Optimization and Mathematical modeling based control of trace element dosing in anaerobic digestion of solid waste

PhD research November 2015 - October 2018

Social Challenges

Climate change is the greatest environmental problem faced by the world in 22nd century. Rise in global temperature has been attributed to large scale use of fossil fuel compounded by the restricted availability of alternative sources of energy. According to International Energy Association (IEA) 81% of world energy demand is fulfilled by fossil fuels where as a renewable sources of energy gratify 13% of the energy demand. Although with small contribution towards net energy production, renewable sources of energy can play a major role in CO_2 mitigation in future. In this regard, energy from biomass is being seen as a crucial contributor to renewable sources of energy especially in the areas devoid of solar and wind energy. Further, adding to the list of environmental problems is the amount of organic solid waste generated from the urban areas and the health problems associated with the untreated organic waste. Keeping in mind the world energy needs and the menace of untreated organic solid waste, anaerobic digestion has been implemented and various aspects of the technology are being scrutinized to develop an economically viable process.

Technological Challenges

Anaerobic digestion is the breakdown of organic matter into simple forms by microorganisms with simultaneous production of methane. Microorganisms need macro and micro nutrients (metals and metalloids) to carry out these metabolic conversions. Internationally there is a huge effort to increase the yield of bioenergy/ bio methane production from anaerobic digestion of organic solid waste. Although there exist an extensive literature on effect of trace elements on anaerobic digestion there are currently no or very limited literature on the dosing of trace elements in anaerobic digestors.

Thus, the purpose of this research is to study the dynamics of trace elements in an anaerobic digestion system so that a trace element dosing strategy can be developed. For which, a mathematical model will be developed in order to quantitatively relate the processes affecting trace elements dynamics, assess the relationship between trace metal speciation and bioavailability and quantify their effects on microbial growth and biogas production rate. Establishing such a quantitative relationship will help define an effective trace element dosing strategy which can maximize process performance. The mathematical model will be based on the approach used in the IWA Anaerobic digestion model no.1 (ADM1) and will incorporate the physicochemical processes affecting trace elements speciation and bio-availability in the form of different submodules (i.e. sulphur; phosphorous; precipitation; adsorption; surface complexation). Trace element bio-uptake, production and release will be considered as well. A sensitivity analysis will be performed in order to provide information about how the model output is apportioned to the model input. In particular, the most insignificant parameters will be individuated and frozen to yield a reduced model. The developed model will then be calibrated and validated by using existing experimental data. Latter, a model predictive control system will be build taking into consideration a trace element dosing scheme.

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