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Distillery Wastewater: Characteristics and Treatment Methods

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ABSTRACT: Effluent originating from distilleries known as spent wash leads to extensive soil and water pollution. Elimination of pollutants and colour from distillery effluent is becoming increasingly important from environmental and aesthetic point of view. The industrial production of ethanol by fermentation results in the discharge of large quantities of high strength liquid wastes. Distillery wastewater is one of the most polluted waste products to dispose because of the low pH, high temperature, dark brown colour, high ash content and high percentage of dissolved organic and inorganic matter with high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) values. Due to the large volumes of effluent and presence of certain recalcitrant compounds, the treatment of this stream is rather challenging by conventional methods. Distillery wastewater, without any treatment can result in depletion of dissolved oxygen in the receiving water streams and poses serious threat to the aquatic flora and fauna. This review paper presents basic overview of various physical, chemical, biological processes and physiochemical treatment methods applied for efficient the treatment of distillery wastewater treatment.

KEYWORDS : Distillery Wastewater, Aerobic Treatment, Anaerobic Treatment, Wastewater Treatment

I. INTRODUCTION

Various organic wastewaters that are known to cause serious problems may be attributed to distillery effluents, paper and pulp effluents, textile effluents and tannery effluents, among others. Among these types' distillery wastewater is highly charged with organic matter, which, when dumped into water sources without treatment or inadequate treatment, causes serious pollution hazard [1]. The pollution potential of the Distillery Waste Water is one of the most critical environmental issues of today. For these reasons, distillery industries are forced to look for more effective technologies for wastewater treatment [2]. The waste water (effluent) generated from distillery is of two types viz. process waste water and non-process waste water. The non-process waste water is comparatively pure and as such can be recycled. The process waste waters of distillery consist of fermenter sludge, spent lees and spent wash. Spent lees is usually recycled. Fermenter sludge has higher biochemical oxygen demand (BOD) and lower volume as compared to spent wash. It is advisable to dewater fermenter sludge and dispose it off without mixing it with spent wash as it will increase the BOD of receiving stream [3]. Even though wastewater is generated at various stages of alcohol production, wastewater from the fermenter sludge, spent wash and spent lees are the main contributors to pollution [4]. Distilleries are industries, where 88% of its raw material is converted into waste. Distilleries also use huge volumes of water during the manufacturing stages and for every liter of ethanol produced, 15L of spent wash is released as dark brown colored wastewater [5]. Chemical composition, turbidity, color and temperature of the effluent categories the severity of the effluent and also decides the required treatment technique. However, there has been no general agreement on the most suitable method for the management of WW yet [6]. Hence, this paper aims to gather wastewater characteristics reported in the literature and to discuss several widely adopted treatment options, such as aerobic- and anaerobic based biological processes, physicochemical, oxidation processes, physical and their combinations in order to present the picture of more effective and sustainable management strategies of DW.

II.CHARACTERISTICS OF DW

The DW is a mixture of agro-based by-product and water, and it is one of the polluting factors of the environment [7].The quantum and characteristics of wastewater generated at various stages in the manufacturing process is provided in Table 1 [142] and their characteristics are shown in Table 2 [142]. The distilleries have been generating huge quantities of high toxic effluents. The production and the characteristics of the spent wash are highly variable and dependent on the raw material used and various aspects of the ethanol production process [8,9,10]. The characteristics of different types of distillery wastewater are given in Table 3. DW is characterized by dark brown colour, high temperature, acidity, COD and BOD [11, 12]. These are attributed to the presence of proteins, reduced sugars, lignin, polysaccharides and waxes [13]. The organic compounds have possessed antioxidant characteristics, that provide toxic substances to available microorganisms that aid in the treatment processes [14]. Usually, raw DW has low pH that ranges from 4.0 to 4.6 [15]. Molasses-based alcohol distilleries generate large volume of dark coloured wastewater. The colour is primarily attributed to a dark brown pigment, melanoidin as well as the presence of phenolics, caramel and melanin [16]. Melanoidins have conjugated carbon–carbon double bonds–C=C– in their structure that are responsible for their brown colour [17]. Spentwash contains 2% melanoidins, which has an empirical formula of $C_{17}H_{26-27}O_{10}N$ [18]. Melanoidins have anti-oxidant properties causing toxicity to many microorganisms involved in wastewater treatment processes [19].

Distillery Operations	Average wastewater generation (kLD/distillery)	Specific wastewater generation (kL wastewater/ kL alcohol)
Spent wash	491.9	11.9
Fermenter Cleaning	98.2	1.6
Fermenter Cooling	355.2	2.0
Condenser Cooling	864.4	7.9
Floor Wash	30.8	0.5
Bottling Plant	113.8	1.3
Others	141.6	1.2

Table 1. Wastewater generation in various operations [142]

III. TREATMENT OF DW

DWW is generally treated by physical, biological and chemical methods [21, 22]. The selection of treatment methods depends on various factors viz. treatment efficiency, treatment cost, local geography, climate, land use, regulatory constraints, and public acceptance of the treatment. [22]. In physical treatment method screening, sedimentation, floatation and air stripping method is generally used. In biological method, anaerobic digestion of SW to produce methane gas followed by aerobic treatment of BDE is common and this method is applied in most of distillery [23, 24]. Furthermore, Biological treatments have been recognized as effective methods of treatment for highly polluted industrial wastewaters. Both anaerobic and aerobic systems are commonly used to treat the wastewaters from agro-industrial plants including distilleries as well [9]. Physicochemical treatment methods are combination of physical and chemical technologies. Various physicochemical methods such as adsorption, coagulation–flocculation, and oxidation processes like Fenton's oxidation, ozonation, electrochemical oxidation using various electrodes and electrolytes, nanofiltration, reverse osmosis, ultrasound and different combinations of these methods have also been practiced for the treatment of distillery effluent [26]**.** All these treatment technologies are discussed in the following section.

3.1 Biological Treatments.

Biological wastewater treatment processes are based on the use of aerobic, anaerobic or combinations of both microorganisms and also on use of different type of reactors [27].

3.1.1 Anaerobic Treatment:

Anaerobic digestion is a natural process in which anaerobic microorganisms utilize organic matter and transform it to biogas, which makes this treatment more attractive than aerobic treatment. The process is conducted by a comprehensive ecosystem in which physiologically different groups of microorganisms function and interact with each other [33]. A number of microorganisms are involved in anaerobic digestion, including acetic acid-forming bacteria (acetogens) and methane-forming archaea (methanogens). The anaerobic digestion can treat high-strength distillery stillage more effectively than aerobic treatment because it degrades concentrated wastewater, produces a small amount of sludge, requires less energy, and produces economically valuable bioenergy (biogas) [28].

3.1.1.1. Anaerobic Sequencing Batch Reactor (ASBR) :

ASBR is highly effective for COD removal for high strength wastewater from brewery production plant [36]. When the organic loading rate is operated between 1.5 kg COD/ m^3dand 5.0 kg COD/m^3d, and hydraulic retention time one day, COD removal efficiency can reach more than 90% even though VFA in the feed was fluctuating from 300 mg/L to 1500 mg/L. Besides COD reduction, the process has the potential to produce energy. The gas production

Parameter	Spent wash	Fermenter cooling	Fermenter cleaning	Condenser cooling	Fermenter wash	Bottling plant
Colour	Dark brown	Colourless	Colourless	Colourless	Faint	Colourless
pH	4-4.5	6.26	5.0-5.5	6.8-7.8	6	7.45
Alkalinity (mg/L)	3500	300	Nil	-	40	80
Total Solids (mg/L)	100000	1000-1300	1000-1500	700-900	5550	400
Suspended solids (mg/L)	10000	220	400-600	180-200	300	100
BOD (mg/L)	45000-60000	100-110	500-600	70-80	15	5
COD (mg/L)	8000-120000	500-1000	1200-1600	200-300	25	15

Table No.2 Typical characteristics of different wastewater streams [142]

Reached as high as 2.40 L/L d. Methane composition varied between 50% and 80%. Granulation can be achieved in ASBR in approximately 60 days. The granular sludge formed in the reactor has a very good settling ability and biomass activity, 0.947 g COD/g VSS d, 0.786 g COD/g VSS d, 0.674 g COD/g VSS d and 0.624 g COD/g VSS d for formate, acetate, propionate and butyrate, respectively. Therefore, ASBR is a potential alternative for brewery Wastewater treatment [37].

3.1.1.2.Upflow Anaerobic Sludge Blanket (UASB) Reactors :

In the recent years, the UASB process has been one of the promising choices which successfully used for the treatment of various types of waste waters [95]. UASB reactor systems belong to the category of high rates anaerobic wastewater treatment and the success of UASB depends on the formation of active and settleable granules [96]. To achieve successful startups, the reactors must be operated at a low loading rate of 4–8 kg COD/m^3d [97].

3.1.1.3. Continuous Stirred Tank Reactor (CSTR)

CSTR can effectively be adopted for the treatment of distillery wastewater. The maximum COD removal efficiency of the CSTR was observed to be 72 to 73% when operated in the favorable pH and temperature ranges. Optimum conditions for COD removal and biogas generation were found to be for OLR 0.10 kg/d to 0.11 kg/d, 15d to 14d HRT, and for VFA to Alkalinity ration around 0.12. Optimum biogas generation with a conversion coefficient of 0.405 was observed to be around 30

L/d for steady-state conditions. Post-methanation effluent still contains high COD and needs to be treated further [9]. The performance towards COD reduction and
Biogas formation can further be enhanced by increasing the buffering capacity of the reactor.
Characterization of seed and or response of seed to micronutrients can also be required to focus in order to enhance the performance of CSTR [37].

3.1.1.4. Fluidized Bed Reactor:

In the anaerobic fluidized bed, the media for bacterial attachment and growth is kept in the fluidized state by drag forces exerted by the up flowing wastewater. The media used are sand, Activated Carbon (AC), plastics, etc. Under fluidized state, each medium provides a large surface area for biofilm formation and growth. It enables the attainment of high reactor biomass hold-up and promotes system efficiency and stability [98]. Irrespective of support media utilized, anaerobic fluidized technology is more effective than anaerobic filters, fundamentally because this technology favors the transport of microbial cells from the bulk to the surface and enhances the contact between the microorganism and substrate phases [29].

3.1.1.5. Fixed Bed Reactor: This involves immobilisation of microorganisms on some inert support to limit the loss of biomass and enhance the bacterial activity per unit of reactor volume. Moreover, it provides higher COD removal at low HRT and better tolerance to organic and toxic shock loadings. In anaerobic contact filters, various packing materials, viz. polyurethane, clay brick, GAC, Polyvinyl Chloride (PVC), plastic media have been employed resulting in 67–98% reduction in COD [32, 99, 100, 101, 102]

3.1.1.6. Anaerobic lagoons:

Anaerobic lagoons are one of the effective and a preferable choice for anaerobic treatment of distillery waste [38]. The results of excellent research work by Rao,1972 in the field of distillery waste management by using anaerobic lagoon treatment in two pilot-scale lagoons in series had shown overall BOD removal ranging from 82 to 92%. However, the lagoon systems are seldom operational, souring being a frequent phenomenon [92] .

3.1.1.7. Anaerobic Fixed Film Reactors: In fixed film reactors, the reactor has a biofilm support structure (media) for the biomass attachment. The colonization process proceeds in three consecutive phases: lag phase, biofilm production phase and steady state establishment phase (establishment of amature biofilm) [103]. The nature of the media used for biofilm attachment has a significant effect on reactor performance. A wide variety of materials like polyureathane foam and sintered glass [104], waste tyre rubber [105], poly (acrylonitrile–acrylamide) corrugated plastic [106] etc., have been used as non-porous support media at laboratory as well as pilot-scale.

3.1.1.8. Down flow Reactor: The application of the down-flow fluidization technology for the anaerobic digestion of red wine distillery wastewater [35]. The system achieved 85% total organic carbon (TOC) removal, at an organic loading rate of 4.5 kg TOC m^3d. Up flow UASB reactor is the most popular high rates digester that has been utilized for anaerobic treatment of various types of industrial wastewaters [107].

3.1.1.9. Semi continuous batch digester: A semi continuous batch digester to investigate biomethanation of distillery waste in mesophilic and thermophilic range of temperatures. The study revealed that there was an important effect of the temperature of digestion and of substrate concentration in terms of BOD and COD loading on the yield of biogas as well as its methane content. Maximum BOD reduction (86.01%), total gas production and methane production (73.23%) occurred at a BOD loading rate of 2.74 kg m−3 at 50°C digestion temperature [37].

3.1.2. Aerobic Treatment:

Although the key dis-advantage of the aerobic processes for the treatment of distillery stillage is high energy consumption, these processes are widely used because of their high efficiency and ease of use . They are applied both as a pretreatment and as a final treatment [108]. A large number of microorganisms (bacteria, cyanobacteria, yeast, fungi, etc.) can be used for treatment of distillery stillage in aerobic conditions. Filamentous fungi can be considered important phenolic-degrading organisms, as they frequently grow on wood, utilizing lignin as a carbon source [109, 110]. The efficiency of treatment depended on the following factors: temperature, pH, COD, and Nutrients [111,112].

3.1.2.1. Conventional Aerobic Methods

3.1.2.1.1. Fungal Treatment

Fungi are very useful system to treat distillery waste water by their superior nature to produce a large variety of extracellular organic acids and other metabolites [119]. Fungi have shown potential for the treatment of various specific pollutants and mixed wastewaters, including dark-colored, phenolic wastewaters such as molasses [123] and olive mill waste [104, 124, 125, 110, 127], which means that fungal treatment of these wastewaters could be used as a pre-treatment step for anaerobic digestion. Another promising approach would be to use enzymes derived from fungi to treat the wastewater [119]. One of the most studied fungus having ability to degrade and decolorize distillery effluent is Aspergillus fumigatus G-2-6, Aspergillus niger, A. niveus, A. fumigates UB260 brought about an average of 60–85% COD reduction along with 65–78% decolorization [128, 129]. Treatment of distillery spentwash with ascomycetes group of fungi such as Penicillium spp., Penicillium decumbens, Penicillium lignorumresulted in about 50% reduction in color and COD, and 70% phenol removal [130].

3.1.2.1.2. Bacterial treatment.

Microbial treatments employing pure bacterial culture to enhance the aerobic degradation have been reported frequently in the past and recent years [29]. Bacterial cultures are capable of bioremediation of distillery spent wash. Bacterial cultures have very high potential for decolorization of anaerobically treated distillery spent wash. Various bacteria applied for treatment of distillery wastewater [22]. Pioneering work on spent wash decolourizarion by bacteria was done by Kumar 1997 [14]. They observed that two aerobic bacterial isolates LA-1 and D-2 brought about maximum decolourization (36.5% and 32.5%) and COD reduction (41% and 39%) under optimized conditions in eight days [14]. The most prominent bacterial species isolated from the reactor liquid belonged to Pseudomonas, while Bacillus was isolated mostly from colonized carriers. Pseudomonas fluorescens, decolourized melanoidin wastewater (MWW) up to 76% under non-sterile conditions and up to 90% in sterile samples [131].

3.1.2.1.3.Cynobacterial/ Algal Treatment

The Cyanobacteria have been reported to be useful for treatment of solid wastes and wastewaters containing phenol [132]. Cyanobacteria are prokaryotic, gram-negative, photoautotrophic eubacteria having the ability to take up their nutrients from DW as sole carbon and nitrogen source, and thereby decolorizing the wastewater resulting in the reduction of color, BOD, and COD. Another advantage of using cyanobacteria is that, apart from the degradation of the melanoidin, it also oxygenates water bodies thereby reducing the energy need of the aerobic treatment [133]. Kalavathi (2001) explored the possibility of using a marine cyanobacterium for decolorization of distillery spent wash and its ability to use melanoidins as carbon and nitrogen source. The organism decolorized pure melanoidin pigment (0.1%, w/v) by about 75% and crude pigment in the distillery effluent (5%, v/v by about 60% in 30 days [16]. Valderrama (2002) studied the feasibility of combining microalgae, Chlorella vulgaris and macrophyte Lemna minuscule for bioremediation of wastewater from ethanol producing units. This combination resulted in 61% COD reduction and 52% color reduction [134].

3.1.2.1.4. Phytoremediation

Phytoremediation of effluents is a low cost technique is used to remediate sites, contaminated with heavy metals and toxic organic compounds. Phytoremediation takes advantage of plants, nutrients utilization processes transpire water through leaves, and act as transformation system to metabolize organic compounds such as oil and pesticides. They may also absorb and bioaccumulate toxic trace elements, such as the heavy metals like lead, cadmium, and selenium [135]. It is an emergent green technology that employs plants and their associated microbiota to remove, reduce, immobilize, and/or degrade harmful environmental pollutants [136, 137]. This can reduce the health risk from contaminated water, sediments, sludge, and soil through contaminant degradation or removal [138, 139, 140]. For the removal of DW contaminants, there is some significant work done by Billore (2001) for a horizontal flow gravel bed constructed wetland (CW) to treat DW. After secondary conventional treatment, the concentrations of COD and BOD5 in DW amounted to 2540 and 13,866 mg L^{-1}, respectively, and, therefore additional treatment was essential. The CW treatment system achieved BOD5, COD, total P and total Kjeldahl nitrogen (TKN) reductions up to 84%, 64%, 79%, and 59%. This study recommended that CW may be a sustainable tertiary treatment technique for the remediation of contaminants present in DW. Similarly various researches have been made on Phytoremediation Techniques [141].

3.1.2.2 Other Aerobic Methods

3.1.2.2.1. Aerobic Membrane Reactor (ABR)

Aerobic membrane bioreactor (ABR) has developed quite a lot of interest among the researchers, as well as the industries. Compared to the old bio filtration processes, MBR process offers distinct advantages of reliable and efficient treatment performance with smaller footprint, reduced sludge generation and high treatability of distillery wastewater, recovering high-quality effluent [114, 115, 116]. Effluent from UASB reactor treating distillery wastewater was treated further in a laboratory-scale MBR and found to achieve 92% of decolourization and 95% of COD reduction [117]. In another study for treatment of distillery spent wash with continuously fed MBR, equipped with submerged 30-μm nylon mesh filters

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and operated at OLR ranging from 3 to 5.7 kg COD/ (m^3d), up to 41% COD removal was achieved [118]; whereas, in the same reactor configuration with 2–8 micron submerged membrane made from waste fly ash, around 36 and 60% of COD and phenol removal were obtained, respectively [119].

3.1.2.2.2. Activated sludge

The most common wastewater treatment is the activated sludge process where in research efforts are targeted at improvements in the reactor configuration and performance. For instance, aerobic sequencing batch reactor (SBR) was reported to be a promising solution for the treatment of effluents originating from small wineries [120]. The treatment system consisted of a primary settling tank, an intermediate retention trough, two storage tanks and an aerobic treatment tank. A start up period of 7 days was given to the aerobic reactor and the system resulted in 93% COD and 97.5% BOD removal. The activated sludge process and its variations utilize mixed cultures. To enhance the efficiency of aerobics systems, several workers have focused on the treatment by pure cultures. Though aerobic treatment like the conventional activated sludge process is presently practiced by various molasses-based distilleries and leads to significant reduction in COD, the process is energy demanding and the color removal is still unsatisfactory [121].

3.2 Physiochemical Treatment Methods

Physicochemical treatment methods are combination of physical and chemical technologies. Removal of suspended solids from the water is physical operation while reduction of the dissolved solid is a chemical process. Both operations are done on waste water with adding chemicals. The coagulation and electro-coagulation are applied commercially for treatment of certain effluents [40].

3.2.1. Coagulation

Coagulation is the use of chemicals to cause pollutants to agglomerate and subsequently settle out during sedimentation [41]. All surface water sources and industrial effluent contain perceptible turbidity. The plain sedimentation is not a very preferred method for the removal of smaller suspended particles. Efficient removal of particles less than 50 m in diameter cannot be expected [42]. However, small colloidal particles can be removed by agglomeration of particle into groups, which increase the size, and are able to settle down [43]. The colloids are separated from each other by zeta potential between colloids having negative charges. When coagulants are added, it reduces the zeta potential which causes of colloids and form large particles (flocks). The pollutants are also entrapped in neutralized mass, as well as it is also carried to settle by sweeping [44, 43]. Applications of the process at optimum pH and coagulant dosages provide best result for various waste water treatment [45]. It is an important unit process in water treatment for the removal of turbidity. Its application in water treatment is followed by sedimentation and filtration [46]. Various types of coagulants are used in practice. The choice of coagulant chemical depends upon the nature of the suspended solid to be removed, the raw water conditions, the facility design, and the cost of the amount of chemical necessary to produce the desired result. Sludge considerations, compatibility with other treatment processes, environmental effects, labor and equipment requirements for storage, feeding, and handling are main factors that should be considered in selecting these chemicals [47].

3.2.2. Electro Coagulation

Electro-coagulation involves consumption of metal from the anode with simultaneous formation of hydroxyl ions and hydrogen gas occurring at the cathode [48]. This process has been proposed since 100 year back for wastewater treatment [49]. It is capable to remove a large range of pollutants under a variety of conditions ranging from suspended solids and heavy metals [50]. In Third Annual Australian Environmental Engineering Research Event 23-26 November, 1999 serious discussion had taken place on application of electro-coagulation technique for castle maine, petroleum products, colour from dye-containing solution; aquatic humus , and deflouridation of water treatment. In the process pH, pollutant type and concentration, bubble size, position of electrode, floc and agglomerate size all influence the operation of electro-coagulation unit [51].

3.2.3. Electro Oxidation

For the complete decomposition of pollutant from the distillery wastewater, complete oxidation of organics to carbon dioxide and water or other oxides is required. The oxidation incurs relatively high energy consumption for large organic molecules [52].The electrochemical oxidation of wastewater or wastes can be classified in two categories:

- Direct anodic oxidation (organics are oxidized along the surface of the electrode)
- Indirect oxidation (a mediator is electrochemically generated to carry out oxidation

Direct anodic oxidation - In a direct anodic oxidation process, the contaminants are first adsorbed on the anode surface and then oxidized (destroyed) by the anodic electron transfer reaction.

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Electro oxidation of pollutants can take place directly on anodes by generating physically adsorbed "active oxygen" (adsorbed hydroxyl radicals) or chemisorbed "active oxygen" (oxygen in the oxide lattice, MOX+1) [53].

Indirect anodic oxidation - Indirect anodic oxidation having several advantages, by this process, strong oxidant such as hypochlorite, ozone, hydrogen peroxide Fenton's reagent or oxidized metallic ion [113] can be regenerated by the electrochemical reactions during electrolysis. All of the oxidants are generated in-situ and are utilized immediately [54].

3.2.4. Ozone Oxidation

Ozonation method was investigated as a chemical means of oxidation and colour removal from the wastewater. One of the most important characteristics of the ozone in industrial wastewater treatment is its ability to convert biorefractory compounds into less toxic and more biodegradable compounds thereby significantly decreasing the time necessary for bioremediation [56, 57, 58]. When ozone is comes in the contact of distillery waste water, ozone reacts with organic compounds in two different ways: by direct oxidation as molecular ozone or by indirect reaction through formation of secondary oxidants like free radical species, in particular the hydroxyl radicals. Both ozone and hydroxyl radicals are strong oxidants and are capable of oxidizing a number of compounds and finally COD value is reduced [59].

3.2.5. Thermolysis

Thermolysis involves chemical decomposition, chemical reaction to form solid and thermal precipitation, caused by heat with the help of metal catalyst (Cu++, Fe++, MnO, CuO,ZnOetc) [55]. There is no oxidation reaction of the matter. Pollutant such as heavy metals when present are also trapped in solid residues [60]. Application of this process has been reported to treat waste water of pulp and paper mills [61], alcohol distilleries [62, 63, 64], textile industries [65, 66] and dyes [67]. It may be economical and a good supplement to the biochemical oxidation processes. In this process, a considerable amount of organic substrate is obtained in the form of solid precipitates, which has moderate heating values [67].

3.2.6. Adsorption

Adsorption on AC is widely employed for the removal of colour and specific organic pollutants due to its extended surface area, microporous structure, high adsorption capacity and high degree of surface reactivity [68]. In DWW treatment the interface is between the liquid and solid surface that are artificially provided. The material removed from the liquid phase is called the adsorbate and the material providing the solid surface is called the adsorbent [69]. Adsorption process is generally considered better in water treatment because of convenience, ease of operation and simplicity of design [70]. Further this process can remove/minimize different types of organic and inorganic pollutants from the water or waste water and thus it has a wider applicability in water pollution control [71, 72, 73]. This process has been also found successful in removing harmful parameter like COD and color from DWW [71]. To remove the air pollutant for air adsorption process is also applicable. The effect of powdered activated carbon (PAC) on the operation of a membrane bioreactor (MBR) for the treatment of DWW has been also reported [68].

3.2.7. Wet Air Oxidation Of DW

The wet oxidation (WO) process is widely used for the treatment of the liquid effluents having pure compound(s), industrial effluents and domestic wastewater; however, very few research papers are available on the wet oxidation of BDE and SW. The wet oxidation process is strongly dependent on various parameters like temperature, pressure, partial pressure of oxidants, degree of mixing, pH, catalyst type and its concentration, and the time of the treatment. A number of research papers have been published on wet oxidation of various chemicals such as phenol [74, 75, 76, 77], polyethylene glycol [78], dye [79], pulp and paper mill effluent [80, 81], distillery wastewater [82, 83, 84], carboxylic acids [85, 86], cyanides [87, 88, 89]and sewage sludge [90, 91].

3.3 Physical Treatments

Physical treatment methods are used at the initial stage of effluent treatment [25]. In physical treatment method screening, sedimentation, floatation and air stripping method is generally used [23, 93]. Adsorption is also a one of the most widely used physical method. Adsorption on activated carbon is widely employed for removal of colour and specific organic pollutants. Physical treatment is used to decrease suspended/settable solids from wastewater which may be removed inexpensively via sedimentation by using the force of gravity to separate suspended material, oil, and grease from the wastewater [94].

IV. CONCLUSION

The distillery industry generates large volumes of dark brown coloured wastewater with high BOD and COD. This review indicates that, a wide range of biological as well as physiochemical treatments have been investigated over the years for the treatment of distillery effluent. The physical and chemical treatment methods remove organic pollutants at low level; they are highly selective to the range of pollutants removed (colour, turbidity, TSS or foul odors and COD). Whereas, Physicochemical treatment methods are effective in both color and COD removal and biological treatments are effective to treat having very high organic load. Nevertheless the disadvantages associated with these methods are excess use of chemicals and sludge generation with subsequent disposal problems. Thus, there is an urgent need to address the limitations in the existing methods and to develop integrated treatment processes that provide a complete solution to the treatment of wastewater from distilleries.

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