Literature Review

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Part I
Anaerobic Wastewater Treatment

Most urban cities in developing countries have ineffective access to water. Sanitation systems and wastewater treatment are important issues in these areas often due to lack of economic support and maintenance [1]. The primary treatment is often done in a septic tank; however, the wastewater is not treated completely in the tanks, and the lack of financial support prevents developing countries from utilizing aerobic treatment processes. In many situations, wastewater is simply reintroduced into the natural environment with no prior treatment. In addition, most developing countries are faced with a lack of skilled operators as well as insufficient energy for the operation of environmentally sustainable wastewater treatment systems [1]. Anaerobic processes do have some advantages over the conventional aerobic processes used in developed countries. Some of these advantages include relatively high efficiencies of the processes, simple, scalable production, and small energy and area requirements with little sludge production. The general disadvantages that our research will address are low pathogen and nutrient removal, long startup times, and a general requirement of post-treatment to meet strict effluent standards [2]. Anaerobic wastewater treatment also effectively addresses the lack of energy supply available in the global south. McCarty et al. propose to treat wastewater as a source of source of water, energy, and nutrients rather than an unfortunate byproduct of human life. Anerobic treatment is posited as one of the best way to recover all three resources, treating the water to a quality that may be reintroduced to natural bodies of water, producing methane gas able to power turbines for electricity, and converting nitrogen and phosphorous into useful fertilizers [3].

Part II

Upflow Anaerobic Sludge Blanket (UASB)

Within the anaerobic treatment sphere, Upflow Anaerobic Sludge Bed (UASB) reactors are some of the most compact in design and have the ability to treat the highest loading rates. These have been selected for initial investigation and adaptation for effective implementation in developing nations. Aiyuk, et al. review the structure and operation of a UASB, the competing biocatalyzed reactions that occur in the reactor, and the challenges that come up during operation, such as ensuring sludge granulation during start-up and inhibiting disintegration over time [4]. The UASB reactor initially inoculated with sludge, often in granular form though it may be in a flocculent form, and operated with liquid flowing upward from the bottom of the reactor. The Upflow operation of the system causes the wastewater to flow by the dense sludge in the bottom of the reactor and fluidize the less dense sludge blanket above. Treatment occurs throughout the reactor, but we hope to characterize the level of treatment carried out in the different zones of the reactor due to the varying sludge formations. The microbes within the inoculum grow throughout the life of the reactor and may evolve sludge of varying qualities; flocculent inoculum may even form granules by itself. Sludge evolution is believed to depend on the Organic Loading Rate (OLR) and Sludge Loading Rate (SLR) during startup, though it has been shown the presence of cations may also play an important role in granule formation [2], [5]. Granules ideally prevent the need for support materials in UASBs, though we plan to investigate the effect of support materials in granule formation.

In a well operating reactor, gas is produced, containing primarily methane and carbon dioxide. The gas serves to further fluidize the reactor, assists in mixing, and the methane within the biogas may serve as an energy source if effectively captured [3]. This depends greatly upon the design of the Gas/Liquid/Solid (GLS) separator, stereotypically a funnel type design to capture as much gas as possible, allow liquids to flow out of the reactor, and direct solids downward back to the body of the reactor. It is believed the sharp angles of the GLS separator assist in the redirection of the solids, though there is little evidence to support this conclusion. We propose a GLS design to more effectively capture the solids of the reactor and improve effluent quality. This will also serve to further increase the independence of the Hydraulic Residence Time (HRT) and Solids Residence Time (SRT) of the reactor, an innate advantage of the UASB design.

If wastewater treatment has any chance of being a net energy producer, methane capture must be extremely efficient. Though COD removal rates and CH4 production rates are historically high for UASBs, Lobato et al. has demonstrated discrepancies between COD rates and CH4 rates, indicating methane within the system[6]. These losses are often unaccounted for, likely due to the absence of methane use for energy in many reactors, especially those constructed in the early days of the technology used for industrial wastewater treatment[7]. The UASB reactor designs have changed and improved since the invention of the technology; however, post treatment is still widely believed to be necessary to meet effluent standards before discharge into the natural environment. Chong et al discuss many possible options. The technologies deemed most appropriate for exploration are constructed wetlands, downward hanging sponges, and pond systems[2]. These systems improve COD, nutrient, and pathogen removal, though other very different strategies have been proposed to improve independence of treatment efficiency from ambient temperature as well as to increase nutrient removal. One simple strategy would be to source separation of nutrients by urine diversion, though this would lead to a very different wastewater.

References

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