Opinion

Candidature of pre-catalysis for enhanced biogas recovery from wastewater sludge in perspective of saudi arabia

Abstract

The management of wastewater sludge is considered as one of the most significant environmental problems in the current scenario. Anaerobic digestion is a competent treatment option for recycling of sludge, as it provides a high energy recovery with little nuisances. However, the efficiency of this process in sludge is hindered due to the presence of complex organics, rate limiting microbial flocs, extracellular polymeric substances, and various toxic compounds. To overcome these rates limiting factors, a pretreatment step can be applied prior to the anaerobic digestion process. Photocatalysis is considered the most effective, environmentally friendly, and advanced oxidation technology that can be used as a pre-treatment for sludge disintegration. It is a promising option in the context of low energy requirement due to the use of solar light, and high economic feasibility. In the above context, the present manuscript provides an overview regarding the potential of anaerobic digestion of wastewater sludge in special perspective of Saudi Arabia.

Keywords: Wastewater sludge, Anaerobic digestion, Biogas, Photocatalysis, Pretreatment, Saudi Arabia

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The generation of wastewater sludge is a fundamental problem which is continuing to increase due to extensive development of the industrial sector and the world economy. The annual amount of sludge production in some developed countries has been estimated, which is about 2.2million tons/y in Japan, 6.0 million tons/y in China and 8.2million tons/y in the USA as reported. Similarly, the rapid growth of industrial sector in Saudi Arabia has led to increasing the number of manufacturing industries over seven thousand in 2016.[1] which is responsible for the generation of huge amount of wastewater sludge every year. Wastewater sludge is the complex, heterogeneous mixture composed of a variety of toxic substances, pathogenic, organic and inorganic materials, and xenobiotic chemicals which may cause serious impacts to environment and health.[2] Extracellular polymeric substances in sludge are the key components which include high-molecular-weight polysaccharides, glycoproteins, proteins, nucleic acids, humic acids, and phospholipids. Wastewater sludge also contains several harmful constituents including heavy metals such as Cd, Pb, Zn, Cu, Mn, Mg, Fe, Pb, Hg and Ni which may accumulate in the soil for a longer period of time.[3] Furthermore, various pathogens have also appeared in wastewater sludge including whipworms (*Trichuris sp.*), ascarids (*Toxocara and Ascaris lumbricoides*), tapeworms (*Taenia sp. And Hymenolepis sp.*), giardia (*Giardia lamblia*) and amoeba (*Entamoeba coli*) which are responsible for various human diseases. Keeping in view the toxic nature of sludge, it must be treated before final disposal. Yet, the sludge disposal processes comprise 60% of the total operating cost of wastewater treatment cost. Anaerobic digestion is a biological process which is globally used for sludge treatment and biogas production. The process is highly advantageous, as it offers a net energy gain in the form of methane and production of nutrient rich biofertilizers, thus compensating for the total disposal cost of sludge.[4] The biogas (methane) produce in the anaerobic digestion process provide a number of benefits e.g. methane can be used as a source of electricity, energy for internal combustion, starting material for biodiesel, methanol, and other hydrocarbons. Wastewater sludge has a high potential of methane production through anaerobic digestion, as reported by Feng et al.[5] that methane production was reached up to 170 l/kg-VSS in 22 days of digestion process in the batch reactor. Moreover, mesophilic anaerobic digestion of sludge from saline fish farm effluents also reported having high methane potential up to 181 l/kg COD.[6] Besides the number of resourceful benefits of anaerobic digestion, the efficiency of the process may be hindered by various inhibitory factors in sludge. These are typically observed due to the presence of recalcitrant microbial flocs, cell walls containing cellulose, extracellular polymeric substances (EPS), lipids and complex proteins.[7] The complex organic substances of sludge are readily available to microorganisms and only are decomposed after being broken down into soluble organic compounds. In anaerobic digestion process, the hydrolysis process mainly converts complex organics into soluble ones thus, recognized as the rate-limiting step. In order to overcome the inhibitory and improve anaerobic digestion of wastewater sludge, a pretreatment step must be required. The pretreatment method may be a physical (thermal, microwave and ultrasonic), or chemical such as acid, alkali etc. However, the cost associated with these methods limit their applicability as in the case of sludge. In our opinion, the use of catalysis process, more specifically photocatalysis using nanocomposite materials could bring more potential for pre-disintegration of sludge and subsequent improvement in anaerobic digestibility for biogas production. Photocatalysis is considered as an effective and environmentally friendly advanced oxidation technology. The method is proven as high economic feasibility in the context of low energy requirement due to the use of visible light (solar) for activation of the catalyst.

Moreover, the catalyst can be recover and reused several times. The chemical oxidation during photocatalysis breakdowns the pollutants from the complex into less simple molecules which become available for further biological degradation in the anaerobic digestion process. Recently, Anjum et al.[8] reported a significant improvement in sludge solubilization using mixed metal based photocatalysis, where anaerobic digestion showed up to 43% increase in the biogas production. Similarly, an increase in biogas potential was also observed using on-site photocatalysis-anaerobic digestion reactor, in which up to 1266.7ml/L_{sludge} of biomethane production was achieved.[9] These studies confirmed that the methanogenesis could be enhanced by photocatalytic pre-treatment that sustained the supply of soluble organics to microorganisms. In more technical terms, the long hydraulic retention time in sludge digestion can be decreased by controlling the rate limiting phase i.e. hydrolysis by pre-disintegration of polymeric substances. Overall, photocatalysis pre-treatment of sludge has following advantages.

a. Disintegration of complex organic compounds of sludge to simpler molecules.

b. Increase solubilization and availability of organic molecules to anaerobic bacteria.

c. Decease hydrolytic retention time of anaerobic digestion process.

Saudi Arabia is listed among the countries which lie under the "absolute water scarcity category". Moreover, the water demand is continuously increasing at a rate of 6% annually due increasing population and industrialization. The desalination plants only contribute to 60% of total water demand; therefore, the focus is shifting towards the development of wastewater treatment plants, in order to ensure the domestic wastewater recycling and reuse. This increasing number of treatment plants also increase the generation of wastewater sludge in Saudi Arabia. Presently, the country has a total capacity of 1.84million m^3/day of wastewater treatment, where most of the facilities are located in big cities such as Riyadh and Jeddah. Overall, the country has immense potential to utilized wastewater sludge for production of biogas, moreover, the ample of solar energy can assist in the photocatalytic pretreatment of sludge to improve the performance of anaerobic digestion and biogas production.

Conclusion

In our opinion, the integrated photocatalysis-anaerobic digestion technology for wastewater sludge management could be helpful in developing an efficient sludge treatment method with the additional benefit of bioenergy production. Moreover, photocatalysis could be advantageous over conventional pretreatment processes due to low energy requirement and utilization of solar light, thus making the process highly economical.

Anknowledgement

None.

Conflict of interest

None.

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