Sewage and Low Strength Wastewater Treatment

The start-up of an anaerobic treatment plant is a time consuming and rather difficult process. Due to the fact that large numbers of parameters are responsible for start-up of the reactor, which aims at development of bacterial mass, adopted to the particular characteristics of the wastewater. If overloading of the reactor occurs during start-up, acid fermentation can become predominant over methanogenic fermentation, resulting in souring reactor contents. However, being low strength wastewater for domestic sewage treatment start-up is less difficult. In addition, the sewage contains the bacterial populations necessary for the anaerobic digestion. Therefore, UASB reactor treating sewage can be started without needing any seed material as inoculum. In empty reactor once the feeding is started, the populations for acid and methanogenic digestion will develop spontaneously.

The buffer capacity of sewage is generally sufficiently high, and hence, the risk of souring of the reactor contents is remote during start-up period. The UASB reactors treating sewage at Kanpur, Pedregal, and Bucarmanga were started without using any seed sludge. [Haandel and Lettinga, 1994]. No difficulties were experienced in these plants and the start-up was complete within 12-20 weeks. In all the plants full sewage flow was applied from the start of the operation. Thus, it can be said that the UASB systems can be started up without any serious problems using the empty reactor at the design flow during sewage treatment. However, to accelerate start-up it is advantageous to use seed sludge. The start-up period can be considered as being complete when the effluent quality remains constant at the design load and the sludge mass present in the reactor also remains constant, both qualitatively and quantitatively.

The correct bacterial populations will develop during the start-up period as a result of the growth of the bacterial groups, capable of converting organic material into methane. The total amount of sludge that can be accumulated in the reactor is limited by physical size of the reactor. When the reactor is full with sludge, the excess sludge generated will be washed out of the reactor. From that instant onwards the sludge mass in the reactor will remain basically constant and the daily mass of sludge generated becomes the daily mass of sludge discharged with the effluent.

To evaluate the performance of the UASB reactor, it is important to know whether the reactor is operated at its maximum sludge hold-up, or under conditions where effluent settleable solids concentration is minimized by applying periodic excess sludge discharge, before the maximum hold-up is attained. Because, the excess sludge present in the effluent will constitute a considerable fraction of the effluent BOD, COD and TSS Concentrations. It is reported that at Pedregal plant operated at maximum sludge hold-up the BOD, COD and TSS removal efficiencies were 85, 75 and 68 percent, respectively for raw effluent [Haandel and Lettinga, 1994]. These values were increased to 91.5, 85 and 83 percent when the effluent was allowed to settle for 30 minutes. Hence, about half of the BOD, COD, and TSS in the raw effluent are attributed to the presence of settleable sludge particles. The average performance of the UASB reactor treating sewage is presented in Annexure I.

Lettinga *et.al.,* [1983] effectively treated sewage in 0.12 m^3 laboratory UASB reactor at 8-20^{0}C temperature in dry weather conditions and reported 65-85% COD removals at hydraulic loads as high as 2 and 3 m^3/ m^3.d. Vieira [1988] and Vieria *et.al.,*[1986] reported several results of experiments with UASB reactors applied to the treatment of domestic sewage. In the operation of a 106 L reactor inoculated with granular anaerobic sludge (grown in settled domestic sewage, at 35^{0}C, in a reactor previously inoculated with digested sewage sludge), at an average temperature of 20^{0}C during winter and 23^{0}C during summer, and HRT of 4 h, BOD removal efficiencies of 69% were observed during sewage treatment. COD removal was 60% and 65% during winter and summer, respectively. Suspended solids removal was 69% during this period. Gas production of 100 and 119 L gas/ kg COD added was obtained during winter and summer respectively. In the operation of a 120 m^3 UASB reactor inoculated with digested sewage sludge, at a temperature of 21-25^{0}C and HRT of 4.7 h, BOD_5 removal efficiencies of 61% were attained. COD removal was 50% and TSS removal was 73%. Gas production of 121 L gas /kg COD added was reported.

Man *et.al.,*[1986] investigated the performance of three UASB reactors of different volumes (0.12, 6 and 20 m^3). The reactors were started using granular seed sludge. They observed that the anaerobic treatment of sewage having COD 500-700 mg/L, at HRT 7 to 12 h, and at temperatures in the range of 12 to 18^{0}C, the COD removal efficiency of 40 to 60% was obtained in pilot-scale UASB reactor. Even at temperature as low as 7-8^{0}C, COD removal efficiency of 45-65% was obtained at an HRT of 9-14 h. These results demonstrated that anaerobic treatment is still fairly efficient at temperatures as low as 7-8^{0}C, although the HRT should exceed 9 h under these conditions. In a second set of experiments performed in the 20 m^3 UASB reactor, Man *et.al.,* [1986] reported that, while treating a very dilute septic tank effluent having COD 350 mg/L and

COD/BOD ratio as 3.5, high efficiencies could not be achieved at an HRT below 12 h and temperature in the range of 6-17^{0}C. In an third set of experiments performed in the 20 m^3 UASB reactor inoculated with granular seed sludge, Man *et.al.,*[1988] observed that COD removal efficiency was decline continuously from 61 to 48% and the gas production dropped from 80 to 31 L CH_4/ kg COD added while treating sewage with COD 740-1280 mg/L. The methanogenic activity of the granular sludge in the reactor dropped to approximately 4% of its original activity. The reactor was operated with HRT of 13-14 h and a temperature range of 10 to 15^{0}C. The causes of this activity loss were points of further extensive investigations.

Monroy *et.al.,* [1988] reported the results of the operation of a 110 L UASB reactor for raw domestic sewage treatment. The reactor was inoculated with anaerobically batch-adopted activated sludge. The sewage temperature was 12 to 18^{0}C and the HRT was 18 h. They obtained COD removal efficiencies of COD as 65% and TSS as 73%. A multi-target study was conducted to assess the feasibility of the UASB reactor system for the anaerobic treatment of raw domestic sewage (low strength complex wastewater, COD_{total} = 200-700 mg/L and CODss = 45-55% of COD_{total}) combined with sludge stabilization process under a moderate temperature of 18 – 20^{0}C [Sayed, *et.al.,*1995]. The study has produced a design of a modified Three-phase separator (TPS) to control the sludge retention inside the UASB reactors as well as the determination of design parameters of the treatment process *viz.* the hydraulic retention time (HRT), the potential period of loading the UASB reactors, and the most convenient digestion time required for advanced sludge stabilization. The study was performed in Two-stage Flocculent–Granular Sludge UASB reactor system. The proposed system was very effective in providing an excellent biological treatment of raw domestic sewage at moderate temperatures of 18-20^{O}C together with an advanced sludge stabilization process.

To assess the feasibility of the UASB process for one-step treatment of raw domestic sewage from a separate sewer system under Dutch-climatic conditions, Lettinga, *et.al.,* [1988] carried out a pilot–scale research at the sewage treatment plant in Leystad. The sewage contained approximately 450 mg/L suspended solids COD, 150 mg/L colloidal COD and 300 mg/L soluble COD. Small scale laboratory experiments indicated that these COD fractions could be removed as 90, 50, and 70%, respectively at temperatures of 10-20^{0}C. The successful performance of a pilot-scale (55 L) UASB reactor treating municipal sewage without any supplementary heating was examined in a 200 day trial [Schelinkhout, *et.al.,* 1992]. Singh, *et.al.,*[1996] has studied the feasibility of anaerobic treatment of a low-strength (500 mg COD/L) synthetic wastewater using a semi-pilot-scale UASB reactor. Under ambient temperature conditions (20-35^{0}C) with a HRT of 3 h and corresponding organic loading of 4 kg COD /m^3.d, 90-92% COD and 94-96% BOD reduction were achieved.

Sousa, *et.al.,* [1996], proposed a combined anaerobic-aerobic system composed of an UASB reactor followed by sequencing batch aerobic reactors (SBR) for domestic sewage treatment. In such a system, the UASB reactor removed considerable fraction of the influent organic matter while the SBRs oxidized part of the remaining organic matter and ammonium nitrogen. A proper system operation also permitted the removal of nutrients (N and P). The system composed of an UASB reactor followed by two SBRs was efficient in removing COD (95%), TSS (96%), and TKN (85%). The low energy consumption for aeration and low excess sludge production, besides the efficient performance are important factors to regard UASB-SBR system as an important alternative for sewage treatment in tropical regions.

A pilot-scale UASB reactor was used to study treatment of municipal landfill leachate (COD 1.5 to 3.2 g/L) at low temperature (13-23^{0}C) and in on-site conditions for 226 days. The reactor was successfully operated by decreasing the process temperature due to the decrease in leachate temperature in winter. Despite changes in leachate quality, 65-75% COD and up to 95% BOD removals were achieved at 18-23^{0}C [Kettunen and Rintala, 1998]. High-rate anaerobic processes (such as, UASB and Anaerobic filter) have been shown to be efficient in the treatment of municipal landfill leachate having a COD higher than 800 mg/L and the BOD/COD ratio higher than 0.3.

Ginter,*et.al.,*[1997] studied manganese removal mechanisms in lab-scale UASB reactor employing stirrer. Mn removal, in the absence of sulphate in the reactor feed, was low as 7.2%, but up to 40% Mn removal could be achieved in the presence of sulphate. Mn was removed by adsorption onto the existing solids in the sludge and onto newly grown biomass, and also by co-precipitation processes, which could be strongly enhanced by other heavy metal ions in solution. In the presence of cadmium in the reactor feed, manganese removal could be increased to 56%. An upflow sludge blanket reactor without a carrier for the biomass was used for nitrate removal by Klapwijik, *et..al.*,[1981]. The feasibility of anaerobic treatment of an electronics manufacturing glycol solvent wastewater by UASB process was studied by Morris, *et.al.,*[1995]. Agrawal *et.al.,* [1997] have reported treatability studies of raw sewage in temperate climate (19-

20^0C) using UASB reactor. For two years operative UASB at 7 h HRT, 90% of COD removal could be achieved.

The world's first full-scale UASB reactor demonstration plant for treatment of municipal sewage was built in Kanpur, Indian 1989 (capacity 5 MLD) under the Indo-Dutch project and has been in successful operation since then [Areceivala, 1995]. Subsequently, under the same project a 14 MLD unit was designed and built in Mirzapur UP, and yet another 36 MLD unit is being commissioned for Kanpur to treat sewage mixed with tannery wastes. A similar plant of 50 MLD capacity is now being designed for Hydrabad city sewage as part of its master planning for Hydrabad [Areceivala, 1995].

Monory *et.al.*, [2000] have reported successful performance of UASB reactor for sewage treatment in Mexico. They have reported performance of full-scale and pilot scale UASB reactors (about 25 nos.) at various places in Mexico. The COD removal efficiencies in the range between 70 and 80% were reported for sewage treatment in UASB reactor. The hydraulic retention time ranging between 6 to 12 hrs and loading of 0.4 to 3 kg COD /m^3.day was reported at various UASB reactors at operating temperature ranging between 15 and 25^OC. For further treatment of the sewage post treatment such as filtration, sedimentation aerobic lagoons, and chlorination were reported for UASB reactor effluent.

It is possible to give separate treatment of small community wastewater in UASB reactor. Zeeman *et.al.* [2000] have reported successful application of UASB reactor for the treatment sewage from large buildings. The UASB reactor, followed by aerobic membrane bioreactor was reported to be feasible for the treatment of crushed organic garbage, filtered prior to UASB reactor. This combined anaerobic-aerobic process is reported to give high treatment efficiency of simultaneous organic carbon and nitrogen removal [Imai *et. al.*, 2000].

Under moderate climate conditions, the ambient temperatures of many wastewaters are considerably lower than the optimal temperature of the biological wastewater treatment process such as, nitrification, denitrification, and methanogenesis [Salih *et.al.,* 1999]. In pilot experiment Castillo *et.al.*, [1997] reported that at 19^oC temperature with Hydraulic Retention Time (HRT) of 3 h, 35 % of TCOD removal was observed in the UASB reactor, and at 12^OC with HRT of 6 h, COD reduction of 47% was reported. Using two Rotating Biological Contactor (RBC) in series as post treatment (hydraulic loading 0.34 m^3/m^2.d) a final TCOD removal of 84% was reported at 19^{O}C and 88% at 12^{O}C (with double HRT). Final BOD value ranging from 7 to 35 mg/ L were reported to obtained for inlet BOD of 283 to 303 mg/L [Castillo *et. al.*, 1997].

The performance of UASB reactor and other high rate anaerobic processes for sewage treatment at low temperature was reported by Elmitwalli, *et. al.* [1999]. For temperature between 12 and 20^{0}C, and HRT of 4 to 18 hrs the UASB reactor was reported to give 30 to 80% COD reduction efficiency. Lower efficiency was reported at low temperature. At 20^{o}C, the efficiency reported was around 75% and for lower temperature, the efficiency reported was about 50%. The anaerobic filter was reported to give about 50% efficiency at HRT of 6 hr at temperature as low as 10^{0}C. Both granular and flocculent form of sludge was reported for UASB reactors and efficiency as high as 80% was reported even with flocculent sludge in the UASB reactor at 20^{0}C [Elmitwalli *et. al.*, 1999].

For an HRT range of 5 to 15 h, it was reported that the organic removal efficiency did not vary appreciably, having maintained a value of about 60% for COD and 70% for BOD and 70% for TSS with effluent quality varying between 80 to 150 mg COD/L [Vieira & Garcia, 1992]. As the domestic sewage has a relatively low organic load, the limiting design parameter is the hydraulic load. For average flows, an HRT of above 6-8 hours is recommended for design. This help in maintaining sufficient organic loading to the reactor so as to help in providing sufficient mixing inside the reactor due to produced biogas.

The loading above 1-2 kg COD/ m^{3}.d is essential for proper functioning of reactor [Lettinga *et. al.*, 1993]. However, very high organic loading is also detrimental for granule formation, but very high organic load can not be achieved for sewage treatment in UASB reactor due to limitations of hydraulic loadings. Alaerts *et. al.*, [1993] reported that, for sewage treatment using UASB reactor under lower organic loading between 0.4 - 0.9 kg COD/ m^{3}.d, the efficiency of COD and BOD removal was 24-54% and 24-53%, respectively at HRT 8 to 15 h. When loading rate was 2 kg COD/m^{3}.d the removal efficiency for COD and BOD removal was 50-75% and 70-90%, respectively, at HRT of 6 h.

The UASB reactor is becoming increasingly popular for the treatment of various wastewaters. The possibility of using UASB reactors is an attractive alternative especially for developing countries where there is a need for low cost and reliable method for wastewater treatment

[Gnanadipathy and Polprasert, 1993]. It is clear from the performance of UASB reactors treating sewage that, the COD, BOD, and TSS removal efficiencies depend on the applied retention time. The optimum retention time to be applied depends on the desired result and whether or not any post-treatment is applied. The treatment efficiency is also correlated with the applied upflow velocity. In general, the upflow velocity less than 0.5 m/h is observed to be favorable for getting COD and BOD removal greater than 70%. For increase in upflow velocity reduction in removal efficiency was reported. [Haandel and Lettinga, 1994].