**INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI**
**SHORT ABSTRACT OF THESIS**

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**SHORT ABSTRACT**

Industrial development and rampant population growth has resulted in energy crisis, global climate change, environmental degradation and health problems. Thus, increasing focus is being placed on clean energy supply and environmental protection for an overall sustainable development. In this context, biotechnological products and processes are considered more economical and feasible than physico-chemical processes due to several advantages, such as low energy requirement, environment friendly, low investment cost etc. This study, therefore, focused on biological carbon monoxide (CO) conversion for biohydrogen and environmental applications.

Initially, the inherent capability of anaerobic biomass collected from five different sources which were mainly large scale sewage treatment plants located at different parts of India, was examined to utilize CO as the sole carbon source. These different bacterial biomass were screened for their ability to utilize CO at pH 7 and temperature 30$^{o}$C. The results revealed that granular anaerobic biomass form upflow anaerobic sludge blanket (UASB) reactor treating sewage was capable of converting CO to methane and carbon dioxide as the main products along with small amount of hydrogen. Further, effect of CO partial pressure, temperature, inoculum size and biomass pre-treatment using taguchi experimental design revealed the robustness of the raw biomass for CO conversion and sulfate reduction. Experiments with 2-bromoethanosulfonate to inhibit methanogenic activity of the biomass showed the CO conversion to methane was via hydrogenotrophic route and methane formation can be avoided by using 10 mmol/L of BES which resulted in a significant increase in final $H_2$ concentration. Metagenomic analysis of the anaerobic biomass from Kavoor STP revealed that bacteria belongs to *Methanomicrobia, Clostridia, Acidobacteria*, *Gammaproteobacter, Bacteroidia* classes are predominantly present in the biomass. Presence of *Desulfovibrio* sp. was also detected in small quantity indicating its role in biological sulfate reduction.

Detailed kinetics of CO conversion by anaerobic biomass revealed that it is able to convert CO to $H_2$ under different initial CO concentrations. The CO utilization kinetics followed first order reaction and was best described by Logistics model as compared with other models tested in this study. The $H_2$ production increased with increase in initial CO concentration and showed best fit to Gompertz kinetic model. The specific CO utilization rate and specific biomass growth rate both increased with increase in initial CO concentration upto 3.1 mmol/L of CO, after which they showed declining profile indicating substrate inhibition at high initial CO concentration. The Edward's and Aiba model were found to be best suited to describe specific CO utilization rate and specific biomass growth rate on CO. The product ($H_2$) concentration was also found to be inhibitory for both biohydrogen production and specific growth rate at high concentration and the inhibition kinetics could be described using modified Han-Levenspiel model. Thus, the study revealed that to achieve high CO conversion efficiency, $H_2$ need to be recovered faster without allowing it to accumulate in the system, or, there need to be some $H_2$ utilization mechanism such as $H_2$ production coupled to sulfate reduction using CO as the sole carbon source.

Simultaneous metal removal and sulfate reduction using CO as the sole carbon and energy source was achieved by the anaerobic biomass. The metal removal efficiency followed the order Cu > Pb > Cd > Zn. This study also showed significant inhibitory effect of Cu, Cd, Zn and Pb on sulafte reduction and CO utilization by anaerobic biomass particularly at a high initial concentration. Among the different heavy metals, Pb showed the maximum inhibitory effect. The heavy metal removal mechanism was attributed to biological reduction of sulfate to sulfide, followed by formation of metal sulfide precipitates. Formation of metal sulfide precipitates was confirmed by characterization of the metal bio-precipitates by Fourier-transform infrared spectroscopy (FTIR) and field-emission scanning electron microscopy (FESEM) with energy dispersive X-ray spectroscopy (EDX) techniques.

Iron naoparticle synthesized using green tea extract was examined to improve CO solubility in water. Detailed characterization of green tea synthesized iron nanoparticle (GT-INP) revealed spherical or semi spherical shaped aggregated nanopartcile with size 50-90 nm. From FTIR analysis results presence of amide, hydroxyl groups on the nanoparticle surface was detected; moreover, the nanoparticle was found to be coated with flavonoids, alkaloids and polyphenols, etc. from green tea extract. Addition of GT-INP in the liquid media increased the CO solubility, with a maximum enhancement of 56 % at 1000 mg/L of GT-INP. Hydrogen production and sulphate reduction were also high with nanoparticle addition when compared with the result obtained without adding nanoparticle.

For continuous CO bioconversion two bioreactors, an internal loop gas lift reactor (GLR) with suspended anaerobic biomass and moving bed biofilm reactor (MBBR) with both attached and suspended ananerobic biomass were evaluated. Both the reactors showed stable performance in terms of hydrogenogenic CO conversion for different inlet CO concentration. However, GLR was slightly better in terms of $H_2$ production and CO utilization, particularly at high inlet CO concentration. The maximum $H_2$ concentration of 23.4 and 19.6 mmol/L was obtained for 36 mmol/L of inlet CO concentration. The results showed that with increase in the inlet CO concentration the $H_2$ production increased for both the reactors, however, the CO conversion efficiency reduced. Performance of both the reactor on sulfate reduction and CO utilization at different process conditions of hydraulic retention time (24 - 72 h), inlet CO concentration (15 - 29 mmol/L) and inlet sulfate concentration (250 - 1000 mg/L) was evaluated. Similar to the hydrogenogenic CO conversion 48 h HRT yielded the maximum sulfate removal efficiency of 95.5 % and 92.7 % with GLR and MBBR, respectively. Best results in term of sulphate reduction (> 90% efficiency) were obtained for low inlet sulfate and high CO loading conditions with both the bioreactor systems, and the CO utilization was more than 80 % only for inlet CO concentration of 15 mmol/L. Thus, the GLR performed better for both sulfate reduction and CO utilization compared with MBBR, however, due to good biomass retention in MBBR, the performance of the system was more stable than that of GLR with only the suspended biomass. More than 10.42 mg/L/h sulfate loading rate was found to be detrimental to high sulfate reduction in both the systems. Overall, this study demonstrated scale up potential of the MBBR system for continuous CO bioconversion, which has not been reported so far in the literature.