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# Mass balance of anionic surfactants through up-flow anaerobic sludge blanket based sewage treatment plants

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ABSTRACT

The outcome of a 21-month monitoring study on anionic surfactants (AS) at five (27–70 ML/d) up-flow anaerobic sludge blanket (UASB) based sewage treatment plants (STPs) is described. The average removals of AS were around 8–30%. Appreciable concentrations of AS were being discharged to the watercourse (average 4.30 mg/L; range 3.60–4.91 mg/L). On an average dried sludge contained 1452 mg AS/kg dry weight. Mass balance at three STPs indicated that, AS load of the order of 5–17% and ≈12% is removed by adsorption in UASB reactors and polishing ponds (PP) respectively. Biodegradation of AS under anaerobic conditions in UASB reactors and PP does not seem to take place. In the sludge stream, appreciable biodegradation (≈46%) of adsorbed AS under aerobic conditions on the sludge drying beds takes place. If influent AS mass flux is normalized to 100 units, than average of ≈74 and ≈7 units are discharged with treated effluent and dried sludge respectively, while 12 and 6 units are adsorbed/settled in PP and aerobically biodegrade on sludge drying beds respectively. At two STPs (34 and 56 ML/d), the filterable fluxes in UASBR increased so that the mass balance could not be computed.



*Keywords:* Anionic surfactants; Up-flow anaerobic sludge blanket reactor; Anaerobic digestion; Mass balance; Sludge drying beds

## 1. Introduction

Anionic surfactants (AS) are the primary cleaning agents used in laundry and cleaning products. Linear alkylbenzene sulfonate (LAS) is most widely used AS. The key for protecting the environment from the negative impact of down-the-drain-chemicals is the treatment of the wastewater/sewage. Activated sludge is most widely used treatment process. Sorption of AS onto the biosludge and biodegradation under aerobic conditions result in 98–99% removal (Cavalli et al., 1993; Water and Feijtel, 1995; Matthijs et al., 1999; Holt et al., 2003). Under aerobic conditions, total mineralization of LAS proceeds through degradation of the alkyl group via ω-oxidation, β-oxidation, desulfonation and finally degradation of the phenyl ring (Haggensen et al., 2002). Biodegradation under anaerobic conditions has been believed not to occur for a long time. LAS degrade very slowly, or that, until now, it has widely been believed that no degradation takes place under anaerobic conditions. However, recently indications of anaerobic biodegradation of LAS have been reported (Denger and Cook, 1999; Angelidaki et al., 2000; Mogensen and Ahring, 2002; Sanz et al., 2003; Lobner et al., 2005) based on studies conducted in pilot and bench-scale UASB reactors. It is concluded that under certain specific conditions AS are biodegraded without the presence of oxygen. However, metabolic pathways of anaerobic biodegradation are yet to be identified and understood.

The amount of surfactants present in the dried sludge is highly dependent on the process used for sludge processing i.e. aerobic or anaerobic. The most important parameter in limiting the surfactant content in the finally dried sludge is the aerobic condition during processing. Biodegradation of AS under anaerobic methanogenic conditions in sludge treatment has not yet been demonstrated. Anaerobically digested sludge contains on an average 10,500 (±5200) mg LAS/kg dry wt. while aerobically digested sludges contain on an average only 150 (±120) mg LAS/kg dry wt. (McAvoy et al., 1993).

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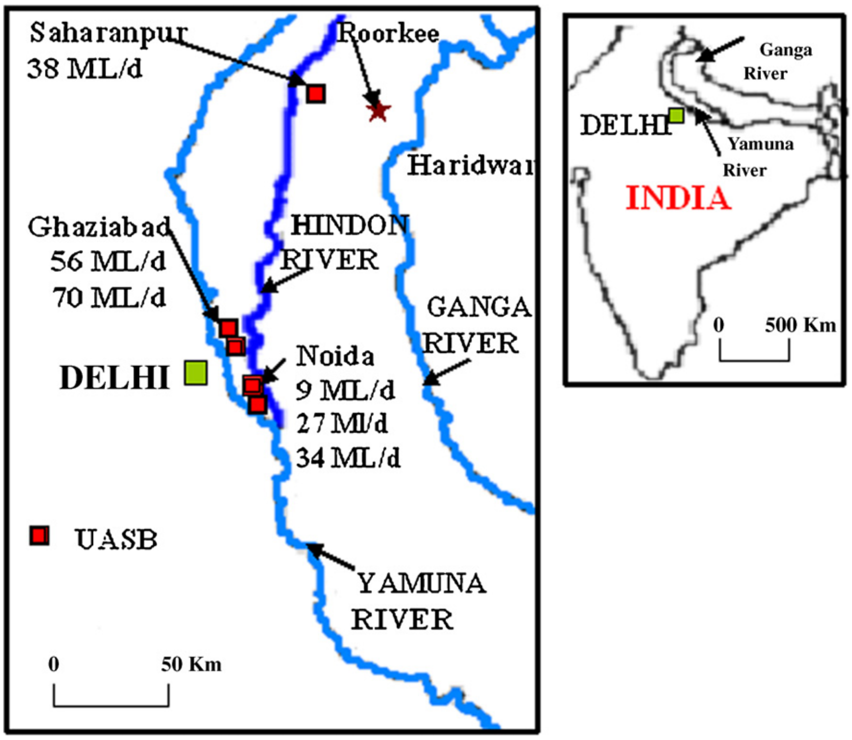


**Fig. 1 – Locations of investigated STPs with their treatment capacities.**

Recently, sixteen full-scale UASB reactors with a total installed capacity of 598 ML/d have been constructed in North India in towns situated along river Yamuna and its tributary Hindon (Fig. 1). Their treatment capacities vary from 10 to 78 ML/d. All were almost identically designed and constructed around the same time (September 1998–January 2004). Hydraulic detention time (HRT) adopted in the design ranged from 8.4 to 10.9 h for the UASB reactors and 1.0–1.6 days for the polishing ponds (PP). However, in-spite of the full-scale application of UASB since over fifteen years, data on the removal or biodegradation of AS in a field UASB reactor is not available. Whatever little work has been done on the removal of AS in a UASB reactor has been carried on laboratory or pilot scale reactors. These studies have been carried out under laboratory conditions which on occasions do not take into account or do so only in part, the actual situation in which AS find themselves after being discharged into the environment. This paper presents the results of a study of the removal/mass balance of AS at the five full-scale UASB-PP based STPs.

## 2. Materials and methods

### 2.1. Site descriptions

Five UASB based STPs, one in Saharanpur (29° 58′ N, 77° 23′ E) of 38 ML/d capacity, two in Noida (28° 20′ N, 77° 30′ E)

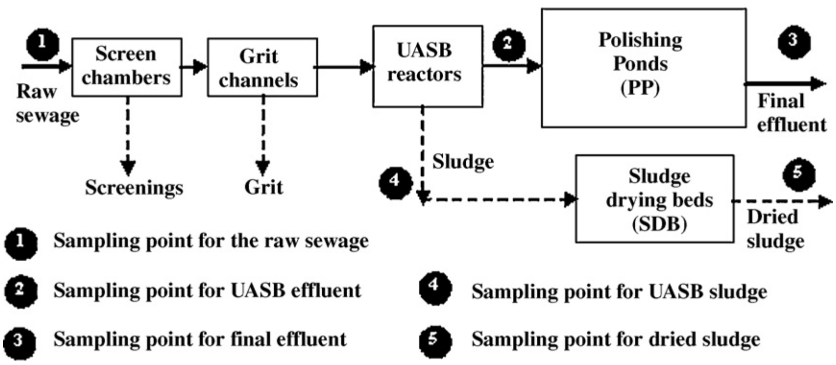


**Fig. 2 – Typical flow diagram of UASB based STPs studied along with sampling locations.**

**Table 1 – Dimensions and other details UASB reactors.**

| Parameters/design flow | 27 ML/d | 34 ML/d | 38 ML/d | 56 ML/d | 70 ML/d |
|---|---|---|---|---|---|
| UASB reactors numbers | 3 | 4 | 4 | 4 | 4 |
| Dimensions, $L \times W \times D$ (m) (each) | 24 × 28 × 6.10 | 24 × 24 × 6.25 | 28 × 24 × 6.05 | 32 × 32 × 6.10 | 32 × 40 × 6.38 |
| Effective depth (m) | 5.55 | 5.90 | 5.55 | 5.60 | 5.88 |
| Effective volume of reactors ($m^3$) | ≈11,200 | ≈13,600 | ≈15,000 | ≈23,000 | ≈30,000 |
| HRT (at average flow) (h) | 9.9 | 9.6 | 9.4 | 9.8 | 10.3 |
| Average operating flow (ML/d) | 25.4 | 31.6 | 30.6 | 42.4 | 59.5 |