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Research Paper

Sludge profiling at varied organic loadings and performance evaluation of UASB reactor treating sewage

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An up-flow anaerobic sludge blanket (UASB) process was investigated for the treatment of domestic wastewater using a 60 l pilot scale reactor. The treatment performance was analysed at 8 h hydraulic retention time under ambient condition (8–40 °C). Biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS) were used to evaluate the performance of organic matter and suspended solids removal. Specific methanogenic activity and solids concentration along the sludge bed height were determined to evaluate sludge quality. An average of 65–85% BOD, COD and TSS removal were achieved under different organic loadings 0.57–6.35 kg [COD] m^{-3} d^{-1}. The removal of organic matter showed a linear correlation with organic loads. The methanogenic activity decreased at lower organic loads. In addition, at low organic loads, high variations in COD reduction and low gas production were observed.

1. Introduction

The UASB technology is represented as a proven sustainable treatment system for a wide variety of wastewater especially for developing countries (Lettinga, 2008; Lettinga & Hulshoff Pol, 1986; Lettinga et al., 1981; Lettinga et al., 1993; Lettinga, van Velsen, Hobma, De Zecuw, & Klapwijk, 1980; Schellinkhout, Lettinga, van Velsen, Louwe Kooijmans, & Rodríguez, 1985; Seghezzo et al., 2002; Siddiqi, 1990; Souza, 1986; von Sperling & Chernicharo, 2005). So far much research has been done on applicability of the UASB process for various industrial and municipal wastewaters (Elmitwalli, Zeeman, & Lettinga, 2001; Khan, Gaur, Lew, Mehrotra, & Kazmi, 2011; Lew, Belavski, Admon, Tarre, & Green, 2003; Singh & Viraraghavan, 2002; Walia, 2007).

Experience has been gained from the full scale application of UASB reactors in Brazil (Chernicharo, 2006; Souza, 1986; von Sperling & Chernicharo, 2005), Indonesia (NIPHEH, 1988), India (Draaijer et al., 1992; Khan et al., 2011a, 2011b; Siddiqi, 1990) and Colombia (Schellinkhout, Jakma, & Forero, 1988) and it has also shown its importance for domestic use (Seghezzo, Geeman, van Lier, Hamelers, & Letinga, 1998). However, recent studies have shown some contradictions

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Nomenclature

APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
FC	Fecal Coliform
HRT	Hydraulic Retention Time
MLD	Million Liters per Day
MPN	Most Probable Number
NH_4–N	Ammonical Nitrogen
NO_3–N	Nitrate Nitrogen
NIPHEH	National Institute for Public Health and Environmental Hygiene
OLR	Organic Loading Rate
ORP	Oxidation Reduction Potential
PO_4–P	Orthophosphate
STP	Sewage Treatment Plants
SMA	Specific Methanogenic Activity
SVI	Sludge Volume Index
TC	Total Coliform
TSS	Total Suspended Solid
UASB	Up-flow Anaerobic Sludge Blanket

regarding the performance of UASB reactors installed in various sewage treatment plants (STPs) in India. The effluent originating from these UASB reactors do not follow the required stringent disposal standards. Khan et al. (2014) investigated 10 full-scale UASB reactors treating domestic wastewater at different cities of India. Results inferred that the treatment performance of these UASB reactors in terms of biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS) were between 55 and 70%. The BOD and TSS of the UASB effluent at all UASB reactors were ranged between 60–120 and 50–150 mg l^{-1} respectively. The poor performance of UASB reactors was mainly due to fluctuations in influent characteristics, improper desludging and poor operation and maintenance. In order to increase the effluent quality up to disposal standards, polishing ponds were used to treat the UASB effluent. Unfortunately, effluent quality did not follow the desired standard limits even after polishing ponds were used (Khan et al., 2011a, 2011b; Sato, Okubo, Onodera, Agrawal, & Ohashi, 2007).

Therefore, based on results of these studies, experience gained from the performance of UASB reactors and their individual post treatment systems, a pilot-scale UASB reactor was commissioned in the Environmental Engineering Laboratory, Department of Civil Engineering, Indian Institute of Technology, Roorkee and extensively monitored for the treatment of sewage under ambient temperatures. In order to compare the treatment performance identical operating conditions were maintained so that the poor performance of full-scale UASB reactors could be investigated. Hydraulic retention time (HRT) was maintained for 8 h throughout the study period, following initial start-up, in order to make it identical to a full scale UASB reactor working in the field. The primary goals of running the pilot scale UASB reactor treating sewage were:

- To evaluate the long term performance of UASB reactor working under controlled operation and maintenance at varying organic loads.
- To investigate the sludge profile by validating the sludge blanket model.

2. Methods

2.1. *Configuration of pilot scale UASB reactor*

Pilot scale UASB reactor of 60 l capacity installed at IIT Campus, Roorkee, India was made of clear acrylic plastic material. The total height, base area and effective volume of the reactor were 1.5 m, 0.2 × 0.2 m (square section) and 45 l respectively. A gas-liquid-solids separator (GLSS) with effluent port and gas collection facility was installed at the top of the reactor as an inverted cone to retain granular sludge. The influent was introduced from the bottom of the reactor through a conical base to ensure the even distribution of the feed across the reactor. Effluent from the UASB reactor outlet flowed into a U-tube seal to prevent the escape of biogas. The schematic diagram of experimental setup is shown in Fig. 1.

The UASB reactor was started with 15 l inoculum/or seed sludge. The seed sludge was collected from a 38 × 10^6 l d^{-1} throughput UASB based STP situated at Saharanpur, India at coordinates (29° 55′ 48.60″ N and 77° 30′ 41.34″ E). The average TSS and volatile suspended solids (VSS) concentrations in the reactor were 24.4 and 10.9 g l^{-1}, respectively. The specific methanogenic activity (SMA) and sludge volume index (SVI) of seed sludge were 0.03 g [CH_4–COD] g^{-1} VSS d^{-1} and 20 ml g^{-1} respectively. To overcome the interference of ambient temperature, the UASB reactor was initially placed inside a chamber to maintain a temperature around 32 ± 3 °C and operated at organic loading of 0.180 g [COD] L^{-1} d^{-1} as per the guidelines given by Lettinga et al. (1980). The start-up period was around three weeks. After this period, the reactor was operated at 8 h HRT for about 3.5 years.

The pilot UASB reactor was stopped for four months to analyse the data and then restarted and operated for another nine months from October, 2010 to June, 2011.

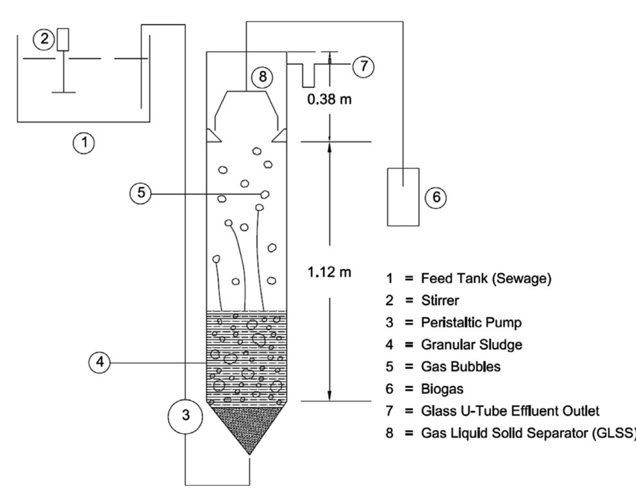

Fig. 1 – Schematic representation of UASB reactor.