Journal of Hazardous Materials 163 (2009) 12–25

Contents lists available at ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

Review

# Distillery spent wash: Treatment technologies and potential applications

Sarayu Mohana, Bhavik K. Acharya, Datta Madamwar*

*BRD School of Biosciences, Sardar Patel University, Vallabh Vidyanagar 388120, Gujarat, India*

ARTICLE INFO

*Article history:*
Received 24 October 2007
Received in revised form 12 May 2008
Accepted 24 June 2008
Available online 28 June 2008

*Keywords:*
Anaerobic reactor
Distillery spent wash
Melanoidin
Physicochemical treatment
Pollution

ABSTRACT

Distillery spent wash is the unwanted residual liquid waste generated during alcohol production and pollution caused by it is one of the most critical environmental issue. Despite standards imposed on effluent quality, untreated or partially treated effluent very often finds access to watercourses. The distillery wastewater with its characteristic unpleasant odor poses a serious threat to the water quality in several regions around the globe. The ever-increasing generation of distillery spent wash on the one hand and stringent legislative regulations of its disposal on the other has stimulated the need for developing new technologies to process this effluent efficiently and economically. A number of clean up technologies have been put into practice and novel bioremediation approaches for treatment of distillery spent wash are being worked out. Potential microbial (anaerobic and aerobic) as well as physicochemical processes as feasible remediation technologies to combat environmental pollution are being explored. An emerging field in distillery waste management is exploiting its nutritive potential for production of various high value compounds. This review presents an overview of the pollution problems caused by distillery spent wash, the technologies employed globally for its treatment and its alternative use in various biotechnological sectors.



**Contents**



* Corresponding author. Tel.: +91 2692 229380; fax: +91 2692 236475/7258.
*E-mail addresses:* sarayu124@yahoo.com (S. Mohana), acharyabhavik@yahoo.com (B.K. Acharya), datta_madamwar@yahoo.com (D. Madamwar).

0304-3894/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.jhazmat.2008.06.079

## 1. Introduction

Distillery spent wash refers to the effluent generated from alcohol distilleries. On an average 8–15 L of effluent is generated for every liter of alcohol produced [1]. The alcohol distilleries are extensively growing due to widespread industrial applications of alcohol such as in pharmaceuticals, food, perfumery, etc. It is also used as an alternate fuel. There are 319 distilleries in India alone, producing 3.25 billion liters of alcohol and generating 40.4 billion liters of wastewaters annually [2]. As per the Ministry of Environment and Forests (MoEF), alcohol distilleries are listed at the top in the "Red Category" industries [3].

Alcohol production in distilleries consists of four main steps viz. feed preparation, fermentation, distillation and packaging [4]. Ethanol can be prepared from various biomass materials but the potential for their use as feedstock depends on the cost, availability, carbohydrate contents and the ease by which they can be converted to alcohol [5]. Nearly 61% of world's ethanol production is from sugar crops [6]. Most Indian distilleries exclusively use cane molasses as raw material for fermentation [7]. Molasses is suitably diluted in order to have desired sucrose level in it. It is then supplemented with assimilable nitrogen source like ammonium sulphate or urea. It is also supplemented with phosphate if necessary. The pH of the fermentation broth is adjusted to below 5 using sulphuric acid. Fermentation is carried out for about 50 h by using 5% active culture of *Saccharomyces cerevisiae*. Ethanol accumulates up to 8–10% in the fermented mash. The fermented mash is then distilled, fractionated and rectified after the removal of yeast sludge [8]. Apart from yeasts, a bacterial strain, *Zymomonas mobilis*, has been demonstrated as a potential candidate for ethanol production [9]. The residue of the fermented mash which comes out as liquid waste is termed as spent wash [8,10,11].

The wastewater generated from distillation of fermented mash is in the temperature range of 70–80 °C, deep brown in color, acidic in nature (low pH), and has high concentration of organic materials and solids. It is a very complex, caramelized and cumbersome agro industrial waste. However, the pollution load of the distillery effluent depends on the quality of molasses, unit operations for processing of molasses and process recovery of alcohols [12].

With government policies on pollution control becoming more and more stringent, distillery industries have been forced to look for more effective treatment technologies. Such technologies would not only be beneficial to environment, but also be cost effective. In 2003, Central Pollution Control Board (CPCB), the national agency responsible for environmental compliance stipulated that, distilleries should achieve zero discharge in inland surface watercourses by the end of 2005 [3]. Consequently, the wastewater needs to undergo extensive treatment in order to meet the stipulated environmental demands.

This review aims to disseminate information about the pollution potential and the strategies implemented for treatment of distillery spent wash. The experiences gained so far and the state of the art technologies are discussed. The potential application of distillery effluent in diverse agro industrial sectors to produce various value added byproducts is also reviewed.

## 2. Environmental hazards of distillery spent wash

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 [2,4]. Wash water used to clean the fermenters, cooling water blow down and broiler water blow down further contribute to its variability [2]. Distillery spent wash has very high biological oxygen demand (BOD), chemical oxygen demand (COD) and high BOD/COD ratio. The amount of inorganic substances such as nitrogen, potassium, phosphates, calcium, sulphates is also very high (Table 1). Its recalcitrant nature is due to presence of the brown polymers, melanoidins, which are formed by Maillard amino carbonyl reaction. These compounds have antioxidant properties, which render them toxic to many microorganisms such as those typically present in wastewater treatment processes [15]. The defiance of melanoidins to degradation is apparent from the fact that these compounds escape various stages of wastewater treatment plants and finally enters into the environment. Apart from melanoidins, the other recalcitrant compounds present in the waste are caramel, variety of sugar decomposition products, anthocyanins, tannins and different xenobiotic compounds [12]. The unpleasant odor of the effluent is due to the presence of skatole, indole and other sulphur compounds, which are not effectively decomposed by yeast during distillation [16]. Spent wash disposal into the environment is hazardous and has high pollution potential. High COD, total nitrogen and total phosphate content of the effluent may result in eutrophication of natural water bodies [15]. The highly colored components of the spent wash reduce sunlight penetration in rivers, lakes or lagoons which in turn decrease both photosynthetic activity and dissolved oxygen concentration affecting aquatic life. Kumar et al. [17] evaluated the toxic effect of distillery effluent on common guppy, *Lesbistes reticulates* and observed remarkable behavioural changes with varying effluent concentration. Kumar and Gopal [18] reported hematological alterations in fresh water catfish, *Channa punctatus*, exposed to distillery effluents. Saxena and Chauhan [19] investigated the influence of distillery effluent on oxygen consumption in fresh water fish, *Labeo rohita* and observed that the presence of inorganic and organic salts in the effluent interfered with the respiration in the fish. The coagulation of gill mucous decreased dissolved oxygen consumption causing asphyxiation. Matkar and Gangotri [20] observed concentration dependent toxicity of distillery effluent on the fresh water crab, *Barythephusa guerini*. Impact of distillery effluent on carbohydrate metabolism of *Cyprinus carpio*, a freshwater fish was studied by Ramakritinan et al. [21]. Stress due to distillery effluent caused defunct respiratory processes in the fish resulting in anaerobiosis at organ level during sublethal intoxication.

Disposal of distillery spent wash on land is equally hazardous to the vegetation. It is reported to reduce soil alkalinity and manganese availability, thus inhibiting seed germination [15]. Kannan and Upreti [22] reported highly toxic effects of raw distillery effluent on the growth and germination of *Vigna radiata* seeds even at low concentration of 5% (v/v). Leaching of protein and carbohydrates from the seeds as well as decrease in activities of important enzymes like alkaline phosphatase and ATPase was also observed.