JIMMAUNIVERSITY

SCHOOL OF GRADUATE STUDIES

COLLEGE OF NATURAL SCIENCE

DEPARTMENTOFCHEMISTRY

EVALUATING THE EFFICIEANCY OF TREATMENT PLANT AND SUITABILITY STUDY OF EFFLUENTS FROM BEDELE BREWERY SHARE COMPANY FOR AGRICULTURAL ACTIVITY

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June 2024

Jimma, Ethiopia

Evaluating the Efficiency of Treatment Plant and Suitability Study of Effluents from Bedele Brewery Share Company for Agricultural Activity

A thesis submitted to Department of Chemistry Jimma University in partial fulfillment of the requirement for the Degree of Master of Science in Applied Chemistry (Industrial Chemistry)

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Declaration page

This is to certify that this thesis entitled **"Evaluating the Efficiency of Treatment Plant and Suitability Study of Effluents from Bedele Brewery Share Company for Agricultural Activity"** submitted to school of graduate studies, Department of Chemistry in partial fulfillment for the requirements of Master of Science Degree in Applied Chemistry (Industrial Chemistry). I TemesgenWakuma hereby declare that this M.Sc. thesis is my original work and has not been presented for a Degree in any other University and that all source of materials used for the thesis have been duly acknowledged.

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June 2024

Jimma, Ethiopia

Acknowledgements

First of all, I would like to thank the Almighty God for giving me health and strength to start and complete my research work. I am very much grateful to my advisors Dr. Tamene Tadesse, Dr. Bizualem Wakuma and Mr. Ahmed Awol for their excellent guidance and assistance from every beginning of this research. My special thanks go to Department of Chemistry, College of Natural Sciences, Jimma University, for its financial support.

I thanks Bedele Brewery Share Company for giving both inlet and outlet water samples. I also thanks, Mr. Dereje Dadi supporting when using different laboratory materials and equipment as well as chemicals. Last but not least I would like to thank my friends for their unlimited support and those family's contributed positively for the accomplishment of this work.

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Abbreviation and Acronyms

APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
BOD_5	Biochemical Oxygen Demand for 5 days
CETP	Common Effluent Treatment Plant
COD	Chemical Oxygen Demand
D_1	Day one
D_2	Day two
D_3	Day three
DO	Dissolved oxygen
EC	Electrical Conductivity
EEPA	Ethiopian Environmental Protection Agency
EPA	Environmental Protection Agency
FAS	Ferrous Ammonium Sulfate
FC	Feacal Coliform
HACH	Water quality testing and analytical instrument
HL	Hecto Liter
NTU	Nephlometeric Turbidity Unit
PVC	Poly Vinyl Chloride
SAR	Sodium Adsorption Ratio

SBR	Sequencing Batch Reactor
SD	Standard Deviation
SP_1	Sample point One
SP_2	Sample Point Two
TC	Total Caliform
TDS	Total Dissolved Solid
TS	Total Solid
TSS	Total Suspended Solid
VFA	Volatile Fatty Acid
VRBA	Violet Red Bile Agar
VSS	Volatile Suspended Solid
WHO	World Health Organization
WWTP	Wastewater Treatment Plant

Abstract

The Brewing industry is an important one in the food industry, economics, and employment in the world. Bedele Brewery Share Company is one of the Brewing industry and it discharges its treated effluent before discharging into the nearby which can serve as an irrigation source for downstream farmers. This study focuses on the evaluations of the efficiency, wastewater treatment plant and suitability of the effluents for potential agricultural irrigation. Temperature, pH, Turbidity and EC were determined on-site by mercury thermometer, multimeter, Palin test, and multimeter respectively. TS, TDS, TSS and VSS were determined by the gravimetric method in the lab. Phosphate was determined by spectroscopic method and chloride as well as COD was determined by titration through Mohr's method. BOD and microorganisms (TC and FC) were determined by incubation and dilution methods respectively. The results demonstrate that the treatment plant efficiently removes various pollutants from the influent. The effluent average of averages for Temperature were recorded as (24.14±0.91), pH (6.61±0.14), Turbidity (429.95±0.82 NTU), EC (222.35±1.07µs/cm), TS (142.55±3.59 mg/L), TDS (114.89±5.22 mg/L), TSS (27.89±2.87 mg/L), VSS (54.44±4.79 mg/L), Cl^- (82.83±6.46 mg/L), PO_4^{3-} (3.77±0.08 mg/L), BOD (65.3±0.63 mg/L), COD (44.8±5.54 mg/L), TC ($9*10^4$±424.26 CFU/mL), and FC (2*104±70.71 CFU/mL, $2*10^4$±282.84 CFU/mL) in across three days. The Bedele Brewery treatment plant was effective in removing a wide range of contaminants from the influent wastewater. The percentage removal of most parameters is above 86% in three different days with slight variations in each parameter. The highest percentage removal was achieved for EC (87.08%), followed by TDS, TS and TSS (94.81%, 94.47% and 95.87%), in three days respectively. The percentage removal for FC and turbidity were also high on three different days with FC (63.99%) and turbidity (63.18%). The percentage removal for BOD (34.94%) and COD with (54.80%). The findings demonstrate that, the effectiveness of the Bedele Brewery treatment plant in reducing various pollutants. However, further improvement is required. .

Keywords: Bedele Brewery, Influent, Treatment, Wastewater treatment, Effluents, Removal efficiency

1. INTRODUCTION

1.1. Background of the study

The brewing industry is an important one in the food industry, economics, and employment in the world. Water plays a significant role in the entire process performance of brewing industry [1]. It has been estimated that approximately 3-10 L of wastewater is generated per liter of beer produced in breweries, despite substantial technological improvements in the past [2].

Breweries typically consumes from 4 to 8 cubic meters per cubic meter of beer produced and generates 3-10 L of wastewater per liter of beer produced [3]. A sewage treatment consists of a series of unit processes used to separate, modify, remove, and destroy objectionable, hazardous, and pathogenic substances carried by wastewater in solution or suspension in order to reduce its threat to public health before it is discharged from the plant. The treatment removes unwanted constituents so that wastewater can be reused or recycled [4].

Treatment processes are chosen based on composition, characteristics, and concentration of materials present in solution or suspension. The processes are classified as pretreatment, primary, secondary, or tertiary treatment, depending on type, sequence, and method of removal of the harmful and unacceptable constituent [5,6].

The rapid growth of industries does not only enhance the productivity but also results in wastewater which plays role in the production and release of toxic substances into the environment, creating health hazards and effected normal operations, flora and fauna. These wastes are potential pollutants when they produce harmful effects on the environment and generally released in the form of solids, liquid effluent and slurries containing a spectrum of organic and inorganic chemicals. Thus, pollution is an indispensable danger to all development. To combat the plethora of environmental evils of present-day society, efficient and environmentally safe organic waste treatment technologies are needed [7,8].

Previous studies indicated that 90% of the industries in Ethiopia release their effluents into water bodies, streams, and land without proper treatment mechanisms[9]. Environmental Protection Authority stated that most of the effluent discharged by industries including breweries in Ethiopia does not meet the national discharge standards as many of them release their effluent with little or no prior treatment [10]. The principal objective of any wastewater treatment is generally to allow industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. Because the treated effluent from the factory is released to the immediate surrounding with residences and surface waters (the stream, river, and lake), it is necessary to ensure its safety for human health and the environment[11].

In Bedele Brewery Share Company, some effluent (treated water) is reused in the company and the remaining effluent is discharged to the nearby Dabana river site, which can be the source of agricultural irrigation for the nearby farmers. As an agrarian society, people here may want to produce vegetable and with other annual crops for consumption or to supply them to the city. Even urban dwellers who are very close to this river may need it to develop agricultural irrigation such as vegetables [12,13].

The removal efficiency of this waste stabilization treatment plant's as well as the impact of its effluent on the receiving river's ecology and downstream users wasn't thoroughly investigated. These may result in negative effects on biological balance of aquatic environments in the downstream and may also cause public health risks for consuming raw vegetables and other agricultural crops produced using those effluent discharged from the company [13].

It is crucial to investigate for the efficacy of the treatment plant and procedure used by Bedele Brewery Share Company. One thing, it is useful to evaluate if its effluent is used for the agriculture (irrigation & animal drinking) of the nearby environments for land without harm and on the other side, it is helpful to set baseline information regarding the impact of the effluent on public health and the receiving water bodies in particular and the environment in general.

1.2. Statement of the problems

In Ethiopia, many industries and industrial parks are constructed and under construction. These industries have been producing different industrial products. The occurrence of pollutants, for instance, in liquid waste is one of the pressing environmental issues globally faced today. Dangerous chemicals, dyes, pathogenic microorganisms, and other harmful substances mostly exist in wastewater discharged from industries such as the textile industry, brewery industry, tannery industry, etc. Brewery wastewater is one of the industrial wastewater, which is very difficult to deal with the difficulty due to the large variability of characteristics. This wastewater can cause a serious challenge to public health and the environment because of its higher concentrations of suspended solids, COD, & BOD [14].

Throughout every year, the Bedele Brewery Share Company in the Buno Bedele Zone of the Oromiya region in Ethiopia uses large volumes of water for production and discharges large volumes of effluent. Due to this effluent which contains moderate organic and acidic content, which results to raise of BOD and COD. High organic load in the wastewater results from dissolved carbohydrates, alcohol, suspended solids, yeast, etc, which has potential to cause considerable environmental problems in polluting lake ecology and leads to low efficiency of municipal treatment works. In order to control pollution and protect the environment, brewery effluent containing moderate concentrations of organic matter should not be discharged into watercourses.

Regularly monitoring & investigating the performance of the Bedele Brewery treatment plant that discharges wastewater and evaluating its effluent suitability for further use can provide baseline information regarding the impact of the effluent on public health and the environmental problems in general. There effluent quality of the Bedele Brewery treatment plant was evaluated in this study physicochemical and biological parameters and their corresponding values was compared with Ethiopian standards as well as world health organization (WHO) standards for domestic and agricultural purposes. Moreover, the effectiveness of the treatment plant needs was assessed for realizing whether its effluent discharged to the nearby river site as well as farmland is harmless so that it can be helpful for agricultural process. Therefore, thorough investigation of the performance of the treatment plant for the known parameters must commence immediately to fill the gap in knowledge about the irrigational suitability of the effluent of the treatment plant.

From this statement of problem the following research questions were derived

- Would treated effluent from the treatment plant be suitable for irrigation purposes depending on specific crop requirements and potential risks?
- Are there any economic or social benefits to consider when evaluating the potential for reusing treated Bedele Brewery effluent for irrigation?
- Does the discharge of the brewery effluent have a measurable impact on the water quality and ecology of the nearby river and farmland?

- ➢ What are the physicochemical and biological parameters used to evaluate the effluent quality of the Bedele Brewery treatment plant?

1.3. Objectives

General Objective

- ❖ To evaluate the efficiency of treatment plant and suitability study of effluents from Bedele Brewery Share Company for agricultural activity.

Specific Objectives

- ❖ To investigate the suitability of effluent for agricultural process.
- ❖ To analyze physicochemical characteristics (turbidity, pH, temperature, EC, TDS, TSS, TS, VSS, BOD, COD, phosphate, chloride) of the treatment plant at the inlet and outlet of the treatment process.
- ❖ To determine the toxicity level of pollutants through comparing with national and international standard level.
- ❖ To measure biological parameters (total coliform, fecal coliform) of the treatment process.

1.4. Significance of the study

Excess physicochemical and biological compositions of the effluent from Bedele Brewery Share Company have long term and possible effects on the biota of river and in the manner for the agriculture. This is valuable information to indicate ways to improve and upgrade the system for safe surface disposal. So this study contributes to the Academic community and community who work in the treatment plant through:

- ❖ It helps improve the performance of wastewater treatment plants.
- ❖ It evaluate if wastewater impacts the environment out of the context of standard.
- ❖ It makes regulators develop monitorial procedures and interfere in eliminating or reducing the potential hazard of the industrial waste.
- ❖ It fills the gap in knowledge if the effluent discharged is helpful for irrigation.

- It adds the beneficiaries for farmers and local residents will reusing the treated effluents for agricultural purpose.
- To serve as a stepping stone for other researchers who will like study in this area in a wider scale.

2. Literature review

2.1. Industrial Activities and Water Pollution

Pollution related to industrialization is becoming one of the challenges in both developed and developing countries. Most of the factories are established very near to a natural water system, in order to dispose their sewage, which is generated through the process of manufacturing. This leads to change in the quality of surface and ground water in a considerable way So, this is now becoming todays ecological concerns in terms of achieving ecological stability [15].

The utmost polluting factories are those, which utilizes huge amount of water and chemically rich substances throughout their manufacturing processes. Disposal of those untreated wastewaters into the natural water has an adverse impact on the biota of the aquatic ecosystem, it also immensely affects the self-cleansing mechanism of the water system through different natural processes [16]. Incessant generation and discharge of this untreated effluent to the natural system have a huge impact on the accumulation of heavy metals in aquatic life then it affects the consumers around the lake system. So that, the biological system and other interactive natural system close to the river will fall in high risk of contamination from the untreated effluent [16].

Nearly, all of industries in developing countries discharge their wastewater directly to the nearby water systems because, majority of them are not equipped with modern or dependable wastewater treatment technology [17]. Untreated wastewater from industries has great impact on the decline of water quality by changing the physicochemical characteristics of the receiving body. This further results in massive degradation of the surface and ground water and make of inferior quality to use them other purposes [18].

In Ethiopia, more than seventy two percent of the industries has not built any modern treatment technology for their wastewater treatment [16]. Some factories has an old system of treating strong wastewater with a simple lagoon system, which are not capable of treating the pollutants in a desired level of quality [19].

2.2. Wastewater

Wastewater, or sewage, originates from human and home wastewaters, industrial wastes, animal wastes, rain runoff, and groundwater infiltration. Generally, wastewater is the flow of used water from a neighborhood. The wastewater consists of 99.9% water by weight, where the remaining 0.1% is suspended or dissolved material. This solid material is a mixture of excrements, detergents, food leftovers, grease, oils, salts, plastics, heavy metals, sands, and grits. Types of wastewaters include: municipal wastewater, industrial wastewaters, mixtures of industrial/domestic wastewaters, and agricultural wastewaters. Typical agricultural industries include: dairy processing industries, meat processing factories, juice and beverage industries, slaughterhouses, vegetable processing facilities, rendering plants, and drainage water of irrigation systems [20].

2.3. The source of brewery wastewater

Analysis of beer brewing process of beer production process easy, each working procedure has wastes (waste megan, cooling solidification protein, yeast mud, waste diatomite, waste of wheat bad, etc.), waste water (wash tank, wash bad water, soaking wheat water bottles, barrels and washing water, etc.).The main source of brewery waste water is the washing of wheat, water, germination and cooling spray, water, washing water and coagulation. The scarification of the process of scarification, the fermentation of the washing water fermentation process and the filtration and washing water; Wash bottle, sterilization, beer and cooling water and finished workshop washing water [21]. Beer brewing involves two main steps, i.e., brewing and packaging of the finished product [22]. The by-products (e.g., spent grains from mashing, yeast surplus, etc.) generated from these steps are responsible for pollution when mixed with effluents [22]. In addition, cleaning of tanks, bottles, machines, and floors produces high quantities of polluted water [21,22]. It is estimated that for the production of 1 L of beer, 3–10 L of waste effluent is generated depending on the production and specific water usage [23,24]. In other words, very large quantities of water are consumed during the beer brewing process.

2.4. Brewery wastewater and its characteristics

The brewery industry discharges large volumes of highly polluting effluents throughout the year [23,25]. It must also be noted that effluents from individual process steps are variable. For example, bottle washing results in a large wastewater volume, but it contains only a minor part of the total organics discharged from the brewery processes. On the other hand, effluents from fermentation and filtering are high in organics/biochemical oxygen demand (BOD), but generally low in volume, accounting for about 3% of the total wastewater volume but 97% of the BOD [26].

Wastewater from a brewery plant may be discharged in several ways including the following [27,28]: (1) directly into a waterway (oceans, rivers, streams, or lakes), (2) directly into a municipal sewer system, (3) into the waterway or municipal sewer system after the wastewater has undergone some pretreatment, and (4) into the brewery's own wastewater treatment plant. The disposal of untreated (or partially treated) brewery wastewater into water bodies can constitute potential or severe pollution problems to the water bodies since the effluents contain organic compounds that require oxygen for degradation [29]. For example, if water of high organic matter content value flows into a river, the bacteria in the river will oxidize the organic matter consuming oxygen from the water faster than the oxygen dissolves back in the river from the air. Furthermore, as regulations become more and more stringent and the cost of water increases, the call for water recycling is currently gaining a lot of momentum.

Brewery wastewater typically has a high chemical oxygen demand (COD) from all the organic components (sugars, soluble starch, ethanol, volatile fatty acids, etc) [28]. It usually has temperatures ranging from 25 °C to 38 °C, but occasionally reaching much higher temperatures. The pH levels can range between 2 and 12 [28] and are influenced by the amount and type of chemicals used in cleaning and sanitizing (e.g., caustic soda, phosphoric acid, nitric acid, etc.) [28,30,31]. Sanitizing chemicals which include chlorine compounds ensure that the surfaces are free of any microorganisms harmful to the brewing industry and the public consuming the beer. Nitrogen and phosphorus levels are mainly dependent on the handling of raw material and the amount of yeast present in the effluent [28,30,31]. Table 1 is an example of the physicochemical characteristics of brewery wastewater from the United Breweries in India [32,33].

Table 1: *Characteristics of brewery wastewater [32,33]*

Parameter	Value
pH	3–12
Temperature (°C)	18–40
Chemical Oxygen Demand (mg L^{-1})	2000–6000
Biological Oxygen Demand (mg L^{-1})	1200–3600
Chemical Oxygen Demand ratio Biological Oxygen Demand	1.667
Volatile Fatty Acid (mg L^{-1})	1000–2500
Phosphates as PO_4 (mg L^{-1})	10–50
Total Solid (mg L^{-1})	5100–8750
Total suspended Solids (mg L^{-1})	2901–3000
Total Dissolved Solids (mg L^{-1})	2020–5940

2.5. Wastewater Treatment Plant

Wastewater treatment is a process, which is being done on the wastewater to change its quality for drinking or other suitable purposes, Wastewater treatment takes place in wastewater treatment plants, which should be designed under different circumstances and there are different criteria being considered in design of wastewater treatment plant (WWTP) [34]. However wastewater treatment plants are facing new challenges to comply with tighter wastewater discharge limits [35].

Wastewater treatment plants (WWTPs) are complex non-linear systems subject to significant perturbations in influent load. The pretreatment is performed with a coarse and fine screen and a vortex-type grit chamber. The deep treatment is performed with a mechanical mixing reaction tank, an inclined tube settling tank, a fiber dial filter chamber, and a disinfection contact tank wastewater [36].

Wastewaters are typically contaminated with physical, chemical and biological composition which has a tremendous negative impact on the environment, where it has the ability to destroy many animal habitats, and cause irreparable damage to many ecosystems [35]. The WWTP includes a primary treatment and a secondary treatment to remove organic matter and suspended solids from wastewater. Primary treatment is designed to physically remove solid material from the incoming wastewater. Coarse particles are removed by screens and many of the organic suspended solids are removed by sedimentation. The primary treatment removes almost one-half of the suspended solids in the influent. Secondary treatment consists of a biological conversion of dissolved and colloidal organic compounds into stabilized, low energy compounds and new biomass cells, caused by a diversified group of microorganisms, in the presence of oxygen [37].

2.6. Wastewater treatment plant methods

Industrial effluent composition is unpredictable which changes as the developments of the production process are improving through time even though, to treat effluents from the industrial processing waste requires several treatment steps which can be applied with a combination of different treatment technologies to obtain an effluent which can meet the standards [6]. The selection of the treatment method depends on the composition of the target wastewater and on the intended use of the effluent and discharge requirements. Treatment method applied for both municipal and industrial wastewater treatment applications can be preliminary/primary, secondary and tertiary treatment which are discussed as follows.

Preliminary treatment

Brewery wastewater is characterized by dark brown color, TSS, TS, etc. that requires pretreatment to minimize suspended particles and other organic loads. Generally, the brewery wastewater pretreatment process is meant to change the physical, chemical and or the biological properties of the feed water. The pretreatment process is carried out by physical, chemical or biological means or combinations of two or more methods. However, the selection of pretreatment method largely depends on the final discharge point of the effluent. For example, in a situation where the brewery does not discharge into the municipal drain, only primary and secondary treatments are required, but if the brewery is allowed to discharge into the municipal drain, pretreatment is required to reduce the organic loads of the municipal treatment plant and to also meet municipal wastewater treatment by laws [38]. The following flow diagram shows those all treatment stages briefly.

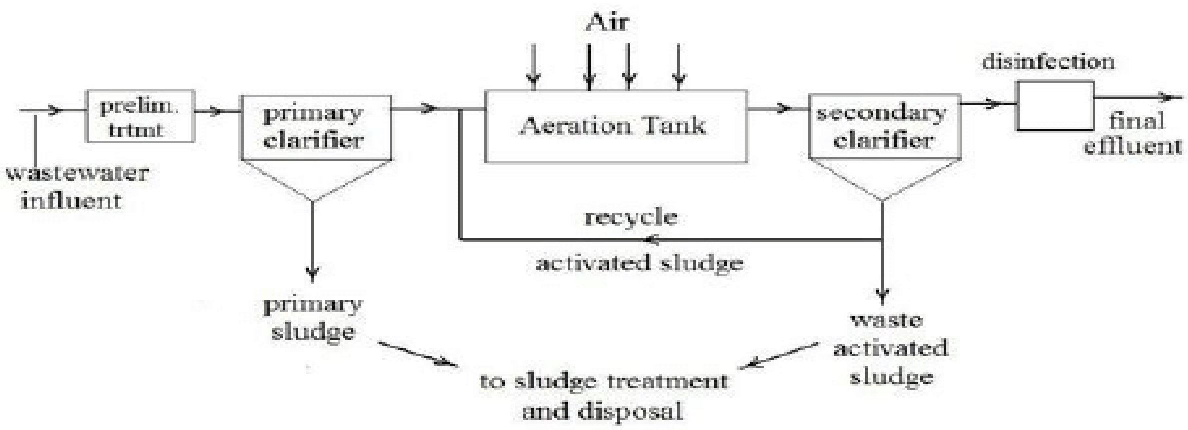


Figure 1: *Flow diagram of wastewater treatment plant [39]*

Primary treatment

Primary treatment is the second step in a wastewater treatment process which helps to separate suspended solids, grease and objects which leaves the preliminary treatment process. In some treatment plants, preliminary and primary stages may be combined into one basic operation [40,41,42]. The effluent is first screened for coarse suspended materials such as yarns, lint, pieces of fabrics, fibers and rags using bar and fine screens [42]. The screened effluent then undergoes settling for the removal of the suspended particles. The floating particles are removed by mechanical scraping systems.

Neutralization is done to reduce the acidic contents of the effluents. Sulfuric acid and boiler flue gas are the most commonly used chemicals to alter the pH. A pH value of 5-9 is considered ideal for the treatment process [43]. In the first step of screening (coarse screening), the effluent is carried out to prevent damage from plastics, metals paper and rags. Coarse screens have an opening of 6 mm or larger. Coarse screening is followed by fine screening (1.5-6 mm opening) and very fine screening (0.2- 1.5mm opening). Fine screening helps in the reduction of suspended solids in the effluent [44]. Screening is followed by sedimentation which makes use of gravity to settle the suspended particles such as clay or silts present in the effluent.

Simple sedimentation was not found to be effective because it does not remove colloidal particles in the effluents [45]. Another disadvantage of the process is the large space it occupies. Therefore, settling could be carried out by coagulation. Colloidal particles in the effluent carry charges on their surfaces and addition of chemicals to the effluent changes the surface property of the colloids hence causing them to clump together and settle. Ferrous sulphate, lime, alum, ferric sulphate and ferric chloride are some of the most commonly used chemicals in the coagulation step [46]. The settled particles are collected as sludge. Disposal of sludge is one of the biggest challenges of treatment plants.

Mechanical flocculation is a physical process which involves slow mixing of the effluent with paddles bringing the small particles together to form heavier particles that can be settled and removed as sludge [47,48]. Some of the disadvantages with flocculation system are: (a) they are in a risk of getting short-circuited and (b) the flock formation in the system is difficult to control. Care should be taken that the sludge disposed from the bottom of the system would not suspend the solids into the system again [49].

Secondary treatment

Biological and chemical processes are used in secondary treatment to remove most of the organic matter and in certain instances, nitrogen and phosphorus. The Secondary treatment process is mainly carried out to reduce the BOD, phenol and oil contents in the wastewater and to control its color. This can be biologically done with the help of microorganisms under aerobic or anaerobic conditions. Aerobic Bacteria use organic matter as a source of energy and nutrients. They oxidize dissolved organic matter to CO_2 and water and degrade nitrogenous organic matter into ammonia. Aerated lagoons, trickling filter and activated sludge systems are among the aerobic system used in the secondary treatment. Anaerobic treatment is mainly used to stabilize the generated sludge [45].

Aerated lagoons are one of the commonly used biological treatment processes. This consists of a large holding tank lined with rubber or polythene and the effluent from the primary treatment is aerated for about 2-6 days and the formed sludge is removed. The BOD removal efficiency is up to 99% and the phosphorous removal is 15-25% [45].The nitrification of ammonia is also found to occur in aerated lagoons. Additional TSS removal can be achieved by the presence of algae in the lagoon [44]. The major disadvantage of this technique is the large amount of space it occupies and the risk of bacterial contamination in the lagoons [50].

Trickling filters are another common method of secondary treatment that mostly operates under aerobic conditions. The effluent for the primary treatment is trickled or sprayed over the filter. The filter usually consists of a rectangular or circular bed of coal, gravel, Poly Vinyl Chloride (PVC), broken stones or synthetic resins [51]. A gelatinous film, made up of microorganisms, is formed on the surface of the filter medium. These organisms help in the oxidation of organic matter in the effluent to carbon dioxide and water. Trickling filters do not require a huge space, hence making them advantageous compared to aerated lagoons. However, their disadvantage is the high capital cost and odor emission [51].

Aerobic activated sludge processes are commonly used. It involves a regular aeration of the effluent inside a tank allowing the aerobic bacteria to metabolize the soluble and suspended organic matters. A part of the organic matter is oxidized into CO_2 and the rest are synthesized into new microbial cells [52]. The effluent and the sludge generated from this process are separated using sedimentation; some of the sludge is returned to the tank as a source of microbes. A BOD removal efficiency of 90-95% can be achieved from this process, but is time consuming [53]. Sludge's formed as a result of primary and secondary treatment processes pose a major disposal problem. They cause environmental problems when released untreated as they consist of microbes and organic substances [54] Treatment of sludge is carried out both, aerobically and anaerobically by bacteria. Aerobic treatment involves the presence of air and aerobic bacteria which convert the sludge into carbon dioxide biomass and water. Anaerobic treatment involves the absence of air and the presence of anaerobic bacteria, which degrade the sludge into biomass, methane and carbon dioxide [55].

Sequential batch reactor (SBR) are modified version of the conventional activated sludge process, which is operated in a batch mode and offers operational flexibility and better process control. The SBR cycle consists of a set of specific treatment phases which include, fill, react, settle, decant, and idle (Figure 2) each of which lasts for a specific duration and can be varied accordingly as per the desired level of treatment. The SBR has become more widely accepted as the most effective option among biological treatment methods due to its ability to reduce organics, nutrients, filamentous bacterial control, and energy consumption [56].

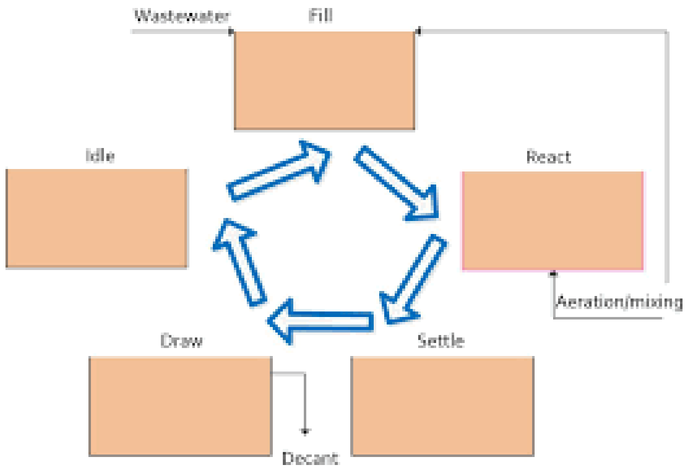


Figure 2: *Typical cycles in sequencing batch reactor (SBR) process [57]*

Table 2: *Reduction in pollution parameters after primary treatment processes [52].*

Properties	(%) Percentage of Reduction
Total suspended solids	80-90
Biological Oxygen Demand	40-70
Chemical Oxygen Demand	30-60
Bacteria	80-90
Total suspended matter	50-70
Organic matter	30-40

Tertiary treatment

There are several technologies used in tertiary treatments including electro dialysis, reverse osmosis and ion exchange:

Reverse osmosis is a well-known technique which makes use of membranes that have the ability to remove total dissolved solid contents along with ions and larger species from the effluents. A high efficiency of >90% has been reported [43]. Cotton dyeing processes use electrolytes such as NaCl in high concentrations. These high concentrations of salts can be treated using reverse osmosis membrane [58].

Electro-dialysis is another process which uses membranes, that has the ability to separate dissolved salts. The electricity used in electro-dialysis influences the ions to get transported through a semi permeable membrane by passing an electrical potential across water allows negatively charged particles to pass through and traps positively charged particles and vice versa. Placing numerous membranes throughout the system hinders the flow of effluent and the effluent would reach a point at which the ions are trapped or settled down and the remaining ions are neutral in charge [59]. Membrane fouling (the process where solutes or other particles get attached to the membrane or into the membrane pore) has to be prevented by removing suspended solids, colloids and turbidity prior to electro-dialysis [60].

Ion exchange is a commonly used tertiary method which involves the passage of effluents through the beds of ion exchange resins. These ion exchange resins are either cationic or anionic charged. Effluent passing through a cationic resin would have its cations removed by the resin and replaced with hydrogen ions making it acidic. When the acid solution is passed through anion resin, the anions would be substituted with hydroxyl ions [61]. Photo catalytic degradation is another method by which a wide range of dyes can be decolourized depending on their molecular structures [62]. Adsorption is also found to be effective in the removal of colors. Thermal evaporation using sodium persulfate is also found to have a good oxidizing potential. This process is found to be ecofriendly because they do not have the property to form sludge and also do not emit toxic chlorine fumes during evaporation [45].

2.7. Physiochemical Parameters of Industrial Wastewater

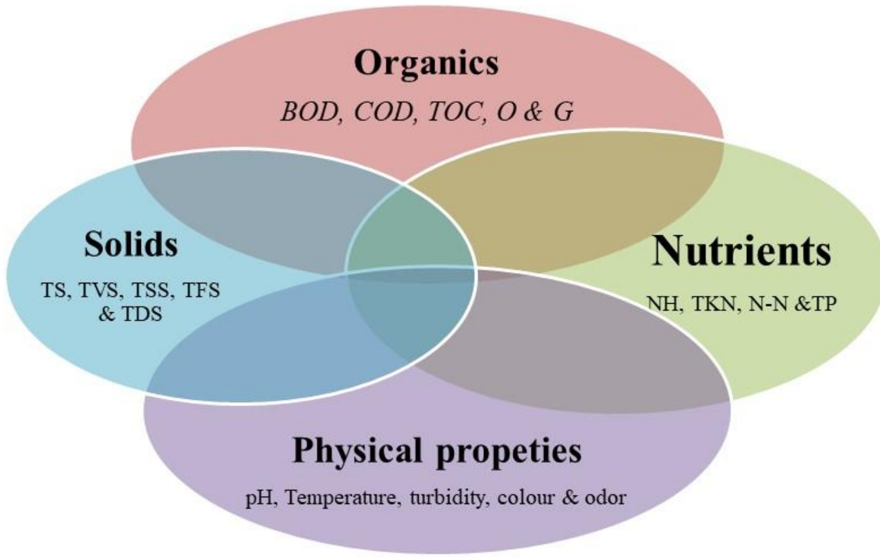


Figure 3: Interaction of Wastewater Analytical Categories [63].

2.7.1. Total Dissolved Solid

Total salt concentration (for all practical purposes, the total dissolved solids) is one of the most important agricultural water quality parameters. This is because the salinity of the soil water is related to, and often determined by, the salinity of the irrigation water. Accordingly, plant growth, crop yield and quality of produce are affected by the total dissolved salts in the irrigation water. Equally, the rate of accumulation of salts in the soil, or soil salinization, is also directly affected by the salinity of the irrigation water. Total salt concentration is expressed in milligrams per litre (mg/L) or parts per million (ppm) [63].

2.7.2. Chemical Oxygen Demand

Chemical Oxygen Demand (COD) is defined as the amount of oxygen used while oxidizing the organic matter content of a sample with a strong chemical oxidant under acidic conditions. In COD determination, the organic matter (both biologically oxidizable like glucose and biologically inert like cellulose) is completely oxidized to CO_2 and H_2O. As it does not differentiate among them, so the COD values are greater than BOD values (which represent the amount of oxygen that bacteria need for stabilizing biologically oxidizable matter). Moreover, it does not provide any evidence of the rate at which the biologically active material would be stabilized under conditions that exist in nature. COD test is therefore widely used for measuring the pollution strength of domestic and industrial wastes. The major advantage of COD test is that the determination is completed in 3 h, compared to the 5 days required for the BOD determination, and therefore, steps can be taken to correct errors on the day they occur. COD is used extensively in the analysis of industrial wastes. COD test is useful in indicating toxic conditions and the presence of biologically resistant organic substances. The test is widely used in the operation of treatment facilities because of the speed with which results can be obtained [64].

2.7.3. Biochemical Oxygen Demand

BOD is simply defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. BOD occurs in two general stages. While calculating the oxygen demand, the carbonaceous stage is taken into account. This stage is almost completed in 5 days, which means that most of the organic content of the sewage is oxidized under aerobic conditions in 5 days. Hence, BOD for 5 days is calculated. Therefore, it is important that a mixed group of organisms commonly called “seed” be present in the test, which is not necessary for food-based industrial wastewater as it itself survives a large community of microorganisms. The results are obviously not reproducible; generally, the purpose of seeding is to introduce microorganism into the sample, a biological population capable of oxidizing the organic matter in the wastewater. The standard seed material is settled domestic wastewater, which has been stored for 24-36 h at 20 °C. The determination of BOD is used to measure the purification capacity of streams and serves regulatory authorities as a means of checking the quality of effluents discharged. Information concerning BOD of waste is an important consideration in the design of treatment facilities [65]. Below is a graph showing how BOD values of influent & effluent concentration as well as efficiency of a treatment plant vary in terms of retention time.

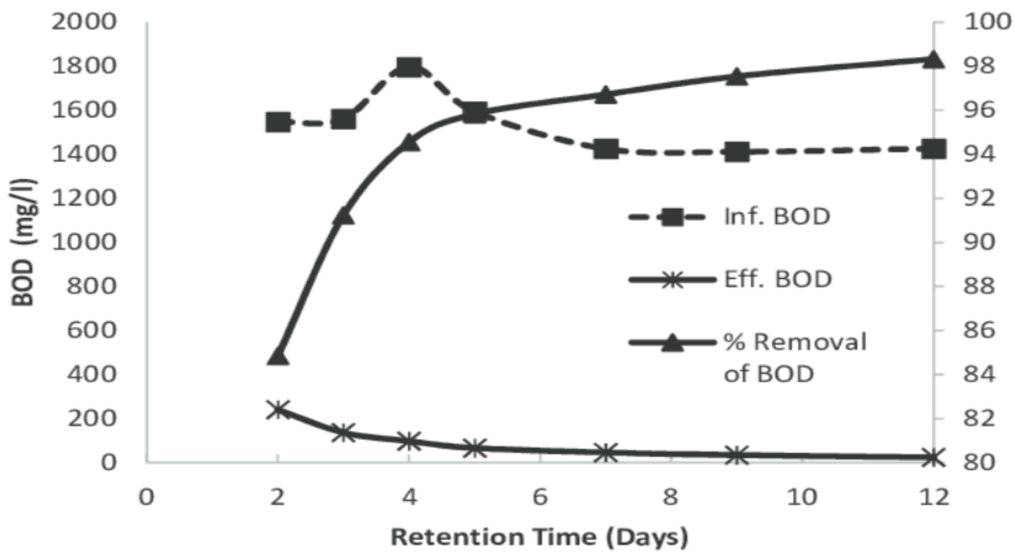


Figure 4: *Influent and Effluent BOD at Different Hydraulic Retention Times [61]*

2.7.4. Dissolved Oxygen

Dissolved oxygen (DO) concentration is a key parameter for characterizing natural and wastewater and for assessing the global state of the environment in general. The decrease of dissolved oxygen levels in the world‘s oceans, which is becoming increasingly obvious, is expected to have an impact on the whole ecosystem of the Earth, including the carbon cycle, the climate, etc. The unsaturated organic matter consumes the dissolved oxygen from water. The disposal of wastewater into reservoirs, lakes, rivers and seas increases the organic matter content of water measured as COD and BOD. The DO content is also one of the important water quality parameters. There is a close relation between DO and COD of water [66].

Removal of organic matter from waste water is very widely investigated area of investigation. The removal of organic matter from wastewater can be carried out by various physical treatment methods followed by secondary, biological treatments. Biological treatments include activated sludge processes and trickling filters. Adsorption is one of the most efficient methods for the removal of organic matter from effluent. Other advanced treatment methods such as membrane separation are also found effective for wastewater treatment [67].

Dissolved oxygen depends on water quality. The high temperature implies low dissolved oxygen as solubility decreases with temperature. Also, it indicates high COD for water. The mechanisms involved in DO variation in water are respiration, deoxygenation, photosynthesis and diffusion. Various investigators have carried out investigations to study various aspects of DO variation in various parts of sea and important rivers, lakes and reservoirs. The present review summarizes research and studies on DO; it's affecting parameters and effect of DO variation on aquatic life [67].

2.7.5. Electric Conductivity

Electric conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. Organic compounds like oil, phenol, alcohol, and sugar do not conduct electric current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported at 25 °C. Conversely, molecules of organic compounds that do not dissociate in aqueous solution conduct a current very poorly. The presence of salt affects plant growth in three ways: (1) Osmotic effect, caused by the total dissolved solids concentration in the soil water; (2) specific ion toxicity, caused by the concentration of individual ions; (3) soil particle dispersion, caused by high sodium and low salinity. With increasing soil salinity in the root zone, plants expend more of their available energy on adjusting the salt concentration within the tissue (osmotic adjustment) to obtain needed water from the soil. Consequently, less energy is available for plant growth in irrigated areas; salts originate from the local ground water or from salts in the applied water [68].

2.7.6. Power of Hydrogen

The pH is a measure of the activity of the hydrogen ion [H^+]; also, it is the reciprocal of the logarithm of the hydrogen ion concentration. pH is known as a measure of the hydrogen ion concentration. It is an important indication of its quality and provides information about various geochemical equilibriums or solubility calculation [69]. However, pH is also one of the most important operational parameters for water treatment such as disinfection or coagulation-flocculation and pH adjustment is a common practice in water treatment [70].

The pH is an important variable in water quality assessment as it influences many biological and chemical processes within a water body and all processes associated with water supply and treatment. When measuring the effects of an effluent discharge, it can be used to help determine the extent of the effluent plume in the water body [71]. If the pH of the water is high, chlorine is less effective in killing pathogens [72].

2.7.7. Total Suspended Solids

Solids that will not pass through a 0.45-micron filter are referred to as total suspended solids (TSS). Since the standard method for measuring TSS involves shaking the sample thoroughly before filtering, the TSS actually includes all none dissolved solids, as opposed to simply the dissolved solids that will not settle under the influence of gravity. Results of the test for settle able solids cannot be subtracted from the results of the test for total suspended solids to obtain the value of the quantity of no dissolved solids in a sample that will not settle under the influence of gravity, because the standard test for settle able solids yields a value in terms of ml/L, while the standard test for TSS yields a value in terms of mg/L. If it is desired to estimate the quantity of nonsalable TSS, a special procedure must be devised and then described thoroughly in the presentation of results [73].

2.7.8. Turbidity

Turbidity is a measurement of the cloudiness of water, and is measured by passing a beam of light through the water photo metrically. It is a measure of water clarity and is inversely proportional to the penetration of light. Cloudiness is caused by materials suspended in water that obstruct light transmission through the water. Clay, silt, organic matter, plankton and other microscopic organisms (bacteria, viruses and protozoa) are typically attached to particulates, cause turbidity in natural water [69].

2.7.9. Total Phosphorous

Controlling phosphorous discharged from municipal and industrial wastewater treatment plants is a key factor in preventing eutrophication of surface waters. Phosphorous is one of the major nutrients contributing in the increased eutrophication of lakes and natural waters. Its presence causes many water quality problems including increased purification costs, decreased recreational and conservation value of an impoundments, loss of livestock and the possible lethal effect of algal toxins on drinking water. Phosphorus releases due to anthropogenic activity promote eutrophication in aquatic ecosystems. For example in the UK, the main sources of P entering rivers are sewage effluent and agricultural run-off [74] with up to 70% being attributed to sewage discharges [75].

This reality has resulted in tightening P discharge standards and increased pressure on the water industry to reduce P loads entering rivers, particularly to ecologically sensitive locations [76,77]. As such, targeted P-removal has become increasingly common in large, urban wastewater treatment plants (WWTPs). However, sensitive watercourses also can be in more remote locations, receiving P discharges from smaller WWTPs. Further, wastewater from smaller communities is often treated less rigorously [78,79] and the potential negative impacts of P release from small treatment works may be underestimated [74]. The removal of P from wastewater can be performed using physicochemical methods, biological treatment, and/or combinations of both, and many large-scale techniques are well established [80].

2.8. Bacteriological Parameters of Industrial Wastewater

In generally there are two bacteriological parameters for industrial wastewater like Total Coliform (TC) and Fecal Coliform (FC).

2.8.1. Total Coliform

The most commonly measured indicators of water quality are the coliform organisms. Gram negative bacteria are cytochrome oxidant negative, non-spore forming, and ferment lactose at 35–37 ^{o}C, within 24 – 48 hours (Morita, op cit.). This defines total coliforms. The group is as diversified as their habits from which they originate [81] .

2.8.2. Fecal Coliforms

The term “fecal coliform” has been used in water microbiology to denote coliform organisms which grow at 44 or 44.5 ^{o}C and ferment lactose to produce acid and gas. In practice, some organisms with these characteristics may not be of fecal origin and the term “thermo tolerant coliform” is, therefore, more correct and is becoming more commonly used. Nevertheless, the presence of thermo tolerant coliforms nearly always indicates fecal contamination. Usually, more than 95% of thermo tolerant coliforms isolated from water are the gut organism Escherichia coli, the presence of which is definitive proof of fecal contamination. As a result, it is often unnecessary to undertake further testing to confirm the specific presence of E. coli. In the laboratory thermo tolerant coliforms are grown on media containing lactose, at a temperature of 44 or 44.5 °C. They are provisionally identified by the production of acid and gas from the fermentation of lactose. Nutrient-rich environments may encourage the growth or persistence of some species of thermo tolerant coliform other than E. coli. This possibility should be considered when, for example, an unusually high result is obtained from water that was thought to be relatively clean. In such a case, the advice of a microbiology laboratory should be sought for the determination of the more specific indicator, E. coli [82].

2.9. Parameters to Qualify Water for Agriculture

The quality of irrigation water is highly variable depending upon both the type and the quantity of the salts dissolved in it. These salts originate from natural (i.e., weathering of rocks and soil) and anthropological (i.e., domestic and industrial discharge sources [83]. One of the agricultural concerns is the effect of dissolved solids (TDS) in irrigation water on the growth of plants. Dissolved salts increase the osmotic potential of soil water and an increase in osmotic pressure of the soil solution thereby increasing the amount of energy which plants must expend to take up water from the soil. As a result, respiration is increased and the growth and yield of most plants decline progressively as osmotic pressure increases. Although most plants respond to salinity as a function of the total osmotic potential of soil water, some plants are susceptible to specific ion toxicity [83].

The following Table shows major important physical and chemical characteristics used in the evaluation of water quality for agricultural practice such as irrigation [84].

Table 3: *Guidelines of Quality of Water for Irrigation [84].*

Potential Irrigation Problems		Degree of Restriction on Use		
		None	Slight to Moderate	Severe
Salinity	EC_w (dS/m)	< 0.7	0.7 - 3.0	> 3.0
	TDS (mg/L)	< 450	450 – 2000	> 2000
Infiltration	SAR^2 = 0 - 3 and EC_w	> 0.7	0.7 - 0.2	< 0.2
Specific ion	Sodium (Na) (SAR)	<3	3-9	>9

toxicity	Chloride (Cl) (mg/L)	<4	4-10	>10
	Nitrogen (NO_3-N)[3] (mg/L)	< 5	5 – 30	> 30
	Bicarbonate (HCO_3) (mg/L)	< 1.5	1.5 - 8.5	> 8.5
	pH	Normal range 6.5-8		

It is commonly accepted that the problems originating from irrigation water quality vary in type and severity as a function of numerous factors including the type of the soil and the crop, the climate of the area as well as the farmer who utilizes the water. Nevertheless, there is now a common understanding that these problems can be categorized into the following major groups: (a) salinity hazard, (b) infiltration and permeability problems, (c) Specific ion toxicity and (d) miscellaneous problems [83,85].

2.9.1. Permeability and Infiltration Hazard

Although the infiltration rate of water into soil is a function of many parameters including the quality of the irrigation water and the soil factors such as structure, compaction and the organic content, the permeability and infiltration hazard typically occurs when high sodium ions decrease the rate at which irrigation water enters the soils lower layers. The reduced infiltration rate starts to show negative impacts when water cannot infiltrate to the roots of the crop to the extent that the crop requires. Hence, these salts start to accumulate at the soil surface. When the crop is not able to extract the required amount of water from the soil, it is not possible to maintain an acceptable yield and the agricultural production is reduced [83].

2.9.2. Chloride

Chloride is ion commonly found in irrigation waters. Its toxic effects are immediately seen as leaf burns or leaf tissue deaths [83].

2.10. Impacts of wastewater on agriculture

The economic impacts of wastewater on crops may differ widely depending upon the degree of treatment, types and nature of crops grown, and the overall farm level water management practices. Normally, as wastewater is a rich source of plant food nutrients, higher than average crop yields may be possible with wastewater irrigation. If crops are under supplied with essential plant food nutrients, wastewater irrigation will act as a supplemental source of fertilizer thus increasing crop yield [86].

However, if plant food nutrients delivered through wastewater irrigation result in an oversupply of nutrients, yields may actually be negatively influenced. Also, since wastewater contains undesirable constituents such as trace elements and heavy metals, organic compounds and salts, crop yields may be negatively affected depending upon their concentrations in the wastewater and the sensitivity of crops to these elements. Thus from an economic standpoint, wastewater irrigation may have threefold impacts on crop production: (1)source of irrigation water; (2)influence on extent of irrigated areas, cropping intensity, crop mix, and on crop yields; and(3)fertilizer application. These aspects have implications for the cost of production and overall profitability of crop production [86].

The use of wastewater for irrigation may add nutrients, dissolved solids and other constituents like heavy metals into the soil over time. Some of these elements may accumulate in the root zone with possible harmful impacts on soil. Long-term use of wastewater could result in soil salinity and waterlogging, breakdown of soil structure and an overall reduction in the productive capacity of soil and lower crop yields. However, the impacts and their intensity will depend on a range of factors including source, intensity of use and composition of wastewater, soil properties and characteristics of plants/crops grown. From an economic viewpoint, soil-related impacts of wastewater can be grouped under (1)potential yield losses; (2) loss of soil productive capacity; (3) depreciation in market value of land; and (4) cost of additional nutrients and soil reclamation measures [86].

The use of wastewater has the potential both to recharge groundwater aquifer (positive externality) as well as pollute groundwater resources (negative externality). Percolation of excess nutrients, salts and pathogens through the soil may cause degradation of groundwater. However, the actual impact will depend upon a range of factors including scale of wastewater use, quality of groundwater, depth to water table, soil drainage, and soil characteristics (porous, sandy). In irrigated areas with shallow sweet water tables, impact of wastewater irrigation on ground water quality is likely to be substantial [86].

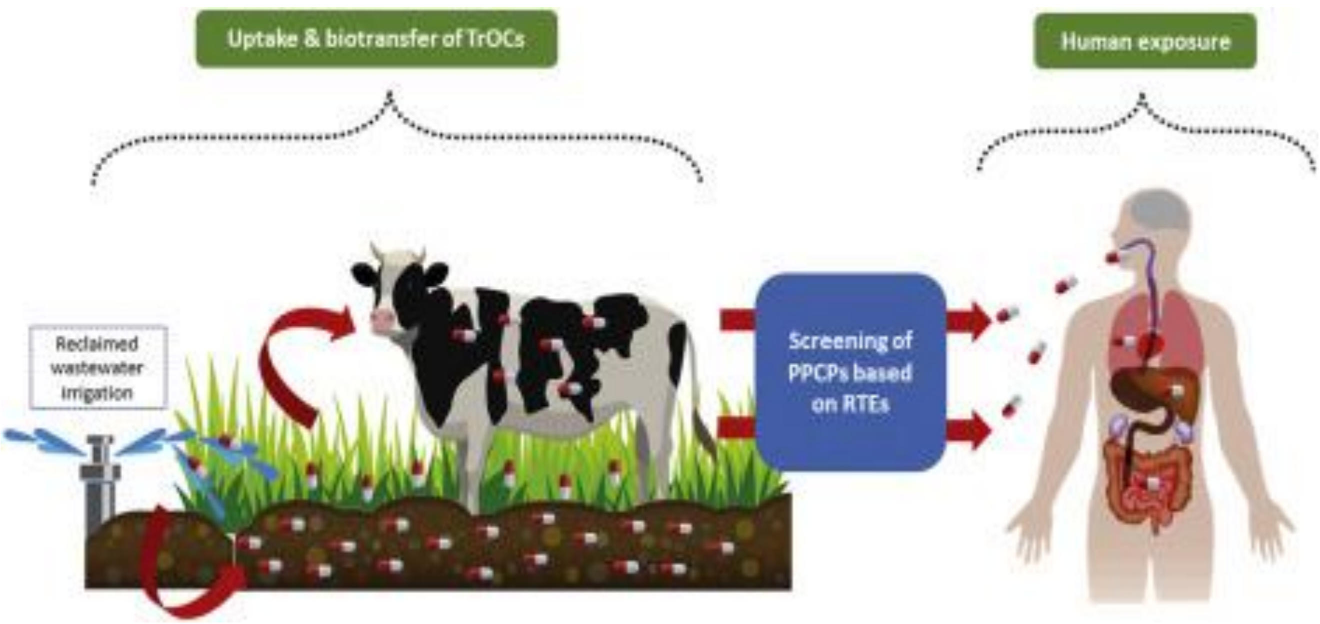


Figure 5: Impacts of wastewater on agriculture (irrigation and animal drinking) [86]

3. MATERIALS AND METHODS

3.1. Description of the study area and periods

Bedele Brewery Share Company was established on October, 1993 in Bedele town, located in the South Western part of Ethiopia's Oromia Region, specifically in Buno Bedele Zone, Sadisa Keble. It is situated approximately 425 km away from Addis Ababa, the capital city of Ethiopia. As per annual report of Bedele Brewery in 2017, the company produces an impressive volume of 486,000 hectoliters (HL) of beer per year. The study was conducted at the Chemistry research laboratory, located in the main campus of Jimma University. Jimma University main campus is situated in Jimma town, which is part of the Jimma zone in the Oromia regional state. This campus is located approximately 346 km away from Addis Ababa, Ethiopia. The study was carried out over a duration spanning from September 2023 to June 2024.

3.2. Study design

Experimental study design was employed to examine the efficiency of Bedele Brewery treatment plant in terms of its bacteriological and physicochemical quality and it's suitability for agricultural process.

3.3. Chemicals and Materials

3.3.1. Chemicals and Reagents

The chemicals and reagents that were used in this study include; sulfuric acid (H_2SO_4, 98%, UNICHEM, Germany), nitric acid (HNO_3, 69%, Loba Chemie Pvt. Ltd. India), hydrochloric acid (HCl, 35.4%, Loba Chemie Pvt. Ltd. India), potassium dichromate ($K_2Cr_2O_7$, 99.5%, LABMERK CHEMICALS PVT. LTD. India), sodium chloride (NaCl, 99.9%, Fisher Chemical, US) and sodium hydroxide (NaOH, 97% Loba Chemie Pvt. Ltd. India), potassium chromate (K_2CrO_4,Central Drug House (P) LTD, India), potassium dihydrogen orthophosphate (KH_2PO_4, 99%, Blulux Laboratories (P) Ltd. India), Violate Red Bile Agar (Central Drug House (P) Ltd. India), MacConky Agar (0.15%, HiMedia Laboratories Pvt. Ltd. India), Ammonium molybdate ($(NH_4)_6Mo_7O_{24}$, 98%, ALPHA CHEMICAL, India), Techno Pharm chem, BAHA DURDARH, India) and FAS ($(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$, 99%, Blulux Laboratories (P)Ltd. India).

3.3.2. Material

The materials required for this study are; beakers, flasks, Erlenmeyer flask, Pipette, measuring cylinders, spatula, funnels, What man No 1filter paper, desiccator, volumetric flasks, micropipettes, icebox, pH meter (Model: Bante902P, USA),Palin test photometer (Model: Palin test Photometer 7500, Germany), BOD incubator (Model: IN-010, GEMMYCO), mercury thermometer (Model 3012, UK),electronic balance (Model:JA103P, China), furnace (Model: SX-4-10, Drawell, China), oven (Model: GENLAB WLDNES, England), UV-vis spectrophotometer (Model: SPECORD 200/PLUS, analytiKjena, Germany).

3.4. Sampling & Sample Points

The main source of the samples was water from the treatment plant system of the Bedele Brewery Share Company. Water samples were collected from two sampling points, i.e., one at influent (SP_1) and the other at effluent (SP_2) on March 1, 2024, for the first time and termed as day one (D_1). The second time samples were taken on March 4, 2024, assigned as day two (D_2) and the third time samples were taken on March 8, 2024 and termed as day three (D_3). The sampling process and selection of sample points for water from a brewery treatment plant were conducted consistently over three days. On each day, duplicate samples were taken (i.e., 1 L at 9:00 AM in the morning and 1 L at 1:00 PM in the afternoon) and homogenized before analysis. The duplicate samples in the morning and afternoon for each day were mixed to ensure a representative sample. A time composite sampling method was used for the collection of water samples. Those sampling points were investigated to characterize its major parameters for the efficiency of the treatment plant as well as for the agricultural process. The collected samples were labelled and immediately transported in iceboxes to the Jimma University of Analytical Chemistry research laboratory for analysis.

3.5. Sample analysis

In this study, two laboratory analyses, such as physiochemical and biological laboratory, were carried out.

3.5.1. Physiochemical analysis

3.5.1.1. Gravimetric method analysis parameters

Total solids, total dissolved solids, total suspended solids, and volatile suspended solids were determined by the gravimetric method [87].

i. Total solid

Total solid concentration in the samples was determined by gravimetric method by pouring an aliquot of water sample into pre-weighed crucibles and subjected to heat in an oven at 180 °C for 2 h. The residue was then cooled in the desiccator and weighed to a constant weight. Total solid (TS) was calculated with the following formula:

$$TS = \frac{W_2 - W_1}{V} \times 1000 \qquad 1$$

where TS is total solid (mg/L), W_1 is weight of crucible in gram, W_2 is weight of crucible with sample after drying in gram and V is sample volume

ii. Total dissolved solid

The gravimetric method was used to quantify the total dissolved solids (TDS) in wastewater samples. The first step was to weigh a clean crucible to a constant weight. The collected wastewater sample was then filtered into a clean conical flask. The filtrate was poured into the crucible in a volume of 10 mL. Afterwards, the crucible was dried at 180°C for 2 h. The residue was then cooled in a desiccator and weighed. The following formula was used to calculate the TDS:

$$TDS = \frac{W_2 - W_1}{V} \times 1000 \qquad 2$$

where TDS is total dissolved solid (mg/L), W_1 is weight of crucible only in gram, W_2 is weight of dried residue and crucible in gram and V is volume of sample in liter.

iii. Total suspended solid

Total suspended solid was determined from the obtained values of TS and TDS through the following formula.

$$TSS = TS - TDS \qquad 3$$

where TSS is total suspended solid in mg/L.

iv. Volatile suspended solid

Volatile suspended solids (VSS) represent the fraction of TSS in a water sample consisting of living or deceased microorganisms and organic material. To measure VSS, 10 mL of each sample underwent filtration, and the remaining material was moved to a crucible. The combined weight of the crucible and the filter was noted as W_1. The crucible with the filter was then put in a muffle furnace at 550 °C for 1.5 h to ensure full combustion of organic material. After cooling for 30 minutes in the desiccator to achieve room temperature and stable weight, the weight of the cooled crucible and residue was recorded as W_2. VSS was determined using the subsequent formula.

$$VSS = \frac{W_1 - W_2}{V} \times 1000 \qquad 4$$

where W_1 is the weight of the crucible and filter before ignition (g), W_2 is the weight of the crucible and residue after ignition (g) and V is the volume of the filtered sample (L).

a. Temperature: The temperature of sample was measured on the site at mo time of sample collection with mercury thermometer.

b. Turbidity: The turbidity of water samples was determined by using palintest photometer.

c. pH: The pH of water samples was measured by a digital pH meter/multimeter.

d. Electrical Conductivity: The Electrical conductivity of water sample was determined by the digital pH/multimeter.

e. Determination of chloride content:

The Mohr method, also known as the argentometric method, is a classic titrimetric technique for determining chloride (Cl^-) concentration in water samples. In this study the chloride content of samples was determined through Mohr method as follows.

The 50 mL of the samples were pipetted into the Erlenmeyer flask and 3 drops of potassium chromate indicator solution was added to the flask, then the solution turned yellow. The burette was filled with 0.1N standard silver nitrate ($AgNO_3$) solution and the initial burette reading was recorded as V_1. On the continuously swirling flask, the sample was slowly titrated with the silver nitrate ($AgNO_3$) solution. The yellow color started to fade as silver chloride (AgCl) precipitate formed. Silver nitrate ($AgNO_3$) was continuously added to the endpoint of silver nitrate ($AgNO_3$). The endpoint was indicated by a permanent brick-red color change in the solution and the final burette reading was recorded as V_2. The reaction is:

$Ag^{+}+Cl^{-}\leftrightarrow AgCl$

Since 1 mole of Ag^+ reacts with 1 mole of Cl^- in the precipitation reaction, the moles of chloride ions in the sample are equal to the moles of silver ions used. So that the chloride content in samples was calculated by the following formula.

$$Cl^{-}(mg/L) = \frac{(V_2 - V_1)\times M}{V} \times Molar\ mass\ of\ Chrorine \qquad 5$$

where M is molarity of silver nitrate (N), V_1 is initial burette reading in mL, V_2 is final burette reading in mL and V is volume of sample in mL [88].

f. Determination of phosphate content:

From the spectrophotometric method of phosphate concentration analysis in samples the molybdate method was carried out in this study. The molybdate method is a popular and established technique for determining phosphate concentration in wastewater due to its simplicity and affordability.

The Vanadate-Molybdate Reagent was prepared by dissolving 0.1 g of ammonium metavanadate (NH_4VO_3) in 50 mL of 1:1 ratio HNO_3. 2.5 g of ammonium molybdate[$(NH_4)6Mo_7O_{24}$]was dissolved in 40 mL of distilled water in the beaker. The prepared reagent was transferred in to 100 ml volumetric flask water to the mark. The series of calibration standards were prepared from stock (1000 mg/L) potassium dihydrogen phosphate (KH_2PO_4). The prepared standard solutions were 0.1 mg/L, 0.5 mg/L, 1 mg/L, 1.5 mg/L, 2 mg/L, 2.5 mg/L, 3 mg/L and 10 mL of the vanadate-molybdate reagent was added to each standard solution. 25 mL of each sample was added in 50 mL volumetric flasks. 10 mL of the molybdate reagent was also added to each one and filled by distilled water to the mark. The all prepared solutions (including calibration standards) to be kept for 10 minutes until the full color was develop before taking absorbance readings. After the full color was developed the absorbance of each standard, sample and blank was measured at 470 nm. Finally the values of samples (i.e., inlet and outlet) were determined from the calibration curve [89].

a. Chemical oxygen demand

The chemical oxygen demand (COD) is an important parameter used to assess the amount of organic matter present in wastewater. The 25 mL of sample, 25 mL of oxidizing agent (i.e., 1000 mg/L $K_2Cr_2O_7$ were added in to the titration flask and 25 mL 0.5M H_2SO_4 was also added. The solution was mixed carefully and 3 drops of ferrion indicator was added and the solutions turn to greenish color. The titration was titrated against standard 0.5M ferrous ammonium sulfate (FAS) solution. This is back titrations, which gives the estimations of unreacted $K_2Cr_2O_7$ the solution and turns greenish to reddish brown when the end point was reached. For the estimations of the whole $K_2Cr_2O_7$ required for the experiment, blank titration was carried out through $K_2Cr_2O_7$, H_2SO_4 and ferrion of the same proportion in conical flask absence of the sample. The amount of COD in wastewater was calculated by using the following equation.

$$COD(mg/L) = \frac{(A-B)\times C}{V} \times 8000 \qquad 6$$

where A = volume of Mohr salt used for blank (L), B = volume of Mohr salt used for sample (L), C = normality of Mohr salt solution (eq/L) and V = volume of sample used (L)[90].

b. Biological oxygen demand

Biological oxygen demand (BOD) is a crucial parameter in assessing the organic pollution level of wastewater. It refers to the amount of dissolved oxygen (DO) needed by aerobic microorganisms to biodegrade organic matter in a water sample over a specific period and temperature.

To ensure BOD content in the samples. (i.e., 10 mL of the water sample was added in to two separate 300 mL BOD bottles. The initial DO concentration in each BOD bottle was measured using a Palin test and the value was record as DO_i. Each of BOD bottle then sealed tightly and incubated in the dark at 20 °C for 5 days. After 5 day, the final DO concentration in each bottle was measured using a Palin test and the value was record as DO_f. The blank control was prepared by filling a BOD bottle with dilution water only and treated identically to the samples.

The final DO concentration in the blank control was measured and value was recorded as B_f. This accounts for any oxygen demand from the dilution water and seed culture. The BOD for each sample was calculated using the following formula.

$$BOD\ (mg/L) = \frac{(DO_i - DO_f) \times B_f}{V} \times Volume\ of\ BOD\ bottle \qquad 7$$

where D_i = Initial DO concentration in the sample bottle (mg/L), D_f = Final DO concentration in the sample bottle (mg/L), B_f = Final DO concentration in the blank control (mg/L), V= volume of sample (mL) and volume of BOD bottle is also in mL [91].

3.5.2. Biological analysis

The serial dilution method is a common technique for quantifying total and fecal coliform bacteria in water. It involves diluting the water sample in a series of steps and testing each dilution to estimate the bacterial concentration per milliliter (mL). The series dilution of water sample was prepared through 10 mL of sample should be added to 10 mL of medium, 1 mL sample to 10 mL and 0.1 mL of sample to 10 mL of medium. By using micro-pipette 0.1 mL of each serial diluted solution was transferred to petri dishes containing MacConkey agar medium for fecal coliform and VRBA medium for total coliform. The inoculated samples in petri dishes was incubated at 37 °C for 48 h and 44.5 °C for 24 h for total coliform and fecal coliform respectively. After the incubation, the colonies on the agar mediums were counted. Colonies that are pink/red on MacConkey agar medium and red/pink on the VRBA medium indicates the existence of fecal coliform and total coliform respectively. The colony-forming units (CFUs) per milliliter of the samples for both total coliform and fecal coliform was calculated based on the dilution factors and the number of colonies counted as follows.

$$\mathrm{CFU/100mL} = \frac{\mathrm{CFU\ counted}}{\mathrm{Volume\ of\ sample\ spread\ (mL)}} \times \mathrm{DF} \qquad 8$$

where DF is dilution factor, CFU is colony forming unit CFU/mL.

3.6. Determination of removal efficiency

To assess the success of a treatment plant, it's crucial to perform a standard analysis of the wastewater and adhere to the proper procedures. This will allow for a determination of the treatment system's capacity and identification of any areas that require further examination. The formula below can be used to calculate the removal efficiency of the effluent treatment plant for various wastewater quality parameters.

$$Percentage\ removale(\%) = \frac{C_i - C_e}{C_i} \times 100\% \qquad 9$$

Where C_i =the influent concentration of waste water in mg/L and C_e= the effluent concentration of waste water in mg/L.

3.7. Data analysis

A combination of Origin Pro 8.5 software and Microsoft Excel was used to record, organize, and summarize the study's data. Physicochemical and biological analyses of water samples were compared with WHO and EEPA standards.

4. RESULT AND DISCUSSIONS

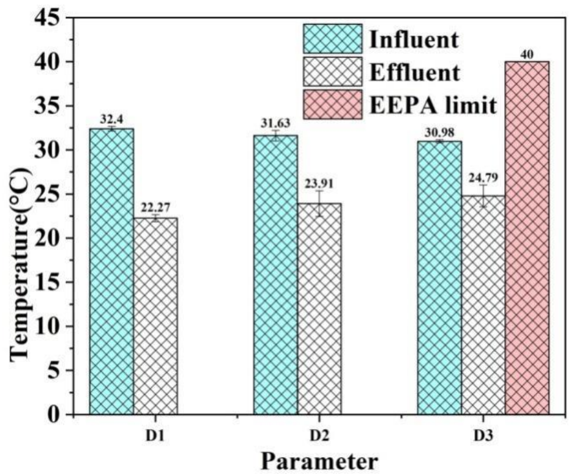
The inlet and outlet of the physicochemical and biological parameters of water sample have been analyzed with the relevant WHO and EEPA limits. The values of each parameters either physicochemical or biological parameters have different inlet and outlet values. Because of the ingredients of inlet and outlet of brewery was differ.

4.1. Physicochemical characteristics of brewery raw wastewater

The physicochemical characterizations of the Bedele Brewery treatment plant reveal important insights into its composition and properties. The Bedele Brewery raw water contains elevated concentrations of TS, TDS, TSS and VSS due to yeast, malt particles, and hop residues. The wastewater exhibits unique physicochemical characteristics due to the brewing process. It typically has a moderate organic content, reflected in elevated BOD and COD, indicating oxygen depletion potential in receiving water bodies. The pH can range from slightly alkaline in influent to acidic in effluent. Furthermore, the wastewater exhibits variations in temperature, EC and turbidity reflecting the diverse nature of the brewing operations. Understanding these physicochemical characteristics is crucial for designing effective treatment strategies to mitigate the environmental impact of Bedele Brewery treatment plant discharge and ensure compliance with regulatory standards.

4.1.1. Temperature determination

Temperatures of water samples taken at the inlet (influent) and the outlet (effluent) were measured to check the effect brewery process on the heat content of water (**Figure 6**). Accordingly, the mean temperature measurement of the influent was 32.40±0.26 °C and ranged between 32.20 to 32.7 °C while the mean temperature measurement of the effluent was 22.27±0.40 °C and ranged between 21.9 to 22.7 °C for D1**.** The mean temperature**s** of D2 and D3 for influent were 31.63±0.59 °C and 30.99±0.16 °C respectively. The mean temperature**s** of D2 and D3 for effluent were 23.91±1.47 °C and 24.79±1.24 °C respectively. Overall, the mean temperature values for the influent and effluent show variation across the three different days. The influent temperatures were relatively high, high lathing the need for temperature reduction during wastewater treatment. The effluent temperature consistently remained lower than the influent temperatures, indicating the effectiveness of the treatment process in reducing temperature. However, there were variations in the effluent temperature ranges suggesting potential fluctuation in the treatment process or external factors impacting the temperature reduction. The temperature decrement in effluent was due to the flow wastewater through pipes and treatment units, it naturally loses heat to the surrounding environment. Both influent and effluent temperature values were within the natural brewery wastewater temperature (40 °C) and possibly rising even higher.



❖ Figure 6: Comparison of industrial influent and effluent temperature with EEPA limit

4.1.2. PH determination

pH is a significant factor in determining the acidity or alkalinity of water. In this research, the influent's average pH value was 9.22±0.01, while the effluent was 6.47±0.02 for D1. The mean temperatures of D2 and D3 for influent were 8.93±0.04 and 9.00±0,08respectively (Table 4). The effluent's D2 and D3 average temperatures were 6.72±0.91 and 6.64±0.20, respectively. As per Table 4, the range of pH values for influent was between 9.21 to 9.23, and for effluent, it was between 6.46 to 6.50 for D1.The mean. pH values for the influent and effluent show slight variations across the three different days. The influent pH values were relativity high, indicating alkaline conditions in the presence calcium carbonets and other rocks. The effluent pH consistently decreased compared to the influent, indicating effective acidification or pH adjustment during the treatment process. However, there were variations in the effluent pH values, suggesting potential fluctuations in the treatment process or external factors impacting the pH adjustment. The pH values obtained for the effluent in this research were within the acceptable range for brewery effluent discharge, which typically falls between 6 to 9.

Table 4: *Comparison of Bedele brewery influent and effluent of pH with EEPA and WHO limit*

Parameter	pH values			EEPA limit	WHO limit
	D1	D2	D3	6–9	6–9
Influent	9.22±0.01	8.93±0.04	9.00±0,08		
Effluent	6.47±0.02	6.72±0.91	6.64±0.20		

4.1.3. Electrical conductivity determination

Inorganic ions have a major influence on the conductivity of water. High values of EC show that inorganic ions are in abundance in the wastewater. EC is directly related to the concentration of dissolved ionized solids in water [92]. In essence, high EC in wastewater is an indication of high total dissolved solids concentration. The obtained EC mean value plus standard deviation was 1753.67±1.53 µs/cm, 221.91±0.86 µs/cm; for influent and effluent respectively in D1. The mean EC for D2 and D3 for influent were 1722.33±3.06 µs/cm and 1689.83±2.90 µs/cm respectively. The average EC of effluent on D2 was 225.18±1.09 µs/cm while on D3 it was219.97±1.28 µs/cm. Over the three different days, there are only slight variations in the influent and effluent mean EC values. A significant electrical conductivity in the incoming water samples was indicated by the influent EC values, which were relatively high. When compared to the influent, the effluent EC consistently decreased indicating that the treatment process effectively reduced electrical conductivity. However, there were slight variations in the effluent EC values, suggesting that the potential fluctuations in the treatment process or slight variations in the influent characteristics. The EC of influent value was above the discharge limit of EEPA, but the effluent value was lower than the discharge limit (**Figure 7**). It was observed that EC decreased downstream and water does not contain excess dissolved salts that provide ions to conduct electricity and also the treatment plant was more effective EC removal.

❖

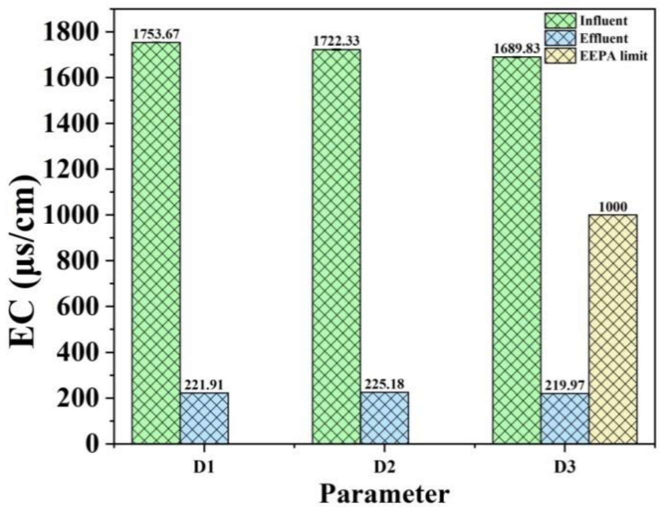
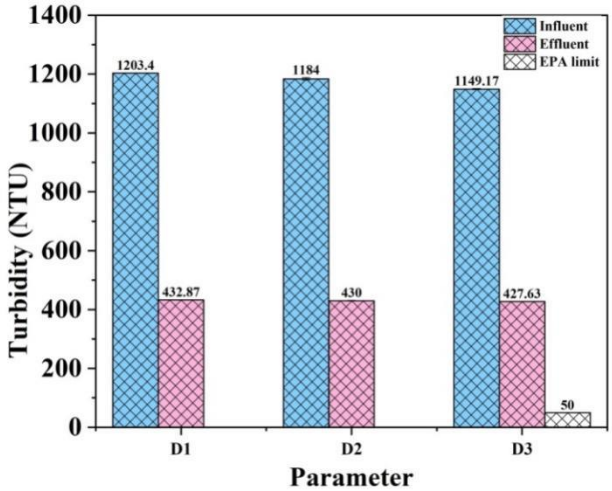


Figure 7: *Electrical conductivity comparison graph of industrial influent and effluent with EEPA limit*

4.1.4. Turbidity determination

Turbidity is commonly caused by the presence of clay, silt, organic matter, algae, and other microorganisms [3]. The mean plus the standard deviation value of turbidity was 1203.40±0.53 and 432.87±0.81 NTU for influent and effluent among the sampling stations respectively. The average turbidity of influent on D2 was 1184.00±4.58, NTU while on D3 it was 1149.16±2.065 NTU. The average turbidity for D2 and D3 for effluent were 430.00±1.00 NTU and 427.00±0.65 NTU respectively **(*Figure 8)***. The mean turbidity values of the influent and effluent exhibit fluctuations throughout the three different days. The influent turbidity values were relatively elevated, indicating the presence of suspended particles or cloudiness in the incoming water samples. The effluent turbidity consistently decreased compared to the influent, indicating a successful reduction of turbidity during the treatment process. Variations in the effluent turbidity values suggest the possibility of fluctuations in the treatment process or variances in the characteristics of the influent. It was observed the result both influent and effluent data were above the EPA discharge limit of wastewater for irrigation [93]. The following figure shows the comparison of both influent and effluent with the WHO limit.



❖

***Figure 8**: Comparison of turbidity industrial influent and effluent with EPA discharge limit*

4.1.5. Gravimetric analysis

Gravimetric analysis is a process used for determining the amount of a substance in a sample by measuring its mass. To carry out this type of analysis, it is important to obtain precipitates that are free of contaminants at a macroscopic level and can be easily filtered. The process of converting the analyte into sparingly soluble compounds of known composition, filtering, washing, and drying is called precipitation gravimetric analysis. Simple gravimetric analysis involves heating the sample, precipitating it, drying it, and separating it to determine the volatile and non-volatile components.

i. Total solid determination

Total solids refer to all non-liquid matter that is either suspended or dissolved in wastewater. Wastewater that enters the treatment plant (also known as influent) typically has high total solids due to the presence of industrial discharges. The total solid value of effluent, or treated wastewater, is lower than the influent value because it undergoes primary treatment, which removes large settleable solids, secondary treatment, which reduces biological particles (especially organic matter), and tertiary treatment, which removes target-specific pollutants.

In this study, the total solids value was 2751.67±2.89 mg/L for influent and 146.67±2.89 mg/L for effluent in D1. The average TS of influent on D2 was 2753.33±5.77 mg/L, while on D3 of it was 2751.66±2.89 mg/L. The average TS for D2 and D3 for effluent were 140.00±5.00 mg/L and 141.00±2.89 mg/L respectively (Figure 9A). Across the three different days analyzed, the average amount of TS varied in both the influent and effluent. Influent TS levels were consistently high, signifying a substantial concentration of solids in the incoming wastewater. The effluent, however, displayed a consistent decrease in TS compared to the influent, suggesting the treatment process effectively removes solids. However, some variation remained in the effluent's TS levels, which could be due to fluctuations in the treatment process itself or changes in the composition of the influent. The removal efficiency of total solids for the company of D1,D2 and D3 was 94.67%,94.92% and 94.85%. (Table 6), which indicates that the treatment plant effectively removed total solids from the wastewater. The total solids removal efficiency of the company was higher than that of other brewery industries.[94]. The presence of this particular solid can have a negative impact on the environment by causing an increase in water cloudiness, a reduction in the amount of oxygen that is dissolved in the water, and harm to aquatic life. However, the results of the study show that the removal efficiency was quite high, and it was able to eliminate the more solid matter. This led to an effective treatment of the wastewater treatment plant.

ii. Total dissolved solid determination

Total dissolved solid are inorganic salts and organic molecules that pass through the filter and remain dissolved in the wastewater. The determination of TDS in brewery wastewater is crucial for several reasons. Such as; compliance with regulations, process optimization and environmental impact assessment**.** The removal efficiency of the plant for TDS of D1, D2and D3 was 94.59%, 94.50% and 94.34% respectively. (Table 6), which has mean values of influent 2093.33±5.77 mg/L and its corresponding effluent 113.33±5.77 mg/L in D1 respectively. The average TDS for D2 and D3 for influent were 2073.67±6.35 mg/L and 2073.00±4.36 mg/L respectively. The effluent's average TDS for D2 and D3 were 114.00±5.29 mg/L and 117.33±4.61 mg/L, respectively (Figure 9A). The influent TDS concentrations were relatively similar on all three days, indicating consistent levels of dissolved solids in incoming water sample. The effluent TDS concentration also showed some similarity ,with slight increase from D2 and D3The removal efficiency of the treatment plant for TDS is very effective compared to other reported literature on brewery industries [2,94]. However the concentration of effluent was above the discharge limit of EEPA, which Is 80 mg/L; but below 133.5±34.3 mg/L reported in the other scholar [3]. So the study revealed that the treatment plant was more effective if the concentration of effluent below the discharge limit.

iii. Total suspended solid determination

Total suspended solid are insoluble particles like sand, silt, organic matter, and algae that can be captured by a filter. The mean concentrations of TSS in the influent for the present study 658.33±7.64 mg/L. Similarly, the average concentrations of TSS in the treated brewery water was 33.33±5.29 mg/L for D1 and the average value TSS for D2, D3 for influent were 679.67±10.50 mg/L,678.67±6.11 mg/L respectively. The effluent's average TSS for D2 and D3 were 26.00±1.72 mg/Land 24.33±4.04 mg/L respectively (Figure 9B).The effluent TSS concentrations on D1 and D3 were lower than both the influent concentrations and the treated brewery water concentrations on D1.This suggests that the treatment process effectively reduced the suspended solids in the water, resulting in improved water quality. The decreasing trend in effluent TSS concentrations over the three days indicates that the treatment plant process was consistently effective in removing suspended solids. The range of these values was between 650 to 665 for influent and 30 to 35 for effluent. Both influent and effluent value of TSS was lower than the results of previous studies [95]. The TSS concentration discharged into the open water was lower than the EEPA, 2003 [96], which couldn't affect the wetland ecological quality and biotic structure. The removal efficiency of the treatment plant of D1, D2 and D3 was 94.94%, 96.17% and 96.41%. (Table 6), which shows the plant effectively treat the concentration of TSS compared to other literature [2 ,94,97].

iv. Volatile suspended solid determination

Volatile suspended solid determination represents the organic fraction of TSS in wastewater. The organic fraction of TSS, VSS, plays a crucial role in managing the Bedele Brewery treatment plant. Understanding VSS concentration and characteristics is essential for effective sludge management, and nutrient loading assessment (i.e., it contributes to nitrogen and phosphorus loading in receiving water bodies, necessitating strategies to minimize nutrient discharge and protect water quality). The mean concentration value of VSS in the influent was found to be 103.33±5.74 mg/L and in the effluent was 54.00±5.29 mg/L for D1. The average value VSS for D2 and D3 for influent were 108.00±3.46 mg/L and 111.33±8.08 mg/L respectively. The effluent's average VSS for D2 and D3 were 56.33±4.72 mg/L and 53.00±4.36 mg/L, respectively

(Figure 9B). The effluent VSS concentrations for D2 and D3 were slightly higher than the effluent concentration on D1 but still lower than the influent concentrations for the respective days. This indicates that the treatment process was effective in reducing VSS. The result suggests that the treatment process generally succeeded in reducing VSS concentrations from the influent to the effluent. However, the slight increase in influent VSS concentrations over the three days and the variability in the effluent concentrations indicate the need for further investigation into the treatment process stability and performance..

The range of these values was between 100 to 110 for influent and 52 to 60 for effluent. The concentration of influent was lower compared to the influent concentration other study (1799±57.1 mg/L) on the beer industry[98]. The removal efficiency of the treatment plant for VSS of D1, D2 and D3 was 47.74%, 47.99%, and 52.39. (Table 6). The following graph shows the comparison of TS, TDS, TSS and VSS with EEPA limit in mg/L.

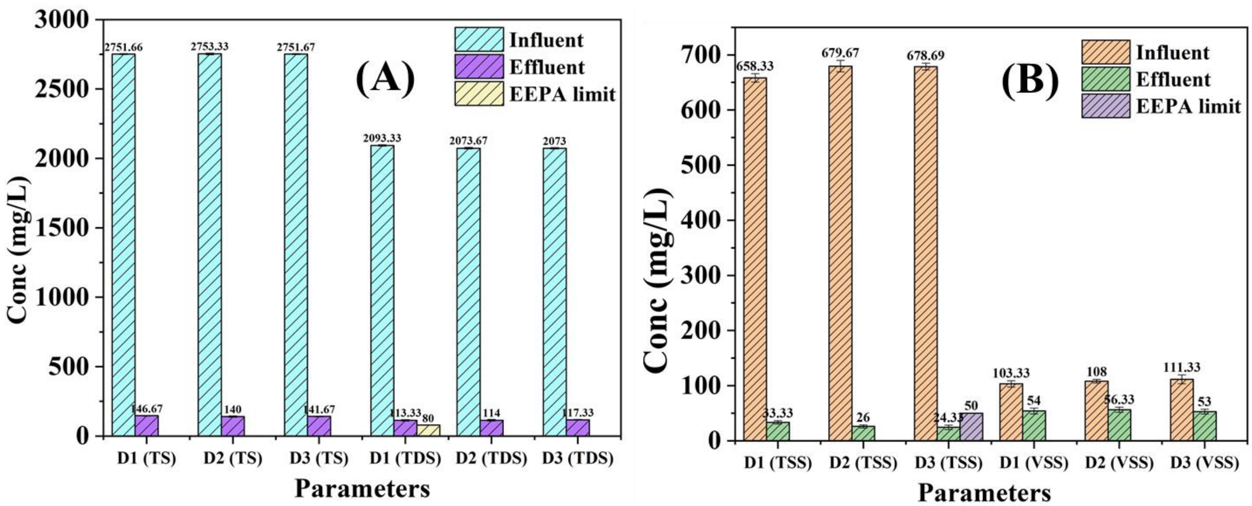


Figure 9: *Gravimetric method result for TS, TDS, TSS & VSS and comparisons with EEPA limit*

4.1.6. Chloride determination

High levels of chloride in water inhibits the growth of plants, cause human illness, affect bacteria and fish in surface water and it can also lead to the breakdown in cell structure [99]. In present study the concentration of chloride ion in the influent was 97.03±4.10 mg/L and 78.10±7.1 mg/L for the effluent in D1. The average value chloride for D2 and D3 for influent was 101.77±4.09 mg/Land 104.13±8.19 mg/L respectively. The effluent's average chloride for D2 and D3 were 87.56±8.19 mg/Land 82.83±4.09 mg/L, respectively (Figure 10). The chloride concentrations in effluent for D2and D3were higher compared to D1, but the remained lower than the concentrations for the corresponding days. This indicates a certain level of effectiveness in reducing chloride ion through the treatment process. Overall, the results suggest that the treatment process generally succeeded in reducing chloride ion concentrations from the influent to the effluent. However, considering the slight increase in influent chloride concentrations over the three days and variability observed in the effluent concentrations, further investigation is necessary to assess the stability and performance of the treatment plant.

The range value were existed between 92.30 mg/L to 99.40 mg/L and 71.00 mg/L to 85.20 mg/L for influent and effluent respectively. The removal efficiency of the treatment plant shows less effectiveness of chloride removal efficiency with the value of 19.51 % (Table 6). Even if, both influent and effluent values of chloride ion were below the discharge limit of EEPA, which is 250 mg/L [96]. So that this study revealed that the requirement of raw materials to generate the chloride ion in the beer processing of the company is low.

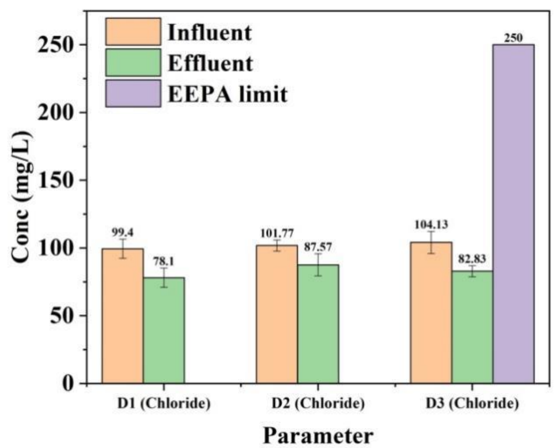


Figure 10: *The comparison of chloride content in the influent and effluent with EEPA limit*

4.1.7. Phosphate determination

Phosphate is an essential nutrient for plant and especially important in water pollution because they are effective nutrient sources for algae (organic phosphorus converted to inorganic phosphate). Excessive presence of phosphate in water causes algal blooms which result in the death of aquatic organisms[100]. In this study the phosphate level in influent and effluent were determined by spectroscopic method of calibration curve (Figure 11A). The mean concentration value of phosphate in the influent was 8.49±0.06 mg/L and 3.64±0.09 mg/L in effluent for D1.

The average value phosphate for D2 and D3 for influent was 8.65±0.06 mg/Land 8.47±0.13 mg/L respectively. The effluent's average values of phosphate for D2 and D3 were 3.89±0.11 mg/Land 3.78±0.04 mg/L, respectively (Figure 11B).

The treatment process effectively reduced phosphate levels in the effluent compared to the influent for all three days. However, D2 and D3 showed slightly higher effluent concentrations compared to D1, indicating some variability in removal efficiency. Additionally, it is noteworthy that the influent phosphate levels have somewhat decreased during the course of the days. Overall, the data suggests a generally successful treatment for phosphate removal, but further investigation is needed to optimize stability and consistency. Likewise, their range of value was between 8.45 mg/L to 8.53 mg/L and 3.57 mg/L to 3.71 mg/L for influent and effluent respectively. The removal efficiency of phosphate from the wastewater of the company was 57.14% (Table 6), which less effective compared to other brewery wastewater treatment plant of phosphate[[101]]. The concentration of after treatment plant was lower than the EEPA, which is 5 mg/L as well as the reported values in the other literature[3,101].

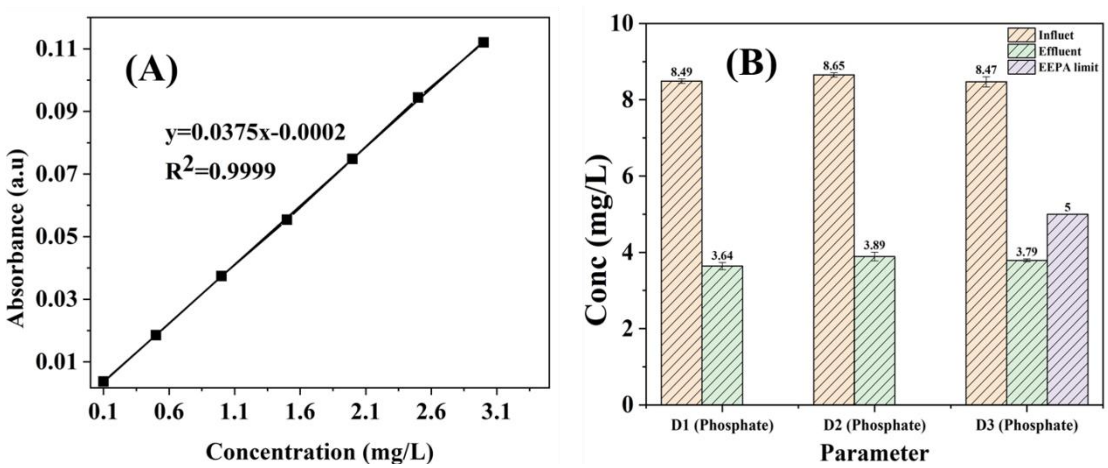


Figure 11: *Calibration Curve (a) and comparison of phosphate concentration with EEPA limit (b)*

4.1.8. Biochemical oxygen demand determination

Biochemical oxygen demand is the amount of oxygen utilized by microbial organisms to decompose organic compounds in water. BOD test is used to determine the extent of pollution of a wastewater and the efficacy of effluent treatment methods. DO is greatly influenced by the BOD level in water. The higher the BOD concentration, the greater the extent of oxygen depletion in the water bodies. This results in the reduction of oxygen available for higher forms of aquatic life which consequently leads to the death of aquatic organisms [100]. The percentage removal of the treatment plant for BOD of D1, D2 and D3 was 35.39%, 35.66% and33.70%. The concentration of BOD of the influent and effluent were found to be 99.60±0.85 mg/L and 64.35±0.64 mg/L respectively in D1.The influent average BOD was 103.05±1.06 mg/Lon D2 and 98.55±0.21 mg/L on D3, with minimal day-to-day variation. The effluent average BOD was 66.30±0.85 mg/L on D2 and 65.25±0.42mg/L on D3 (Figure 12).The treatment process significantly reduced BOD (organic matter) in the effluent compared to the influent for all three days, D2 and D3 showed slightly higher effluent levels than D1. This suggests some variability in treatment efficiency. The minimal day-to-day variation in influent BOD indicates a consistent source of organic pollutants. Overall, the data suggests a generally effective treatment process for BOD removal, but further investigation is needed to optimize its stability and consistency. The value of influent was ranged between 99.00 mg/L to 100.20 mg/L and 63.90 mg/L to 64.80 mg/L for effluent. The value of both influent and effluent concentration was did not comply with EEPA, which is 60 mg/L [96]. The effluent value and removal efficiency was lower compared to reported values in the other scholars of brewery wastewater [2]. So that the treatment plants requires other treatment methods, that adds the BOD removal efficiency and lowers the effluent concentrations from the limit value so the water is has high content of organic matter and has counts of microbial organisms. (Figure 12) shows the comparisons of influent and effluent of BOD with EEPA limit.

4.1.9. Chemical oxygen demand determination

Chemical oxygen demand is the measure of oxygen equivalent of the organic content of the sample that is susceptible to oxidation by a strong chemical oxidant. It is an evaluation used to measure the level of water contamination by organic matter [102]. The COD value was higher than the BOD because some organic materials in the water that are resistant to microbial oxidation and hence not involved in BOD could be easily chemically oxidized. The COD of the wastewater generated from company was 101.33±9.24 mg/L and the treated water value was 42.67±9.24 mg/L D1. The average value COD for D2 and D3 for influent were 104.00±8.00

mg/Land 104.53±8.05 mg/L respectively. The effluent's average values of COD for D2 and D3 were 45.33±4.62 mg/L and 46.4±2.77 mg/L, respectively (Figure 12).

The COD concentrations in the effluent on D2 and D3 were slightly more than on the D1, although they were still far lower than the amounts in the influent on those days. Even though the results varied a little, this suggests that the treatment method was successful in lowering organic contaminants. The treatment process proved generally successful in lowering COD concentrations from the influent to the effluent, which led to a significant decrease in organic pollutants, according to the data supplied. Organic contaminants are consistently input, as indicated by the small daily change in influent COD values. The variation in the effluent concentrations and the requirement for further investigation into the effectiveness and stability of the treatment process should be observed. It was noted that comparison of the laboratory results was done with the effluent standard limit value of beverage industries and it indicated that the measured value of COD was below the standard of 250 mg/L [96]. It also revealed that the COD concentration effluent value was lower than the COD concentration of brewery industries by other scholars [97]. The value COD was ranged between 240 mg/L to 320 mg/L and 120 mg/L to 160 mg/L for influent and effluent respectively. Results obtained after treatment gave 52.38% reduction efficiency in COD levels of Bedele Brewery industry (Table 6), which was not effective compared to other study with removal efficiency of 96.7% for COD [94].

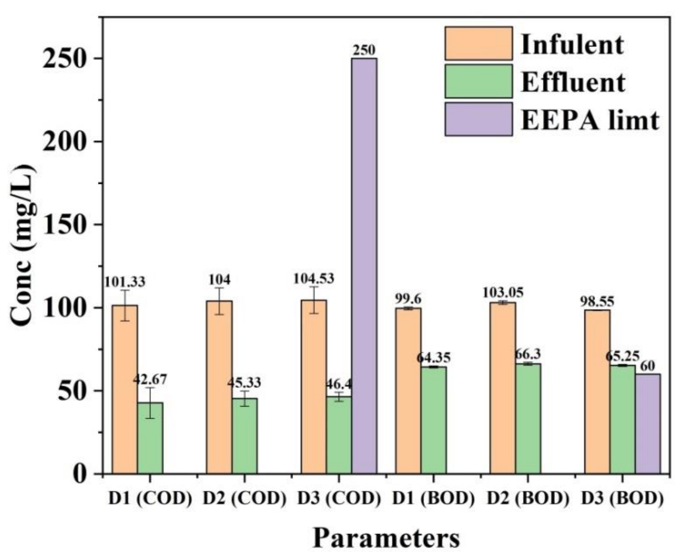


***Figure 82**: Comparison of BOD and COD with their corresponding EEPA limit*

4.2. Biological analysis

4.2.1. Total and fecal coliform determination

Testing for fecal coliforms involves inoculation of MacConkey agar followed by incubation at 44.5 °C for 24 h. Growth accompanied by development of red colonies are considered to be positive results for MacConkey agar. Fecal coliforms are involved in food spoilage and cause illness in both humans and animals [103]. The Violet Red Bile Agar (VRBA) medium is used as a selective medium for the identification of total coliform by incubation at 37 °C for 48 h. Total and fecal coliforms were isolated from influent and effluent. As shown in Table 5, the total coliform per samples spreading on VRBA ranged from $1.94*10^5$CFU/100 mL to $1.95*10^5$**(** CFU/100 mL and $9.5*x10^4$CFU/100 mL to $9.56*10^4$CFU/100 mL for inlet and outlet respectively for D1. The fecal coliform numbers in water inlet sample grow on MacConkey agar ranged from $5.5*10^4$CFU/100 mL to $5.62*10^4$CFU/100 mL and outlet of water ranged from $2.0*10^4$CFU/100 mL to $2.01*10^4$CFU/100 mL for D1. The total coliform of influent for D2 and D3 were ranged between $1.845*10^5$CFU/100 mL to $1.85*10^5$CFU/100 mL and $1.998*10^5$CFU/100 mL to $2.0*10^5$CFU/100 mL respectively. The total coliform of effluent for D2 and D3 were ranged between $8.49*10^4$CFU/100 mL to $8.5*10^4$CFU/100 mL and $9.0*10^4$CFU/100 mL to $9.11*10^4$CFU/100 mL respectively. The fecal coliform of influent for D2 and D3 were ranged between $6.0*10^4$CFU/100 mL to $6.14*10^4$CFU/100 mL and $5.0*10^4$CFU/100 mL to $5.12*10^4$CFU/100 mL respectively. The fecal coliform of effluent for D2 and D3 were ranged between $2.45*10^4$ to $2.5*10^4$CFU/100 mL and $1.44*10^4$CFU/100 mL to $1.5*10^4$CFU/100 mL respectively. The presence of coliform bacteria was confirmed in the water samples. Influent counts remained consistent across the three days, similar to both total and fecal coliform counts. While the treatment process appears to reduce coliform bacteria (due to lower effluent counts compared to influent), some variability in effluent counts requires further investigation.

__Table 5:__ Summary of TC and FC of the influent and effluent

Parameters	Day	Samples and Nº of colonies (10^3)		Mean of CFU (CFU/100mL)		Log (CFU)		WHO limit
		Influent	Effluent	Influent	Effluent	Influent	Effluent	< 1
Total coliform	1	19.50	9.50	$1.95*10^5$	$9.5*10^4$	5.29	4.98	
	2	18.50	8.50	$1.85*10^5$	$8.5*10^4$	5.27	4.9	
	3	20.00	9.00	$2*10^5$	$9*10^4$	5.3	4.95	
Fecal coliform	1	5.50	2.00	$5.5*10^4$	$2*10^4$	4.74	4.3	
	2	6.00	2.50	$6*10^4$	$2.5*10^4$	4.78	4.39	
	3	5.00	1.50	$5*10^4$	$1.5*10^4$	4.67	4.18	

4.3. Wastewater treatment plant efficiency

The performance of the Bedele brewery wastewater treatment plant was evaluated on the basis of its removal efficiency of major parameters including; temperature, pH, turbidity, EC, TS, TDS, TSS, VSS, Cl^-, PO_4^{3-}, BOD, COD, TC and FC as shown in the (Table 6). The removal efficiency of the treatment plant was effective for the removal of TS, TDS, TSS and EC. Bedele Brewery treatment plant has high efficiency for TS, TDS, TSS and EC, with compared to others scholar report on brewery treatment of TS, TDS, TSS and EC; 65.5%, 70.2%, 57.2% and 29.1% respectively [94]. Effective removal of organic compounds from wastewater is important to avoid anaerobic conditions in receiving waters[30].However, the removal efficiency of BOD (35.39%) and COD (52.38%) from the wastewater of the treatment plant was less effective compared to previous study with BOD 96% and for COD 92% [2].

Table 6: Overall Pollutant removal efficiency of the treatment plant

Parameters	Mean ± STD values						Change of influent and effluents			EEPA limit
	Influent			Effluent						
Temp (°C)	32.40±0.26	31.63±0.59	30.99±0.16	22.27±0.04	23.91±1.47	24.79±1.24	31.28	44.41	19.95	40
pH	9.22±0.01	8.93±0.04	9.01±0.08	6.47±0.02	6.72±0.19	6.64±0.21	29.79	24.75	26.22	6-9
Turbidity (NTU)	1203.40±0.53	1184.00±4.58	1149.16±2.065	432.87±2210.81	430.00±1.00	427.00±0.65	63.03	63.73	62.79	
EC (µs/cm)	1753.67±1.53	1722.33±3.06	1689.83±2.90	221.91±0.86	225.18±1.09	219.97±1.28	87.35	86.93	86.98	1000
TS (mg/L)	2751.67±2.89	2753.33±5.77	2751.66±2.89	146.67±2.89	140.00±5.00	141.00±2.89	94.67	94.92	94.85	
TDS (mg/L)	2093.33±5.77	2073.67± .35	2073.00±4.36	113.33±5.77	114.00±5.29	117.33±4.61	94.59	94.50	94.34	80
TSS (mg/L)	658.33±7.64	679.67± 10.50	678.67±6.11	33.33±2.87	26.00±1.72	24.33±4.04	94.94	96.17	96.41	50
VSS (mg/L)	103 33±5.74	108.00±3.46	111.33±8.08	54.00±5.29	56.33±4.72	53.00±4.36	47.74	47.99	52.39	

Cl^- (mg/L)	97.03±4.10	101.77±4.09	104.13±8.19	78.10±7.10	87.56±8.19	82.83±4.09	19.51	13.95	20.46	250
PO_4^{3-} (mg/L)	8.49±0.06	8.65±0.06	8.47±0.13	3.64±0.09	3.89±0.11	3.78±0.04	57.14	55.03	55.25	5
BOD (mg/L)	99.60±0.85	103.05±1.06	98.55±0.21	64.35±0.64	66.30±0.85	65.25±0.42	35.39	35.66	33.79	60
COD (mg/L)	101..00±40.00	104±8.00	104.53±8.05	42.67±9.24	45.33±4.62	46.40±2.77	52.38	56.41	55.61	250
TC (CFU/mL)	$1.95*10^5$± 707.10	$1.85*10^5$±353.55	$2*10^5$±141.42	$9.5*10^3$±424.26	$8.5*10^3$±70.71	$9*10^3$±777.82	51.28	54.05	55.00	< 1
FC (CFU/mL)	$5.5*10^3$± 848.52	$6*10^4$±989.94	$5*10^4$±848.52	$2*10^4$±70.71	$2.5*10^4$±353.55	$1.5*10^4$±424.26	63.64	58.33	70.00	< 1

4.4. Effluent Suitability for agricultural irrigation

Brewery effluent, the wastewater generated during beer production, presents a potential source of irrigation water. However, its suitability depends on various factors, including its composition, treatment processes, and local regulations. Based on the provided parameters, the Bedele brewery effluent exhibits both promising and concerning aspects for agricultural irrigation. Here's a detailed breakdown:

i. **Temperature:** The temperature falls within the typical range for brewery effluent (Table 7) and is not expected to pose significant concerns for irrigation unless combined with other unfavorable factors [93].

ii. pH: Slightly acidic and within the acceptable range for irrigation (Table 7) according to EPA guidelines [93]. However, it is important to monitor pH closely as acidic effluent can acidify soil over time, impacting nutrient availability and plant growth.

iii. Turbidity: Significantly higher than the recommended limit (Table 7) for irrigation water (50 NTU) [93], indicating the presence of suspended solids. High turbidity can clog irrigation systems (i.e., hindering water distribution and potentially damaging equipment, reduce light penetration in soil (i.e., impacting plant growth and beneficial microorganisms), and potentially harbor pathogens like bacteria and coliforms present in the effluent. Further treatment is necessary to reduce turbidity before using this effluent for irrigation.

iv. Electrical conductivity: According to EPA guidelines for the brewing industry does not specify a limit for EC. However, elevated salinity levels in irrigation water can affect soil structure, water uptake, and crop growth (Table 7).

v. Total solid and Total dissolved solid: The TS of present study was (142.55±3.59 mg/L) and TDS was 114.89±5.22 mg/L (Table 7), while the guideline of EPA doesn't provide a direct limit for TS and TDS in brewery effluent. However, high levels of solids can clog irrigation systems and affect soil structure. Proper treatment, such as sedimentation of filtration, may be required to reduce solid content.

vi. Total suspended solid: According to EPA godliness no specific limit exists for TSS in irrigation water'. In this study TSS was 27.89 ± 2.87 mg/L (Table 7). High TSS levels can be problematic for irrigation by clog irrigation systems (i.e., hindering water distribution and potentially damaging equipment), reduce light penetration in soil (i.e., impacting plant growth and beneficial microorganisms) and harbor pathogens if they contain organic matter or microorganisms.

vii. Volatile suspended solid: The EPA guidelines for brewing industry recommended a maximum VSS limit of 20 mg/L for wastewater discharges [93]. The provided VSS (54.44 ±4.79 mg/L) level exceed this limit (Table 7), indicating a need for adequate treatment to reduce VSS content before using the effluent for agricultural irrigation. Excessive amounts of VSS can deplete soil oxygen, hindering root development and beneficial microbial activity, contribute to odors as well as create nuisance conditions.

viii. Chloride (Cl^-): The EPA does not specify a limit for chloride in brewery effluent. However, high chloride levels can be harmful to sensitive crops and affect soil fertility (Table 7). It is advisable to consult regional guidelines or crop specific requirements to determine acceptable chloride levels irrigation.

ix. Phosphate (PO_4^{3-}): The EPA guidelines for the brewing industry do not provide specific limits for phosphate (Table 7). However, excessive phosphate levels can lead to eutrophication of water bodies. Nutrient management practices should be implemented to prevent nutrient imbalances in soil and water bodies.

x. Organic matter overload: The BOD (65.30±0.63 mg/L) and COD (44.8±5.54mg/L) indicate potentially excessive organic matter (Table 7). While some is beneficial, too much can deplete soil oxygen (i.e., hindering root development and beneficial microbial activity), contribute to odors and create nuisance conditions. Adequate treatment processes like advanced oxidation should be applied to reduce organic pollutants before using the effluent for irrigation.

xi. Microbiological contamination: The levels of total coliform ($9*10^4$±424.26CFU/mL) and fecal coliform ($2*10^4$±282.84CFU/mL) significantly exceed acceptable limits for irrigation water, posing a significant health risk 0). So that proper treatment, such as disinfection, should be applied to ensure microbial safety before using the effluent for irrigation. The following table shows summary of suitability of Bedele brewery effluent for agricultural irrigation purpose.

❖

Table 7: *Suitability of Bedele Brewery effluent for agricultural irrigation purpose compared to EPA[93].*

Parameters	Effluent values	EPA Guideline for Irrigation Water	Suitability for Irrigation
Temperature(°C)	24.41±0.04	No specific limit	Acceptable
pH	6.61±0.02	6.0 - 8.5	Acceptable, but monitor closely
Turbidity (NTU)	429.95±0.81	< 50	Highly unsuitable, requires significant treatment
EC (µs/cm)	222.53±0.86	Site-specific based on soil properties and crop tolerance	Requires further analysis of ionic composition for salinity assessment
TS (mg/L)	142.55±2.89	No set restriction	Depending on certain constituents, monitoring can be necessary
TDS (mg/L)	114.89±5.77	No specific limit	May require monitoring depending on specific constituents
TSS (mg/L)	27.89±2.87	No specific limit, but high levels can impact irrigation systems	Contributes to high turbidity, requires treatment
VSS (mg/L)	54.44±5.29	20	Part of total suspended solids, contributes to organic matter content
Cl^- (mg/L)	82.83±7.10	Site-specific depending on crop tolerance and soil	Potentially concerning for salt-sensitive plants, requires further analysis

		characteristics	
PO_4^{3-} (mg/L)	3.77±0.09	No specific limit, but can contribute to nutrient loading	May be beneficial depending on crop needs and soil nutrient status
BOD (mg/L)	65.3±0.64	No set limit	Requires treatment to reduce oxygen demand in soil
COD (mg/L)	44.8±23.09	No specific limit, but high levels indicate organic matter overload	Has to be treated in order to lower oxygen demand in soil
TC (CFU/mL)	$9*10^4$±353.55	< 2 per 100 mL	Highly unsuitable, poses significant health risk
FC (CFU/mL)	$2*10^4$±141.42	< 1 per 100 mL	Extremely inappropriate and dangerous for one's health

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The Bedele Brewery treatment plant shows promising signs for solids removal. The treatment plant achieves high removal rates for TS, TDS and TSS for all respective days with the removal efficiency more than 94%. This indicates efficient solids removal, addressing a major concern for irrigation suitability. In addition to the solid pollutants the treatment plants effectively remove EC with 87.35% in D1, 86.93% in D2 and 86.98% in D3. These indicate that, the treatment plant has satisfactory performance in reducing the levels of these pollutants. The treatment plant also partial reduction of organic matter (i.e., removal of BOD with 35.39% in D1, 35.66% in D2 and 33.79% in D3 and COD with 52.38% in D1, 56.41% in D2 and 55.615% in D3), which suggests some organic matter breakdown although higher reductions might be desired for optimal irrigation use. The plant achieves moderate removal of chloride and phosphate in all three days; it indicates the potentially mitigating salinity and nutrient loading concerns depending on specific crop tolerance and soil characteristics. However,critical limitations remain regarding to turbidity and microbial contamination. Despite a 64.03% reduction, the treated effluent still has significantly high turbidity (432.87±0.81 NTU), exceeding the recommended irrigation limit by a factor of 8.6 in D1. Similarly 63.73% and 62.79% of reduction of pollutants with high amount of turbidity (430.00±1.00 NTU and 427±0.65) in D2 and D3 respectively.Further treatment for turbidity reduction is essential. While some reduction in coliforms occurs for TC and FC in three different days with slight variations. While the treated effluent still exhibits levels far exceeding acceptable limits for irrigation in coliforms, posing a significant health risk and the treatment plant has limited microbial inactivation. This indicates that further improvements are needed to achieve the desired water quality standards for these parameters. The treatment plant reduces the temperature and pH of the effluent, with removal efficiency of 31.28% and 29.79% respectively in Dl. In the manner it reduces 44.41% and 19.95% of temperature in D2 and D3 respectively as well as 24.75% and 26.22% in D2 and D3 for pH respectively. Although these results demonstrate positive impact, it is important to ensure compliance with any specific temperature or pH requirement for agricultural irrigation.

5.2. Recommendations

From the current study of Bedele brewery treatment plant performance evaluation the following points were recommended.

- ❖ Implement additional treatment steps like sedimentation, coagulation and filtration or advanced clarification to achieve acceptable turbidity levels for irrigation.
- ❖ Employ more effective disinfection methods like UV irradiation or ozonation to significantly reduce coliform levels and ensure microbiological safety.
- ❖ Conduct a comprehensive risk assessment to evaluate the potential long-term impacts of using the treated effluent on soil quality, crop yields, and human health.
- ❖ Collaborate with agricultural and environmental professionals to design and implement necessary treatment upgrades, monitor long-term performance, and comply with local regulations for wastewater reuse in agriculture.
- ❖ Since the removal percentages for chloride and phosphate are not optimal, implementing specific treatment techniques like biological nutrient removal or chemical precipitation can assist in achieving better results for these parameters.
- ❖ Consult with experts for treatment upgrades and regulatory compliance.

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