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Environmental and Health Consequences of Distillery Wastewater and Ways to Tackle: A Review

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ABSTRACT

Liquid sludge, due to its low pH, elevated temp, dark brown hue, high ash content, a high proportion of organic and inorganic dissolved materials, and high biochemical oxygen demand, distillery wastewater is one of the most harmful pollutants that must be disposed off. The brightly colourful quality of the washed wash, which may obscure sunlight and reduce water oxygenation through photosynthesis, is the first way that the washed wash polluted the water bodies. This is harmful to aquatic life. The second problem is that it has a high contamination load that may lead to eutrophication in polluted water sources. Because of the numerous industrial uses of ethanol, including in chemicals, medicines, cosmetics, drinks, food, and perfumes, distilleries are expanding all over the world. The industrial manufacture of ethanol by fermentation results in the release of significant amounts of elevated BOD and COD levels. The food stock and different elements of the ethanol manufacturing process affect its features. To have a better understanding of the phenomena, the function of numerous microorganisms and their enzymes in wastewater treatment has been addressed. Without treatment, distillery wastewater can seriously endanger aquatic life by reducing the amount of dissolved oxygen in the water currents it enters. This paper includes a thorough analysis of current biological treatment methods as well as a list of issues related to distillery wastewater concerns.

Keywords- distillery wastewater, physicochemical treatment, biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

I. INTRODUCTION

In order to make rum for the military, the first distillery in India was established in Kanpur (formerly Cawnpore) in 1805. There are currently roughly 315 distilleries with a combined annual production capability of 3250 thousand barrels of liquor and 40.4 billion litres of pollutants (Mohana et al., 2009). As 88% of its raw resources are turned into the trash and released into aquatic bodies, distilleries are one of the most polluting businesses. In the brewery, approximately 15 litres of wasted washing are discharged for every litre of alcohol manufactured (Ravikumar et al., 2011). Liquor is a fundamental active compound for many different chemical industries, so distilleries will be required to produce more ethanol to fulfil growing needs.

Distilleries, fermenting businesses, sugar mills, and various molasses-based businesses produce effluent-containing molasses. Because of its widespread availability and low cost, molasses from the sugarcane sector is a typical raw material utilised in the manufacturing of ethanol (Kalavathi et al., 2001). In Asia, India is second in terms of ethanol production. In India, there are 319 distilleries with a 3.25 billion litre capacity for liquor (Uppal, 2004). The distilleries business is one of India's top 17 polluting sectors, according to the central pollution control board (CPCB). An Average distillery making alcohol from cane molasses creates close to 500,000 litres of wastewater per day, or 10-15 litres of wastewater for every litre of ethanol manufactured (Tiwari et al., 2007). For the manufacturing of 2.3 billion litres of alcohol, about 40 billion litres of effluent are produced yearly in India alone. Among the most hazardous and economic expansion sectors are distilleries, regarding the degree of water contamination and the volume of produced sewage in India. According to estimates, distillery waste has a population of up to 6.2 billion people, indicating that its contribution to organic pollution in India is around 7 times greater than that of the whole people (Kanimozhi and Vasudevan, 2010). They are primarily composed of resistant substances with a dark brown colour known as melanoidin polymers, which are the result of the Maillard reaction between the amino acids and carbonyl groups in molasses (Wedzicha and Kaputo, 1992). These effluents are environmentally hazardous due to their high biochemical oxygen demand. If released into water bodies, they deplete the oxygen supply and cause related issues. They decrease the soil's alkalinity and trace elements accessibility, impede germination rate, and affect greenery if released into the soil. Melanoidin colours are poisonous to the microbial community in soil and water in addition to discolouring water and soil anesthetically (Agarwal et al., 2010). Such effluents' dark brown hue is extremely resistant to microbe decay as well as other bioremediation. Because melanoidins include resistant compounds, traditional cleaning techniques are ineffective for completely removing colour from this stream; in fact, colour can actually rise after anaerobic operations due to component re-polymerization (Satyawali and Balakrishnan, 2007). The dark brown sludge that results from the anaerobic digestion of effluents is utilised as fertiliser, and the

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coloured water is released after being diluted with water numerous times. Thus, fresh water, a resource that is valuable in most places around the world, is eventually squandered. The wastewater is highly coloured, has a high amount of dissolved organic and inorganic materials, and has a very high chemical oxygen demand (COD) load. The normal ranges for the biochemical oxygen demand (BOD) and chemical oxygen demand (COD), two indicators of how toxic the substance is, are 35,000–50,000 mg L^{-1} and 80,000–1,000,000 mg L^{-1}, respectively. In addition to having a high organic content, distillery effluent also includes nitrogen, phosphorus, and potassium elements that can cause water bodies to become eutrophic.

Due to the buildup of non-biodegradable recalcitrant pollutants that are primarily coloured and present in a massively complicated state, wastewater disposal is hazardous. It has a high pollution potential even after conventional treatment. Melanoidin has anti-oxidant properties that cause toxicity to many microorganisms involved in wastewater treatment processes (Sirianuntapiboon et al., 2004a). Some of the biggest issues caused by distillery wastewater include lowering the pH value of the streams, increasing the organic load, and offensive odour. In various parts of the nation, the water quality is seriously threatened by distillery effluent. Disposal on land is also harmful because it lowers soil alkalinity and prevents seed germination. Additionally to pollution, stricter ecological restrictions are prompting breweries to enhance ongoing medication and look into alternate effluent management techniques.

II. WASTEWATER CHARACTERISTICS

According to reports, distillery effluent is a medium- to high-strength organic wastewater. The wastewater from molasses-based distilleries, also known as wasted wash, stillage, slop, or vinasse, is often acidic and dark brown in colour (MWW). The characteristics of the effluent depend on the raw material utilised, and 88% of the components of molasses are thought to be wasted (Jain et al., 2002).

Additionally, cane molasses effluent includes low molecular weight substances such as acetic acid, lactic acid, glycerol, and ethanol. According to the raw material distilled, such as the kind of wine, the lees, etc., distillery effluents often contain a high level of organic compounds, are acidic, and have a brown colour (Bustamante et al., 2005). Acidic distillery wastewaters with a high organic content can seriously harm the ecosystem. The pH levels of effluent from wine distilleries range from 3.5 to 5.0 (low pH), which is harmful for many living forms (Badar et al., 2017). Iron and zinc were detected in wine distillery wastewaters, as well as metal ions such as Ca^{2+}, K^{+}, and Na^{+} (Nataraj et al., 2006). The discharge of wastewater from wine distilleries into water bodies is hazardous due to the high quantities of these components, as well as other nutrients like nitrate and phosphate, which can lead to eutrophication and other negative environmental impacts (Collins et al., 2005)

Table 01: Physicochemical Characteristics of distillery wastewater (Pant et al., 2006**)**

Parameter	Anaerobically treated wastewater (released in field)
Electrical Conductivity (mS/cm)	33
pH	8.2
BOD5 (ppm)	5000
COD (ppm)	25,000
Total Kjeldahl nitrogen (%)	3.5
Sodium (ppm)	500
Potassium (ppm)	2500
Manganese (ppm)	259
Magnesium (ppm)	98
Zinc (ppm)	273
Copper (ppm)	396
Total dissolved solids (ppm)	21,256
Total sugar (%)	2.8
Reducing sugar (%)	0.23

Due to the melanoidins in the distillery wastewater it is resistant and gives the effluent colour. These substances have antioxidant characteristics and are therapeutic process inhibitors. A typical distillery effluent from an Indian sugarcane molasses-based distillery has been described (Gonzalez et. al, 2000). Around 2% of a dark brown pigment called melanoidins, which gives the effluent its colour, is also found in cane molasses. Melanoidins are low- and high-molecular-weight polymers created as one of the byproducts of the Maillard reaction, a browning process that doesn't require the use of enzymes and is caused by the interaction between reducing sugars and amino acids. Above 50 °C and a pH of 4–7, this process can occur well. Melanoidins' structural makeup is still mostly unknown. In the traditional anaerobic-aerobic wastewater treatment procedure, only 6-7% of the melanoidins are degraded. Melanoidins are hazardous to many microorganisms used in wastewater treatment because of their antioxidant capabilities. Distillery effluent also includes additional colourants such phenolics, caramel, and melanin in addition to melanoidins. While melanin is prominent in beet molasses effluent, phenolics are more evident in cane molasses wastewater (Godshall, 1999).

The high toxicity of wine distillery effluent and its suppression of biodegradation owing to the presence of polyphenolic compounds have caused a number of issues during biological treatment, displaying the antibacterial activity documented in prior research (Duarte et al., 1997). In certain distillery effluents, polyphenol concentrations range from 29 to 474 mg/l (Bustamante et al., 2005).

Due to the hazards, they bring to the environment and human health, polyphenols, which have potent inhibitory effects on microbial activity, must be eliminated during wastewater treatment. Diarrhoea, black urine, mouth ulcers, and mouth burning significantly increased in humans exposed to phenol at 1300 mg/l concentration (Garg and Sharma, 2016).

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III. TREATMENT APPROACHES FOR DWW

Since DWW is a significant contributor to soil and water contamination, it must be properly treated before being released into the environment. This can be accomplished for the most successful therapy by utilising different physical, chemical, and/or biological therapeutic procedures, either alone or in combination.

3.1. Conventional treatment approach for DW

Remediation facilities were obligated to successfully decrease organic loading to the permitted limit prior to their release into the environment because of the destructive nature and regulation on the discharge of distillery pollutants. Treatment facilities for distilleries frequently employ conventional remediation methods. The effectiveness and cost of therapy, locality, weather, land use, regulatory restraints, and public acceptance of the treatment technology are all important elements that influence the choice of therapy techniques.

a) Coagulation/flocculation

Utilizing flocculation chemicals and occasionally coagulant aids, coagulation is the instability of colloidal particles by counteracting the forces holding them apart. In contrast to flocculation, which involves the formation of linkages among flocs and the binding of molecules to create huge agglomerates or clusters, colliding molecules lead to the growth of bigger molecules (flocs). Several coagulants are reportedly utilised in the management of DWW, including aluminium sulphate ($Al(SO_4)_3$), ferric chloride ($FeCl_3$), ferrous sulphate ($FeSO_4$), alum, iron aluminium, calcium salts, poly-aluminium chloride (PACl), etc. According to reports, such coagulants lower the organic load and suspended solids (SS) from DWW (Wagh and Nemade, 2015; Prajapati and Chaudhari, 2015).

Table 02: Advantages and disadvantages of different treatment technologies of distillery wastewaters Adapted and modified from Chowdhary et al. (2018).

Treatment Approach	Advantages	Disadvantages
Adsorption	Adsorption and degradation of several pollutants at the same time	Highly sensitive to temperature and pH cost commercial adsorbents cost is high
Coagulation/Flocculation	Simple and cost-effective Widely accepted Separates many kinds of particles from wastewater Enhances the filtration process Uses abundant and low-cost chemicals	Highly pH sensitive Full oxidation Excessive loss of energy Excess use of chemicals
Oxidation process	Can be applied pretreatment stage of final treatment stage	Ozone may attack the double bonds and other functional groups such as $-OCH_3$, $-OH$ and $-CH_3$ in acid or neutral conditions with limited concentrations
Membrane treatment	Efficient colour removal	High membrane fouling, clogging, scaling and cleaning
Aerobic treatment/Anaerobic treatment reactors	Removal of multiple contaminants	Low production efficiency, needs pretreatment
Bacterial treatment	Eco-friendly and cost-effective	High dilution is required
Fungal treatment	Eco-friendly and cost-effective	Slow process Requires longer period treatment requires a large area
Microalgae	Eco-friendly, cost-effective/no additional nutrient requires	Light and temperature dependent
Constructed wetland	Eco-friendly	Very slow
Vermifiltration technology		Slow/time consuming
Laccases	Eco-friendly	
Peroxidases		Every slow process and not suitable for large-scale production
Oxidoreductases	Reusable in nature	
Cellulolytic enzymes	Enzymatic biotransformation of industrial pollutants	
Cyanidase		
Proteases		
Amylases		

Coagulation factors, on the other hand, are ph levels, and the kind, quantity, and qualities of the wastewater to be treated all affect how successful they are. Using polyaluminum chloride (PACl), $AlCl_3$, and $FeCl_3$, Chaudhari et al. (2005) showed 71.5%, 61%, and 56% COD reduction and 93%, 87%, and 84% colour decrease in DWW. $FeCl_3$ and $AlCl_3$ were examined by Sowmeyan and Swaminathan (2008) for the adequate therapy of DWW, and they found 92% and 77% reductions in colour and total organic carbon, accordingly. Additionally, utilising traditional coagulants like alum, ferrous sulphate, and ferric sulphate under alkaline conditions resulted in the maximum colour removal (up to 99%) from biologically treated DWW (Pandey et al., 2003). Additionally, Prajapati et al. (2015) showed that $FeCl_3$, alum, $AlCl_3$, and $FeSO_4$ at concentrations of 60 mM/dm3 at pH 5, 5, 6, and 5, correspondingly, reduced COD by 81%, 91%, 72%, and 93% and 82.8%, 81.64%, 75.19%, and 82.8% from DWW. In addition, David et al. (2015) used Moringa oleifera seed extract as the coagulant in combination with chemical coagulants such as aluminium sulphate and calcium sulphate and discovered 97% colour elimination.

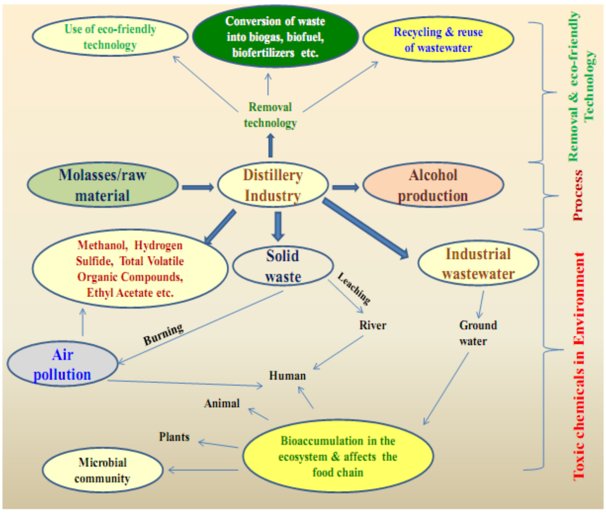

Figure: Environmental impact of distillery wastewater and technologies to fight the threat.

b) Adsorption

Adsorption, a physiological phenomenon dependent on surfaces, is utilised to remove organic

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contaminants from industrial effluents. Investigations utilising biosorbents such as synthetically produced sugarcane bagasse, powdered activated carbon (PAC), activated charcoal, pyochar, chitosan, etc. for DWW remediation are well documented in the research (Prajapati and Chaudhari, 2015). Extremely large surface area, microporous structure, adsorption ability, and high level of surface reactivity, activated carbon (AC) has been described as an effective absorbent (Arimi et al., 2014). The elimination of colour, polyphenols, and particular organic contaminants from different industrial effluents is common for AC (Prajapati and Chaudhari, 2015). Chandra and Pandey (2000) found that employing commercially activated carbon with a surface area of 1400 m2/g from anaerobic environment processed distillery spentwash resulted in reductions of colour, BOD, and COD of >98%, 71%, and 91%, correspondingly. Lalov et al. (2000) utilised Chitosan as an adsorbent for the efficient treatment of DWW at a concentration of 10 g/L for a 30 min contact period, and they discovered a 97% and 98% reduction in colour and COD, accordingly. Furthermore, Mane et al. (2006) achieved a 50% colour decrease from DWW utilising biologically treated bagasse (0.4 g/100 ml wastewater) utilizing 3-chloro-2-hydroxypropyl tri-methyl ammonium chloride (CHPTAC) and 2-diethylaminoethyl chloride hydrochloride (DEAE). Additionally, Shivayogimath and Inani (2014) observed that employing bagasse-activated carbon reduced DWW COD, colour, and TDS by 94.4%, 61.84%, and 87.8%, accordingly.

3.2. Biological treatment approaches

Ecologically responsible biotic remediation techniques for reducing industry pollution entail stabilising contaminants by converting them into harmful compounds through either anaerobic or aerobic processes.

a) Anaerobic process

The best method for reducing wastewater with a large organic carbon concentration, like that from distilleries and the pulp and paper sector, is anaerobic decomposition. The basic purpose of anaerobic decomposition is to turn spent wash into biogas. Bioremediation is preferable to direct aerobic treatment due to the high chemical concentration of molasses spent wash (Satyawali and Balakrishnan, 2008). Anaerobic digestion is a process in which microorganisms break down the organic components in DWW to create biogas (about 61% CH_4 and 39% CO_2). 1 m^3 of wasted wash typically yields 38 - 40 m^3 of biogas. The anaerobic shredder also produces digested sludge, which is extremely nutrient-rich, and processed spent wash. The high nutritional content of this digested sludge makes it suitable for use as green manure (Nandy et al., 2002). Up-flow anaerobic sludge blanket (UASB) is the most used anaerobic method for treating DWW (Wilkie et al., 2000).

Because of the existence of numerous antimicrobial substances, including 2,3-dimethylpyrazone, 2,2-bifuran-5-carboxylic acid, 2-nitroacetophenone, 2,2-bifulan, 2-methylhexane, methylbenzene, 2,3-dihydro-5-methylfuran, p-chloroanisole, 3-pyrroline, and acetic acid, anaerobic treatment procedures are limited. Microorganisms may break these substances into various substances such 2,3-dihydro-5-methylfuran, indole, 2-methylhexane, 2-nitroacetophenone, and p-chloroanisole (Jimenez and others, 2004). Chemical inhibitors are still present in diluted DWW even after anaerobic decomposition, despite the significant COD elimination. In order to get rid of the residual black hue and COD, BOD, etc., further treatment is necessary. Another way to increase the effectiveness of anaerobic treatment methods is to pretreat DWW with ozone, UV light, and titanium dioxide before aerobic digestion (Martin et al., 2002). Therefore, it is advisable to treat the DWW anaerobically first before using additional therapeutic techniques.

b) Aerobic treatment

In the presence of oxygen, microorganisms use the aerobic treatment method to break down organic contaminants in wastewater into carbon dioxide and other biomass. The reactor needs a sufficient supply of oxygen and biomass to effectively treat the waste. The main popular treatment approach is activated sludge. The arrangement enables wastewater to flow into an agitating, oxygenated vessel that has been prepared with activated sludge. Aerated devices then extensively mix the tank's suspended microorganisms (Simate et al., 2011). Aerobic digestion systems are only used in DW treatment to lower BOD and COD. Although aerobic wastewater treatment is known for its high COD, nitrate and phosphorus removal, and low CO_2 emission (Driessen and Vereijken, 2003), its viability is questionable because of numerous drawbacks like managing and disposing of excess sludge created during the treatment, the cost of aeration and cooling (Sennitt, 2005). An additional drawback of both aerobic and anaerobic treatment procedures is their slowness, need for a lot of areas, considerable dilution, and potential for increased water shortages.

Fungal treatment

The process by which fungus breaks down organic molecules in wastewater is known as fungal wastewater treatment. The utilisation of fungal biomass as a source of high-protein animal feed has lately brought attention to the treatment of fungal wastewater. Due to their ease of adaptation to variations in temperature, nutrients, aeration, and pH, filamentous fungus are primarily employed in wastewater treatment (Satyawali and Balakrishnan, 2008). Numerous workers have used fungi to cure DW, including *Geotrichum candidum*, *Aspergillus fumigatus*, *Trametes sp.*, *Aspergillus niger*, *Citeromyces sp.*, *Flavodon flavus*, and *Emericella nidulans var. lata*. (Bezuneh, 2016). The

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efficacy of A. niger combined with coagulants on DW was reported by Shukla et al. in 2014. As a consequence, the colour was decreased by 95.2% by A. niger. A single factorial experiment was conducted to test the decolonization of distillery waste wash that had been anaerobically treated, and Cladosporium cladosporioides was chosen as the test organism. At 35 degrees Celsius, the authors successfully reduced colour (53.6%) and COD (61.5%) (Ravikumar et al., 2011). The authors' subsequent research again led to reductions in colour (61.5%) and COD (74.6%), respectively, when the same Cladosporium cladosporioides was used under various conditions (Ravikumar et al., 2013).

Bacterial Treatment

Microbes (bacteria) were utilised in this remediation procedure to biochemically decompose alcohol waste water into stable final products. According to a study by Dahiya et al. (2001), Pseudomonas was the bacterial species that was most frequently recovered from reactor liquid, whereas Bacillus had been typically extracted from colonised carriers. Pseudomonas fluorescens reduced the colour of wastewater containing melanoidin by around 71% when it wasn't sterilised and by about 91% when it was sterilized.

When *Pseudomonas putida* and *Aeromonas* sp. were used in DW treatment, Ghosh et al. (2002) found that COD and colour reduction were reduced. The wastewater COD significantly decreased by 65% within a 24-hour period after the treatment by the authors, who exploited the carbonaceous chemicals in the wasted wash as a carbon source. However, P. putida also eliminated 61% of the colour and 45% of the COD. Bacillus megaterium and Bacillus cereus were also employed to reduce the COD and colour of predigested distillery effluent by 82 and 76%, correspondingly. *Melanoidins* in DW can be oxidised and decomposed by acetogenic bacteria, whereas wasted wash's chloro-ride content is detoxified and reduced by nitrifying bacteria like *Nitrosococcus oceanus*. The use of bacteria (microbial) biotechnology in waste water treatment has positive economic and environmental effects. The technique uses a straightforward, natural mechanism to break down contaminants in wastewater without adding any new pollutants. However, a lack of beneficial bacteria in the treatment facility can result in inadequate flocculation, an excess of filamentous bacteria and phosphorus, and a low rate of nitrogen removal. Chlorine can be used to eliminate unwelcome germs and solve these issues.

Biocomposting

Within that procedure, press mud from sugar mills is combined with DWW to create compost (Torres-Climent et al., 2015). For the treatment of DWW, aerobic and anaerobic composting techniques are also being employed. Composting with wastewater from a bio-methanation plant is also used in certain purification facilities. Among the most useful thermophilic activities is biocomposting, which yields a humus-rich end product that is utilised as fertiliser in agricultural areas. On sugarcane pressmud, the spentwash is sprayed carefully either before or after biomethanation. The latter is the filter cake that sugar manufacturers obtain during the clarification of juice. According to Jimenez and Borja (1997), the phenolic content and colour of beet and molasses spentwash were reduced by 74% and 40%, respectively, after aerobic pretreatment with Penicillium decumbens. Many Indian distilleries connected to sugar mills with available land have chosen to use this strategy.

3.3. Emerging Treatment Approaches

Researchers have already developed improved distilleries waste treatment techniques and other industrial waste management strategies. The oxidation process and membrane treatment are two of these newly developed treatment methods.

a) Membrane filtration

Municipal water treatment has been done with the use of membrane technology. The technique has recently been included into the wastewater purification process. As per Prodanovi and Vasi (2013), Membrane technique is associated with excellent nutrient extraction efficiency, use of fewer sophisticated instruments, and cost-effectiveness. The technique is often applied following a biological therapy strategy. Using a physical barrier filters out all SS found in the effluent (Chowdhary et al., 2018). Membrane filtering has been praised for its minimal maintenance requirements, excellent pollution rejection, and environmental safety (Abid et al., 2012). According to a study by Rai et al. (2008), using nanofiltration (NF) for the treatment processes of DW that has undergone aerobic treatment resulted in reductions of 95 to 98.55% in COD, 84 to 96% in TDS, and 97 to 96% in colour. Comparing the conventional activated sludge process to the membrane bioreactor method, COD removal is claimed to have increased by 99%. (Kraume et al., 2005). In a different study, Vlyssides et al. (1997) treated vinasse from beet molasses using electrodialysis using titanium alloy anode, stainless steel cathode, and 5% (w/v) NaCl as an electrolytic agent. This has caused a noticeable 88% decrease in COD. By using polymeric reverse osmosis (RO) and NF membrane technique, Madaeni and Mansourpanah (2006) biologically treated high COD alcohol wastewater. This approach led to a 100% COD removal. In order to treat DW, both hybrid NF and RO using a thin film composite membrane were employed. The NF membrane lowered TDS (80%), conductivity (95%) and chloride concentration (45%), while the RO membrane reduced COD (99%). Due to its potential, this procedure has recently been used for wastewater treatment (Zhang et al., 2018). However, due to their limits on the environment, ultrafiltration techniques like polyvinyl fluoride and polysulphone membranes cannot be used extensively (Padaki et al., 2015).

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b) Advanced Oxidation Process

Recalcitrant organic molecules are eliminated using the advanced oxidation process (AOP), which involves both oxidation and reduction. The method is used to decrease COD, odour, colour, and sludge in wastewater by combining free hydroxyl radicals with organic molecules in a reactor. When previous treatment steps are complete, the procedure is utilised as a last step to remove any remaining organic burdens (Bergendahl and O'shaughnessy, 2004). According to Satyawali and Balakrishnan (2008) and Arimi et al. (2015), activated carbon is frequently used to remove colour, specific organic loads, and polyphenols from a variety of industrial wastewaters. In a pilot-scale experiment by Bergendahl et al. (2003), Fenton's oxidation was used to lower the quantity of organic pollutants in the water. The concentration was much lower by 81.8% at the conclusion of the experiment. DW was subjected to photodegradation utilising UV light (Vineetha et al., 2013). Under the testing conditions of 0.4 M hydrogen peroxide concentration, pH 7, and 0.2 g/L of Titanium (IV) oxide molecule as a catalyst, the result demonstrated a 78% decrease of colour. Asaithambi et al. (2015) came to the conclusion that an ozone-photo Fenton system could eliminate all colour and COD from DW in under 5 hours. The technique has shown to be one of the most efficient ways to treat wastewater. However, the device is ineffective in eliminating ozone and may need further treatment, which might raise the cost of care. Additionally, the wastewater's turbidity and NO_3 levels impede the treatment process.

c) Constructed Wetlands

Constructed wetland (CW) is a sustainable, eco-friendly remedy for DW that uses straightforward construction and minimal maintenance methods. By analysing the impact of a reduced holding period on the CW, Mulidzi (2010) evaluated the COD reduction potential of CW. The results demonstrated a 61% decrease in COD in DW during the course of the trial. In a different research, CW with gravels, Typha latipholia, and Phragmites karka decreased BOD and COD from anaerobically treated effluent by 84 and 65%, respectively (Billore et al., 2001). Using T. *latipholia*, Trivedy and Nakate (2000) also treated diluted distillery effluent in a lab setting, about 77% gravel and 24% sand were put into the bed zone. In just six days, the COD was reduced by 75% as a consequence. Construction of CW is comparatively less costly, efficient, and environmentally benign. However, relative to normal remediation procedures, the technique is sluggish, time-consuming, and needs a lot of space. Additionally, if poorly designed and implemented, CW might reveal the smell of the waste stream.

IV. CHALLENGES FOR THE BIOREMEDIATION OF DWW POLLUTANTS

According to reports, the DIs barely produces 7 to 9% of the ethanol using sugarcane molasses, with the majority contributing as effluent. Since there are no quick and practical treatment methods, treating this large amount of wastewater takes a long period. The Effluent Treatment Plant (ETP) continues to struggle to lower these pollutant characteristics below the allowable levels established by several environmental protection organisations because of extremely high BOD, COD, and TDS levels. The main colouring chemicals in DWW, melanoidins, are very recalcitrant by nature, or difficult to biological/microbial breakdown. Another significant difficulty for DIs is managing the significant amounts of sludge produced during the physical, chemical, and biological treatment of DWW. A significant obstacle to sustained growth is the absence of sophisticated and workable therapeutic methods for the efficient treatment of DWW in a short amount of time. Poor capacity utilisation also contributes to greater financial costs and overhead expenses. Additionally, the very high costs associated with operating and maintaining wastewater treatment facilities are unaffordable, thus governments should also offer economic assistance to enterprises in order to promote responsible growth.

V. CONCLUSION

The procedures now employed by distilleries for wastewater treatment include composting with or without biomethanization, followed by a two-stage biological treatment and disposal in watercourses or land usage for irrigation. To a certain extent, these methods treat wastewater. These technologies, however, restrict complete adherence to the established standards. Different treatment technologies, including physical-chemical treatment, composting, and biological treatment, have all been examined by researchers. Low level organic pollutants are removed using physical and chemical treatment techniques; these techniques are very selective for the toxins they remove (color, turbidity, total suspended solutes or bad odours and COD). However, the drawbacks of these techniques include their excessive reliance on chemicals, the production of sludge, which causes disposal issues, high running costs, and sensitivity to the input of fluctuating water.

These restrictions result from either high treatment costs or a technological barrier that prevents the system from safely and acceptably removing some pollutants, such as TDS and colour, at levels that can be disposed off in surface or terrestrial waters. Wastewater cannot be entirely treated with a single method.

Wastewater decolorization frequently involves an anaerobic treatment followed by biological aerobic oxidation. However, these procedures are ineffective in treating these substantial amounts of coloured effluent. More study of this continuous culture configuration would be necessary to see whether a large-scale application of the technique could be implemented while minimising the amount of additional nutrients and extending the biomass activity for a longer time. The total removal of colour and other pollutants from this stream cannot be accomplished using conventional biological treatment techniques (such as anaerobic digestion, anaerobic lagoons, active sludge process, etc.).

Several researches have demonstrated anaerobic techniques that enable biogas recovery to be the most promising technology for the treatment of wasted washing. It is necessary to develop a perfect, financially successful, and commercially viable treatment plan that starts with biomethanization, moves on to physical-chemical treatment and finishes with aerobic treatment. Emerging treatment modalities, like enzyme therapy, offer technological benefits but are still developing, so they need to take economic factors into account before they can be used on the size of the plant. Enzymes appear to have a lot of potential in a lot of waste treatment fields.

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