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Water quality and environmental assessment of sugar mill effluent

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ABSTRACT:

Waste water samples from sugar industry were collected and analyzed for various water quality parameters like appearance, colour, odour, temperature, turbidity, Total dissolved solids (TDS), electrical conductivity(EC), pH, Total Suspended Solids(TSS), chloride (Cl^-), sulphate, Calcium, Magnesium, carbonate, bicarbonate, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Total acidity (TA), Iron, Sodium and dissolved phosphate for a period of six months in order to understand the extent of pollution. Sugar mill effluent showed the pH 7.5, low value of dissolved oxygen, high values of BOD (123 mg/l) and electrical conductivity (1799 mmhos/cm) which indicates that it affects the aerobic respiration of organisms and hence it is not suitable for aqua culture and irrigation purposes. Sodium Absorption Ratio (SAR), Kelly's Ratio (KR), Percent Sodium (PS), Magnesium Ratio (MR), Residual Sodium Carbonate (RSC) and Water Quality Index (WQI) were computed. Even though SAR (5.41), KR (0.24), PS (40.98) and MR (33.19) are well below the desirable limits suitable for irrigation, high RSC (579.17mg/l) and WQI (114.35) indicate the high pollution nature of sugar mill effluent. Therefore the sugar mill effluent is unsuitable for aquatic life and irrigation. It must be treated before discharge in to the land and water system.

Keywords:
Sodium Absorption Ratio (SAR), Kelly's Ratio (KR), Percent Sodium (PS), Magnesium Ratio (MR), Residual Sodium Carbonate (RSC) and Water Quality Index (WQI).

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INTRODUCTION

There are about 369 sugar factories located in India, Manohar Rao (1987). During 1991-92, 134 million tonne of cane was crushed by 392 sugar factories out of 239 million tonne of cane produced from an area of 3.8 million hectare in India, Anonymous (1993). During sugar production, more than 4.02 million tonne press mud was produced in 1991-92, Jambhekar (1992) and the annual production of press mud was estimated to be five million tonne. This will create environmental pollution to the environment. There are thirty eight sugar mills in Tamil Nadu of which sixteen mills are in cooperative sector, three mills are in public sector and nineteen mills are in the private sector, Bakkialalakshmi and Vinodhini (2008). Sugar industry offers employment potential and contributes substantially to economic development. Apart from sugar and alcohol, these factories generate many by-products and waste materials. For example, large amount of organic and inorganic chemicals are being generated, Rajukkannu and Manickam (1997).

The studies of Dasarath et al (2005) on effluents generated from Nizam Deccan Sugar factory at Bodhan, Nizamabad, District of Andhra Pradesh, India revealed that electrical conductivity found in between 1557-13050 µmhos/cm and higher BOD values. The studies further revealed that the water is neither useful for drinking nor for the agricultural fields, not applicable for long term application of such water for irrigation and may also spoil the soil permanently for cultivation. Studies of Nomulwar et al (2005) on the sugar factory effluents revealed that most of the parameters such as colour, odour, total dissolved solids, chemical oxygen demand, total alkalinity, pH, temperature, phosphate and sulphate have exceeded ISI limits. The effluents contain high amount of total hardness, total dissolved solids, biological oxygen demand (BOD) and chemical oxygen demand (COD). The effluent not only affects the plant growth but also deteriorate the soil properties when used for irrigation, Maliwal et al (2004).

In addition to that, some traceable amount of heavy metals such as Zinc, Copper and lead were also present in the effluent, Borale et al (2004). These effluents not only increase the nutrient level but also excess the tolerance limit and cause toxicity, Mishra et al (1999). The discharge of effluent will create pollution to the environment. Therefore it is essential to evaluate the impact of sugar mill effluent on the surrounding areas. The present study was undertaken to analyze the effects of effluent.

MATERIALS AND METHODS

The effluent samples for this study was collected every month from October 2010 to March 2011 from the effluent discharge stream of sugar mill. On the day of sampling, the samples were collected in two litre polythene can, once in four hour for 24 hour and mixed in equal proportions to get uniform homogeneous samples, Rainwater et al (1960).

The bottles for sample preservation were thoroughly cleaned by rinsing with 8M Nitric acid solution followed by washing it with distilled water and finally with double distilled water. Then, the bottles were rinsed thrice with the effluent samples and the effluent samples were stored in a refrigerator at temperature approximately 4ºC, after adding the necessary preservatives, APHA (1985). This is essential for retarding biological action, hydrolysis of chemical compounds and complexes and reduction of volatility of constituents. For COD, Sulphuric acid was added to bring pH to 2, for phosphates 20 mg of mercuric chloride was added and refrigerated. The mixed, homogeneous effluents were taken out from the refrigerator only at the time of analysis.

These samples were used for analysis of water quality parameters such as colour Jhakrani et al (2009), Odour Andrew et al. (1995), turbidity AOAC (1998), Oil and grease (OG), total dissolved solids, electrical conductivity, pH, temperature, total solids, total suspended solids, chloride, sulphate APHA (1985); Jeffery et al (1996), Sodium, Calcium, Magnesium, Iron Ademoroti (1996), carbonate and bicarbonate Thomas et al (1960), BOD, COD, DO USEPA (1986); Young et al (1981), total acidity and dissolved phosphate APHA (1998).

The parameters like SAR, KR, PS, MR, RSC, WR and WQI were calculated using the equations given below:

Calculation of Sodium Absorption Ratio (SAR)

The formula for calculating Sodium Absorption Ratio (SAR) was

$$SAR = \frac{Na^{+}}{[(Ca^{2+} + Mg^{2+})/2]^{1/2}}$$

Calculation of Kelleys Ratio (KR)

The formula for calculating Kelleys Ratio

(KR) was

$$KR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}}$$

Calculation of Percent Sodium (PS)

The formula for calculating Percent Sodium (PS) was

$$PS = 100 \times \left[\frac{(Na^{+} + K^{+})}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \right]$$

Calculation of Magnesium Ratio (MR)

The formula for calculating Magnesium Ratio (MR), Kannan et al (2003) was

$$MR = 100 \times \left[\frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \right]$$

Calculation of Residual Sodium Carbonate (RSC)

The formula for calculating Residual Sodium Carbonate (RSC), Machiraju et al (2009) was

$$RSC = [CO_3^{2-} + HCO_3^{-}] - [Ca^{2+} + Mg^{2+}]$$

Calculation of Wilcox Ratio

The formula for calculating Wilcox Ratio, Wilcox (1948) was

$$WR = \left[\frac{Na^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \right]$$

Calculation of Water Quality Index

For the calculation of water quality index, Pradhan et al (2000) the following equations have been used in different steps:

Step 1:

$$\text{Quality rating, } q_n = 100 \times \left[\frac{V_n - V_i}{V_s - V_i} \right]$$

Where,

V_n – Actual amount present in polluted water on nth parameter

V_i – The ideal value of parameter

V_i = 0 for the suitable water except pH and DO which is 7.0 mg/l and 14.6 mg/l, respectively.

V_s – standard value of the parameter

Step 2:

Unit weight (W_n) for various parameters is inversely proportional to the recommended standard (S_n) for the corresponding parameter.

$$W_{n1} = K / S_{n1}$$

$$\text{Where } K = \frac{1}{1/(s_1)^{½} + 1/(s_2)^{½} + \ldots\ldots + 1/(s_n)^{½}}$$

$\sum_{n=1}^{15} W = 1$, Considered here.

Step 3:

Sub indices (SI) = $(q_n)^{Wn}$

Step 4:

The overall water quality index was calculated taking the geometric mean of these indices $(SI)_n$

$$WQI = \sum_{n=1}^{15} (SI)_n = \sum_{n=1}^{15} (q_n)^{Wn}$$

$$WQI = \text{Anti Log}_{10} \left[\sum_{n=1}^{15} W_n \text{Log}_{10} q_n\right]$$

RESULTS AND DISCUSSION

The physical parameters and chemical parameters for water sample from sugar mill were tabulated in **Table 1 and 2** respectively.

The sugar mill effluent collected during off-season (October and November) was colourless and clear. But the effluent was slight turbid during December and January, and it was turbid during the months of February and March (on-season). The colour of the sugar mill effluent showed an average of 150 Hazen which was above the desirable limit (colourless) of CPHEEO standards. The odours of the samples were analyzed qualitatively. The effluent samples collected during October and November were odourless but the samples collected during December to March were objectionable as described by CPHEEO standards.

The measured turbidity showed an average of 77.4 which was very high compared to the CPHEEO standard value of 10. Turbidity was due to the presence of dissolved and suspended solids. The physical parameter oil and grease was found to be high during the month of December and January. It was due to the leakage and spill over of oil and grease from the lubricating and cooling systems, floor washings and juice extraction processes. The average temperature of the effluent was 25.7 ºC. The minimum-maximum range of temperature was 24.5-26.9 ºC. This indicated that the effluent sample was found to be ambient and hence not thermally polluted.

Table 1. Physical parameters for water sample from sugar mill

S. No	Physical parameters	Oct 2010	Nov 2010	Dec 2010	Jan 2011	Feb 2011	Mar 2011	Range	Average	Standards
1	Appearance	clear	clear	Slight turbid	Slight turbid	turbid	turbid	-	-	-
2	Colour Hazen	400	420	20	18	24	16	16-420	150	Colourless (CPHEEO)
3	Odour	Unobjectionable	Unobjectionable	objectionable	objectionable	objectionable	objectionable	-	-	Unobjectionable (CPHEEO)
4	Turbidity	2.8	2.6	100	118	126	115	2.6-126	77.4	10 (CPHEEO)
5	Oil and Grease	32	30	43	41	39	31	30-43	36	-
6	Temperature °C	25	24.8	24.5	26.7	26.5	26.9	24.5-26.9	25.7	Shall not exceed 40 (IS)
7	Total Dissolved solid mg/l	1890	1670	750	782	874	809	750-1890	1129	500 (CPHEEO)
8	Electrical conductivity mmhos/cm	2920	2716	1282	1236	1341	1299	1236-2920	1799	331-1752 (BIS)

Total dissolved solid was mainly due to carbonate, bicarbonate, chloride, sulphate, phosphate, nitrate, Nitrogen, Calcium, Sodium, Potassium and Iron, Kannan et al (2004). According to CPHEEO standard, the recommended limit of TDS for effluent discharge was 500 mg/l. The average and the range of TDS in the effluents were 1129 mg/l and 750-1890 mg/l respectively. These values of TDS were indicative of high level of pollution.

The electrical conductivity ranged between 1236-2920 mmhos/cm and the average was 1799 mmhos/cm which was above the BIS value of 331-1752 mmhos/cm. The importance of electrical conductivity was its measure of salinity. The presence of salts in the waste water increases the electrical conductivity of the effluent and affects the taste, Srinivas et al (2000). `The pH of the effluent sample varied from7.2-7.8 and the mean value was 7.5 which was slightly alkaline. But the value was within the WHO prescribed limit of 7.5-8.5. The slight alkalinity was due to the usage of caustic soda and soda ash for cleaning purposes in heaters ETPI (2001). The average value of total suspended solid was 66 mg/l which was below the IS value of 100 mg/l. Due to extremely high level of TDS in the sugar mill effluent, the average and range of total solid were found to be high of the order of 1195 mg/l and 839-1908 mg/l respectively.

The average and range of chloride and sulphate ions were 183 mg/l, 258 mg/l and 109-325 mg/l, 115-514 mg/l respectively which were well below the IS value of 250 mg/l and 400 mg/l respectively. Chloride and sulphate were released during sulphitation and finishing processes in the sugar mill.

Calcium and Magnesium showed an average of 164 mg/l and 88 mg/l respectively. The ranges of Calcium and Magnesium were 122-191 mg/l and 45 -162 mg/l respectively. Calcium was found to exceed the IS limit of 75 mg/l while Magnesium was well below the CPHEEO limit of 150 mg/l. The use of Calcium hydroxide in the defecation process was the reason for the high value of Calcium in the sugar mill effluent.

Carbonate and bicarbonates were produced during carbonation process in the sugar mill. The average and range of Carbonate and bicarbonates were 241 mg/l, 591 mg/l and 159-393 mg/l, 386-976 mg/l respectively. High load of organic compounds in the effluent might cause an increase in BOD and COD load and simultaneous depletion of DO concentration. The average BOD and COD

Table 2. Chemical parameters for water sample from sugar mill

S. No	Chemical parameters	Oct 2010	Nov 2010	Dec 2010	Jan 2011	Feb 2011	Mar 2011	Range	Average	Standards
1	pH	7.3	7.2	7.6	7.8	7.4	7.5	7.2-7.8	7.5	7.5-8.5 (WHO)
2	Total solids	1908	1687	839	873	966	897	839-1908	1195	-
3	Total suspended solids	18	17	89	91	92	88	17-92	66	100 (IS)
4	Chloride mg/l	320	325	109	116	119	111	109-325	183	250 (IS)
5	Sulphate mg/l	514	506	126	140	148	115	115-514	258	400 (IS)
6	Calcium mg/l	129	122	182	189	191	173	122-191	164	75 (IS)
7	Magnesium mg/l	162	158	45	52	60	48	45-162	88	150 (CPHEEO)
8	Carbonate mg/l	393	387	156	168	173	166	156-393	241	-
9	Bicarbonate mg/l	976	960	396	405	420	386	386-976	591	-
10	BOD mg/l	59	51	153	159	167	147	51-167	123	30 (IS)
11	COD mg/l	222	216	168	175	183	172	168-222	189	250 (IS)
12	DO mg/l	6.9	5.8	Nil	Nil	Nil	Nil	0-6.9	2.1	5 (WHO)
13	Total acidity mg/l	22	18	14	16	17	20	14-22	18	-
14	Iron mg/l	0.19	0.11	0.17	0.28	0.32	0.25	0.11-0.32	0.22	0.1 (CPHEEO)
15	Sodium mg/l	85	78	49	52	56	47	47-85	61	200 (WHO)
16	Dissolved Phosphate mg/l	1.6	1.2	0.17	0.19	0.2	0.16	0.16-1.6	0.59	5 (IS)

of the effluent samples analyzed were 123 mg/l and 189 mg/l respectively. BOD was high compared to the IS limit of 30 mg/l while COD was well below IS limit of 250 mg/l.

Dissolved Oxygen was minimal during January to March. It indicated that the DO was completely depleted due to organic compounds used in the sugar mill, Sharma et al (1998). The average value of total acidity was 18 mg/l which was low due to the alkalinity of the effluent. Heavy metal such as Iron (average - 0.22 mg/l, range - 0.11-0.32 mg/l) was found to be present in sugar mill effluent. It was higher than the CPHEEO standard value of 0.1 mg/l. High BOD created septic conditions, generating foul-smelling hydrogen sulfide which in turn precipitated Iron.

Metal ion such as Sodium (average - 61 mg/l) was well below the WHO standard of 200 mg/l. The use of soda ash and caustic soda in various processes in the sugar mill lead to the presence of Sodium in the effluent. Sugar mill effluent consisted of dissolved phosphate ions (average - 0.59 mg/l, range - 0.16-1.6 mg/l) which resulted from the usage of phosphoric acid during phosphitation process.

Sodium Absorption Ratio (SAR), Kelleys Ratio (KR), Percent Sodium (PS), Magnesium Ratio (MR) and Residual Sodium Carbonate (RSC) were computed and tabulated in **Tables 3, 4, 5 and 6.** The minimum, maximum, average values of SAR (SAR_{min}, SAR_{max}, SAR_{av}), KR (KR_{min}, KR_{max}, KR_{av}), PS (PS_{min}, PS_{max}, PS_{av}), MR (MR_{min}, MR_{max}, MR_{av}) and RSC (RSC_{min}, RSC_{max}, RSC_{av}) with the status for irrigation were tabulated in table 3.

Kelley (1951) pointed out the importance of considering the concentration of Sodium ions in assessing the suitability of water for irrigation. According to him excess of Sodium ions in irrigation waters reacts with soil to reduce its permeability as a result of clog. According to the

Table 3 . SAR, KR, PS, MR and RSC of sugar mill and its status for irrigation

Parameter	Minimum	Maximum	Average	Status for irrigation
SAR	4.47	7.05	5.41	0-10 Excellent 10-18 Good 18-28 Fair Above 28 Poor
KR	0.21	0.29	0.24	Less than 1
PS	36.49	43.69	40.98	Less than 50
MR	19.82	56.43	33.19	Less than 50
RSC	325	1078	579.17	<1.25 Safe for irrigation 1.25-2.5 Used with due Caution >2.5 Unsuitable for irrigation

US Salinity Laboratory (1954), the SAR predicts reasonably well, the degree to which irrigation water tends to enter cation exchange reactions in soil. High values for SAR imply a hazard of Sodium ions, replacing absorbed Calcium ions and Magnesium ions, a situation ultimately damaging soil structure. Therefore, the SAR is used for adjudicating the irrigation waters. Irrigation waters are classified by Richards (1954) based on SAR.

Based on the above classification, the sugar mill effluent (SAR_{av} = 5.41) was found to be excellent for irrigation. The average value of KR was found to be less than one (KR_{av} = 0.24). Therefore sugar mill effluent was suitable for irrigation. PS_{av} and MR_{av} were 40.98 and 33.19 respectively which were less than 50; hence the effluent can be used for irrigation, Wilcox (1948); Venkatesware Rao et al (1996). The average value of RSC was found to be 579.17 which was very high compared to the value of 2.5.

Wilcox ratio calculated for different months were tabulated in **Table 4.** The WR was maximum during October and November (0.16) compared to other months. The average value was found to be 0.14 which was very low compared to the critical value of 0.80. Since water quality parameters and RSC were very high, the sugar mill effluent was unsuitable for irrigation.

The concept of water quality indices to represent gradation in water quality was first proposed by Horton (1965). It indicates the quality by an index number, which represents the overall quality of water for any intended use. It is defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water, Deininger and Maciunas (1971); Harkins (1974); Tiwari and Manzoor (1988).

WQI can also be used to aggregate data on water quality parameters at different times and in different places and to translate this information into a single value defining the period of time and spatial unit involved, Jafari et al (2010). The value of q_n was depicted in **Table 5**. The value of W_n and V_s was given in **Table 6.** Value of $W_n \log q_n$ during different months was tabulated in table 7. The value of W_n and V_s was given in table 6. Value of $W_n \log q_n$ during different months was tabulated in **Table 7.**

The overall water quality was measured by water quality index. The water quality index computed during October and November (off-season) were 152.62 and 106.69 respectively. The WQI value decreased to 25.95 during December. But the values were high during January, February

Table 4 Wilcox Ratio for different months

Months	Wilcox Ratio
October	0.16
November	0.16
December	0.12
January	0.12
February	0.14
March	0.14

Table 5 Water quality rating (q_n)

Parameter	Oct	Nov	Dec	Jan	Feb	Mar
Turbidity	28	26	1000	1180	1260	1150
TDS	378	334	150	156.4	174.8	161.8
TSS	18	17	89	91	92	88
EC	882.2	820.5	387.3	373.4	405.1	392.4
pH	97.3	96	101.3	104	98.7	100
Cl^-	128	130	43.6	46.4	47.6	44.4
SO_4^{2-}	128.5	126.5	25.2	35	37	28.8
Ca^{2+}	172	162.7	242.7	252	254.7	230.7
Mg^{2+}	108	105.3	30	34.7	40	32
BOD	196.7	170	510	530	556.7	490
COD	88.8	86.4	67.2	70	73.2	68.8
DO	138	116	0	0	0	0
Fe	63.3	36.7	5.7	93.3	106.7	83.3
Na	42.5	39	24.5	26	28	23.5
PO_4^{3-}	32	24	3.4	3.8	4	3.2

Table 6. Water quality parameters, their icmr, who standards and assigned unit weights

Water quality parameters	ICMR/ WHO/ CPHEEO/ IS standards	Unit weights W_n
Turbidity	10	0.01654
Total dissolved solids	500	0.00033
Total suspended solids	100	0.00165
Electrical conductivity	0.5	0.3308
pH	7.5-8.5	0.0221
Chloride	250	0.00066
Sulphate	400	0.00041
Calcium	75	0.0022
Magnesium	150	0.0011
BOD	30	0.0055
COD	250	0.00066
DO	5	0.0331
Iron	0.3	0.5513
Sodium	200	0.00083
Phosphate	5	0.0331

and March (on-season). The high value of WQI (146.44) was calculated during March. The WQI status was given in **Table 8.**

Average value of water quality index was 114.35 and the range was 25.95-152.62. The value was above 100, indicating the high level of pollution with a heavy load of organic and inorganic pollutants in the effluents.

Numerous studies on water quality assessment have made use of water quality indices, Kannel et al (2007); Parparov (2006). The WQI approach has many variations in the literature and comparative evaluations have been undertaken, Bordalo et al (2001). Some of the WQI approaches that have been frequently employed in public domain for the purpose of water quality assessment, Said et al (2004) are: US National Sanitation Foundation Water Quality Index, NSFWQI, Brown et al (1970), Canadian Water Quality Index, Council of ministers of the environment (2001), British Columbia Water Quality Index and BCWQI, Zambergen and Hall (1998).

Sanchez et al (2006) calculated the objective water quality index using the following equation:

$$WQI = k \frac{\sum_{i=1}^{n} C_i P_i}{\sum_{i=1}^{n} P_i}$$

where n is the total number of parameters, C_i is the value assigned to parameter i after normalization and P_i is the relative weight assigned to each parameter. P_i value range from 1 to 4, with 4 assigned to a parameter that is most important for aquatic life preservation (DO) and value of 1 assigned to the parameter that has a smaller impact (chloride). k is the objective constant and is equal to 1.

The water quality classification system adopted here is proposed by Kannel et al (2007); Jonnalagadda and Mhere (2001), Dojlido et al (1994). According to which, WQI in the range of 0–

Table 7. Value of w_n log q_n during different months

Parameter	Oct	Nov	Dec	Jan	Feb	Mar
Turbidity	0.023935	0.023404	0.04962	0.050809	0.051280	0.050624
TDS	0.000851	0.000833	0.000718	0.000724	0.00074	0.000729
TSS	0.002071	0.002030	0.003216	0.003234	0.00324	0.003208
EC	0.97439	0.96398	0.85613	0.85088	0.86258	0.85801
pH	0.043937	0.043808	0.044323	0.044576	0.044074	0.0442
Cl^-	0.0031391	0.0013952	0.0010821	0.0010999	0.001107	0.108727
SO_4^{2-}	0.0008657	0.000862	0.000575	0.000633	0.000643	0.000598
Ca^{2+}	0.004918	0.004865	0.005247	0.005283	0.005293	0.005199
Mg^{2+}	0.002237	0.002225	0.001625	0.001694	0.001762	0.001656
BOD	0.012616	0.0055	0.01489	0.014984	0.015101	0.014796
COD	0.001286	0.001278	0.001206	0.001218	0.001231	0.001213
DO	0.070829	0.068334	0	0	0	0
Fe	0.993114	0.862600	0.416714	1.085996	1.118127	1.058852
Na	0.001352	0.0013206	0.001153	0.001174	0.001201	0.001138
PO_4^{3-}	0.049820	0.045685	0.017592	0.019191	0.019928	0.016720
WQI	152.62	106.69	25.95	120.64	133.75	146.44

Table 8. Water Quality Index and its status

WQI	Status
0 – 25	Excellent
26 – 50	Good
51 – 75	Poor
76 – 100	Very Poor
100 and above	Unsuitable for drinking, propagation of wild life, fish culture and irrigation

25 is very bad, 26 – 50 is bad, 51 – 70 is medium, 71 – 90 is good and 91 – 100 is excellent. Table 9 gives the different parameters that were used in the evaluation process, as well as their relative weights and the normalization factors. These values were adopted from various literatures, Pesce and Wunderlin (2000); Cude (2001); Debels et al (2005); Sanchez et al (2006); Kannel et al (2007). The objective WQI values calculated for different months were tabulated in **Table 10.**

The WQI values were high (49.6 and 46.4) during October and November compared to other months. The values ranged from 40 – 42 during December to March. The average water quality index was found to be 43.6 which were between 26-50 limit indicating that the status was bad.

CONCLUSION

The colour of the sugar mill effluent prevents the penetration of sun light and they are difficult to biodegrade. Colloidal matter along with oily scum increase the turbidity and so produce a bad appearance and foul smell. Oily scum interferes with Oxygen transfer mechanism at air-water interface. The colloidal matter clog the pores of soil by forming an impervious mat thus reducing the water holding capacity of soils.

High amount of dissolved solids from sugar mill effluent increases the tendency to incrust. The Sodium ions in dissolved solids reduce the Calcium and Magnesium content of soil and prevent the penetration of roots. Besides it also exhibits deflocculating effect. The most serious effect of sugar mill effluent was depletion of dissolved oxygen. Organic matter produces immediate Oxygen demand where as colour exhibits a long term Oxygen demand. Thus sugar mill effluent produces a serious environmental impact and hence it is to be discharged only after proper treatment in order to sustain the environment.

From the above studies, it is inferred that sugar mill is one of the most polluting industries of higher solid and BOD contents in effluents and use of hazardous chemicals. Though air and water pollution is created at every stage of sugar mill production, water pollution is significant in terms of vast quantity of waste water and a good number of chemicals. The pH of the effluent is alkaline. Moreover, it has grayish colour with heavy load of suspended particles. Hence the discharge of effluent with dilution is recommended which might be beneficial for plant growth and make it less harmful to the environment.

Table 9 Variable used in WQI calculation, scores of normalization and relative weights

Variable	RW	Normalization factor										
		100	90	80	70	60	50	40	30	20	10	0
Temperature °C	1	21/16	22/15	24/14	26/12	28/10	30/5	32/0	36/”2	40/”4	45/”6	>45/”6
pH	1	7	7-8	7-8.5	7-9	6.5-7	6-9.5	5-10	4-11	3-12	2-13	1-14
EC mmhos/cm	1	<750	<1000	<1250	< 1500	< 2000	< 2500	< 3000	< 5000	< 8000	< 12000	>12000
DO mg/l	4	>=7.5	>7	>6.5	>6	>5	>4	>3.5	>3	>2	>=1	<1
TDS mg/l	2	<100	<500	<750	< 1000	< 1500	< 2000	< 3000	< 5000	< 10000	< =20000	> 20000
TSS mg/l	4	<20	<40	<60	<80	<100	<120	<160	<240	<320	<400	>400
Ca mg/l	1	<10	<50	<100	<150	<200	<300	<400	<500	<600	<= 1000	>1000
Mg mg/l	1	<10	<25	<50	<75	<100	<150	<200	<250	<300	<=500	>500
Cl^- mg/l	1	<25	<50	<100	<150	<200	<300	<500	<700	<1000	< =1500	>1500
SO_4^{2-} mg/l	2	<25	<50	<75	<100	<150	<250	<400	<600	<1000	< =1500	>1500
DP mg/l	1	< .025	<0.05	<0.1	<0.2	<0.3	<0.4	<0.5	< 0.75	<1	< =1.25	>1.25
BOD mg/l	3	<0.5	<2	<3	<4	<5	<6	<8	<10	<12	<=15	>15
COD mg/l	3	<5	<10	<20	<30	<40	<50	<60	<80	<100	<=150	>150

Table 10 Water Quality Indices for different months

Months	WQI
October	49.6
November	46.4
December	42.0
January	41.2
February	40.8
March	41.6

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