DISTILLERY SPENT WASH BIOLOGICAL TREATMENT TECHNIQUES: A REVIEW

Prof.Y.S.Khandekar*
Civil Engineering Department, Sipna COET, Amravati, (MS), India
yogeshskhandekar@rediffmail.com
Dr.N.P.Shinkar
Civil Engineering Department, Govt. Polytechnic, Amravati, (MS), India
shinkarnp@gmail.com

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Abstract: The alcohol industries are growing extensively worldwide due to widespread industrial applications of alcohol such as in chemicals, pharmaceuticals, cosmetics, beverages, food and perfumery industry, etc. During production of alcohol by fermentation process results in discharge of highly polluted wastewater known as spent wash. Distillery spent wash wastewater is called highly polluted waste products because of low pH value, dark brown colour, high temperature, and organic content. If it disposed untreated into water it creates troublesome situations for the rivers, aquatic life, and fertility of soil. So, it is very necessary to arrest such situations to keep environment healthy. Due to treating such type of wastewater organic and inorganic pollutants in the spent wash can be removed. This paper reviewed in detail existing biological treatments. The biological treatments are based on anaerobic and aerobic processes. This study dealing with role of microorganism's viz., bacteria, fungi, algae in degradation of spent wash. In which microorganisms converts the complex organic compound into simpler and more stable compounds.
Keywords: Spent wash; biological treatments; aerobic methods; anaerobic methods; phytoremediation;

I. INTRODUCTION

India, an agro based country, is the 2nd largest producer of alcohol (preferably ethanol) in distillery based on sugarcane molasses, grains, grapes, sugarcane juice, and barley malt. There 319 distilleries in India produce 3.25 billion litres of alcohol and generating 40.4 billion litres of wastewater annually. The enormous distillery wastewater has potential to produce 1100 million cubic meters of biogas. India is facing severe problems of collection, treatment and disposal of effluents due to rapid industrialization and urbanization. Effluents from distilleries contain large amounts of dark brown coloured molasses spent wash. Because of its acidic pH (4-5), dark brown colour, high ash content (Potash as K_2O), high percentage of dissolved organic and inorganic matter. Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) of spent wash range between 30,000 to 60,000mg/lit and about1,00,000 mg/lit. Due to high BOD and COD values distillery effluent must be treated before it is disposed into the environment which helps to minimize the adverse effect posed by the effluent. Generally, wastewater treatment methods can be categorized as physical, chemical and biological methods. Physicochemical treatment methods such as adsorption, sedimentation, screening, coagulation, pH adjustment, reverse osmosis, ultrafiltration, flotation, oxidation, electrolysis, membrane filtration and evaporation have been used for treatment of distillery effluents.

Physicochemical methods of wastewater treatment have so many drawbacks such as consumption of chemicals, high cost, large amount of sludge left after treatment, and possible formation of harmful by-products. As a result of this, in recent years, biological wastewater treatment using microorganisms has attracted the attention of researchers all over the world. Microbial degradation and decolourization of distillery effluents have been found as cost effective and environmental friendly alternative to physicochemical methods. Various types of microorganisms as bacteria, fungi, and algae have been reported for their potential in degradation and decolorization of distilleries.

II. GENERATION OF DISTILLERY SPENT WASH

In India bulk of the alcohol is being produced from sugar cane molasses. Molasses is a thick viscous by-product of the sugar industry which is acidic in nature. For manufacturing alcohol, the molasses is diluted with water into a solution containing 15-16% of sugars. This solution is then inoculated with yeast strain and is allowed to ferment at room temperature. The fermented wash is distilled in a series of distillation columns to obtain alcohol of adequate. The residue of alcohol is the spent wash. Quantity of spent wash about 8 to 15 litres per litre for alcohol produced. Generation of spent wash is shown in Fig. 1.

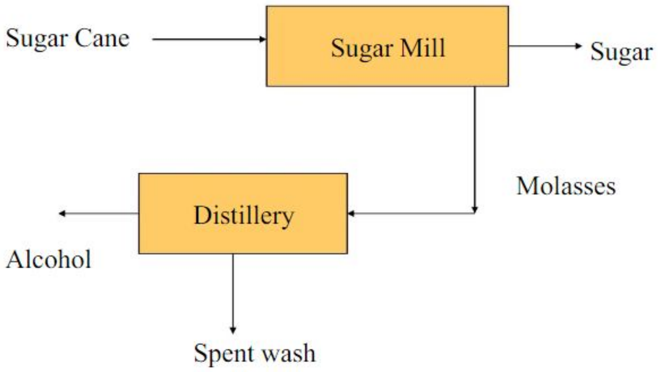

Fig. 1. Generation of Spent wash (Source 1)

III. BIOLOGICAL TREATMENTS

Biological treatments are very effective methods for highly polluted industrial wastewater such as distillery wastewater. Distillery wastewater needs to treat in order to meet set out regulations. Physical/chemical treatments are unfailingly costly and are less employed in industries. So, in recent years biological treatment systems have attracted the attention of environmental engineers throughout the wold and helped to solve the problems regarding treatment of effluent of distilleries and their reuse. Biological treatments are efficient and low cost wastewater treatment system.

This approach can remove biological organics, chemical oxygen demand (COD) and colour. Biological treatments are of two types are explained below.

A. Anaerobic treatments in the absence of O_2.
B. Aerobic treatments in the presence of O_2.

A. Anaerobic Treatment

Anaerobic digestion is a natural process in which various microbial species operate and communicate together in the absence of O_2. In the anaerobic digestion process, biogas and biomass are produced, while pathogenic and indecent organic matters are reduced. Therefore anaerobic digestion have two advantages i.e., it can be used as pollution reduction system and energy generation tool. There are three basic anaerobic digestion processes: psychrophilic, mesophilic, and thermophilic, which take place over different temperature ranges. Psychrophilic digestion is a low temperature (<20°C) processes. Mesophilic digestion takes place between 20 and 45°C, which can take a month or two to complete, and thermophilic digestion between 45 and 65°C, which is faster, but its microorganisms are more sensitive. Anaerobic digestion process occurs in successive 4 steps and is accomplished by four groups of bacteria. These bacteria form a food chain and final production of synergistic relationship is methane and carbon dioxide shown in Fig.2. The anaerobic food chain mainly consist of three groups of microorganisms, namely hydrolytic fermentative bacteria, acetogens (acetic acid - forming) and methanogens (methane-forming archaea).

Anaerobic digestion involves 4 major biological and chemical stages:
i) hydrolysis
ii) acedogenesis
iii) acetogenesis
iv) methanogenesis [37, 14].
In the hydrolysis step, the feedstocks of insoluble large polymers are broken down into soluble substrates (e.g., sugar and amino acids) by enzymes. Fermentations of the monomeric products are most important in which sugar, amino acids, and fatty acids are converted into ammonia, organic acids, hydrogen (H_2), and CO_2. Volatile fatty acids are also produced along with CO_2 and H_2. In acetogenesis step, volatile fatty acids are broken down into acetic acids, CO_2 and H_2. Finally, methanogenesis step converts acetate, formaldehyde, and H_2 to CH_4 and water. Thus, the AD consumes carbon of waste to produce biogas (CH_4,H_2, and CO_2) and digestate [29]. Various anaerobic treatment method device are available, viz. anaerobic lagoons, fixed bed reactor, anaerobic sequencing batch reactor, two-stage processes and hybrid reactors, up flow anaerobic sludge blanket UASB, anaerobic fluidized bed reactor. These reactors have been tried at pilot and full scale operation.

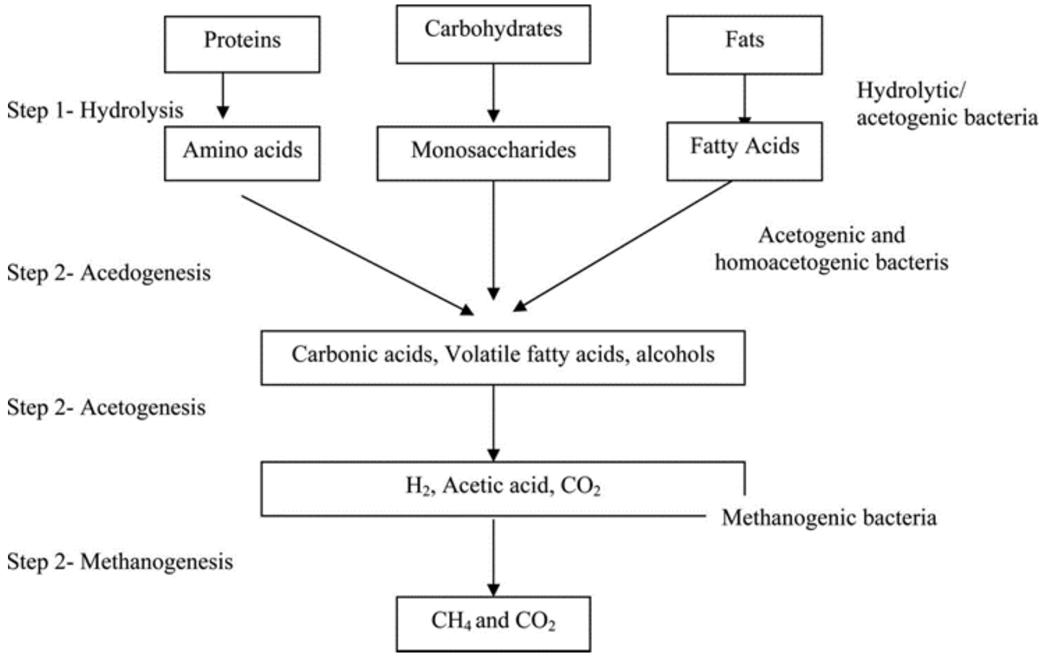

Fig. 2: Schematic diagram of anaerobic digestion indicating the process steps and the four bacteria groups involved in the process (Source 14).

Anaerobic digestion is the most suitable for treatment of high organic loading rate. Also it produces biogas and methane gas, which can be utilized for steam generation in boilers. Thus it lowers fuel consumption cost. The performance and treatment efficiency anaerobic process can be influenced both by inoculum source and feed pre-treatment. Anaerobic lagoons are the simplest option for the anaerobic treatment of distillery spent wash. [2] carried out semi-full scale and full scale pilot plant experiments in the field of distillery waste management with two lagoons in series. Also reported that the BOD removal efficiency of 90-95 % and a volatile solids reduction of 78 %.

The Up flow UASB is a well- established and proven technology for the treatment of high-strength organic wastewater due to the high biomass and microbial communities within the reactor. The UASB system is widely applied for treating wastewaters from the food industry, distilleries, tanneries and municipalities [1]. [30] reported that reduction in COD by 90% in UASB plant treating distillery wastewater. Compared to aerobic system, it has slow growth rate, mainly associated with methanogenic bacteria. Therefore it requires a long retention time, and also only a small portion of the degradable organic waste is being synthesized to new cells [9 and 19]. UASB systems most of the times are operated under mesophilic conditions, but thermophilic operation results in higher methanogenic activity. [18] reprted that removal of 39-67% with corresponding BOD removal of 80%, presence of Methanothrix in the UASB reactor is the main key factor for the degradation.

Fixed bed reactor provided with an inert filter medium with a high specific surface for on-growth of biomass (today mostly plastic material), mostly with external separation and recirculation of sludge. It provides higher COD removal at low hydraulic retention time (HRT) and better tolerance to toxic and organic shock loadings. Whereas upflow anaerobic filter (UAF) packed with special support type was resulted in 76% COD removal [31]. The fluidised bed reactor, where the carriers for the biofilm are fluidised by liquid recirculation. The carriers are particles or inert material. It contain appropriate media such as sand, gravel or plastics for bacterial growth and attachment. The reactors can be operated either in upflow or downflow. Fluidized bed technology is an effective anaerobic technology for treatment of high strength waste water. Treatment of Shochu distillery waste water using anaerobic distillery wastewater. The concentrations of BOD and total organic carbon (TOC) in the supernatant decreased to 56% and 72%, respectively [4]. Two-stage processes is a reactor in which an anaerobic filter followed by a UASB reactor. [25] reported that the separation of acidogenic and methanogenic phases are more suitable for the methanogenesis. Also observed that in COD reduction was 54% and 93% in the first and second stage. Anaerobic hybrid reactor was successfully be employed for the treatment of distillery-spent wash. The optimum COD removal efficiency of the hybrid reactor found to be 79% corresponding to optimum HRT and organic loading rate of 5 days and 8.7 kg COD/ m^3/d [13].

B. Aerobic Treatment

Aerobic processes is a biological processes and can be takes place in the presence of oxygen. Aerobic digestion is an alternative method of treating the organic sludge produced from various treatment operations. It can reduce the availability of essential mineral nutrients by trapping them into immobilized organic forms, and may produce phytotoxic substances during decomposition. There are strict regulations on discharge of colored effluent may hamper when direct discharge of anaerobically treated effluent. Therefore, aerobic treatment of sugarcane molasses wastewater has been mainly attempted for the decolourization of the major colorant, melanoidins, and for reduction of the COD and BOD. The aerobic treatment of industrial wastewater depends oxidative activities of microorganisms. Large number of microorganisms such as bacteria (pure and mixed culture), cyanobacteria, yeast and fungi have been used in recent years for the treatment of spent wash. The major advantage of this treatment is that process takes minimum time for stabilization and fast in nature compared to other processes. Trickling filters, activated sludge process, aerobic stabilization ponds, aerated lagoons are the treatment methods are employed for distillery effluent treatment.

1) Bacterial Treatment

Bacterial cultures are capable of bioremediation of distillery spent wash. Some of the bacteria applied for the treatment of distillery spent wash are summarized in Table I. [5] isolated bacterial strains were useful for the reduction of COD. [6] isolated bacteria L-2 belonging to Lactobacillus group. Also reported that this strain was capable to decolorize the distillery waste by 31% and remove COD 57% in 7 days.

2) Fungal Treatment

In recent years several basidiomycetes and ascomycetes type fungi have been used in the decolorization of natural and synthetic melanoidins in connection with colour reduction of wastewaters from distilleries. The aim of fungal treatment is to purify the effluent by consumption of organic substances thus reducing its COD and BOD. Several fungi have been investigated for their ability to decolorise distillery wastewater shown in Table II. White rot fungi is another group of widely used in distillery effluent bioremediation. White rot fungi produce isoforms of extracellular oxidases which are responsible for degradation of distillery effluent [7].

3) Algae Treatment

The prokaryotic, cyanobacteria are considered useful for treatment of distillery effluent. Table III gives details about different algae employed in degradation of distillery effluent.

4) Phytoremediation/Constructed Wetlands

Phytoremediation of effluents is a low cost technique 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 bioaccmulate toxic trace elements, such as the heavy metals like lead, cadmium, and selenium. Wetland is an artificial constructed system that uses soil and organisms to treat distillery effluent, municipal sludge, industrial wastewater, grey water etc. Constructed wetland has been designed to remove organic, constituents such as suspended solids, volatile matter and nutrients like nitrogen and phosphorus.

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TABLE I - BACTERIA EMPLOYED FOR THE BIODEGRADATION OF DISTILLERY SPENT WASH

Bacteria	COD removal (%)	Colour removal (%)	Reference
Aeromonas sp.	66	Nil	Ghosh et.al.2002
Pseudomonas putida	44	60	
Aeromonas formicans	57	55	Jain et al. 2002
Pseudomonas sp.	63	56	Chavan M., N., et al. 2006
Pseudomonas aeruginosa,Stenotrophomonasmaltophila, and Proteusmirabilis	51	67	Mohana et al. 2009
Bacillus sp.	21	30	Kaushik and Thakur 2009
Bacillus sp.	65	Nil	K.D. Singh 2006
Pseudomonas aeruginosa	77	48	Sankaran K. 2011
Bacillus subtilis	Nil	38	
Mixed Culture (Pseudomonas aeruginosa + Bacillus subtilis)	Nil	43	
mixed culture of B.thuringiensis, B.brevis, Bacillus sp.	64	Nil	Kumar P. et al. 2006
Microbacteriumhydrocarbonoxydans,Achromobacter xylosoxidans,Bacillussubtilis,B.megaterium,B.anthracis, B.licheniformis,A.xylosoxidans,Achromobactersp., B.thuringiensis,B.licheniformis,B.subtilis,Staphylococcus epidermidis,Pseudomonasmigulae,Alcaligensfaecalis,an d B.cereus	85-86	76	Chaturvedi et.al. 2006

TABLE III - FUNGI EMPLOYED FOR THE BIODEGRADATION OF DISTILLERY SPENT WASH

Fungi	COD removal (%)	Colour removal (%)	Reference
Phanerochaete chryso- sporium MUCC19343 (ATCC24725), Mycelia sterilia (ATCC 20350), Coriolus versicolor and Geotrichum can- didum	Nil	53%	FitzGibbon F., et al. 1998
Coriolus versicolor	71.5	90	Kumar V., et al. 1998
Phanerochaete chrysospotium	53.5	73	
Citeromyces sp.	100	75	Sirianuntapiboon S., et al 2004
Aspergillus	84	84	Shayegan J., et al. 2004

TABLE IIIII -ALGAE EMPLOYED FOR THE BIODEGRADATION OF DISTILLERY SPENT WASH

Algae	COD removal (%)	Colour removal (%)	Reference
Oscillatoria boryana BDU 92181	Nil	96	Patel et al. 2001
Lyngbya	Nil	81	
Synechocystis	Nil	26	
Algae Chlorella vulgaris	61	52	Valderrama et al. 2002
Mixed culture of green algae (Chlorella, Chlorococcum Chlamydomonoas, Pandsorina, Eudorina, Diatoms, Flagellates, Cyanobacteria Microcystis , Anabaena)	55-60	Nil	Tarlan et al. 2002
Chlorella sorokiniana	92.5	Nil	Solovchenko et al. 2014
Oscillatoria boryana	Nil	75	Kalavathi et al. 2001

IV. CONCLUSIONS

1. Biological treatment is promising technique for the decolorization and biodegradation of spent wash.
2. Biological treatment is a cost effective, eco-friendly compared to chemical decomposition process for treatment of spent wash.
3. Microorganisms as fungi, bacteria and algae plays key role in bioremediating toxic pollutants from distillery spent wash.
4. For the treatment of industrial distillery wastewater, biological treatments can be applied for their treatment and their reuse.

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