suspended solids (TSS): Total suspended solids are the portion of solids that usually remains on the filter paper. For TSS analysis, known amount of sample was filtered through the pre weighed filter paper. Filter paper was then dried at 103-105°C. TSS was determined by using following formula:

TSS mgL^{-1} = (final–initial weight) (amount of sample)-1 × 1000

Total dissolved solids (TDS): Total dissolved solids (TDS) are the measure of total inorganic salts and other substances that are dissolved in water. TDS was determined by using Electrical Conductivity (EC) meter.

Biological oxygen demand (BOD): Biological oxygen demand (BOD) which is expressed as weight of oxygen consumed per unit volume of water during a defined period of time at a define the temperature was calculated. For this the sample of waste was incubated for 5 d at 20° C in the dark. The reduction in dissolved oxygen concentration during the incubation period yields a measure of the biochemical oxygen demand.

Dissolved Oxygen: Dissolved oxygen was determined by Winker's titration (Huang *et al.*, 2009).

Chemical oxygen demand: The COD is determined by titration with (0.25 M) Ferrous sulphate, using 1:10 phenanthroline (UK, Dept. of Environ, 1974).

Nitrate-nitrogen (NO^{3-}) and Orthophosphate ($PO4^{3-}$): It was determined with spectrophotometer (HACH DR/2010, USA) according to HACH instructions.

Trace element analysis: For the analysis of heavy metals, Arsenic (As), Cadmium (Cd), Lead (Pb), Mercury (Hg), Nickel (Ni) and zinc (Zn). Samples were analyzed on Atomic Absorption Spectrophotometer for concentration by using specific cathode lamp. AAS was calibrated for each element using standard solution of known concentration before sample injection (APHA, 2005).

Result and discussion

This study has showed the various effect of breweries effluent on the physico-chemical parameters of Shinta River. There was an observed increase in most of the parameters studied with little fluctuations in some of the parameters. The physico-chemical parameters investigated showed some variation along the sampling points.

pH: There were variations in the pH with the highest recorded for sample points 1 and 7. The low pH value recorded for station 2 up to sample point 7 down the stream this may be due to the organic load from brewery effluent. All the sample points except sample point 1 show pH value below the lower limit of irrigation water set by USEPA (2003).

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Table 1. Comparison of laboratory analysis result of water samples.

Parameters	Unit	Samples							USEPA (2003) standard
		S1 (up-stream)	S2 (at the point of discharge)	S3 (100 m)	S4 (200 m)	S5 (300 m)	S6 (400 m)	S7 (500 m)	
pH	-	6.5	5.6	5.7	5.9	6.1	6.1	6.3	6.5-9
Temperature	^{o}c	22.5	32	28	26	25	24	23	Greater by 1°C from ambient temp.
EC	μScm^{-1}	197.75	1200.6	1105.94	806.25	523.3	331	279	1000
TDS	MgL^{-1}	13	37	33	30	28	22	17	1500
TSS	MgL^{-1}	10.2	38	35	26.5	23	18	14.5	30
DO	MgL^{-1}	3.2	2.1	2.2	2.4	2.6	2.7	2.9	>-5
COD	MgL^{-1}	800.2	872.6	870	863.2	854.9	832.4	817.8	250
BOD	MgL^{-1}	636	745	727	713	705	693	687	50
Nitrate	MgL^{-1}	2.3	16	14	11	8	5.2	3.6	50
Phosphate	MgL^{-1}	1.2	6	5.8	5.2	4.8	3.5	2.2	2

Table 2. Laboratory analysis result of trace elements.

Trace elements	Sample point 1	Sample point 2	Sample point 3	Sample point 4	Sample point 5	Sample point 6	Sample point 7	FAO	USEPA
Arsenic	ND	<0.1	<0.1	<.1	ND	ND	ND	0.1	0.1
Cadmium	ND	ND	ND	ND	ND	ND	ND	0.01	0.01
Lead	0.01	0.2	0.003	0.002	0.001	0.001	0.001	5.0	5.0
Mercury	ND	ND	ND	ND	ND	ND	ND	-	-
Nickel	ND	0.1	0.02	0.02	0.01	ND	ND	0.2	0.2
Zinc	0.01	1.25	1.01	0.75	0.86	.02	.01	2.0	2.0

Temperature: High temperature was recorded in the sample points 2 and 3 (Table, 1), the decrease down the stream. The high temperature values could be attributed to discharges of hot liquor and steam condensates in the receiving water. All the temperature values down the stream starting the point of discharge of brewery effluent were above the standard set by USEPA (2003).

Electrical conductivity (EC): Conductivity is the ability of the water to conduct an electric current, and is an indirect measure of concentration of ions. The more ions present, the more electricity can be conducted by the water. In this study, electrical conductivity values varied between from sample 2 to sample 7. The lowest conductivity (197.75 µs/cm) was recorded in the upper stream sampling point. The high conductivity value in sample points 2 (1200.6 µs/cm) and other downstream sampling points indicate the effect of industrial wastes discharge into the river. Dashen beer factory release waste to the Shinta River, thus it is responsible for the increasing values of the conductivity at sample point 2. Starting from sampling point 2 towards the sampling point 7 the EC decreased which reflects the dilution of surface water. Except the sampling point 2 and 3 all the EC values downstream sites were within the USEPA (2003) standards for effluent discharges to surface water (Table 1).

Nitrate- Nitrogen (NO^{3-}-N): Sample point 2 showed high nitrate concentrations, which decreased along the sampling points down the stream. Nitrate generally occurs in trace quantities in surface waters, most coming from organic and inorganic waste discharges. An excess nitrate in river water promotes high primary productivity and is taken as a warning for algal blooms (eutrophication). In this study, the levels of nitrate ranged from 16 mg/L (sample point 2) to 2.3 mg/L (sample point 1). The decrease in the concentration of nitrate from sample point 2 to sample point 7 might be due to dilution and self-purification along the stream. In this study, all the samples show low value of nitrate concentration that is below the standard set by USEPA (2003) (Table 1).

Phosphate ($PO4^{3-}$): Phosphate concentration was low in all sampling stations. These ions, especially phosphate is limiting nutrients in aquatic ecosystem (Atlas and Bartha, 1993). Phosphate concentration ranged between 6 mg/L (sampling point 2) and 1.2 mg/L (sampling point 1).

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The levels of phosphate downstream of Shinta river was high and of great concern. Relatively lower phosphate levels were recorded in the upstream of the river (1.2 in sampling point 1). The higher levels of phosphate starting from sample point 2 to sample point 7 were recorded in impacted sampling points. The discharge of phosphate salts and detergents used for washing in the factory is a regular source of phosphate at the discharge point. In all samples, except sample point 1 and 2, phosphate concentrations were higher than 2 mg /L, which is considered as the higher limit for river waters to pose a risk of eutrophication by EPA irrigation water standard (2003) (Table 1).

Total Suspended Solids: TSS concentration is a measure of the amount of materials suspended in water which includes a wide range of sizes of materials from silt and plankton to industrial wastes and sewage. Total suspended solids in river water can decrease light penetration, leading to a decrease in photosynthesis. The resultant primary production reduces food availability for aquatic organisms higher up in the food chain. TSS values in the seven sites varied between 38 mg/L and 10.2, in sample point 2 and sample point 1 respectively. The TSS result that has been obtained from sampling point 2, 3, 4 and 5 had the maximum values of 38 mg/L, 35 mg/L, 26.5 mg/L and 23 mg/L, respectively. The total suspended solid concentration is more pronounced at these sampling points, these sample points are located near Dashen beer factory in which the effluents might contribute to the load of total suspended solids. There was a gradual decrease in the values of TSS from sampling point 2 to sampling point 7. This decrease could be as a result of sedimentation of some of the suspended substances in the effluents discharge as it moves down stream (Haslam, 1990). All the total suspended solid values at the downstream were below the EPA (2003) standards for effluent discharges to surface water (Table 1).

Dissolved Oxygen (DO): Surface waters are normally saturated with DO but such DO can be rapidly removed by the oxygen demanding organic wastes and the management of DO provides a broad indicator of water quality (DFID, 1999). The DO levels in the impacted sites ranged from 2.1 mg/L (sample point 2) to 2.9 mg/L (sample point 7). The lower value recorded for DO in brewery effluent might be as a result of organic pollution. The value in upstream were higher than the values of downstream sites. Thus, in references high DO levels indicate good water quality. The depletion of dissolved oxygen at sample point 2 and 3 could be due to discharge of organic and in organic loads, which required high levels of oxygen for chemical oxidation, decomposition or break down. The gradual revival of DO at sampling points down the stream might be due to aeration and the dilution of the river water. All DO values were found to be below the standard set by USEPA.

Biological Oxygen Demand (BOD5): The 5 d BOD is the most widely used parameter of organic pollution applied to surface waters. It is the amount of dissolved oxygen taken up by aerobic microorganisms to degrade oxidizable organic matter present in stream measured over the period of 5 d. BOD normally gives an indication of the amount of biodegradable organic matter. Sampling point 2 had the highest value of BOD (745 mg/L) and the upper sampling point (1) had the lowest value (636 mg/L). The sampling points 3, 4, 5, 6 and 7 were also characterized with higher levels of BOD5 concentrations due to discharge of organic effluents by Dashen Brewery industry. All the BOD5 values were above the USEPA standards for irrigation water quality (Table 1). In all impacted sites, BOD is above the ambient standard value for surface waters (50 mg/L). Compared to maximum concentration at sampling point 2 (745 mg/L BOD5), the passage of the effluent through long distance along the river and due to the dilution of river water the values for BOD gradually decreases.

Chemical Oxygen Demand (COD): The chemical oxygen demand (COD) is used as a measure of equivalent amount of oxygen required to completely oxidize both biodegradable and non-biodegradable organic and inorganic matter. COD values ranged between 872.6 mg/L and 800.2 mg/L in the sampling points. The maximum amount of COD was recorded in sampling point 2 (brewery effluent) which was river (872.6 mg/L). The higher levels of COD could be ascribed to the discharge of effluent by Dashen Brewery industry to the river. Results of the analysis revealed a fall in the chemical oxygen demand (COD) from 872.6 mg/L in the brewery effluent to 817.8 mg/L in the sampling point 7 downstream. The COD concentration at all sampling sites were above the USEPA standards for effluent discharges to surface water (Table 1). All the reference and impacted sites had COD values above the ambient standard value for surface waters (50 mg/L).

Trace elements: As show in the Table 2, the results of the laboratory analysis of trace elements (As, Cd, Pb, Hg, Ni and Zn) in Shinta River were found below the limit set by FAO and USEPA. This shows that there is no pollution of Shinta River water by trace element for irrigation purpose.

Conclusion

The results indicated that pH and temperature were above the range of permissible limit for surface waters down the stream. Very high nutrients, BOD, COD and suspended solids load were observed, indicating the river is impaired. The water quality of Shinta River shows spatial variation by which the water quality at site upper from the point of discharge of brewery effluent is better than the water quality down the stream.

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The levels of most parameters responsible for water quality downstream were higher than the corresponding levels upstream. There was a gradual decrease in conductivity, BOD, COD, TSS, nitrate and phosphate from discharge point to downstream but dissolved oxygen increases. The water quality of the samples located near the factory does not fulfill the EPA irrigation water quality guidelines in most water quality parameters. It indicates the effects of discharging of effluent released from such industry. Thus, the brewery effluent is responsible for the high level of water contamination around the discharge point. Generally the physico-chemical results from this study showed that some of the parameters measured in the river were above reference values, the standards set out by USEPA irrigation water quality guideline. The concentration of EC, BOD, COD, $PO4^{3-}$, and TSS at the discharge point and downstream were above the ambient environmental standard. Therefore, the elevation in levels of indicator parameters downstream (up to 500 m) subsequently render the river water unwholesome for intended beneficial purposes. The development of Brewery industries in developing countries like Ethiopia is an encouraging phenomenon from economic and social development point of view but industrial wastes should be effectively treated and managed properly.

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