INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: STUDIES ON THE USE OF THERMOALKALI TREATED RICE STRAW AS CARBON SOURCE FOR OXYANIONS REMOVAL BY BIOLOGICAL PROCESS

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Thesis Submitted to the Department/ Center	:	Civil Engg
Date of completion of Thesis Viva-Voce Exam	:	02/09/2022
Key words for description of Thesis Work	:	Arsenic, Arsenosulfide, Rice Straw, Nitrate, Orpiment, Realgar, Thermoalkali Treatment, Sulfate

SHORT ABSTRACT

Rice straw is one of the most abundant, renewable lignocellulosic biodegradable crop residues, but a waste material all over the world. Burning in situ, rice straw leads to air pollution. Hence, it is the uttermost requirement to sustainably utilize agricultural waste such as its use as a carbon source in biological oxyanion removal process. Oxyanions such as sulfate, nitrate, arsenate, etc. are some of the common water pollutants. Utilization of rice straw has been reported for various purposes such as bio-ethanol production, H^+ production, and methane generation. Despite having great potential, its performance on oxyanion removal has not been explored so far. In the present study, the utilization of rice straw as a carbon source in biological systems for the removal of oxyanions has been studied. The target oxyanions in this study are sulfate, nitrate, and arsenic.

The present work can be broadly divided into five major parts viz; i) collection, processing, and study on the effects of thermoalkali treatment (here pre-treatment) on the hydrolysis and change in physicochemical properties of rice straw; ii) use of the raw rice straw and thermoalkali pre-treated rice straw as a carbon source in biological reduction of oxyanions in batch mode; iii) Fabrication, operation and performance evaluation of an attached growth continuous flow bioreactor on oxyanions reduction using fermented liquor of pre-treated rice straw (RS-NaOH); iv) characterization of bio solids, and v) determination of bacterial community structure in bioreactors used.

The present study demonstrates that the pretreatment in hot air oven was more effective than the autoclave pretreatment in all cases based on the hydrolyzate and compositional characteristics of rice straw. Based on the hydrolysis of rice straw during the pretreatment, the optimized temperature and time were 85^{o}C and 240 min in the case of the hot air oven and 121^{o}C and 20 min in the case of the autoclave. The optimum doses of alkali were 2.5% (w/w) $Ca(OH)_2$, 1% (w/w) NaOH, and 0.4% (v/v) ChOH for both of the cases in a hot air oven and autoclave in terms of COD, TRS, and VFA production. The maximum COD, TRS, VFA %, and hydrolysis rate % in the hot air oven treatment (at 85^{o}C corresponding to 240 min) with 1% (w/w) NaOH was 44±1.8 %, 27±3.1%, 3±0.01%, and 26.8 % respectively. Effectiveness of reacting agents was in the sequence of NaOH > ChOH > $Ca(OH)_2$. Production of COD, TRS, and VFA from rice straw hydrolyzate and alteration in various parameters (lignocellulosic compounds, CHNS

%, residual char %, increment in Cr Index %, biodegradability fraction, and hydrolysis rate %) is suggesting that rice straw hydrolyzate, as well as amorphous rice straw both of them, has enough potential to be used as a carbon source for the microorganism.

Based on batch studies it can be summarized rice straw can efficiently remove the oxyanions (single/multiple) from the wastewater containing sulfate (1000-3000 mg/L), nitrate (500-2000 mg/L), and arsenic (500-2000 µg/L) with the removal efficiency of 62-95% and 64-94 %, 89-94 % respectively within 40 days of HRT using biological process.

Performance evaluation of continuous reactor was investigated for simultaneous removal of sulfate, nitrate, and arsenic using the biological process in packed bed continuous reactor. This reactor can treat the wastewater with initial sulfate, nitrate, and arsenic concentration of 1500 mg/L, 100-1000 mg/L, and 1000-2000 µg/L leaving the final effluent concentration in the range of 150-524 mg/L, 20-140 mg/L, and 54-230 µg/L respectively. This reactor and the process adopted in this research work are suitable for industrial application and for treating wastewater containing sulfate, nitrate, and arsenic. The characterization of bio solids from reactors SA3, SAN3, and PBCR confirmed the bio precipitation as As-S, As_2S_3, and As_4S_3 were the removal mechanisms of arsenic and sulfate. FETEM analysis suggested the formation of stable bio-sludge in the bioreactor, which is of stable nature, thus the sludge-handling problem can be expected to be low. The belt structure showed distinctive clear lattice fringes with a d-spacing of 0.299 nm, 0.32 nm, and 0.27 nm of bio solids from SA3, SAN3, and attached growth reactor (PBCR), respectively. The crystalline nature of the obtained precipitates suggests the stable nature of bio solids which ensures their safe disposal in a landfill.

Metagenomic studies (16S rRNA analysis, TRFLP test, and Taxonomic profiling) of the raw paper mill sludge and reactors SN3, SA3, and SAN3, confirm the presence of sulfate, nitrate, and arsenic removing microorganisms. Overall, rice straw was found to be efficient enough for treating the sulfate, nitrate, and arsenic polluted wastewater in batch and continuous reactors.