ABSTRACT

The present work focuses on the removal of hydrogen sulphide (H_2S) from biogas via sustainable approach. So, this study aims to develop an adsorption based hydrogen sulphide removal reactor using char and spent slurry of biodigester. De-oiled cakes of pongamia is used for production of biogas in a 20 cubic meter digester. The study is divided into two levels namely, Initial feasibility study and Performance study of a model packed bed reactor. As the primary targeted users in this study are rural entrepreneurs, the char was produced using waste leaves, Mixed Leaf waste was carbonised at three different temperatures 200 °C, 300 °C and 400 °C through slow pyrolysis for a period of 3 hours using a traditional kiln. Consequently, biochar prepared from mixed leaf waste at different temperatures 200 °C, 300 °C and 400 °C, are denoted as LWB200, LWB300, and LWB400, respectively. The biochar generated in the kiln was ground to a mesh size less than 500 microns. Adetailed characterization of prepared biochar as well as H_2S adsorbed biochar (after saturation) was done. Moreover, freshly prepared biochar and saturated biochar were characterized using series of characterizations including CHNS elemental analysis, Brunauer–Emmett–Teller (BET) analysis, Attenuated Total Reflectance Fourier Transform Infrared spectroscopy (ATR-FTIR), X-ray Diffraction (XRD), Scanning Electron Microscopy and Energy Dispersive Spectrometer (SEM-EDX) to develop an insight into the adsorption mechanism.

After detailed characterization, LWB400 was found to be a promising adsorbent for desulphurization of biogas with high H_2S removal efficiency during feasibility study. Thus,

LWB400 leaf waste biochar was used for further detailed performance study. An evaluation of the adsorption capacity of leaf waste biochar in terms of mg H_2S removal per gram of biochar was also determined. Also, a suitable equilibrium isotherm model was identified to describe the current adsorption process. The detailed optimization of parameters like the effect of flow rate and the effect of pressure was done. The adsorption isotherm equilibrium models were examined for comprehending the adsorption process of H_2S better and their associated parameters were determined. This optimization would help to determine the best suitable pressure and flow rate required for efficient H_2S removal. It was concluded that the highest adsorption capacity is 15.9 mg H_2S/g with removal efficiency of 98.6% was obtained at flow rate of 3m^3/h and pressure of 3 bar. However, at flow rate, 3 m^3/h and pressure 2 bar with the adsorption capacity of 15.1 mg H_2S/g and removal efficiency 98.4%, which was found to be the best possible condition for biogas desulphurization in terms of breakthrough time and lesser energy consumption. The isotherm analysis results showed that the Freundlich isotherm model with a higher R^2 value of H_2S is 0.9903, which is the most suitable to describe the adsorption isotherm of H_2S. So, it was concluded from the current adsorption isotherm data that the adsorption process is multilayer, not monolayer. These obtained results provides an insight into the H_2S adsorption mechanism onto the biochar. This was attributed to higher pH which led to an increased rate of dissociation of H_2S and higher elemental sulphur conversion rates. Amongst several factors affecting H_2S adsorption, the surface area played an important role in adsorption along with the associated factors like higher alkaline pH, carbonization temperature and mineral elements present on the surface of biochar. The SO_4^{2-} produced in the biochar was more likely to combine with Ca and K (mineral elements) to form useful sulphates for soil health enhancement. Finally, the reusability and practical applications of the saturated biochar as a soil ameliorant were investigated to reduce environmental impact and solve problems associated with the saturated adsorbent disposal. S-enriched biochar is proven as a beneficial agricultural S fertilizer for promoting mustard crops or other oil-producing crops, which can become bioavailable to plants as S-micronutrient. Therefore, the plot experiments of saturated biochar were done to utilize S-enriched biochar for crop production of *Brassica nigra* (Mustard seeds). From the results, it was observed that the amending S-enriched biochar resulted in significant enhancement of the physiological indexes including plant height, fresh and dry weight, and accumulation of nutrients like N, P, K, S, Na, Mg, and Fe in mustard crop with 4 times increase in S content as compared to plot with no amendment (Blank).So it was concluded that the present approach of H_2S removal results in the sustainable production of organic nutrient with efficient H_2S removal via a holistic approach.

On the other hand, an alternative technology for utilizing biogas digested slurry for biogas desulphurization is discussed as well as nutrient value enrichment in saturated slurry. It was observed that the highest removal efficiency of 88.7% obtained at pressure 1 bar and flow rate 2 m^3/h with outlet H_2S concentration 115 ppm. The total experiment run was of 41 hours for 25 L (5% TS) of biogas slurry with a total of 73.5 m^3 biogas was treated. After saturation, the spent slurry was assessed for nutrient value addition. From the results, it was witnessed that after treatment digested slurry gets enriched about two times with sulphur S (%) than initial sulphur S (%) present in the untreated slurry. Also the P (%) and N (%) showed a visible increase after H_2S treatment.