CHEMICAL, PHYSICOCHEMICAL AND PHYSICAL PROPERTIES OF WASTEWATER FROM THE SUDANESE FERMENTATION INDUSTRY (SFI)

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ABSTRACT

Large amounts of untreated waste water of baker's yeast industry from the Sudanese fermentation industry (SFI) are discharged in two different forms; molasses waste (MW) and wastewater from all processing operations. The objectives of the present study were to determine the chemical and physical properties of the wastewater from (SFI). Part of these characteristics is considered as parameters for measuring the strength of the effluent. Samples of wastewater were collected from four sources in the fermentation plant: molasses wastewater (MW), separator wastewater (SW), Filter wastewater (FW) and the main drain well wastewater (MDW). The study shows that all wastewater samples contain higher amounts of micro-elements and lower amounts of macro-elements. The MW contents of sodium, potassium and calcium were 443, 7000 and 3810ppm, respectively. The study also shows that MW had a higher BOD value (640 mg/l) and COD (4500 mg/l) compared to SW, FW and MDW which had a BOD value of 250, 450 and 148 mg/l, respectively. However, the COD values of SW, FW and MDW were 250, 160 and 80 mg/l, respectively. The wastewater was found to be rich in minerals and nutrients, for this reason it is useful to use it in agriculture, irrigation and energy purposes after being treated.

Keywords: Wastewater, Chemical oxygen demand, Biological oxygen demand, Minerals

1. INTRODUCTION

Wastewater is any water that has been adversely affected in quality by anthropogenic influence. It comprises liquid waste discharged by domestic residences, commercial properties, industry, and/or agriculture and can encompass a wide range of potential contaminants and concentrations. In the most common usage, it refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewaters from different sources (http://en.wikipedia.org/wiki/Wastewater [1]).

Wastewater generated from agricultural and food operations has distinctive characteristics that set it apart from common municipal wastewater managed by public or private wastewater treatment plants throughout the world: it is biodegradable and nontoxic, but that has high concentrations of biochemical oxygen demand (BOD) and suspended solids (European Environment Agency [2]. The constituents of food and agriculture wastewater are often complex to predict due to the differences in BOD and pH in effluents from vegetable, fruit, and meat products and due to the seasonal nature of food processing and postharvesting.

Processing of food from raw materials requires large volumes of high grade water. Vegetable washing generates waters with high loads of particulate matter and some dissolved organics. It may also contain surfactants.

Sometimes, industrial wastewaters are treated partially before their discharge into sewers, or else are treated separately through suitable treatment processes so that the treated effluent is safe (Punmia [3]).

Industrial wastewater disposal needs proper considerations from the points of view of manufacturer, public and the sanitary engineer alike. From the public point of view, industrial wastes cause pollution to stream making it unfit for domestic, recreational and commercial purposes, deteriorate sewers and treatment, and increase cost of treatment.

Every fermentation plant utilizes raw materials, which are converted to a variety of products. Depending on individual process, varying amounts of a range of waste materials are produced (Fisher [4]; Hill [5]).

The characteristics and the treatment of waste water are the serious problem in the Sudanese fermentation industry. In the past there were no records for waste analysis, but now there is a sample for analysis after the plant has started working.

The waste water in the Sudanese Fermentation Industry (SFI) exists at four main places, those places include, and molasses waste (Sludge) which is kept separately in a small pond, separator waste, filter waste and main drain waste. This main drain waste consists of filter waste and separator waste. Also it may contain unconsumed inorganic and organic media components, microbial cells and other suspended solids, filter aids, waste of wash water from cleaning operation, cooling water, and water containing trace of solvents, acids and alkalis. Also it contains the laboratory water. The present method of disposal consists of pumping the waste water, mixing it with the effluent of an adjacent textile factory (Sadaga Textile Factory) and then disposes with another pump to an open solar drying pond outside the industrial area.

The objectives of the present was to evaluate the wastewater produced in the Sudanese Fermentation Industry (SFI) through determination of the chemical and physiochemical and physical properties of samples of wastewater.

2. MATERIALS AND METHODS

2.1 Materials

Samples of wastewater were collected from four sources in the fermentation plant (El-Hassaheissa, Gezira State): (i) molasses wastewater (MW), (ii) separator wastewater (SW), (iii) filter wastewater (FW), and (iv) the main drain well wastewater (MDW).

2.2 Determination of Chemical Oxygen Demand (COD)

The COD was determined according to the method reported by (Rand *et al.*, [6]). Ten ml of the sample were taken in a100 ml bottle then 5 ml of conc. H_2SO_4 was added and about 1g of copper sulphate ($CuSO_4$) also added. Then 3 ml of prepared N/40 $KmnO_4$ solution was added and immersed the bottle in boiling water for 30min while keeping the surface of the boiling water at the higher level than the surface of the sample. Then 3 ml prepared N/40 sodium oxalate ($Na_2C_2O_4$) was added and immediately titrated with N/40 potassium permanganate ($KmnO_4$) until violet colour appeared then repeated for the blank separately under same condition using 10 ml of distilled water instead of 10 ml of sample. Then,

$$\text{COD as mg } O_2/L = \frac{(1/40) \text{ x } 8000 \text{ x } (A - B)}{\text{ml of sample}} \tag{1}$$

where:

A = ml of $KmnO_4$ used for sample.
B = ml of $KmnO_4$ used for blank.
1/40 = Molarity of $KmnO_4$.
8000 = milliequivalent weight of oxygen × 1000 ml/L.

2.3 Determination of Biochemical Oxygen Demand (BOD)

The BOD-5 was determined using Winkler method as described by (Rand, *et al.*, [6]. Two 100 ml bottles was obtained with lid and cleaned well. 25 ml sample was taken in each bottle and 75 ml of distilled was added to the two bottles. Then the two bottles closed well .One bottle was kept in the incubator at (20-22)°C for 5 days. Then 10 ml of manganese sulphate solution and 2 ml of alkali- iodide solution were added to the other bottle well below the surface of the liquid by using a syring. Then the bottle closed and mixed by inverting the bottle several times. When the precipitate settles leaving a clear supernatant above the precipitate shaked again slowly by inverting the bottle, and when the setting has produced at least 50 ml supernatant 8 ml of con. HS_2O_4 were added. Then the bottle was closed and mixed by gentle inversion until dissolution was completed. Then 100 ml of the sample was titrated with 0.05 M $Na_2S_2O_3$ solution until a pale yellow solution is reached. Then 2 ml of freshly prepared starch solution was added and titration was continued until a blue colour appeared. The procedure was then repeated using 100 ml distilled water (blank). Then, repeated for incubated sample after 5 days. The BOD was calculated as follows:

$$\text{BOD as mgO}_2\text{/L} = 16(V_1 - V_2) \qquad (2)$$

where:

V_1 = ml of $Na_2S_2O_3$ used for the sample before incubation.
V_2 = ml of $Na_2S_2O_3$ used for the sample after incubation.

2.4 Determination of Minerals and Minerals Salts

The macro- and micro-elements, present in the ash as metallic oxides, were converted to chlorides by HCl and diluted. Flame Atomic Absorption Spectrophotometer (FAAS) with a variant spectrometer (SPECTR AA-10) was used to determine calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), iron (Fe), zinc (Zn), copper (Cu), cadmium (Cd), lead (Pb), cobalt (Co) and manganese (Mn). The mineral salts were also determined using standard methods according to Early [7]. The mineral salts included: chloride, nitrate and sulphate. The concentrations of all elements were expressed in ppm, and the instrumental analysis conditions are shown in Table 1.

Table 1. The instrumental analysis conditions of the macro and microelements

Element	Wave length	Slit	Relativity noise	Sensitivity (mg/l)	Sensitivity check (mg/l)	Linear range
Ca	422.7	0.7	1.0	0.092	4.0	5.0
Cd	228.8	0.7	1.0	0.028	1.5	2.0
Cu	324.8	0.7	1.0	0.077	4.0	5.0
Co	242.5	0.2	1.0	0.12	7.0	3.5
Fe	248.3	0.2	1.0	0.10	5.0	5.0
Mg	285.2	0.7	1.0	0.0078	0.3	0.5
Mn	279.5	0.2	1.0	0.052	2.5	2.0
Na	589.0	0.4	1.0	0.012	0.5	1.0
Pb	217.0	0.7	1.0	0.19	9.0	20.0
Zn	214.0	0.7	1.0	-	1.0	1.0

2.5 Determination of Total Solids and Volatile Solids

The total solids and volatile solids of the samples were determined as described by (Punmia [3]. Cleaned dish was taken and ignited to constant weight (W_1). Then 25 ml of well mixed sample transferred to the above dish. Then the sample evaporated to dryness at 103°C for 24 hours, in constant temperature oven. Then cooled the dish in a desicator and weight was determined (W_2). Then the dish was ignited at 600°C in furnace for 30 min. The dish was cooled in a desicator and its weight was determined (W_3).

The total solids content was calculated as follows:

$$\text{Total solids } (S_T) = \frac{(W_2 - W_1)}{V} \times 100 \text{ mg/l} \quad (3)$$

$$\text{Total volatile solids } (S_V) = \frac{(W_2 - W_3)}{V} \times 100 \text{ mg/l} \quad (4)$$

where:

W_1 = Weight of empty dish.
W_2 = Weight of the dish after evaporation.
W_3 = Weight of the dish after ignition.
V = Volume of the sample.

2.6 Determination of Suspended Solids (Non-Filterable Solids)

The total suspended solids were determined according to the method described by Punmia [3]. Cleaned crucible with filter paper was ignited to constant weight in an oven (W_1). Then 25 ml sample was taken and filtered through the crucible. Then the crucible was dried in a constant temperature oven maintained at 103°C for 24 hours. Then cooled in a dedicator and weight (W_2). The suspended solids were then calculated as follows:

$$\text{Suspended solid} = \frac{(W_2 - W_1)}{V} \times 100 \text{ mg/l} \quad (5)$$

where:

W_1 = Weight of empty crucible plus filter paper.
W_2 = Weight of the crucible and filter paper after drying.
V = Volume of the sample.

2.7 Determination of total dissolved solids

Total dissolved solids were determined by evaporating the waste samples to dryness AOAC [8]. In this method 50 ml of sample were transferred to a weighed evaporating dish, and evaporated to dryness by heating for 1-2 hours at 180°C to a constant weight. Total dissolved solids were calculated as follows:

$$\text{mg/l of TDS} = \frac{\text{mg residue}}{\text{ml of sample}} \times 1000 \quad (6)$$

2.8 Determination of Temperature

The temperature of waste samples was measured using thermometer at room temperature (29°C).

2.9 Determination of Viscosity

The viscosity of samples was measured by brook filed viscometer using spindle 4. A sample of 200ml waste was taken and the readings were recording at 32°C. The results were expressed in Pascal units.

2.10 Determination of Colour

The colour was measured using Lovibond Tintometer (model E). It is a visual colorimeter used widely in the oil industry, but it is used in foods that are in liquid form was also reported (Pomeranz and Meloan [9]). The instrument has a set of permanent glass colours filters in the three primary colours: red, yellow and blue. The colours are calibrated on a decimal scale in units of equal depth through out each scale. The waste samples were placed in glass cell and the filters were introduced into the optical system until colour match was obtained. The results were expressed in Lovibond units.

2.11 Determination of Density

The density of each sample was determined according to the method described by Eldardiri [10]. Using density bottle has a volume of 25 ml. The density bottle was ignited in an oven at 115°C for 10 min then transferred to a desciator and cooled then its Weight was determined. After that the density bottle was filled by each samples and reweighed.

The density for each sample was calculated using the following equation:

$$\text{Density (gm/ml)} = \frac{\text{Loss in weight}}{\text{Volume of sample}} \tag{7}$$

2.12 Determination of Turbidity

The turbidity was determined photoelectrically using photometer 7000. The turbidity of waste water depends on the quantity of solid matters present in the suspension state.

Turbidity is a measure of light-emitting properties of waste water, and turbidity test is used to indicate the quality of waste discharges with respect to colloidal matter. The turbidity depends up on the strength of waste water. The stronger or more concentrated the waste, the higher is it is turbidity. The results were expressed in term of formazin turbidity units (FTU).

3. RESULTS AND DISCUSSION

Table (2) shows that molasses wastewater (MW) was found to contain 3810 ppm (calcium), 1050 ppm (magnesium), 4430 ppm (sodium) and 7000 ppm (potassium). In addition, it contained relatively high contents of micro-elements such as 0.525 ppm (cobalt), 0.141 ppm (cadmium), 1.17 ppm (copper), 26.82 ppm (manganese), 0.657 ppm (lead), 3.05 ppm (zinc) and 243.9 ppm (iron). In contrast, the separator wastewater (SW) was found to contain smaller amounts of micro and macro elements compared to molasses wastewater. It contained 110 ppm (calcium), 48 ppm (magnesium), 76.4 ppm (sodium), 90 ppm (potassium), 0.074 ppm (cobalt), 0.28 ppm (manganese), 2.04 ppm (iron) and 0.03 ppm (copper). However, the filter wastewater (FW) was found to contain higher amounts of minerals compared to separator wastewater, it contained: 135 ppm (calcium), 226.5 ppm (sodium) and 300 ppm (potassium). And the filter waste contained very small amounts of copper (0.07 ppm), iron (0.026 ppm) and manganese (0.46 ppm). The main drain wastewater (MDW) contained small amounts of minerals compared to the other wastewater samples, it contained 106 ppm (calcium), 58.7 ppm (sodium) and 20 ppm (potassium), also contained 44 ppm (magnesium) and very small quantities of heavy metals, 0.04 ppm (cooper) and 0.37 ppm (manganese).

The micro-elements zinc, lead, cadmium and cobalt were not detected in most of the examined wastewater samples (SW, FW and MDW).

Table 2. Mineral and minerals salts contents of wastewater of the Sudanese fermentation industry (ppm)

Sample	Ca	Cd	Cu	Co	Fe	Mg	Mn	Na	Pb	Zn	K
MW	3810	0.141	117	0.525	243.9	1050	26.82	443	6.657	3.05	7000
SW	110	ND	0.03	0.074	2.04	48	0.28	76.4	ND	ND	90
FW	135	ND	0.07	ND	0.026	15	0.46	226.5	ND	ND	3000
MDW	106	ND	0.04	ND	6.4	44	0.37	58.7	ND	ND	20

ND= Not detected.

The mineral salts contents of the various wastewater samples are shown in Table (3). The nitrate was detected in all samples of wastewater except the filter wastewater, while sulphate was found in all wastewater samples, and chloride was absent in molasses wastewater and found in the other wastewater samples.

The large amounts of micro and macro elements in all samples of wastewater may be due to the mineral salts and their acids or bases used as nutrients in the yeast industry such as ammonia solution, ammonium sulphate, ammonium chloride, urea, monoammonium dihydrogen phosphate, diammonium Hydrogen phosphate, super phosphate, phosphoric acid (50%), magnesium sulphate, magnesium chloride.

The presence of large amounts of minerals has many advantages; it may be used for the waste treatment of the plant which produces good bio-manure for soils. Also mineral act as nutrient for the microorganism present in the waste and help it in degradation of the waste to generate gas which can be used as a fuel in the boilers.

The results in the present study indicated that molasses could be used as a best substance for yeast production as it contains large amounts of nutrients.

Table 3. Minerals salts contents, BOD and COD (mg/l) values of the waste water of the Sudanese fermentation industry

Sample	Chloride (mg/l)	Nitrate (%)	Sulphate (%)	COD (mg/l)	BOD (mg/l)
WS	_	0.48	6.99	4500	640
SW	975	0.084	7.79	250	250
FW	680	ND	7.94	450	160
MDW	120	0.11	8.3	80	148

ND= Not detected

The required oxygen demand expressed as BOD and COD is an important parameter for the evaluation of wastewater (Speer, 1995). Chemical oxygen demand (COD) test can be used to measure content of organic matter of wastewater which is useful in the control of treatment processes. The values of COD and BOD are shown in Table 3. The COD of molasses wastewater (MW), separator wastewater (SW), filter wastewater (FW) and main drain wastewater (MDW) were 4500, 250, 450 and 80 (mg/l), respectively. COD value is often greater than BOD value (Speer [11]).

The Biochemical oxygen demand (BOD) test is the most widely used parameter of organic pollution applied to the wastewater. The BOD may be defined as the oxygen required for the microorganism to carry out biological decomposition of dissolved solids or organic matter in the wastewater under aerobic conditions at standard. The results of BOD test of molasses wastewater (MW), separator wastewater (SW), filter wastewater (FW) and main drain wastewater (MDW) were 640, 250, 160 and 148 (mg/l), respectively. These values were less than the range of BOD in milk processing plant, breweries and fruit canning industry which were 1000-2500, 500-1300 and 500-1650 (mg/l), respectively, as reported by Early (1992). Generally, the BOD values were extremely lower than COD values. It is clear from the results of BOD and COD, that the Sudanese fermentation industry has a weak effluent. The local governmental instruction does not allow disposal of industrial waste of BOD-5 more than 800 ppm to the sewer. The same act also does not permit disposal of any living matter to an open solar drying pond, and to prevent unaccepted odours which may cause disease and allergy to public, BOD-5 must not be more than 30ppm as reported in Industrial Research and Consultancy Center Report [12].

3.1 Physicochemical and Physical Properties

The physical characteristics are important in the selection of a suitable method for waste treatment. Table (4) shows the result of various physical analyses.

The total solids content of wastewater is defined as all the matter that remains as residue up on evaporation to 103 to 105°C. Total solids of molasses wastewater (MW) was found to be 56.8 and the volatile solids was 31.2 mg/l. While separator wastewater (SW) and filter wastewater (FW) both contained 0.4 mg/l total solids. In addition SW and FW contained 0.16 and 0.44 mg/l volatile solids, respectively. The total solid of the main drain wastewater (MDW) was 0.24 mg/l and the volatile solids was 0.12 mg/l.

Total solids in waste water exist in two different forms:

1- Suspended solids (non filterable solids).
   The suspended solids of molasses in mg/l were found to be 22.6 while separator, filter and main drain waste does not contain any suspended solids.
2- The Total dissolved solids of molasses waste was found to be 0.42×10^6 mg/l and is considered higher compared to the total dissolved solids of the SW, FW and MDW which were 0.002×10^6, 0.005×10^6 and 0.002×10^6 mg/l, respectively. From the results it is clearly seen that molasses wastewater has a high value of total solids and suspended solids. The high value of suspended solids gives idea of the presence of high COD and BOD values in molasses wastewater. Separator wastewater water and main drain wastewater had similar values of total dissolved solids.

The temperature of MW, SW, FW and MDW was 33, 30, 35, 27°C, respectively; this indicates that industrial wastewater had higher temperature than that of the water supply. The change in temperature affects the waste water in the following ways: firstly, as the temperature rises, its viscosity increases with a corresponding increase in its tendency to precipitate. Extremely low temperature affects adversely the efficiency of sedimentation. Secondly, the bacterial activity increases with increase in temperature up to about 60°C. Thirdly, the solubility of gases in waste water decreases with the increase in temperature.

The viscosity is an important physical property of a fluid from the point of view of study of fluid mechanism; also it is the property that determines the ease in which a fluid will flow. This property is very important, both the velocity of fluid and the flow rate in pipes are influenced by viscosity. The viscosity of molasses wastewater (MW), separator wastewater (SW), filter wastewater (FW) and main drain wastewater

(MDW) were found to be 13.3, 1.6, 10 and 3.3 Pascal, respectively. The determination of viscosity of the waste is very important, it is related to the velocity of fluid and the flow rate, and affect the selection and operation of treatment process.

The turbidity of MW was not detected because that the sample was very concentrated. However, the SW, FW and MDW waste had values of turbidity amount to 1200, 6800 and 600 FTU, respectively. It was reported that the turbidity of the samples depends up on the strength of waste water. The stronger or more concentrated the waste the higher its turbidity.

The colour of molasses wastewater (MW) was relatively blue (red 0.3, yellow 0.3 and blue 44) Lovibond units. Separator wastewater (SW) had red yellow colour (red 17, yellow 30.2 and blue) Lovibond units. Filter wastewater (FW) was completely yellow (red 12.3, yellow 24.1 and blue -) Lovibond units. The main drain wastewater (MDW) was slightly yellow (red 2, yellow 9.9 and blue -) Lovibond units. It was reported that the colour of industrial waste water depends upon the chemical process used in the plant (Punmia [4]).

All samples of waste were found to contain higher values of density compared to water density. The densities of molasses wastewater (MW), separator wastewater (SW), filter wastewater (FW) and main drain waste water (MDW) were found to be 1.27, 1.002, 1.002 and 1.006 gm/ml, respectively.

Table 4. Physicochemical and physical properties of wastewater of the Sudanese fermentation industry (ppm)

Sample	Total solids (mg/l)	Volatile solids (mg/g)	Total dissolved solids	Temperature (°C)	Viscosity (Pascal)	Turbidity (FTU)	Colour (Lovibond units)	Density (gm/ml)
MW	56.8	31.2	0.42×10^6	33	13.3	-	44 blue	1.27
SW	0.4	0.16	0.002×10^6	30	1.6	1200	17.2 red	1.00
FW	0.4	0.44	0.005×10^6	35	10	6800	24.1 yellow	1.003
MDW	012	0.12	0.002×10^6	27	3.3	600	9.9 yellow	1.006

4. CONCLUSION

Most of the Sudanese food industries have no treatment systems for their wastes, specially in Gezira State (Bagair, Wad Madeni and Hasaheisa). The present study aimed at analyzing the chemical, physicochemical and physical characteristics of the wastewater of the Sudanese fermentation industry plant. The solids content of the liquid waste stream were found to be 0.8 - 1%, of which about 51-75% were organic matter. The stream possessed a biochemical oxygen demand after 5 days of 148 to 640 ppm which is a very low value.

The treatment of waste is quite important. More attention and concentration are being given to industrial waste disposal both nationally and internationally. The Sudanese government must be concerned with the treatment process by providing a complete treatment system in the industrial areas and these results in minimizing the cost of production and will generate revenue to the country.

REFERENCES

[1] http://en.wikipedia.org/wiki/Wastewater, 2009.
[2] European Environment Agency. Copenhagen, Denmark. "Indicator: Biochemical oxygen demand in rivers (2001).
[3] Punmia, B.C., Ashok Jain, (1998) Waste water Engineering. (2nd Edition). Arihant Consultant, Bombay.
[4] Fisher, N.S. (1977) Legal aspects of pollution. In: Treatment of industrial effluents, pp. 18-29 (Editors Callely, A.G., Forster. C.F. and Stafford, D.A.). Hodder and Stoughton, London.
[5] Hill, F. (1980). Effluent treatment in the Bakers, yeast industry. In effluent treatment in the Biochemical industries, process Biochemistry's 3rd International Conference.
[6] Rand, Aronold. M.C., Greenberg. E. Michael. J. Taras, (1975). Standard methods for the examination of water and waste water, American Public Health Association.
[7] Early, R. (1992). Wastewater in the dairy industry: primary and secondary treatment in: The Technology of Dairy Products. Marcel Dekker, pp. 681-683, New York, U.S.A.
[8] AOAC, (1990). Official methods of Analysis. Helrich K. (Ed.). 15th ed., Association of Analytical chemists, Inc., USA p777.
[9] Pomeranz, Y. and C.E. Meloan (1987). Food Analysis. Theory and practice. 2nd edition. Van Nostrand Reinhold Comp., New York.
[10] Dardiri, M. Moawia (1985). Laboratory experiments for food analysis, pp.84, Food Science and Technology- University of Gezira.
[11] Speer, E. (1995). Wastewater in: Milk and dairy product technology. Marcel Dekker, INC., pp. 443-447. New York, U.S.A.
[12] Industrial Research and Consultancy Center- Khartoum (1998). Report about the baker's yeast production at the Sudanese fermentation industry.