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Physico-chemical analysis of sugar mill waste of Meham sugar mill

Sangeeta[1], Rani Devi[2], Gita Rani[3*]
[1, 2] Department of Energy and Environmental Sciences, Chaudhary Devi Lal University, Sirsa, Haryana, India
[3] Department of Chemistry, Chaudhary Devi Lal University, Sirsa, Haryana, India

Abstract
Use of sugar mill effluents for irrigation practices in agricultural fields with some level of dilution is in practice internationally. This research paper is representing significant water quality parameters with respect to its use in agriculture. Physico-chemical analysis of sugar industry effluents of Cooperative Sugar Mills, Meham, Haryana, India were done which includes: color, odour, pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), total solids (TS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), total alkalinity, carbonate, bicarbonate, sulphate, chloride, total hardness, calcium, magnesium, sodium, potassium, and phosphate. All the effluent parameters were analyzed as per the APHA (2012) standard methods.

Keywords: dilution, sugar mill effluents, BOD, COD, Odour, pH

Introduction
The water quality for irrigation purpose is indispensable for maintaining soil quality. Therefore quality of water used for irrigation can be tested by its physico-chemical analysis. Chemical characteristics of water are essential parameters to assess the suitability of water for irrigation purpose. The concentration and composition of soluble constituents in water determine its suitability for its use in agriculture.

Study Area
The present research is about the physico-chemical analysis of sugar industry effluents of Cooperative Sugar Mills, Meham, Haryana, India. It is located at 28°59'49.2"N 76°14'30.1"E. Sugar mill effluent (SME) samples were collected and analyzed for various parameters.

Result and Discussion
Physico-chemical characteristics of sugar industry effluents and their values are shown in Table-1.

Color
The color of the effluent was observed visually and it was observed that the effluents released from the main outlet of sugar mill were dark brown/grey in color. Its brown color could be due to the presence of melanoidin, which is condensation product of sugar amine. The appearance of water is very important for the aquatic life to make food using sun rays and it should be colorless as per BIS standards.

Odour
Odour of BWW, 25 % SME, 50 % SME and 100 % SME was analyzed as given in Table 1. BWW was odourless while 25 % SME, 50 % SME and 100 % SME samples were having unpleasant smell. It was categorized as objectionable or non-objectionable by direct smelling of the sample and it was observed that it had a smell of decaying molasses. The unpleasant smell might be due to the presence of sulphur compounds (Rath, 2010) [9]. Odour must have some indirect impact on plant growth.

Temperature
Temperature of BWW, 25 % SME, 50 % SME and 100 % SME are 32ºC, 38ºC, 38ºC and 40ºC respectively as shown in Table 1. Temperature of the effluents should not rise beyond 35ºC which is the permissible limit of BIS. The rise in temperature leads to the depletion of oxygen by accelerating its liberation from water.

pH (Hydrogen Ion Concentration)
pH of BWW, 25 % SME, 50 % SME and 100 % SME are 7.48±0.03, 6.22±0.02, 5.41±0.01 and 4.8±0.001 respectively along with their standard deviation as shown in Table 1. The pH of 50 % SME and 100 % SME was acidic in nature might be due to the use of acids of phosphorus and sulphur used during clarification of sugarcane juice and is dangerous in discharging effluents. It is also clear from the results that pH decreases with increase in concentration of SME showing increase in acidic nature of soil as shown in Figure 1. This was also supported by the earlier studies (Ayyasami *et al.*, 2008, Memon *et al.*, 2006, Manivasakam, 1987) [1, 5, 6]. Palharyal *et al.*, (1993) [8] reported essentiality of pH in formation of algal blooms, which cause water unfit for irrigation and soil becomes acidic causing poor yield of crops. Matkar and Gangotri (2002) [7] observed pH of sugar mill effluent and it was 4.5. Kataria (1995) [4] observed a decrease in pH of about 0.45 occurs with rise in temperature by 25ºC.

Table 1: Physico chemical parameters of Meham sugar factory effluents

Parameters	BWW	25% SME	50/% SME	100% SME	BIS Limits (IS 2490-2009)
Color	Colorless	Grey Brown	Grey Brown	Grey Brown	Colorless
Odour	Odourless	Unpleasant	Unpleasant	Unpleasant	Odourless
Temp.(°C)	32	38	38	40	35
pH	7.48±0.03	6.22±0.02	5.41±0.01	4.8±0.001	5.5-9.5
EC (dS/cm)	1.14±0.01	1.50±0.025	2.14±.025	2.70±0.015	2.0
TDS (mg/L)	151.55±7.5	433.3±18.76	661.93±15.6	1551.12±18.9	2100
TSS (mg/L)	43±1.03	101±1.11	171±2.41	251±2.69	600
TS (mg/L)	195±8.35	534±15.26	833±11.88	1810±12.54	2700
BOD (mg/L)	4.50±0.020	201.18±0.2	703.04±10.0	1016.67±51.3	50.0
COD (mg/L)	60.49±0.02	260.87±6.4	1031.24±31.9	2004.54±15.2	250
CO_3^{2-} (mg/L)	97.97±0.13	139.02±5.15	194.79±5.68	220.21±7.53	600
HCO_3^- (mg/L)	178.98±0.1	216.90±4.0	370.72±20	626.28±11.78	450
SO_4^{-2} (mg/L)	13.86±0.07	171.01±1.99	446.83±6.45	961.31±11.50	1000
Cl^- (mg/L)	12.80±0.02	204.21±6.80	378±6.29	1067.13±10.6	600
Ca^{+2} (mg/L)	39.36±0.21	209.74±8.16	363.29±10.1	803.08±6.36	200
Mg^{+2}(mg/L)	11.23±0.09	54.71±2.86	93.07±5.32	198.27±6.41	100
Na^+ (mg/L)	12.12±0.90	43.4±2.05	123.29±4.46	273.5±5.011	200
K^+ (mg/L)	11.53±0.57	50.43±2.03	141.17±2.63	340.04±6.60	200

Electrical conductivity (EC)

EC of BWW, 25 % SME, 50 % SME and 100 % SME are 1.14±0.011 dS/m, 1.50±0.025 dS/m, 2.14±.025 dS/m and 2.70±0.015 dS/m respectively along with their standard deviation as shown in Table 1. EC was found to be high due to presence of large number of ions in sugar mill effluents, values of EC increase with increase in concentration of SME from 25 % SME, 50 % SME and 100 % SME. It is above the permissible limit of BIS in 50 % SME and 100 % SME in discharging effluents. High EC values showed a pollution load of effluent in terms of ions and which might affect plant growth. Comparative analysis of pH and EC revealed that their values are increasing with the increase in concentration of SME and are also directly proportional to each other as shown in Figure 1.

Total Solids (TS)

TS of BWW, 25 % SME, 50 % SME and 100 % SME are 195±8.35 mg/L, 534±15.26 mg/L, 833±11.88 mg/L and 1810±12.54 mg/L respectively along with their standard deviation as shown in Table 1.

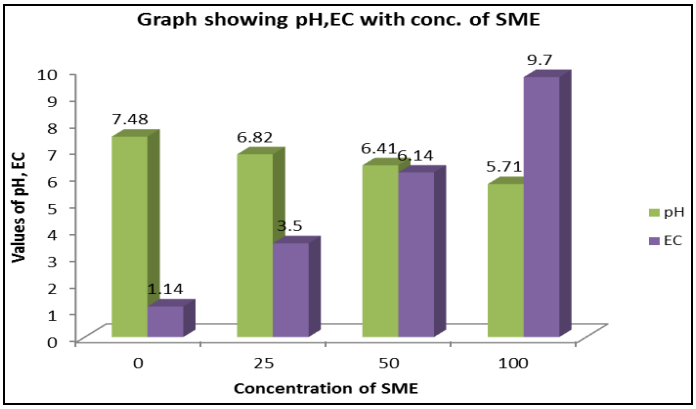

Fig 1: Comparative analysis of pH, EC with different concentration of SME

In effluents, total solids are mainly composed of carbonates, bicarbonates, chlorides, sulphates, nitrates, Ca, Mg, Na, K *etc.*, organic matter and other particles. In the present investigation, the range of TS was 534-1810 mg/L and which is well within permissible limits of 2700 mg/L of BIS in discharging effluents.

Total Suspended Solids (TSS)

TSS of BWW, 25 % SME, 50 % SME and 100 % SME are 43±1.03mg/L, 101±1.11 mg/L, 171±2.41 mg/L and 251±2.69 mg/L respectively along with their standard deviation as shown in Table 1. In the present investigation, it contained fewer amounts of suspended solids 251 mg/L (100 %) and which is well within permissible limits of 600 mg/L of BIS in discharging effluents.

Total Dissolved Solids (TDS)

TDS of BWW, 25 % SME, 50 % SME and 100 % SME are 151.55±7.54 mg/L, 433.3±18.76 mg/L, 661.93±15.6 mg/L and 1551.12±18.91 mg/L respectively along with their standard deviation as shown in Table 1. The total dissolved solids (TDS) mainly indicate the presence of various kinds of minerals like ammonia, nitrite, nitrate, phosphate, alkalies, some acids, sulphates and metallic ions *etc*. It is also an

important chemical parameter of water (Shetty *et al.*, 2009) [10]. In the present study, concentration of TDS in sugar mill effluents was in the range of 500-1600 mg/L with different SME concentrations. That is in the acceptable limit for TDS (2100 mg/L) in discharging effluents as per norms of BIS. It was observed that value decreases with increase in dilution of sugar mill effluent.

A comparative analysis of TS, TDS and TSS is shown in Figure 2 which reveals that concentrations of TS, TSS and TDS are increasing with increase in concentration of SME in linear fashion and are directly related to each other and TSS are much lower than TDS.

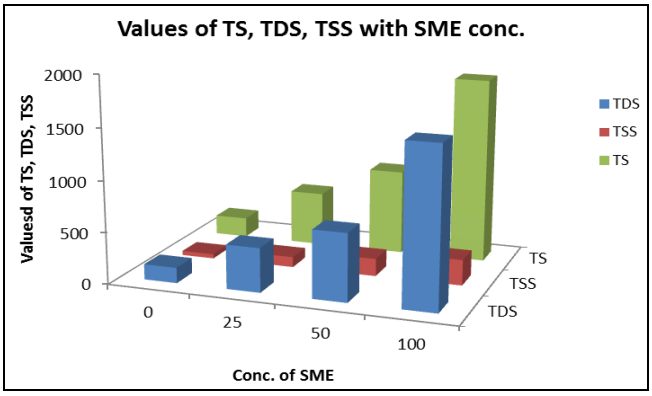

Fig 2: Comparative analysis of TDS, TSS and TS with different concentration of SME

Biochemical Oygen Demand (BOD)

BOD of BWW, 25 % SME, 50 % SME and 100 % SME are 4.50±0.020 mg/L, 201.18±0.22 mg/L, 703.04±10.0 mg/L and 1016.67±51.37 mg/L respectively along with their standard deviation as shown in Table 1. Biological oxidation is a slow process and organic matter is decomposed by micro-organisms into carbon dioxide and water using dissolved oxygen. Hence, value of DO is decreasing and increasing measure of BOD. BOD is an important parameter to indicate the magnitude of water pollution. In the present study, the BOD value of effluents was found in the range of 200-1000 mg/L depending on concentration of SME. That is much higher than the maximum acceptable limit for BOD (50 mg/L) in discharging effluents as per norms of BIS. It was observed that value decreases with increase in dilution of sugar mill effluent as given in Figure 3.

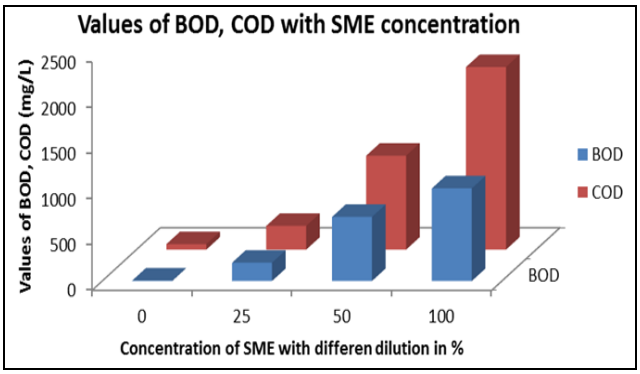

Fig 3: Comparative analysis of BOD and COD with different concentration of SME

Chemical Oxygen Demand (COD)

COD of BWW, 25 % SME, 50 % SME and 100 % SME are 60.49±0.020 mg/L, 260.87±6.46 mg/L, 1031.24±31.9 mg/L and 2004.54±15.28 mg/L respectively along with their standard deviation as shown in Table 1. COD is an important test used to measure the pollution of domestic and industrial waste. COD and BOD test collectively are used to indicate the level of toxic conditions of any water body. In the present study, concentration of COD in sugar mill effluents was in the range of 260-2000 mg/L with different SME concentrations which is much higher than the maximum acceptable limit for COD (250 mg/L) in discharging effluents as per norms of BIS showing toxicity of effluents and is unsafe for aquatic life. It was observed that value decreases with increase in dilution of sugar mill effluent as given in Figure 3.

Comparative analysis of BOD and COD revealed that their values are increasing in linear fashion with the increase in concentration of SME and are also directly proportional to each other as shown in Figure 3.

Carbonate (CO_3^{2-})

CO_3^{2-} of BWW, 25 % SME, 50 % SME and 100 % SME are 97.97±0.13 mg/L, 139.02±5.15 mg/L, 194.79±5.68 mg/L and 220.21±7.53 mg/L respectively along with their standard deviation as shown in Table 1. In the present study, concentration of CO_3^{2-} in sugar mill effluents was in the range of 150--250 mg/L with different SME concentrations. That is in the acceptable limit for CO_3^{2-} (600 mg/L) in discharged effluents as per norms of BIS. It was observed that value decreases with increase in dilution of sugar mill effluent.

Bicarbonate (HCO_3^-)

HCO_3^- of BWW, 25 % SME, 50 % SME and 100 % SME are 178.98±0.12 mg/L, 216.90±4.0 mg/L, 370.72±20 mg/L and 626.28±11.78 mg/L respectively along with their standard deviation as shown in Table 1. In the present study, concentration of HCO_3^- in sugar mill effluents was in the range of 200-400 mg/L with different SME concentrations. That is in the acceptable limit for HCO_3^- (450 mg/L) in discharged effluents as per norms of BIS. It was observed that value decreases with increase in dilution of sugar mill effluent. It might be due to carbon-dioxide released from decaying organic matter, so its content rises in the effluent (Elango *et al.*, 2003) [2].

Sulphate (SO_4^{2-})

SO_4^{2-} of BWW, 25 % SME, 50 % SME and 100 % SME are 13.86±0.07 mg/L, 171.01±1.99 mg/L, 446.83±6.45 mg/L and 961.31±11.50 mg/L respectively along with their standard deviation as shown in Table 1. In the present study, concentration of SO_4^{-2} in sugar mill effluents was in the range of 150-1000 mg/L with different SME concentrations. Although the presence of sulphate is sufficiently found to be higher but is in the acceptable limit for SO_4^{-2} (1000 mg/L) in discharging effluents as per norms of BIS. It was observed that value decreases with increase in dilution of sugar mill effluent.

Chloride (Cl^-)

Cl^- of BWW, 25 % SME, 50 % SME and 100 % SME are

12.80±0.02 mg/L, 204.21±6.80 mg/L, 378±6.29 mg/L and 1067.13±10.6 mg/L respectively along with their standard deviation as shown in Table 1. In the present study, concentration of Cl^- in sugar mill effluents was in the range of 200-1100 mg/L with different SME concentrations. That is much higher (little less than two fold) than the maximum acceptable limit for Cl^- (600 mg/L) in discharging effluents as per norms of BIS. It was observed that value decreases with increase in dilution of sugar mill effluent.

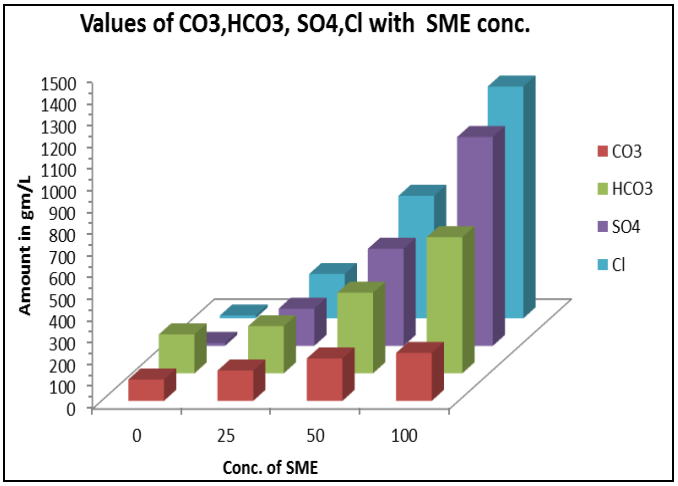

Fig 4: Comparative analysis of anions (CO_3^{2-}, HCO_3^{2-}, SO_4^{2-} and Cl^-) with different concentration of SME

Trend of concentrations of anions (CO_3^{2-}, HCO_3^-, SO_4^{2-} and Cl^-) analyzed in present study were also compared. A comparative account of these anions in different concentration of SME is shown in Figure 4. On comparing concentration of anions, it is found that concentration of all the anions is increasing with the increase in the concentration of sugar mill effluent (from 0 %, 25 %, 50 % to 100 %). It also revealed that the trend observed regarding anions concentration is like this: $Cl^- > SO_4^{2-} > HCO_3^- > CO_3^{2-}$. It also found that the concentration of chloride is slightly comparable with sulphate but concentration of carbonate is many fold lesser than both chloride and sulphate.

Calcium (Ca^{2+})

Ca^{+2} of BWW, 25 % SME, 50 % SME and 100 % SME are 39.36±0.21 mg/L, 209.74±8.16 mg/L, 363.29±10.10 mg/L and 803.08±6.36 mg/L respectively along with their standard deviation as shown in Table 1. In the present study, concentration of Ca^{+2} in sugar mill effluents was in the range of 200-800 mg/L with different SME concentrations. That is much higher than the maximum acceptable limit for Ca^{+2} (250 mg/L) in discharging effluents as per norms of BIS in all the concentration of SME. It was observed that value decreases with increase in dilution of sugar mill effluent.

Magnesium (Mg^{2+})

Mg^{+2} of BWW, 25 % SME, 50 % SME and 100 % SME are 11.23±0.096 mg/L, 54.71±2.86
mg/L, 93.07±5.32 mg/L and 198.27±6.41 mg/L respectively along with their standard deviation as shown in Table 1. In the present study, concentration of Mg^{+2} in sugar mill effluents was in the range of 50-200 mg/L with different SME concentrations. That is much higher than the maximum acceptable limit for Mg^{+2} (100 mg/L) in discharging effluents as per norms of BIS. It was observed that value decreases with increase in dilution of sugar mill effluent.

Sodium (Na^+)

Na^+ of BWW, 25 % SME, 50 % SME and 100 % SME are 12.12±0.90 mg/L, 43.4±2.05 mg/L, 123.29±4.46 mg/L and 273.5±5.011 mg/L respectively along with their standard deviation as shown in Table 1. In the present study, concentration of Na^+ in sugar mill effluents was in the range of 40-280 mg/L with different SME concentrations. That is higher than the maximum acceptable limit for Na^+ (200 mg/L) in discharging effluents as per norms of BIS. It was observed that value decreases with increase in dilution of sugar mill effluent.

Potassium (K^+)

Ka^+ of BWW, 25 % SME, 50 % SME and 100 % SME are 11.53±0.57 mg/L, 50.43±2.03 mg/L, 141.17±2.63 mg/L and 340.04±6.60 mg/L respectively along with their standard deviation as shown in Table 1. In the present study, concentration of K^+ in sugar mill effluents was in the range of 10-3500 mg/L with different SME concentrations. That is much higher than the maximum acceptable limit for K^+ (250 mg/L) in discharging effluents as per norms of BIS. It was observed that value decreases with increase in dilution of sugar mill effluent.

Concentration of Na and K is significantly high and increases with increase in concentration of SME as shown in Figure 5.

Trend of concentrations of cations (Ca^{+2}, Mg^{+2}, Na^+ and K^+) analyzed in present research were also compared. A comparative account of these cations in different concentration of SME is shown in Figure 5. On comparing of cations, it is found that concentration of all the cations is increasing with the increase in the concentration of sugar mill effluent (from 0 %, 25 %, 50 % to 100 %). It also revealed that the trend observed regarding cations concentration in the present research is like this: $Ca^{+2} > K^+ > Na^+ > Mg^{+2}$. It also found that the concentration of calcium is slightly comparable with potasium but concentration of magnesium is many fold lesser than both calcium and potasium.

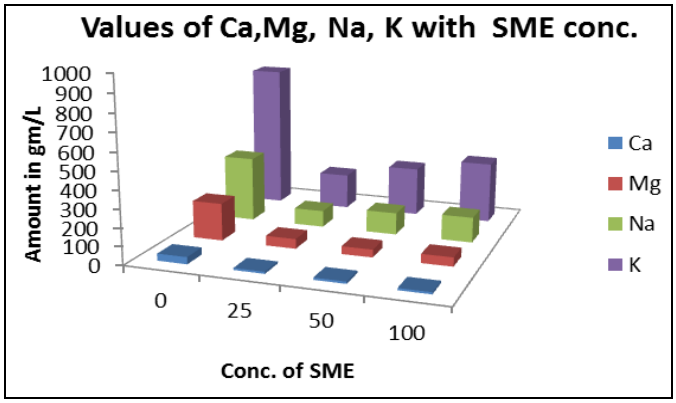

Fig 5: Comparative analysis of cations (Ca^{+2}, Mg^{+2}, Na^+ and K^+) with different concentration of SME

An overall analysis of cations and anions is shown in Figure 6 given below.

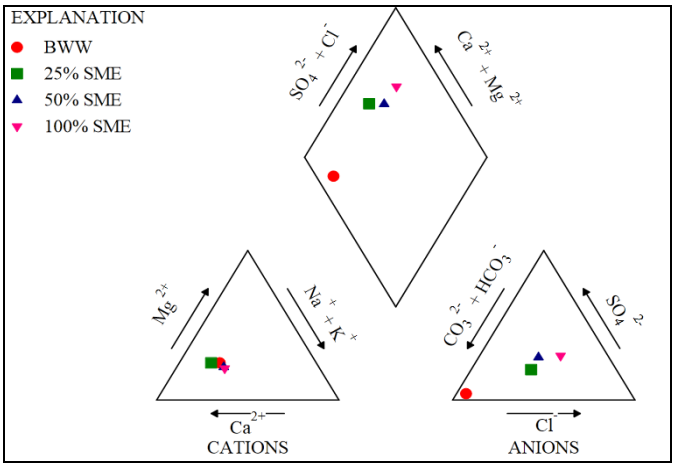

Fig 6: Comparative analysis of anions (CO_3^{2-}, HCO_3^{2-}, SO_4^{2-} and Cl^-) and cations (Ca^{+2}, Mg^{+2}, Na^+ and K^+) with different concentration of SME

On carefully analyzing the results of physico-chemical parameters of effluent as shown in Table 1, only solids and sulphates were within the permissible limits in discharging effluents as per norms of BIS. Almost all the anions and cations are much higher than the permissible limits. Considerable high values of BOD and COD were observed which indicated high organic load. This is in conformity with the earlier finding of (Ezhilvannan *et al*., 2011, Shivappa *et al*., 2007 & Thamizhiniyan *et al.,* 2009) [3, 11, 12]. So, necessary treatment should be done before discharging this SME in water table, canal and river or on soil otherwise it is seriously deteriorating the near by agricultural fields, crop yield and plant nutrients, and microorganisms of soil which are very essential for maintaining soil fertility and crop production.

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