Scholars Journal of Engineering and Technology

OPEN ACCESS

Abbreviated Key Title: Sch J Eng Tech
ISSN 2347-9523 (Print) | ISSN 2321-435X (Online)
Journal homepage: https://saspublishers.com

Treatment of Cane Sugar Industry Wastewater Using Aerobic Digestion: A Case Study of Kenana Sugar Factory, Sudan

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DOI: https://doi.org/10.36347/sjet.2026.v14i02.004 | **Received:** 03.01.2026 | **Accepted:** 18.02.2026 | **Published:** 27.02.2026

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Abstract **Original Research Article**

The sugarcane industry in Sudan produces large amounts of organic wastewater, and untreated discharge from factories threatens the environment and public health. The objectives of the present study were to determine the physiochemical and physical properties of the wastewater from (KSF) and compare it with standard specifications both international and local. The samples of wastewater were collected from (KSF). The study showed that all wastewaters contain very high levels of biological oxygen demand (BOD) and chemical oxygen demand (COD) values, which are (1860 mg/L) and (2800mg/l), respectively. Wastewater has badly dour and colour and this indicated that the wastewater contained high amounts of elements. For these reasons the wastewater is not useful to be used for irrigation unless it has been treated. The results obtained show that cane sugar wastewaters have to be treated by each of the processes considered, to use method of treatment after six days of aerobic digestion. The dissolved organic reductions of biological oxygen demand (BOD) and chemical oxygen demand (COD) values, were noticed These are (488 mg/L) and (900mg/l), respectively. These values are permissible to use for any purpose according to standard specifications both internationally and locally. It is recommended that all sugarcane wastewater undergo aerobic treatment before discharge or reuse to protect public health and the environment.

Keywords: Sugarcane industry, wastewater treatment, aerobic digestion, environmental pollution, water reuse.

INTRODUCTION

The sugarcane industry is regarded as an organized sector. One of the top economic sectors in the nation is this one. The primary sources of sugar are sugarcane and sugar beet. According to studies, during the many phases of handling raw materials and processing sugar mills, between 20–30% of the total sucrose produced by sugarcane plants is wasted. One of the sugar industry's most concerning issues is post-harvest sugar loss, which has garnered a lot of attention lately. (Widatallaa, *et al.,* 2025). Produced mostly from sugarcane and sugar beet, sugar is a necessary commodity for human nutrition. Production of cane sugar has a long history in Sudan, a subtropical country, where the Sudan Sugar Corporation runs a number of mills. But the massive volumes of organic wastewater that sugar mills release seriously contaminate river systems. (Lehninger, A.L.1993**)**. Untreated effluent is dumped from sugar factories into open catchment fields via open drains. This results in swamps, which may have an impact on the soil, water, and overall ecosystem. (El Hassan, 1998; Qureshi *et al.,* 2015). When sugarcane is processed, handled, and transformed, it produces large volumes of effluent that include both liquid and solid discharges. This process is quite complex. These discharges come from the extraction, reaction, heating, cooling, and washing processes, as well as from the control of other rejected specification byproducts. These discharges vary widely in terms of both quantity and quality. The water's pollution load, which includes organic matter and other contaminants, greatly increases as it moves through chambers and tanks throughout the extraction and sugar crystallization processes. (Sahu, 2018). Since highly purified wastewater provides the foundation of 70% of Israel's irrigated agriculture, treated wastewater can be used in industry (cooling towers), artificial aquifer replenishment, agriculture, and the restoration of natural ecosystems. Agricultural and food-related wastewater differs from regular municipal wastewater treated by public or private wastewater treatment facilities worldwide in that it is biodegradable and nontoxic, but it also contains high levels of suspended solids and biochemical oxygen demand (BOD). (EEA, 2001). The seasonality of food processing and post-harvesting, as well as the variations in BOD and pH in effluents from vegetable, fruit, and animal products, make it difficult to estimate the contents of wastewater from food and agricultural. In the presence of oxygen, aerobic digestion processes decompose organic materials. Similar to the continuation of the activated sludge process, aerobic digestion is a bacterial process that takes place in the presence of oxygen. (Yuan *et al.,* 2014; Pronk *et al.,* 2015). In aerobic environments, the organic matter is quickly consumed by bacteria, which then transform it into carbon dioxide. Lack of organic substance causes the bacteria to perish and become food for other bacteria. At this point in the process, this is referred to as endogenous respiration, the number of participants' declines. (Demirbas, *et al.,* 2017). Wastewater in White Nile State poses a significant environmental challenge, as effluents from longstanding sugar factories negatively impact humans, animals, and other living organisms. The use of contaminated wastewater has been linked to the spread of diseases such as asthma, poisoning, and other serious health issues. Moreover, wastewater from Kenana Sugar Factory adversely affects agricultural land due to its elevated levels of biological and chemical oxygen demand (BOD and COD). The objective of this study is to assess the efficiency of aerobic digestion in treating wastewater from Kenana Sugar Factory and to determine the physicochemical characteristics of raw cane sugar wastewater, including pH, electrical conductivity (EC), total dissolved solids (TDS), and total suspended solids (TSS), BOD_5, and COD.

MATERIALS AND METHODS

Study area

The study area included the following state where the sugar cane plants are located. The wastewater, were collected from an area of approximately 500m radius within sub area Kenana, near Rabak on the Eastern bank of the White Nile River,300 km South of Khartoum.

Sampling

Sampling Location Locations were taken from wastewater in Kenana Sugar Factory. Wastewater samples were collected from out section of the process composite sample from final drain carrying wastewater of all sections and going to outside the plant premises

Laboratory Work

The apparatus was used throughout this study include:

(1) Digital Atomic Absorption spectrophotometry (AAS) shimadzul (Model AA6200) Japan double.
(2) Flame Atomic spectrophotometer (AFS) Model 3110, Perkin Elmer Corporation, (USA) in Flame acetylene – air (3) EC214 Conductivity Meter (Portugal)
(4) PH211 Microprocessor pH-Meter (Portugal)
(5) Electronic Digital balance (O512) (China)
(6) Microscope Olympus Model (X21FS1- mode in Philippine
(7) Water Bath – Mumbai – 400 013 (India)
(8) Close Electric Stove ART. NO. ES2615 (China)
(9) Incubation 06287 AKyoet (Turkey)
(10) Autoclave H.T30 psi (Turkey).
(11) Tubidmeter IS021 (Turkey)
(12) Viscometer TS018 (India
(13) Laboratory glass ware Equipment's burette – pipette – graduate cylinder Test tube – Thermometer – etc.
(14) Laboratory consumptions (gloves - facemask – Cotton – soap – etc.)
(15) Lovebird Tintometer (Model) (18) Thermometer

Methods

Total dissolved solids (TDS)

Total dissolved solids were determined by evaporating the water samples to dryness following (AOAC, 1984).

Procedure 20ml of each sample were transferred to weighed evaporating dish (petri dish) and evaporated to dryness by heating for (1- 2hr) at l00ºC to constant weight

Calculation mg/l of TDS = mg residue×1000 ml sample

Electrical conductivity (EC)

Kent ETL model 214 conductivity meter was used with specific conductance cell (Platinum electrode cell) has cell constant 1.00 3-Reagents.

- Deionized water
- KCL solution (0.0IM)

Procedure: 745.8mg of AR KCL was dissolved and diluted to one Liter with deionized water make standard reference solution. The conductivities of the samples were determined in the same manner (as described by (AOAC, 1984).

PH-value measured by Kent EIL model 211 Microprocessor pH-meter

Reagens: Three standards buffer solutions were prepared using buffer tablets. The buffer tablets are (4, 7, and 9). Each tablet was dissolved in 100ml distilled water to form the buffer solutions specified.

Procedure: The pH-meter was calibrated by the buffer solutions of pH 4, 7 and 9 at 25Cº. The pH values of the samples were then by recorded as described.

Chemical Oxygen Demand (COD): $KMnO_4$ titrimetric method was used as described in standard method by (EEA, 2001).

Reagents: Sulphric acid (conc.) - Copper Sulphate (1g) - Potassium Permanganate (0.025N). - Sodium Oxalate (0.025N).

Procedure: 10mls of the sample was taken in 100ml bottle then 5mls of concentration.H_2SO_4 was added and about 1g of copper sulphate ($CuSO_4$) also added. Then 3mls of prepared (0.025N $KMnO_4$) 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. Three mills were then prepared 0.025N Sodium Oxalate ($Na_2\ C_2\ O_4$) was added and immediately titrated with 0.025N Potassium Permanganate ($KMnO_4$) violet color appeared, and then repeated for the blank under the same condition using 10mls of distilled water instead of 10mls of samples.

Calculation COD as mg/L = $(sample of mlB)$ $(A$ 8000×0.025) $ml of sample$ Where: A= ml of $KMnO_4$ used for sample;
B= ml of $KMnO_4$ used for blank; 0.025(1/40) = Normality of $KMnO_4$ 8000 = ml-equivalent weight of oxygen in 1000ml/l.

Biochemical Oxygen Demand (BOD)

Winkler titrimetric method was used as described by (EEA, 2001).

Reagents - Sulphric acid (H_2SO_4). - Starch indicator. - Iodide sodium. Manganese sulphate.

Procedure: Two 100mls bottles were obtained with lid and cleaned well. Twentyfive mills sample was taken in each bottle and 75mls of the sample was added to each of the two bottles. Then the two bottles closed well. One bottle was kept in the incubator (06287 AKyurty) at (20-22ºC) for 5days. Then 10mls of manganese sulphate solution and 2mls of alkali-iodide solution was added to the other bottle below the surface of the liquid by using a syringe. Then the bottle closed and mixed by inverting it several times. When the precipitate settles leaving a clear supernatant above the precipitate, shaken again slowly by inverting the bottle and when the setting has produced at least 50mls supernatant 8mls of concentration. $H_2SO_4$was added. Then the bottle was closed and mixed by gentle inversion until dissolution was completed. One-hundred mills of the sample were titrated with 0.05M Na_2S2O_3 solution until a pale-yellow solution reached. Then 2mls of freshly prepared starch solution was added and titration was continued until a blue color appeared. The procedure was then repeated using 100mls distilled water (blank). Then, repeated for incubated sample after 5days.

CALCULATIONS:

The BOD was calculated as follows BOD as mg/l = 16(V1-V2) Where: - V1 = ml of $Na_2S_2O_3$ used for the sample before incubation. V2 = ml of $Na_2S_2O_3$ used for the sample after incubation. The total solids of the samples were determined by (Punmia and Ashok, 1998).

Total Suspended Solid: The total suspended solid was determined according to the method described by (Punmia and Ashok, 1998).

Procedure

Cleaned crucible with filter paper was ignited to constant weight in an oven (W1). Then 25mls sample was taken and filter through the crucible. The crucible was dried in a constant temperature oven maintained at 103Cº for 24 hours; cooled in a dedicator and weight (W2). The suspended solid were then calculated.

Calculations

mg/l SS = $W1 \times W2 \times 1000/\ V$
Where: - W1= weight of empty crucible plus filter paper.
W2= weight of crucible and filter paper after drying.
V= volume of the sample.

RESULTS AND DISCUSSION

Environmental pollution resulting from manufacturing wastes is often harmful if these wastes are not properly managed or treated. Such pollution can negatively affect both human health and other forms of life. To better understand the nature of this problem, several pollutant parameters of oily wastewater were measured in order to identify the characteristics and composition of the wastewater.

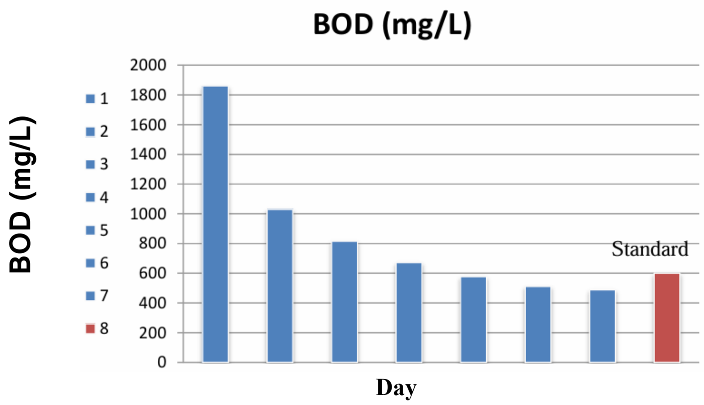


Fig 1: Relation of Biochemical Oxygen Demand and Time with standard

Figure 1 for BOD was (1860mg/L) a higher concentration than the standard (600 mg/L). chemical oxygen demand (COD) values divided by biochemical oxygen demand (BOD) values (COD/BOD) where values range between (1 to 3) that means usually organic materials were decomposed biologically processes, which require that bacteria feed on the organic matter of waste and BOD to reduce.

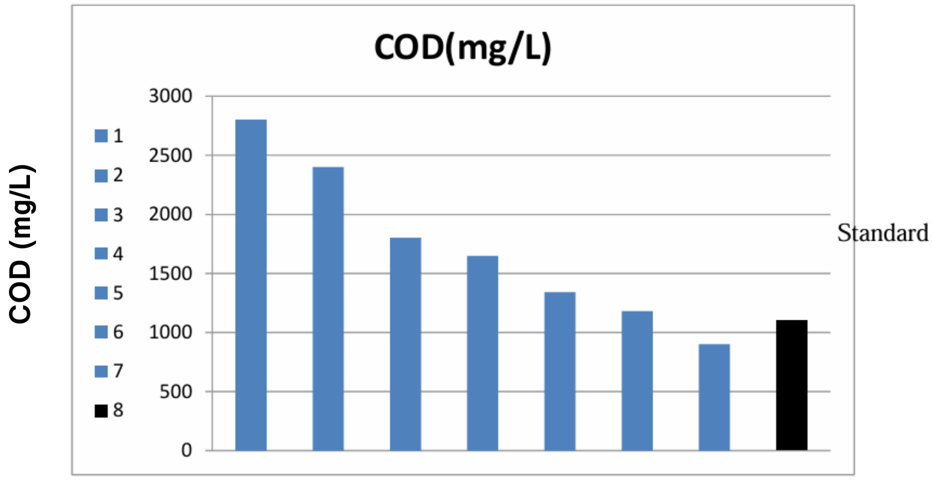


Fig 2: Relation of Chemical Oxygen Demand and Time with standard

Figure 2 the COD (2800 mg/L) higher concentration than the standard (1100mg/L). Aerobic oxidation both (organic material and bacteria and oxygen). The results state that the concentration of the (COD) was high due to presence of organic constituents, quantity of organic constituents and types of organic constituents. that chemical oxygen demand (COD) values divided by bio chemical oxygen demand (BOD) values (COD / BOD) where a raised these values then equal or exceed (5) then there are doubt on the availability of bio logical decomposition if the organic materials. In this cause, this organic material may need a long time to be occurred or it may content some component that inhibit the process of decomposition and may stop the process of biological oxidation.

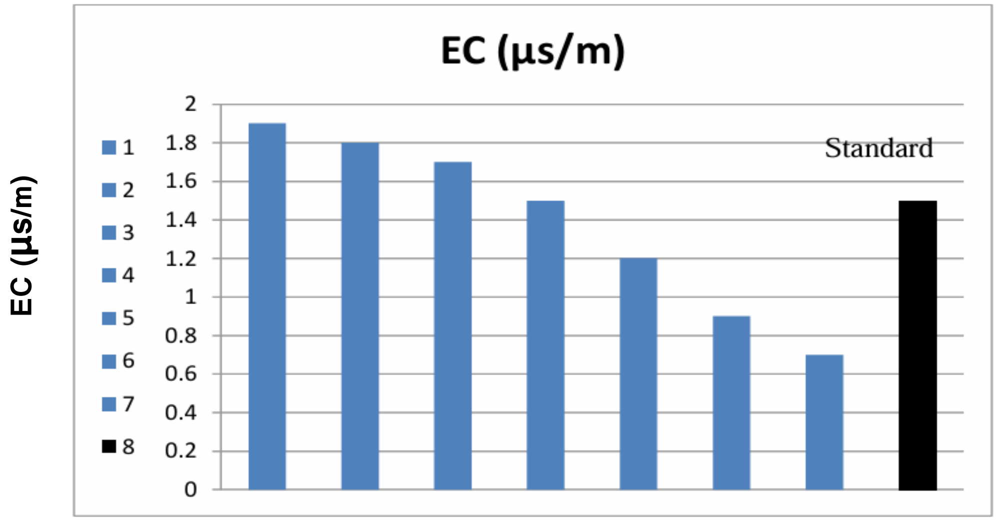


Fig 3: Relation of Electrical Conductivity (EC) and Time with standard

Figure 3 the EC was (1.9µs/m) high concentration than the standard (1.5µs/m) higher concentration when compared with the standard, the higher ratio of EC concentration was indicated to the elements and compound decomposed completely to give rich positive and negative charges, which inform may give arise to high concentration of EC. After treated the result state that the concentration of EC was lower because there was many factors affected such as the elements and compound, to give anxious and cations or positive and negative change consequently, but absent decrease the EC.

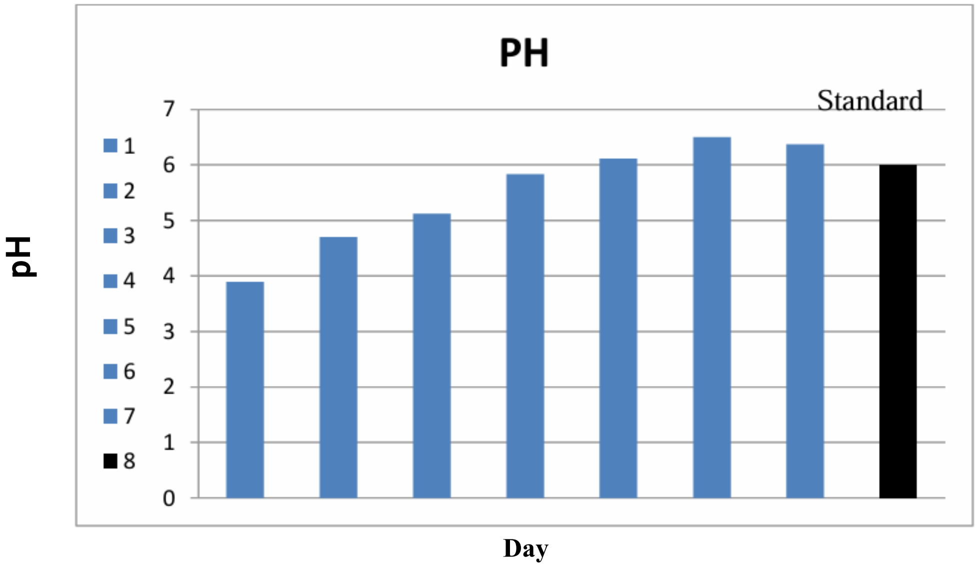


Fig 4: Relation of PH and Time with standard

Figure 4 the pH was (3.89) lower concentration than the standard (6.0). The influent pH has significant impact on wastewater treatment is possible to treat organic wastewaters over a wide pH range, however the optimum pH for microbial growth is between 6.0 and 7.5. It is interesting to note that bacteria grow best at slightly alkaline water. The response to pH is largely due to changes in enzymatic activity. Utilized oxygen dissolved organic matter to carbon dioxide and leaving that reduced acids. The season was expected to become alkaline due to addition of (lime) for purification of the juice, which often mixed with wastewater.

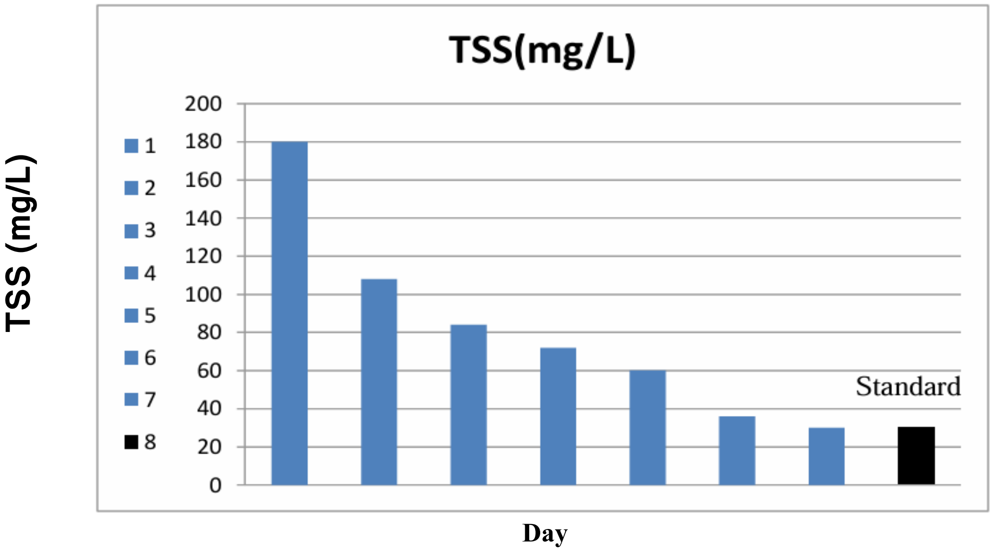
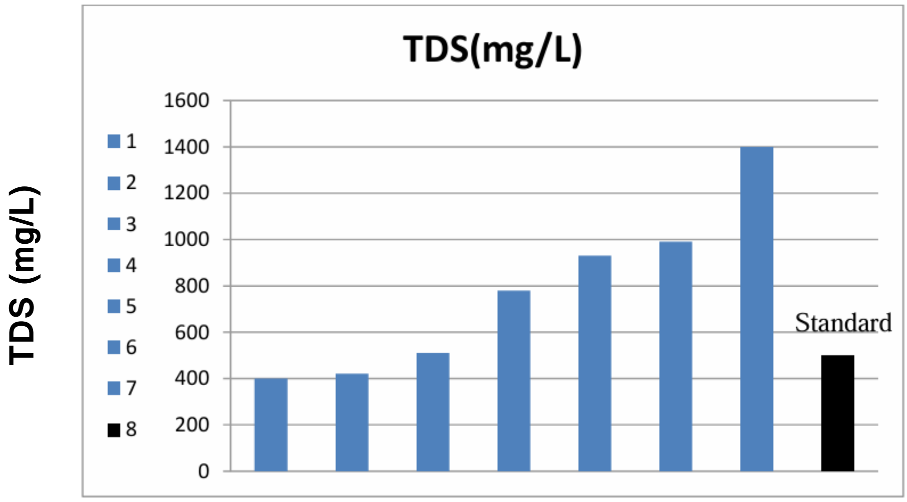


Fig 5: Relation of Total suspended solids and Time with standard

Figure 5 the physical characteristics are important in selection of a suitable method for wastewater. The total solids content of waste water is defined as all the matter that remains as residue TSS values is not in permissible level compared with stated by table means the water sample contains organic matter, gases, crystals. For TSS mg/L in the same table (4-7) the result indicated that the TSS was highest concentration (180 mg/L) when compound with the standard (30 mg/L). The study explain that the wastewater was consist of different solid material on its way from factory throughout location the concentration of TSS, and dissolved in wastewater to oxidized the TSS reduce.



Day

Fig 6: Relation of Total dissolved salts (TDS) and Time with standard

For TDS mg/L in the same Figure (6) the study observed that TDS (400mg/l) lower concentration than the standard (500mg/l) that may increase the concentration of all parameters, because some of the compounds dissolved in wastewater.

CONSOLATION

The Consolation of this study indicate that wastewater from the Kenana sugarcane factory contains high levels of biochemical and chemical oxygen demand (BOD and COD), as well as other physical and chemical properties exceeding permissible limits, making it unsuitable for use in agriculture, irrigation, or any other purpose without treatment. Aerobic digestion significantly reduced BOD and COD levels and improved other properties such as electrical conductivity and pH, bringing the treated water within international and local standards. Therefore, aerobic digestion is an effective method for treating sugarcane industry wastewater, and the treated water can be safely reused. Additionally, implementing integrated treatment systems in industrial areas helps protect the environment and provides economic benefits.

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