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Bioremediation: Treatment of Wastewater Technology for a Sustainable Environment

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Abstract

Beer is a beverage with both economic and cultural significance that is hard to quantify and substitute. Aside from tea, carbonates, milk and coffee, beer is the world's fifth-most consumed beverage. Beer production is a water-intensive process. The discharge of such wastewater towards water bodies absent previous treatment generates major pollution concerns. Most companies, particularly especially developing counties like India. Rivers, lakes, as well as other water bodies a low-cost sources of wastewater discharges. The elemental analysis of the company's industrial effluent revealed that the readings for Cd, Cr, Pb, and Fe did not fall below the range of the WHO standard. According to the study, the Beer Industry effluent had BOD, COD, pH, and colour levels that were higher than the necessary WHO standard. This has definitely harmful consequences for both the environment and living beings, including people. Because the findings of the investigations revealed that the effluents from the Beer Industry were not properly treated, it has been advised that industrial wastewater be treated using Bioremediation Technology. The technique uses microorganisms' metabolic capability to clean up polluted surroundings and has been offered as an appealing option due to its cheaper cost and greater efficiency when compared to conventional physicochemical approaches.

Keywords: Beer Production, Physiochemical, Waterbodies, Bioremediation, Sustainable Environment

Introduction

People mostly in the twenty-first century are more concerned about the harm they inflict to the world and the atmosphere. Developed countries devise methods to lessen the negative environmental effect of their operations. Unfortunately, their contribution to the general cleanliness of the planet has been little thus far. Nonetheless, the demand for the purity of the surrounding environment is growing. Water is a vital need in all human endeavors. Water consumption varies with civilization in terms of volume and technique of use (Stéphanie, 2018). Water is viewed as a natural resource that flows freely, either below or as surface water, and its source or availability for usage is not infinite (Grogan *et al.,* 2017). Many people are concerned about water quality, but the real magnitude of the problem is unknown. Furthermore, in the home or industrial use, a large volume of freshwater is converted into wastewater and discharged into surface water or groundwater, either treated or untreated (Chaurasia *et al.,* 2018). Furthermore, water source contamination is a big issue, particularly in third-world nations, with an estimated 90% of sewage and 70% of industrial effluent released into the environment untreated (Cooley *et al.,* 2014).

Brewing is a significant economic sector in the food industry, with annual global beer output topping

1.34 billion hL in 2002 (FAO Source, 2003). Beer is a beverage with both economic and cultural significance that is difficult to quantify and substitute. Beer is the world's fifth-most consumed beverage, behind tea, carbonates, milk, and coffee, and it remains a popular drink with an average consumption of 9.6 L/capita by the population over the age of 15 (OECD Health Data, 2005), and the sector as a whole is worth roughly 500 million Euros (MarketLine, 2020). This drink has grown with mankind, becoming ingrained in the daily lives of millions of people who drink beer and consider it more than just a beverage. Because of these factors, beer is a product that, despite global economic volatility and an uncertain future, is expected to increase gradually in the next years (Bart Haas, 2020).

Beer production is a water-intensive process. It is believed that it takes around 300 liters of water to create one liter of beer (Li, 2009) between the cultivation of water and hops, mashing, wort boiling, chilling, and bottling. Brewers also use a lot of energy during the wort boiling, mashing, and fermentation processes, which results in a lot of emissions being emitted into the environment (Boden, 2012). Other byproducts of this process include solid trash from discarded grains and yeast, as well as wastewater, which, if not properly disposed of, is damaging to the environment and to individuals who come into touch with it.

According to Amoriello and Ciccortti (2021), the production of one litre of beer generates around 10 liters of effluent. All of these problems contribute to a larger problem: a shortage of water, excessive emissions, toxicity in lands and bodies of water, and a lack of trash disposal space.

One of the most polluting businesses is the brewing industry, which produces alcohol. It entails the fermentation of cereal grains into fermented alcoholic drinks such as beer and ale. The process of malting and brewing consists of two basic processes. Brewery waste is mostly made up of liquor extracted from wet grain and wash water from various departments. The residue that remains after the distillation of the alcohol process is known as "distillery slops" or "still bottoms." The brewing business uses a lot of water, around 10 gallons of treated water every gallon of product. The Biochemical Oxygen Demand levels are fairly high, as are the total solids, with the brewing operation producing almost half of the BOD and more than 90% of the suspended particles. There are also solid wastes such as discarded grains, hops, and sludge that are produced during this and the malting procedures that must be disposed of. The discharge of such effluent into watercourses without previous treatment generates major pollution concerns (H.Z. Ninnekar, 1992). When such wastes are dumped into an open drain, they undergo aerobic breakdown and produce offensive odours. Untreated wastewater discharged indiscriminately into watercourses or onto land always pollutes the ecosystem (Mala and Saravana Babu, 2006). It also has a negative impact on aquatic, fauna, and flora, as well as groundwater. As a result, treatment of brewery effluent is a critical concern before disposal.

Both taste and smell are subjective and difficult to measure. The decomposition of organic nitrogen, phosphorus, and sulfur compounds causes the disagreeable odors associated with dirty rivers/streams. Humans and other animals have developed senses that allow them to judge the potability of water by avoiding too salty or rotting water (J. Candau, 2004). The alkalinity of water is a measure of its capacity to neutralize acids. Although oceanographers invented the word "alkalinity," (United States Environment Protection Agency. "Total Alkalinity") It is used by hydrologists to explain transitory hardness. Furthermore, measuring alkalinity is crucial for evaluating a stream's ability to neutralize acidic contaminants from rainfall or wastewater. It is one of the most precise assessments of the stream's acid sensitivity (S.S. Kaushal *et al.*, 2013). Despite the fact that not all organic matter is biodegradable, the BOD test remains the most widely used method of evaluating organic matter. The BOD level indicates water pollution as a result of oxygen deprivation (O.O. Awotoye *et al.*, 2011).

The range of brewing-specific waste materials produced by beer, over and above standard manufacturing materials such as packaging are listed in the table below.

Table 1

Material	Volume per HL 4% abv Beer	Source/Origin	Brewing Use	Destination(s)	Difficulties
Water	3 – 10 HL	Mains or bore hole	Product, cleaning, heating and cooling	Product, Effluent discharge	Chemical composition from acids & alkalis
Spent grain	14 Kg dry wt	Barley and other cereal malts	Source of sugars for fermentation	Agricultural	Hygiene, odour, High BOD
Spent hops	0.166 Kg dry wt	Hop flowers	Bitterness and other flavours	Agricultural	Anti microbial, unpalatable to animals
Trub	0.350 Kg dry wt	Precipitation from wort	Unwanted by product	Effluent discharge	High BOD and TSS
Yeast	3 Kg dry wt	Previous brew	Fermentation	Effluent discharge	High BOD and TSS
Caustic and acid cleaners		Chemical suppliers	Cleaning	Effluent discharge	Acidity effects on effluent
Waste beer	Variable	Contamination Production errors	Nil	Low value sales or effluent discharge	High BOD

Material and Methods

Sample Collection

The wastewater from a beer wastewater sample obtained in Delhi-NCR (India) was collected and released in freshwater bodies using 250 ml polyethylene bottles cleaned with detergent and rinsed with distilled water. For preservation, samples were promptly examined and stored in the refrigerator in pre-rinsed plastic containers with airtight plastic coverings. pH, Turbidity, Odour, Color, Temperature (°C), Total Suspended Solid (TSS), Total Hardness (TH), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Sulphate (SO_{4-}), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Chromium (Cr), Chloride (Cl), Cadmium (Cd), Iron (Fe), Lead (Pb), Oil and grease. Analysis of the metals Pb, Cr, Fe, and Cd were done using an atomic absorption spectrometer. An atomic absorption spectrometer was used to analyse the metals Pb, Cr, Fe, and Cd. The concentration of each heavy metal was determined using an atomic absorption spectrophotometer at certain wavelengths. The samples (100 mL each) were digested with 5mL of nitric acid (HNO_3) to release organic compounds, then heated at 45° C to 65° C before being transported to the sensitive laboratory. Chemical parameters were determined using separate titrations for each variable. The collected results were compared to the World Health Organization's stated standard.

Methods

The analytical methods used for the assessment of all parameters in wastewater followed the protocol described in Standard Methods for the Examination of Wastewater (APHA 2005). All samples were tested for a variety of physical, chemical, and heavy metal criteria.

Results and Discussion

To investigate the characteristics of composite wastewater in the beer industry, wastewater samples from several processing plants totalling were collected for their general qualities. The exam results are shown in the table below.

Table 2

Sr. No.	Parameters	Sample	WHO (Standard)
1	Odour	Beer	Odourless
2	Colour	Brown	Colourless
3	Turbidity (NTU)	0.351	5
4	pH	9.1	8.5
5	TDS (mg/l)	8.25	1000
6	TSS (mg/l)	91	1000
7	Total Hardness (mg/l)	200	100
8	Chloride ion (mg/l)	30	250
9	Cr (ppm)	7.0059	0.05
10	Fe (ppm)	2.80683	0.003
11	Pb (ppm)	2.02904	0.03
12	Cd (ppm)	0.38749	0.003
13	NO_3 (mg/l)	6.0864	0.03
14	Oil and grease (mg/l)	78.00	10
15	SO_4^{2-} (mg/l)	0.48	250
16	DO (mg/l)	7.2	100
17	BOD (mg/l)	12.8	2
18	COD (mg/l)	151.07	80

Discussion of Results

The physicochemical examination of industrial effluents (Table 2) revealed a substantial variance in contrast to the World Health Organization-approved norm (WHO).

The results demonstrate that the stench in the brewery effluent from the sample did not meet the WHO criteria (odourless). The effluent also contains colour from the sample, which did not meet WHO standards (colourless). The turbidity of the brewery industry's wastewater was significantly below the WHO limit of 5 mg/l.

The pH value of the Brewery effluent at the site of release (9.1) suggests excessive alkalinity in comparison to the WHO-approved limit of 8.5, and the mild acidity/basicity of the effluent in the sample was most likely owing to the high concentration of hydrogen ion [H+] at the point of discharge. When low pH effluent enters water bodies, it inhibits the development of bacteria species in the receiving water body. The inefficiency of the brewery industry's wastewater treatment facility might be ascribed to the high basicity of their effluent.

The company's BOD levels above the WHO-recommended limit of 2 mg/L. Because aquatic animals employ oxygen to oxidise organic waste, high BOD concentrations endanger the survival of the aquatic biota in the receiving stream. The total dissolved oxygen (TDS) value for the brewery industry is under the WHO standard of 1000 mg/l. The Brewery effluent has a high Chemical Oxygen Demand (COD) (more than double the WHO standard of 80 mg/l). Because COD is used to indirectly quantify the quantity of organic compounds in water, this indicated that the effluent was heavily polluted with organic contaminants.

NO_3 is derived through the oxidation of other forms of nitrogen, such as ammonia and nitrite, to nitrate. As indicated in Table 1, the NO_3 content in Brewery effluent after treatment falls under the WHO-approved limit of 0.03 mg/l. Because the Brewery effluent contained both inorganic and organic waste, DO was absorbed by microbes during the degradation of organic stuff.

The value of Total Dissolved Oxygen (TDS) in Brewery Effluent is within the WHO standard (1000 mg/L). TDS is a measure of the total amount of organic and inorganic compounds in water.

The hardness of the industrial effluent from the untreated brewery facility was 200 mg/l. Hardness was quite high in comparison to the WHO standard of 100 mg/l for drinking water; following treatment, it reached the WHO level. Hard water is normally not detrimental to health, but it can cause calcification of taps, boilers, kettles, and other water-handling equipment.

The SO_4^{2-} ion concentration in the wastewater samples analysed was determined to be within the WHO acceptable range of 250 mg/L. The TSS value obtained from the wastewater collected from the sample is within the WHO permitted limit. If this effluent is immediately sprayed to agricultural fields or released into rivers and streams, it may become unfit for aquatic life. Total dissolved solids (TDS) readings obtained for all samples tested were under the allowable limit of 1000 mg/L.

According to the study, a significant value of chromium was identified in the Brewery Effluent, which is above the limit of 0.05 ppm.

Cadmium concentrations were found to be high when compared to the WHO permitted limit of 0.00 ppm. Cadmium has been linked to respiratory and renal disorders. The concentration of Pb in brewery effluent discharges was higher than the WHO threshold.

According to the results of the analysis, the concentration of iron in the brewery effluent was higher than the WHO norm, as indicated in Table 2.

Conclusion and Recommendations

A. Conclusion

According to the study, the effluent from the beer and wine industries had BOD, COD, and colour levels that were higher than the necessary WHO threshold. This has definitely harmful consequences for both the environment and living beings, including people. The wastewater from the beer industry in Delhi-NCR (India) is contaminating the environment, despite the fact that majority of the criteria studied were within acceptable effluent quality norms.

B. Recommendations

Based on the outcome of this study, industrial wastewater treatment by Bioremediation Technology:
Several research have been done to reduce or remove heavy metals in the environment. Precipitation, reverse osmosis, adsorption onto activated carbon or alumina, and redox reactions are examples of conventional procedures. However, due to their high cost, these technologies are regarded as inefficient. High harmful compounds are turned into less toxic chemicals by biological processes in bioremediation by microorganisms, which generally employs one kind of microbe. The technique uses microorganisms' metabolic capability to clean up polluted surroundings and has been offered as an appealing option due to its cheaper cost and greater efficiency when compared to conventional physicochemical approaches. Hazardous compounds can be decomposed or transformed by microorganisms into less harmful metabolites or degraded to nontoxic end products. Microorganisms can also live in polluted environments because they have the metabolic ability to utilize pollutants as possible energy sources.

Microorganisms having biological activity, such as bacteria, can be employed in their naturally occurring forms in bioremediation. A microorganism's cell wall comprises a variety of macromolecules with a large number of charged functional groups, such as carboxyl, imidazole, and sulfhydryl, thioether, phenol, carbonyl, amide, ester sulphate, amino, and hydroxyl groups. Adsorption happens when the positively charged metal in the solution gravitates toward these functional groups. The culture form of microorganisms can alter cell wall composition, which can be used to increase the microorganisms' adsorption capability. Bacteria may remove heavy metals from wastewater using functional groups in their cell walls such as ketones, aldehydes, and carboxyl groups, resulting in less chemical sludge. Metals are taken up by both gram-positive and gram-negative bacteria. Some functional proteins in bacteria, such as uronic acid with carboxyl and sulphate groups, xylans, galactans, and alginic acid, may exchange ions. The advantage of utilising algae as biosorbents is that, unlike other microorganisms such as bacteria, they do not create poisonous chemicals.

Many microbes can naturally break down metals, but this is insufficient on a global basis. As a result, engineered microbes can be created via genetic engineering as a solution to this problem. A deeper knowledge of how eukaryotes and prokaryotes absorb heavy metals, as well as the detoxification routes, would allow future researchers to deal with this sort of environmental problem more effectively. On an industrial scale, the most promising form of biomass must be chosen while taking into consideration its cost and availability. Microorganisms should be simple to get and culture. Industrial-scale use, for example, would be uninteresting if the microbe is difficult to culture, a rare species, or a species in risk of extinction.

Although substantial progress has been made in recognizing the relevance of microorganisms in the decontamination of contaminated streams, numerous critical issues remain unresolved. However, a new obstacle for science has developed. As a result, future research should concentrate on the creation of new clean, ecologically acceptable technologies with economic viability.

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