

Start-up of an UASB-septic tank for community on-site treatment of strong domestic sewage

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Abstract

Two community on-site UASB-septic tanks were operated in parallel over a six months period under two different hydraulic retention times (HRT) of 2 days for R1 and 4 days for R2 at mean sewage temperature of 24 °C. The sewage was characterised by a high COD_{tot} concentration of 1189 mg/L, with a large fraction of COD_{sus} , viz. 54%. The achieved removal efficiencies in R1 and R2 for COD_{tot} , COD_{sus} , BOD_5 and TSS were “56%, 87%, 59% and 81%” and “58%, 90%, 60% and 82%” for both systems, respectively. R2 achieved a marginal but significant ($p < 0.05$) better removal efficiencies of those parameters as compared to R1. The COD_{col} and COD_{dis} removals in R1 and R2 were respectively 31% and 20%, and 34% and 22%. The sludge accumulation was very low suggesting that the desludging frequency will be of several years. Accordingly, the reactor can be adequately designed at 2 days HRT.

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1. Introduction

Developing countries suffer from the lack of proper wastewater collection and treatment facilities, especially in rural areas. The centralised collection and treatment systems are apparently too costly and complex to solve their wastewater problems. In Palestine about 73% of the West Bank households have cesspit sanitation and almost 3% are left without any sanitation systems (PCBS, 2000). The cesspits are left without lining, so sewage infiltrates into the earth layers and eventually to groundwater. Consequently, cesspits themselves pose increasing environmental pollution problems. Even for developed countries, the connection of dispersed human settlements like remote houses, summer houses, farms and recreation facilities to sewerage system is too costly. For instance, in Finland wastewater from rural areas (20% of the population) is a concern due to water sources pollution (Luostarinen and Rintala, 2005), and about 20% of the United States population,

resembling more than 20 million homes, are served with onsite wastewater treatment facilities of mainly septic tanks (Scandura and Sobsey, 1997). Definitely, decentralised wastewater management is inevitable for comprehensive wastewater treatment and environmental protection world wide.

The septic tank is the most known and commonly applied system for on-site anaerobic pre-treatment of sewage. However, the performance of the septic tanks is rather poor despite the long operated HRT due to their inherent design feature, viz. the horizontal flow mode of the influent sewage (Lettinga et al., 1991; Mgana, 2003). A significant improvement of the septic tank was achieved by applying upward flow and gas/solids/liquid separation device at the top, which resulted in the so called UASB-septic tank system (Lettinga et al., 1991; Bogte et al., 1993; Zeeman et al., 2000). The reactor is operated in an upflow mode as a UASB reactor resulting in both improved physical removal of suspended solids and improved biological conversion of dissolved components, and sludge gradually accumulates and stabilises in the reactor, as in a septic tank (Zeeman et al., 2000; Luostarinen et al., 2007).

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Studies with UASB-septic tanks treating domestic sewage are scarce, and to our knowledge so far only a one research project had been conducted on the use of a UASB-septic tank system for the onsite sewage treatment at Dutch and Indonesian ambient conditions by Lettinga and his co-workers (Lettinga et al., 1991, 1993; Bogte et al., 1993). Nonetheless, the system has not been applied and demonstrated in other countries of different environments and sewage characteristics nor it has been optimised. For instance, in Palestine and Jordan in the Middle East sewage is characterised with high COD concentrations exceeding sometimes 1500 mg/L with high fraction of COD_{ss} (up to 70–80%) (Mahmoud et al., 2003; Halalsheh et al., 2005). Leitão et al. (2006) pointed out that the use of the UASB system for the treatment of sewage with relatively high COD concentration is still undergoing trials and argued that such knowledge is important to improve the reliability of anaerobic processes. This is because knowledge of the performance of anaerobic reactors treating municipal wastewater in extreme situation is limited. Moreover, as the UASB-septic tank system is an accumulation system with respect to solids, the influence of sludge bed development on solids physical removal, i.e. suspended and colloidal solids removal, and conversion, i.e. hydrolysis, acidification and methanogenesis, is still to be elucidated. The main objectives of this research were to assess the process performance of the community onsite UASB-septic tank for the treatment of domestic sewage with high total COD (COD_{tot}) concentration and with high fraction of suspended COD (COD_{ss}) and also to increase the knowledge on the system design. In view of that, two UASB-septic tank reactors treating domestic sewage in Palestine had been operated under ambient conditions for a six months period at HRTs of two and four days.

2. Methods

2.1. Experimental set-up

Two pilot scale UASB-septic tank reactors, namely R1 and R2, were installed in parallel at the main wastewater treatment plant (WWTP) of Al-Bireh city/Palestine. The reactors were made of galvanized steel with working volumes of 0.8 m³ (height 2.50 m; diameter 0.638 m). Nine sampling ports were installed along the reactor height at 0.25 m for sludge sampling, with the first port at 0.15 m from the bottom of the reactors. The influent was distributed in the reactor through polyvinyl chloride (PVC) tube with four outlets located 5 cm from the bottom. Biogas was passed through a 16% NaOH solution for CO₂ scrubbing, and then methane quantity was continuously measured by wet gas meters.

2.2. Pilot plants start-up, operation and monitoring

The UASB-septic tank reactors were started up during spring, ca. April, for a period of 6 months. The reactors

were fed with domestic sewage pre-treated with screens and grit removal chamber. The sewage was pumped every five minutes to a holding tank (200 L plastic container), with a resident time of about 5 min, where the reactors were fed and the influent was sampled. The reactors were inoculated with anaerobic sludge obtained from a cesspit serving a house (R1 and R2, respectively, with 10% and 20% of the reactors volume), and operated in parallel at ambient temperature. The inoculum sludge characteristics in terms of COD_{tot}, TS, VS, VS/TS, TSS, VSS and stability were 18.3 g/l, 13.78 g/l, 9.58 g/l, 0.7, 11.15 g/l, 8.59 g/l and 60%, respectively. Stability stands for the percentage of COD converted to CH₄ out of a certain incubated amount of sludge expressed as COD (see Eq. (1)). The sludge stability was measured after 100 days of batch incubation at 30 °C. Daily monitoring was started since the onset of the experiment including wastewater and ambient temperature and biogas production measurements. Grab samples of raw sewage and reactors effluents were collected and analysed two to three times a week. The atmospheric pressure was measured *in situ*.

2.3. Analytical methods

Total suspended solids (TSS), volatile suspended solids (VSS), total solids (TS), volatile solids (VS), ammonium (NH₄⁺), kjeldahl-nitrogen (Kj-N), chemical oxygen demand (COD), biological oxygen demand (BOD), total PO₄-P, dissolved PO₄³⁻-P, SO₄²⁻ and sludge volume index (SVI) were measured according to *standard methods* (APHA, 1995). Raw samples were used for measuring total COD (COD_t), 4.4 m folded paper-filtered (Schleicher and Schuell 5951/2, Germany) samples for paper filtered COD (COD_p) and 0.45 m membrane-filtered (Schleicher and Schuell ME 25, Germany) samples for dissolved COD (COD_{dis}). The suspended COD (COD_{ss}) and colloidal COD (COD_{col}) were calculated as the difference between COD_t and COD_p and the difference between COD_p and COD_{dis}, respectively. The volatile fatty acids (VFA) analysis was carried out as described by (Buchauer, 1998). All samples were analysed in duplicate except, VFA and SVI in single.

Biodegradability of raw sewage and effluents samples were measured once in triplicate using 500 mL working volume batch reactors incubated at 30 °C for a period of 120 days as described by Mahmoud et al. (2003). Sludge stability was measured three times in duplicate as described by Mahmoud (2002).

2.4. Calculations

2.4.1. Nomenclature

COD_{tot}: amount of total COD in the tested sample (mg COD/l)

COD_{tot, inf} and COD_{tot, eff}: amount of total COD in influent and effluent (mg COD/l)

COD_{dis, inf} and COD_{dis, eff}: amount of dissolved COD in influent and effluent (mg COD/l)

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