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Ultrasound and ozone assisted biological degradation of thermally pretreated and anaerobically pretreated distillery wastewater

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Abstract

The present work is aimed at increasing the overall efficiency of the treatment process of distillery spent wash using a combination of different treatment techniques. Initially the effluent samples were subjected to Thermal Pretreatment (TPT-DW) and anaerobic treatment (ANA-DW). Advanced oxidation techniques, viz., Ultrasound (US) and Ozone were then used for further COD reduction followed by the conventional aerobic oxidation using mixed microbial consortium.

Pretreatment of TPT-DW with US and Ozone (as stand alone techniques) enhanced the subsequent aerobic oxidation rate. For US treated sample, a maximum of 13% COD reduction was attained at the end of 48 h of aerobic oxidation, while for the ozone treated effluent a maximum of 45.6% COD reduction was obtained as compared to mere 1.8% COD reduction for the control (TPT-DW directly subjected to aerobic oxidation) indicating a 25 times increase in the rate of aerobic biodegradation of ozonated sample.

Anaerobically treated effluent sample (ANA-DW) could be successfully treated aerobically. In this case, however, the use of advanced oxidation techniques did not result in any synergistic effects. The rate of the aerobic oxidation was slightly higher for the control (ANA-DW directly subjected to aerobic oxidation) as compared to the sample pretreated using ultrasound or ozonation. TOC analysis revealed that between the two pretreatments studied, ozone was found to be superior over US as it led to both COD as well as TOC reduction during the aerobic oxidation step for ANA-DW effluent stream.

Keywords: Thermally-pretreated distillery wastewater (TPT-DW); Anaerobically treated distillery wastewater (ANA-DW); Aerobic treatment; Ultrasound; Ozone

1. Introduction

Possible applications of ultrasound have increased enormously both in number and diversity since the development of sonochemistry revealed a new and very promising technique for energy introduction. This has led to an application of this technique in the treatment of industrial and domestic wastewater with encouraging results. The driving mechanism for the effects of ultrasound (US) is the phenomena of cavitation, which can be described as the formation and activity of gaseous bubbles or vaporous cavities in a liquid. The net effect is the generation of reactive radicals that can react with refractory compounds and/or generation of local hot spots resulting into the process of pyrolysis (Suslick et al., 1984; Shah et al., 1999; Gogate, 2002). Many reports have been published in the literature demonstrating the usefulness of ultrasound in the field of wastewater treatment (Chiua et al., 1997; Tiehm et al., 2001; Onyeche et al., 2002; Sivakumar and Pandit, 2002; Gonze et al., 2003).

Another established process for the treatment of water and wastewater is the use of ozone. Ozone is an unstable gas, which can be produced at the point of use, acting as a strong oxidizing agent. Its effectiveness is based on the multiple effects produced by the oxidative activity of ozone

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Nomenclature

ANA	anaerobic treatment
ANA-DW	anaerobically treated distillery wastewater
AO	batch subjected to aerobic oxidation
BOD	biochemical oxygen demand (mg/l) or (mg)
COD	chemical oxygen demand (mg/l) or (mg)
DNSA	dinitrosalicylic acid
DO	dissolved oxygen (mg/l)
ETP	effluent treatment plant
MLSS	mixed liquor suspended solids (mg/l) or (mg)
NA	nutrient agar slant
Ozone	ozone pretreated
S/S_0	residual substrate concentration, in terms of COD
T/T_0	residual substrate concentration, in terms of TOC
TOC	total organic carbon (mg/l) or (mg)
TPT	thermal pretreatment
TPT-DW	thermally pretreated distillery wastewater
US	ultrasonically pretreated

and ozone-derived oxidizing species such as OH-radicals (Gottschalk et al., 2000). 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 readily biodegradable compounds, thereby significantly decreasing the time necessary for bioremediation (Scott and Ollis, 1995). Recent works have demonstrated the combined use of ozone and aerobic oxidation for the treatment of synthetic and real distillery wastewater (Beltran et al., 1993, 1999, 2001; Peria et al., 2003).

Distilleries are one of the highly polluting industries with reference to the water pollution and the quantity of the wastewater generated. Amongst the different waste utilization and treatment schemes proposed (Sheehan and Greenfield, 1980; Lele et al., 2000) biological methods are the most adopted ones. Thermal Pre-Treatment (TPT) followed by anaerobic or aerobic method and anaerobic treatment (ANA) followed by aerobic polishing represent two such biological treatment schemes.

Thermal pre-treatment of the distillery wastewater offers a way of COD reduction and involves heating of the effluent in the absence of oxygen to the temperatures of 170–230 °C for a fixed period of 1–2 h. This treatment results in 40%–60% reduction in the COD by forming an insoluble residue having properties similar to coal and shows a possibility of energy recovery (Dhar et al., 1998). Since the reduction is only in the range of 40%–60%, further treatment is required before its discharge into the environment. Anaerobic treatment of the distillery spent wash followed by aerobic polishing forms another most widely adopted treatment schemes. The treatment technology encompasses degradation of organic matter using biomicroflora in the absence of oxygen. Though the technology offers important advantages like treatment of high strength wastewater (COD ~ 30 000–40 000 ppm), low energy input, low sludge generation and net benefit of energy generation in the form of biogas; however, this technology possesses nagging problems like, frequent instabilities in the digesters due to the production of undesirable compounds, long start-up time of the digesters, long retention time, low conversion of organic constituents to biogas due to the slow growth of the methanogenic and non-methanogenic microorganisms, disfavoring the economic production of biogas and overall productivity of the process (Barford, 1988; Lettinga et al., 2001). The anaerobic treatment is generally followed by aerobic oxidation, as the polishing step and this scheme still is unable to achieve the overall treatment goal of a complete economically viable treatment option. To overcome these deficiencies in the degradation schemes, a hybrid scheme of TPT or ANA with ultrasound, ozone and conventional aerobic oxidation has been evaluated for destruction of the real distillery wastewater. The first part of the work presents the efficacy of ultrasound and ozonation as a pretreatment step before the classical aerobic oxidation step for treating the TPT-DW. The second part is devoted to the application of ultrasound and ozone as a pretreatment for treating the effluent from the anaerobic treatment plant. Their efficacies have been tested in terms of COD removal efficiencies during the subsequent aerobic oxidation. The effects of these pretreatment strategies on the removal of TOC have also been discussed.

2. Experimental

2.1. Materials and setup

2.1.1. Distillery wastewaters

Cane-molasses based distillery spent wash was procured from the alcohol distillery (Terna Shetkari Sahakari Sakhar Karkhana, Osmanabad, Maharashtra, India). The raw effluent sample was subjected to thermal pretreatment procedure as described in details in our earlier work (Dhar et al., 1998) and was taken for the further studies. The anaerobically treated effluent (ANA-DW) was obtained from the anaerobic digester of the same distillery. The effluent sample was centrifuged (8000 rpm, 20 min, REMI-Centrifuge, India) in order to remove the suspended solids and the supernatant was taken for further studies. The characteristics of these effluents used in this study are presented in Table 1.

2.1.2. Sonication setup

In the present study, the ultrasonic irradiation was introduced using ultrasonic bath. The ultrasonic bath was