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# Feasibility of sewage water treatment in Skaka City using up-flow anaerobic sludge blanket (UASB) reactor.

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Feasibility of using up-flow anaerobic sludge blanket (UASB) reactor for the treatment of sewage water was studied. Three similar UASB reactors were operated at three different hydraulic retention time (HRT) of 6, 8 and 10 hrs. The reactors were operated with activated sludge inoculation in June 2011. Sample Collection was carried out after the steady state has been reached (around two months). The results showed that the efficiency of UASB reactors were comparable for the removal of chemical oxygen demand (COD), biological oxygen demand (BOD) and total suspended solids (TSS). On the other hand, the removal of fecal coliform (FC) did not exceed two log units in most cases. The results revealed that the quality of the effluent was not complying with WHO regulatory standards for reuse for irrigation. Consequently, post treatment step is of vital importance to protect the environment.

**Key words: UASB, Anaerobic Treatment, domestic wastewater, COD, BOD, TSS.**

The increasing scarcity of water in the world along with rapid population increase in urban areas raises a great concern and the need for appropriate wastewater reuse practices, especially for irrigation. An adequate protection of the environment is of vital importance for all living creatures. Considering the world-wide deterioration of the environment, it is of utmost importance to find sustainable solutions in the very near future. Scarcity of water resources represents one of the major challenges facing the world in general and the Kingdom of Saudi Arabia (KSA) in particular (Al-Zahrani, 2010).

Built-up and usually expensive and sophisticated systems for wastewater treatment usually fail at short notice, especially in developing countries: no manpower, no finances for operation, maintenance of equipment, etc (Crites and Tchobanoglous, 1998). There is a great need and demand to develop reliable technologies that treat domestic wastewater in these urban regions. Requirements remain simplicity, non-sophisticated equipment, high system output, low capital costs, and low operating and maintenance costs. In addition, consonant with population growth and increase in urbanization, the cost and availability of land is becoming limiting, and ‘‘footprint size’’ is increasingly becoming important in the choice of a treatment system. One thus searches for simple, sustainable and compact designs (Sunny *et al*., 2006).

The technology of anaerobic digestion has became well established in the treatment of industrial and urban effluents because of factors such as its low implementation and maintenance costs, its excellent organic matter removal rate and the production of methane (Lettinga et al., 2001). A better understanding of the microbiological and hydraulic mechanisms that regulate the system had contributed to the development of more compact and modern high-rate reactors, such as the upflow anaerobic sludge blanket (UASB), which combines operational simplicity and efficiency (Miranda et al., 2005). The success of the UASB process lies in its capability to retain a high concentration of immobilized active biomass because of the granulation of sludge particles (Hulshoff Pol, 1989).

From the foregoing, anaerobic digestion presents a high potential in most developing countries for domestic wastewater treatment, and thus is a suitable and economical solution (Foresti, 2001). The anaerobic process can serve as a viable alternative, compared to conventional aerobic processes (Lettinga, 1995; Schink, 2002), for a variety of reasons. The fact that the process can be carried out in decentralized mode means also that this application can lead to significant savings in investment costs of sewerage systems (Kalogo and Verstraete, 2001; Lettinga et al., 2001; Verstraete et al., 2002 ; Sunny et al., 2006). It was therefore, the purpose of the present work is to study the feasibility of using UASB reactor for the treatment of domestic wastewater.

## MATERIALS AND METHODS

### UASB Reactor:

Three similar UASB reactors were designed, manufactured and used in this study. The UASB reactor consists of a cylindrical column (height: 2 m & internal diameter of 0.2 m) with a flat shaped bottom and gas/solid separator (GSS) at the top (Figure 1). The reactor was provided by 4 ports along its length for sludge sampling. The UASB reactor was inoculated with activated sludge from the wastewater treatment facility. The total amount of digested sludge added to the reactor was approximately 12 l, which represents 60% of the total reactor volume.

This work was carried out at three different hydraulic residence time (HRT), 6, 8 and 10 hours (table1). The following Table shows the HRT, hydraulic loading rate (HLR) as well as organic loading rate (OLR) throughout the study.

### Sampling and analytical methods

Composite samples of raw sewage and UASB effluent were collected and analyzed for chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), total phosphorus (TP), total Kjeldahl nitrogen (TKN), ammonia, total coliform (TC), fecal coliform (FC).

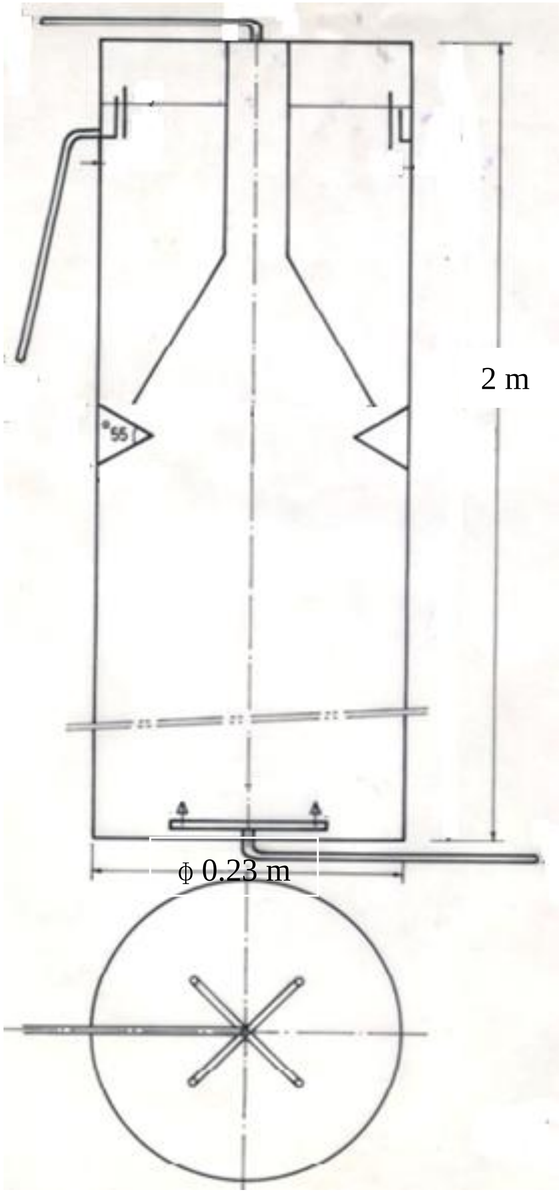


**Figure 1: The dimensions of the UASB reactor used in the study**

**Table 1: Operating conditions of the UASB reactor throughout the study**

| Item | Run 1 | Run 2 | Run 3 |
|---|---|---|---|
| **HRT (hr)** | 6 | 8 | 10 |
| **HLR (l/day)** | 332 | 249 | 199.2 |
| **OLR (kg/m$^3$/day)** | 3.4 | 2.55 | 2.04 |

Physicochemical analyses were carried out according to Standard Methods for Examination of Water and Wastewater (APHA, 2005).

### Microbiological examination

Three-fold dilutions were prepared from each sample and used to determine the bacterial indicators TC, FC (APHA, 2005).

### Statistical analysis

The arithmetic averages of percent removal and descriptive statistics were applied to the collected data using Microsoft Excel XP version 2003.

## RESULTS AND DISCUSSION

### Raw sewage:

The COD values were in the range of 620-980 mg/l with an overall average of 850 mg/l while, the concentration of BOD and TSS were in the range of 420 - 690 mg/l and 185 – 365 mg/l, respectively (table 2). The ratio of BOD/COD is about 0.7. The average concentration of TKN, ammonia and TP were 62, 45 and 5.5 mg/l, respectively.

### Run 1:

Table 3 shows the performance of the UASB reactor for the treatment of sewage water at 6 hours detention time. The concentrations of COD, BOD and TSS were reduced by 66.5%, 67.8% and 70.6%, with corresponding concentrations of 285, 190 and 78 mg/l, respectively. The concentration of organic nitrogen was reduced from 17 to 13 mg/l by removal efficiency of 23.5%. On the other hand, concentration of TP was reduced from 5.5 to 4.8 mg/l with removal efficiency of 12.7%. The bacterial count represented by TC and FC was reduced only by two log units during this run. TC and FC was reduced from 8 x $10^8$ and 6.2 x $10^7$ to 5x$10^6$ and 6x$10^5$ MPN/100 ml, with removal efficiency of 99.375% and 99.032%, respectively.

### Run 2:

The HRT in Run2 was fixed at 8 hours and the performance of the UASB reactor was evaluated (table 4). The concentration of organic load represented by COD and BOD was reduced from 850 and 590 to 238 and 160 mg/l with removal efficiency of 72% and 72.9%, respectively. The concentration of TSS was reduced by 78.5% with residual concentration of 57 mg/l. The organic nitrogen was reduced from 17 mg/l to 9 mg/l with removal efficiency of 47%. The removal of bacterial indicator (FC) count didn't exceed two log units. The counts of TC and FC were reduced from 8 x $10^8$ and 6.2 x $10^7$ to 3.6x$10^6$ and 5.5x$10^5$ MPN/100 ml, with removal efficiency of 99.55 and 99.113% respectively.

### Run 3:

The HRT was 10 hours in Run 3. The efficiency for removal of COD, BOD and TSS was found to be 74.7%, 75.4% and 81% with residual concentration of 215, 145 and 48 mg/l, respectively (table 5). The organic nitrogen was greatly reduced from 17 mg/l to 2 mg/l with conversion efficiency of 88.2%. The removal of bacterial counts (TC and FC) didn't exceed two log units. The efficiency of removal of TC and FC was 99.625% and 99.194%, with residual concentration of 3x$10^6$ and 5x$10^5$ MPN/100 ml.

### Comparison between the treatment runs

Figure 2 shows the efficiency of the UASB reactor for removal COD, BOD and TSS at different operating conditions. It was noted that the efficiency of the removal increased gradually by increasing the HRT.

The concentrations of TKN, Ammonia, organic nitrogen and TP are presented in figure 3. It was clear that the organic nitrogen was reduced by increasing the RT from 6 to 10 through 8 hours. Organic nitrogen entrapped within the biological anaerobic system and conversion of some of TKN to ammonia took place by ammonification process. The organic nitrogen removal was found to be a function of HRT (El-Khateeb & El-Gohary 2003, Klimiuk and Kulikowska, 2006). The removal of TP increased by increasing the HRT.

The effectiveness of wastewater treatment systems with respect to the elimination of microbiological pollution is often measured by determining the densities of TC and FC in effluent of wastewater treatment plants. WHO has recognized coliforms (TC and FC) as the key fecal indicators (WHO, 2002).

The counts of TC and FC were not affected by the increasing of HRT (figure 4). The major part of bacteria (TC as well as FC) are associated with the suspended solids and removed by entrapment in the UASB sludge bed (El-Khateeb et al., 2006; Mungray and Patel, 2011). The enhancement of removal of bacteria (especially colifroms) can be achieved by integration of bacteria to the biofilm created in the reactor (Tawfik et al., 2004). But in all runs the FC count was found to be more than 1x$10^{3}$ which is the permissible level for treated effluent reuse for irrigation (WHO 1989). The dotted line in Figure 4 is the permissible level of FC stated by WHO for treated effluent reuse.

**Table 2: Characteristics of raw sewage**

| Parameter | N* | Unit | Raw sewage |
|---|---|---|---|
| **COD** | 25 | mg/l | 850 (± 295) |
| **BOD** | 25 | mg/l | 590 (± 155) |
| **TSS** | 25 | mg/l | 265 (± 95) |
| **TKN** | 19 | mg/l | 62 (± 12) |
| **Ammonia** | 19 | mg/l | 45 (± 10) |
| **TP** | 19 | mg/l | 5.5 (±1) |
| **Organic nitrogen** | 19 | mg/l | 17 (± 8) |
| **TC** | 17 | MPN/100 ml | 8 x $10^{8}$ (± 3 x $10^{8}$) |
| **FC** | 17 | MPN/100 ml | 6.2 x $10^{7}$ (± 2 x $10^{7}$) |

* Number of samples

**Table 3: Performance of the UASB reactor at 6 hours detention time**

| Parameter | N* | Unit | Raw sewage | UASB Effluent | %R |
|---|---|---|---|---|---|
| **COD** | 25 | mg/l | 850 (±295) | 285 (±100) | 66.5 |
| **BOD** | 25 | mg/l | 590 (±155) | 190 (±65) | 67.8 |
| **TSS** | 25 | mg/l | 265 (±95) | 78 (±33) | 70.6 |
| **TKN** | 19 | mg/l | 62 (±12) | 54 (±23) | 12.9 |
| **Ammonia** | 19 | mg/l | 45 (±10) | 46 (±18) | -2.2 |
| **TP** | 19 | mg/l | 5.5 (±1) | 4.8 (±1.7) | 12.7 |
| **Organic nitrogen** | 19 | mg/l | 17 (± 8) | 13 (± 6) | 23.5 |
| **TC** | 17 | MPN/100 ml | 8 x $10^{8}$ (± 3 x $10^{8}$) | 5x$10^{6}$(±2x$10^{6}$) | 99.375 |
| **FC** | 17 | MPN/100 ml | 6.2 x $10^{7}$ (± 2 x $10^{6}$) | 6x$10^{5}$ (±1x$10^{5}$) | 99.032 |

* Number of samples

**Table 4: Performance of the UASB reactor at 8 hours detention time**

| Parameter | N* | Unit | Raw sewage | UASB Effluent | %R |
|---|---|---|---|---|---|
| **COD** | 25 | mg/l | 850 (±295) | 238 (±102) | 72.0 |
| **BOD** | 25 | mg/l | 590 (±155) | 160 (±63) | 72.9 |
| **TSS** | 25 | mg/l | 265 (±95) | 57 (±29) | 78.5 |
| **TKN** | 19 | mg/l | 62 (±12) | 61 (±25) | 1.6 |
| **Ammonia** | 19 | mg/l | 45 (±10) | 52 (±21) | -15.6 |
| **Organic nitrogen** | 19 | mg/l | 17 (± 8) | 9 (±4) | 47 |
| **TP** | 19 | mg/l | 5.5 (±1) | 4.5 (±2) | 18.2 |
| **TC** | 17 | MPN/100 ml | 8 x $10^{8}$ (±3x$10^{8}$) | 3.6x$10^{6}$ (±2x$10^{6}$) | 99.55 |
| **FC** | 17 | MPN/100 ml | 6.2 x $10^{7}$ (±2x$10^{7}$) | 5.5x$10^{5}$ (±1x$10^{5}$) | 99.113 |

* Number of samples

**Table 5: Performance of the UASB reactor at 10 hours detention time**

| Parameter | N* | Unit | Raw sewage | UASB Effluent | %R |
|---|---|---|---|---|---|
| **COD** | 25 | mg/l | 850 (±295) | 215 (±99) | 74.7 |
| **BOD** | 25 | mg/l | 590 (±155) | 145 (±62) | 75.4 |
| **TSS** | 25 | mg/l | 265 (±95) | 48 (±26) | 82 |
| **TKN** | 19 | mg/l | 62 (±12) | 58 (±21) | 6.5 |
| **Ammonia** | 19 | mg/l | 45 (±10) | 56 (±23) | -24.4 |
| **Organic nitrogen** | 19 | mg/l | 17 (±8) | 2 (±0.9) | 88.2 |
| **TP** | 19 | mg/l | 5.5 (±1) | 4.2 (±2) | 23.6 |
| **TC** | 17 | MPN/100 ml | 8 x $10^8$ (±3x$10^8$) | 3x$10^6$ (±1x$10^6$) | 99.625 |
| **FC** | 17 | MPN/100 ml | 6.2 x $10^7$ (±2x$10^7$) | 5x$10^5$ (±1x$10^5$) | 99.194 |

** Number of samples*

**Figure 2: Concentration of COD, BOD and TSS in raw sewage as well as treated effluents**

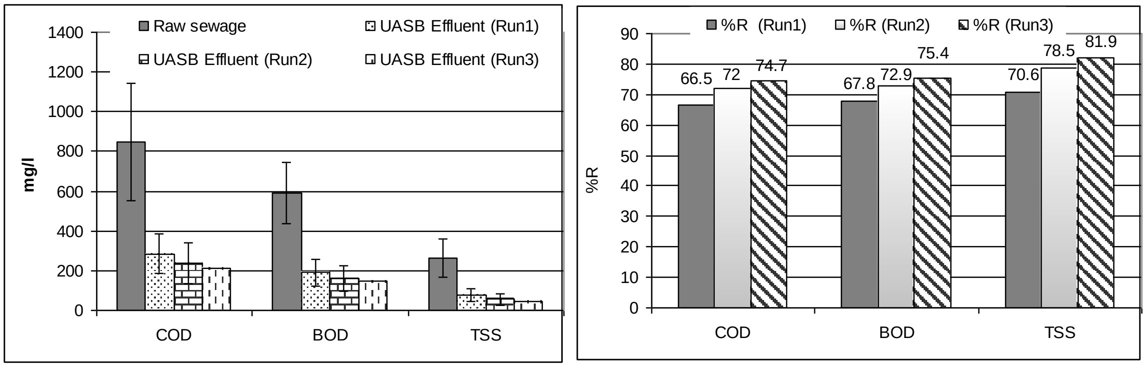


**Figure 3: Concentration of TKN, Ammonia, Organic nitrogen and TP in raw sewage as well as treated effluents**

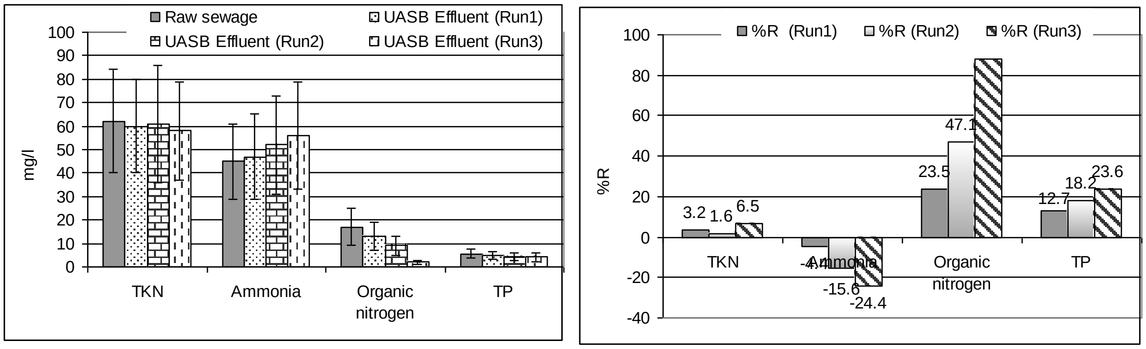
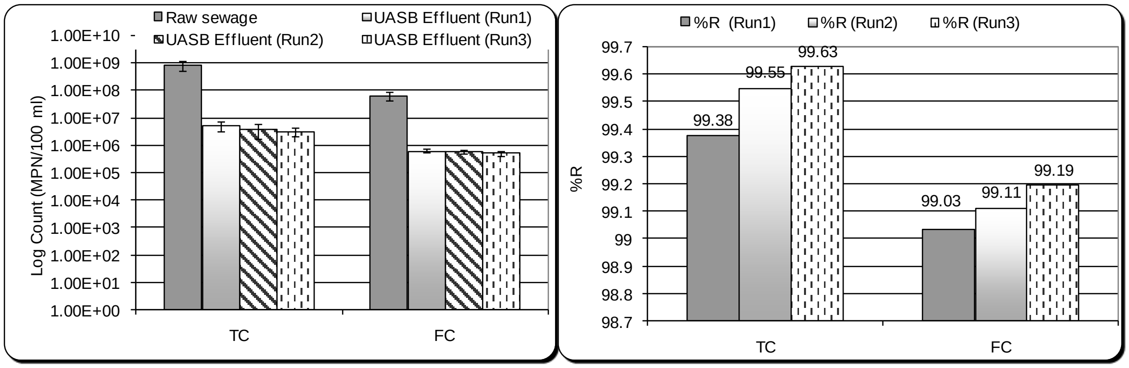


**Figure 4: Efficiency of TC and FC removal**



## Conclusions

It was observed that the finally treated effluents still contained significant count of TC and FC (at different HLR). Table 6 summarized the efficiency of the UASB reactor for removal of FC at different HLR as well as the WHO guidelines for treated effluent reuse. The removal of TC and FC was not a function of RT, but the removal depends on the efficiency of sedimentation in such type of treatment (Mungray and Patel, 2011).

**Table 6: Residual FC count in the effluent of UASB compared with WHO guidelines for treated effluent reuse**

| | |
|---|---|
| **Run 1** | 6 x $10^5$ (MPN/100 ml) |
| **Run 2** | 5.5 x $10^5$ (MPN/100 ml) |
| **Run 3** | 5 x $10^5$ (MPN/100 ml) |
| **WHO guidelines (1989)** | ≤$10^3$ (MPN/100 ml) |

The TF and FC counts are greater than the permissible limit (log 3 or 1000 MPN/ml) specified by WHO for unrestricted irrigation. This indicated the presence of microbes in water which in turn proved that these systems failed to work effectively. Therefore, an additional treatment step or an additional disinfection step is required to remove microorganism more effectively. It is strongly recommended that post treatment step must be added to meet the WHO standards for treated effluent reuse.

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