INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Experimental Investigations for the Enrichment of Biogas Employing Biomass-Based Scrubbing Agents and Bio-Electrochemical Approaches

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SHORT ABSTRACT

Biogas produced from anaerobic digestion of organic waste is one of the potential alternative biofuels and is economically feasible, which might benefit the future energy supply demands as well as contribute to a reduction of greenhouse gas emissions. Biogas is primarily composed of methane (CH_4) and carbon dioxide (CO_2) as the major constituents, with trace amounts of other components like water vapour, hydrogen sulphide (H_2S), hydrogen (H_2), and nitrogen (N_2). The presence of H_2S in biogas needs special attention for cooking, power generation, as well as upgrading to bio-methane due to its foul-smelling odor, corrosion, health issues, and environmental problems. Scrubbing of CO_2 is also essential for the upgradation of biogas, which increases the calorific value of the treated gas and enhances its efficiency for being used as vehicular fuel and power generation. Among various purification technologies, the absorption and adsorption methods are found to be simple, cost-effective, and easy to operate for the removal of CO_2 and H_2S from decentralized biogas plants installed in rural areas. Generally, the use of different alkaline chemicals in the chemical absorption and adsorption processes is a common technique for the removal of CO_2 and H_2S from biogas. But, the problem arises in the disposal of the used chemicals due to their toxic and environmentally unfriendly nature.

Using a natural base ash solution prepared by ashing different parts of banana plant is a traditional practice amongst the rural communities of Assam, India. As a contribution to the research on the purification of biogas, this thesis aimed to synthesize, characterize, and apply natural base ash solutions and locally available biomass-derived adsorbents for CO_2 and H_2S removal from biogas and to alleviate the adverse effects of using chemical bases. Six different scrubbing agents and adsorbents, namely, banana pseudostem (BPS) ash solution, *Musa balbisiana* peel (MBP) ash solution, *Musa acuminata* peel (MAP) ash solution, bamboo biochar (BB), banana peel biochar (BPB), and biochar-clay composite (BCC) were chosen out of ten based on their physico-chemical properties for CO_2 and H_2S removal from raw biogas using absorption and adsorption techniques. Results of high pH, rich mineral compositions, and porosity

indicated that the scrubbing agents and adsorbents are naturally alkaline and can be utilized for the removal of CO_2 and H_2S from raw biogas.

The selected biomass-derived adsorbents, *viz.,* BB, BPB, and BCC, were used for the removal of H_2S directly from a 3 m^3 Deenbandhu model biogas plant using cattle dung as the only feed material. It was found that BPB could effectively remove 89.2% H_2S from raw biogas, followed by BB (87.7%) and BCC (78.4%) in a fixed bed adsorption scrubber. For a comparative study, the compositional, morphological, and structural properties of all the three adsorbents before and after treatment were analyzed using pH, EDX, FESEM, XRD, and FT-IR. The adsorption of H_2S strongly depends on pH, oxygen, BET surface area, mineral compositions, and textural properties of the adsorbents. Also, the calculated equilibrium adsorption value obtained from the pseudo-second-order kinetic model was best fitted for all the adsorbents, with the experimental data having a correlation coefficient, R^2 = 0.99. The observed results indicate that BB, BPB, and BCC can be used for H_2S adsorption at a much lower cost compared to commonly used chemicals.

The effects of natural base ash solutions (BPS, MBP, and MAP) with different molar concentrations of KOH (0.1, 0.3, 0.5, 0.7, and 1.0 M) on CO_2 scrubbing from biogas were investigated and compared. The scrubber with natural base ash solution from MBP could enrich the CH_4 content in biogas from 56.9% to 86.3%, followed by MAP (78.4%) and BPS (76.8%), which is nearly equivalent to 0.3 M KOH (88.6%). Also, the kinetic study shows that the rate constant *k* for MBP was nearly equivalent to that of 0.5 M and 0.7 M KOH, with an R^2 value of 0.99. The experiments revealed that banana peel ash solutions had the nearly equivalent potential to KOH for CO_2 absorption from biogas. The biomass availability, easy preparation method, and environment-friendly nature of the scrubbing agents and adsorbents render them potential candidates for CO_2 and H_2S removal from decentralized biogas plants.

Additionally, a single chamber, above-ground, portable anaerobic digester (AD) was developed, which was hybridized with a membrane electrode assembly (MEA) to facilitate the generation of enriched biogas and electricity as a byproduct. The highest concentration of CH_4 and CO_2 in control was 56.3±1.5% and 43.7±0.9% whereas in AD-MEA the concentration of CH_4 increased to 73.7±3.9% and CO_2 reduced to 26.3±0.5, respectively. Enrichment of CH_4 concentration in the hybridized AD-MEA system proved that the presence of a conductive surface in the anaerobic chamber of the AD-MEA system could promote the enrichment of methane by stimulating a synergistic mechanism between exoelectrogens and hydrogenotrophic methanogens for the conversion of CO_2 directly to CH_4. The hybridized AD-MEA setup could produce as much as 496±7 mV of OCV with a maximum average power density of 2.87 mW/m^2 and a 70 mA/m^2 current density, respectively. Also, the average experimental data of biogas production obtained from the control and AD-MEA systems were fitted using three different non-linear mathematical models. The kinetic parameters evaluated from the three models confirm that the modified Gompertz model (R^2 = 0.99) was best fitted to the experimental biogas production data, followed by the Logistic and Transference function models.