

Upflow Sludge Blanket Filtration (USBF): an Innovative Technology in Activated Sludge Process

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Abstract

Background: A new biological domestic wastewater treatment process, which has been presented these days in activated sludge modification, is Upflow Sludge Blanket Filtration (USBF). This process is aerobic and acts by using a sludge blanket in the separator of sedimentation tank. All biological flocs and suspended solids, which are presented in the aeration basin, pass through this blanket. The performance of a single stage USBF process for treatment of domestic wastewater was studied in laboratory scale.

Methods: The pilot of USBF has been made from fiberglass and the main electromechanical equipments consisted of an air compressor, a mixing device and two pumps for sludge return and wastewater injection. The wastewater samples used for the experiments were prepared synthetically to have qualitative characteristics similar to a typical domestic wastewater (COD= 277 mg/l, BOD₅= 250 mg/l and TSS= 1 mg/l).

Results: On the average, the treatment system was capable to remove 82.2% of the BOD₅ and 85.7% of COD in 6 h hydraulic retention time (HRT). At 2 h HRT BOD and COD removal efficiencies dramatically reduced to 50% and 46.5%, respectively.

Conclusion: Even by increasing the concentrations of pollutants to as high as 50%, the removal rates of all pollutants were remained similar to the HRT of 6 h.

Keywords: Domestic wastewater, Treatment, USBF process, BOD₅, COD

Introduction

Nowadays, the problem of municipal wastewater treatment is being considered from different viewpoints in developed and developing countries (1, 2). The main viewpoints of industrial countries are the reuse of wastewater and developing laws and rigid standards for wastes disposal to the environment. With respect to this attitude, they try to use modern processes of wastewater treatment with more capabilities. On the other hand, the main viewpoint of developing countries is to treat wastewater for prevention of infectious diseases in human communities (3, 4). Thereupon, in the developing countries, the main processes are still the processes which can only eliminate the bulk contaminants of wastewater namely organics and pathogens. However, these countries should try to use the modern processes of wastewater treatment. Upflow sludge blanket filtration (USBF)

which is a new modification of activated sludge is considered as an outstanding technology for municipal wastewater treatment. It is also claimed to be ideal for use in water reclamation, industrial wastewater treatment and existing plants retrofits (5, 6).

In USBF process, the sludge that enters an anoxic zone is drawn by gravity into an aeration compartment and then to the bottom of the USBF clarifier, from where it overflows. The remainder is then recycled from the bottom-using airlift pumps, which require no power due to the internal loop configuration. USBF process is comprised of several units. These are coarse screening, pumping, grit chamber, primary sedimentation, activation (aeration and secondary sedimentation, nitrification and denitrification), disinfection, and dewatering (5, 7).

The design and operation of USBF process can be done either in one single stage or in two stages. In the double stage USBF process, anaerobic con-

ditions needed for P-biological removal are provided by imhoff tanks and 2 h retention of wastewater at the first phase of operation. However, in single-stage USBF, imhoff tanks are displaced and P-removal is accomplished by lime addition. Since by this system all the required processes are integrated into one bioreactor, the equipment size and costs can be reduced substantially compared to other modifications of activated sludge (8-10).

The main purpose of this project, which has been accomplished in 2006, was to determine the best conditions of treatment for organics removal from domestic wastewater by use of the single-stage USBF process.

Materials and Methods

The single-stage USBF reactor used for this project was a four-compartment reactor made from fiberglass of 4 mm thickness. The overall liquid volume of this reactor was 4 L. The compartments were as follows: 1- primary sedimentation, 2- denitrification, 3- aeration and 4- separators for final sedimentation. Fig. 1 shows the diagram of the experimental system. The operation of the five steps of treatment needed for USBF process was practicable by use of this simple reactor. These stages were as follows:

First stage: In this stage, the influent was entered the system for primary sedimentation. For this stage, a minimum of 60% decrease in TSS concentration is expected.

Second stage: In this stage, raw influent (after aeration) was entered the special elimination system for organic carbon. Nitrification process could also be accomplished in this stage. The hydraulic retention time was about 2 to 8 h.

Third stage: In this stage, the wastewater was entered the denitrification stage after aeration and nitrification. Nitrate may be converted to nitrogen gas (N_2) in this stage.

Fourth stage: In this stage, the wastewater was passed from the separators and was filtered from a sludge blanket.

Fifth stage: In this stage, the pre-settled wastewater was passed from the channels which were

placed on the separators and then was discharged from the system.

As mentioned above, the influent to the system was entered the aeration unit, after passing from the primary-sedimentation and denitrification units and then it was passed from the separators of sedimentation basin. The influent to the separator of sedimentation stage returned to the denitrification unit by an electro pump after the process of nitrification. The rate of returned wastewater to the denitrification unit had been adjusted at about 3 to 5 times the influent to the aeration unit. The required aeration was done by two aquarium pumps such that dissolved oxygen was permanently kept between 2-3 mg/l. For preparing the required fine bubbles of oxygen, two diffusers with high oxygen transfer capacities had been used.

Adaptation of biological mass with the synthetic wastewater samples was started after seeding, and this function was continued about two weeks. At the end of the adaptation period, the formed sludge in the sedimentation separators was considered completely stable and compact with a density of about 1.03 kg/l. The specifications of the synthetic wastewater influent to the USBF pilot were as follows:

$BOD_5 = 250 \text{ mg/l}$

$COD = 277 \text{ mg/l}$

$TSS = 1 \text{ mg/l}$

The only compound that was used in preparation of the wastewater samples was dry condensed milk and TSS was the same as tap water. USBF pilot was operated in three different aeration times (HRT of 6, 4 and 2 h with increase of influent BOD_5 to 1.5 times). In all these stages, the sludge age had been adjusted to be about 20 d and the concentrations of MLSS and MLVSS had been kept at about 6000 and 8000 mg/l. Sampling and testing of the influent of USBF pilot was done after adaptation period. In this study, the parameters that were measured in both the effluent and influent samples of the USBF pilot include BOD_5 (as the biodegradable compounds), COD (as the total organic compounds), and TSS. Analyses of these parameters have all been accomplished according to the procedures described in Standard Methods (11).

Results

The results obtained in four stages were all presented in Figs. 2, 3 and Table 1. Fig. 2 shows the BOD of the final effluent at different HRT as low as 20 mg/l with their removal efficiencies up to 82%. Fig. 3 shows the COD of the final effluent at different HRT as low as 23 mg/l with their removal efficiencies up to 85%. The results of BOD,

COD, TSS, and turbidity of the effluent for different stages of wastewater treatment are shown in Table 1. In most cases, the TSS concentration in effluent had been less than 1 mg/l and one of the main reasons was formation of compact sludge clots in the sedimentation separators of the system. This phenomenon reduced the possibility of sludge escape from the system.

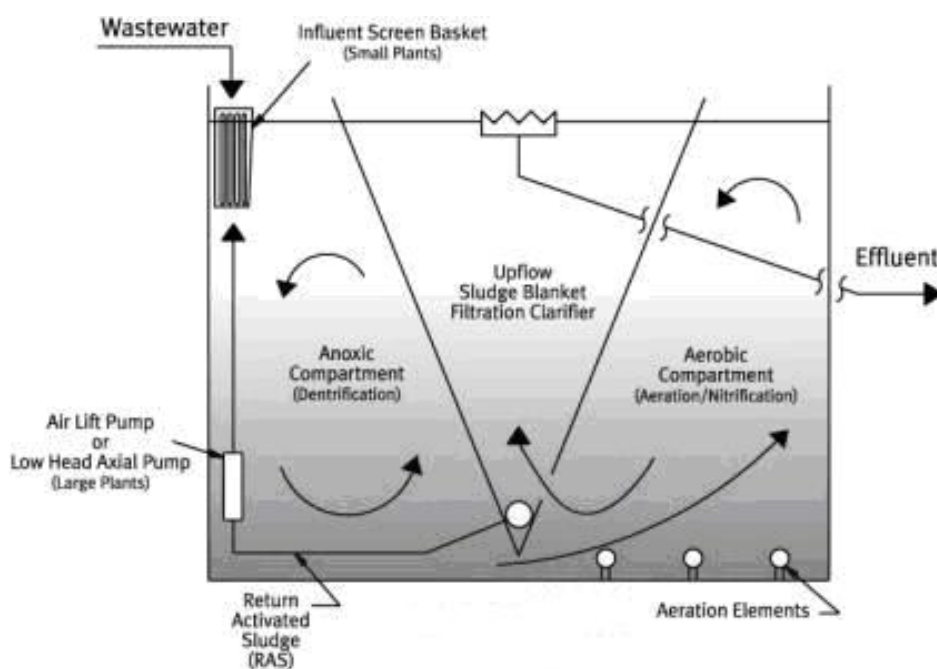


Fig. 1: The experimental setup used in this study.

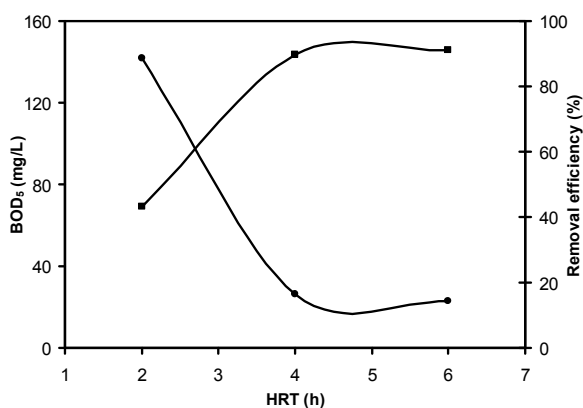


Fig. 2: BOD₅ effluent concentration and its removal efficiency at different HRTs

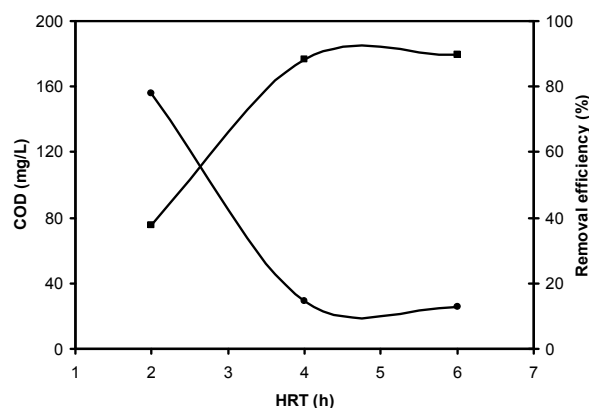


Fig. 3: COD effluent concentration and its removal efficiency at different HRTs

Table 1: Results of wastewater treatment

| Operation stage | Test/sample | 1 | 2 | 3 | 4 | Avg. |
|---|-------------------------|-----|-----|-----|-----|-------|
| Stage 1 (HRT = 6 h) | BOD ₅ (mg/l) | 25 | 22 | 24 | 20 | 22.75 |
| | COD(mg/l) | 28 | 25 | 27 | 23 | 25.75 |
| | TSS(mg/l) | 0.9 | 0.6 | 0.8 | 0.7 | 0.75 |
| | Turbidity (NTU) | 1.1 | 0.8 | 0.9 | 0.8 | 0.9 |
| Stage 2 (HRT = 4 h) | BOD ₅ (mg/l) | 31 | 27 | 24 | 24 | 26.25 |
| | COD(mg/l) | 34 | 30 | 27 | 26 | 29.25 |
| | TSS(mg/l) | 0.9 | 0.8 | 1 | 0.9 | 0.9 |
| | Turbidity (NTU) | 1.5 | 1 | 1 | 1 | 1.125 |
| Stage 3 (HRT = 2 h) | BOD ₅ (mg/l) | 120 | 145 | 155 | 148 | 142 |
| | COD(mg/l) | 132 | 160 | 170 | 162 | 156 |
| | TSS(mg/l) | 1.8 | 1.9 | 1.8 | 1.8 | 1.825 |
| | Turbidity (NTU) | 2 | 2.5 | 2 | 2 | 2.125 |
| Stage 4 (HRT = 6 h by increasing influent BOD ₅ and COD to 375 and 416 mg/l, respectively) | BOD ₅ (mg/l) | 32 | 31 | 30 | 30 | 30.75 |
| | COD(mg/l) | 36 | 35 | 34 | 33 | 34.5 |
| | TSS(mg/l) | 0.8 | 1 | 0.9 | 0.9 | 0.9 |
| | Turbidity (NTU) | 1 | 1 | 1 | 1 | 1 |

Raw wastewater: COD = 277 mg/l, BOD₅ = 250 mg/l

Discussion

Until now, limited data are available on the USBF operation. Mosquera-Corral et al. (9) studied on treating the wastewater of a canning fish factory using USBF. Results clearly have shown significant removal of organic and nitrogen compounds plus production of a large volume of methane gas due to the primary anaerobic phase of this treatment. Fernández et al. (12) used USBF process for treating municipal wastewater. The results of this study indicated the feasibility of USBF process from the technical as well as the economical viewpoints.

As shown in Figs. 2, 3, the removal efficiencies of both BOD₅ and COD could be increased by increasing the time of wastewater retention in the reactor. In this respect, it was found that the removal rate of BOD₅ had been improved from 75% (by applying the HRT of 2 h) to 92% at the stage of applying the HRT of 6 h. This high difference was mainly due to the increased adaptation of MLSS to the characteristics of the synthetic wastewater along with growth of more bacteria in the aeration zone. It should be noted that

in this research, the minimum HRT needed for reaching to an acceptable removal of BOD₅ from the final effluent to meet the discharge standards was 4 h, and in less than the HRT of 2 h the concentration of BOD₅ was not reached to less than 128 mg/l. We may conclude that single stage USBF process should not be operated in aeration periods of less than 4 h. Similar to 4 h aeration stage, in the stage of applying the HRT of 6 h there was no considerable difference in BOD₅ removal efficiencies of different samples. This can be attributed to the fixed rate of organics load as well as uniform environmental conditions, regular mixing and firm aeration. Finally, as shown in Figs. 2 and 3 in the stage of 6 h HRT and by increasing the initial BOD₅ to 1.5 times, the treatment efficiency had improved by time from the initial 45.4% to about 88% for the last sample. Again, the rate of BOD₅ removal had remained nearly constant for the last four samples, which can be attributed to the same reasons mentioned for previous stages.

With regard to the performance of the system in COD removal, it was found that maximum 94% reduction was possible by applying 6 h HRT. How-

ever, treatment efficiency of as high as about 90% was also obtainable in the stage of applying 4 h HRT.

Since all of the wastewater samples used in these experiments were prepared synthetically, the effect of USBF process on TSS removal cannot be interpreted easily. Results certainly showed that the TSS concentration in the effluent of the treatment system had never exceeded 2.8 mg/l. By comparison with the initial concentration, a slight increase of TSS after treatment was often denoted which should be attributed to the appearance of MLSS in the final effluent. Regarding that the sludge blanket formed in a USBF process is dense enough to prevent escape of suspended solids and in fact the problem of forming fine flocs is insignificant, the low TSS treatment efficiency of the system which was less than 33% may still be considered sufficient for meeting the current standards regulated by environmental protection agencies.

Comparison of the results of this study with those of other processes indicated that the USBF process is a promising alternative for treatment of domestic wastewater. Naghizadeh et al. (13) investigated the performance of hollow fiber membrane bioreactor for municipal wastewater treatment. Removal efficiencies of this process for COD, total Kjeldahl nitrogen (TKN), total nitrogen (TN) and total phosphorous (TP) were determined to be 99.3, 98.1, 85.5 and 52.0%, respectively. In recent years, sequencing batch reactor (SBR) has been one of the most studied technologies for domestic wastewater treatment due to its proper performance (14-17). According to Mahvi et al. (18), the removal efficiencies of BOD₅, COD, TSS, TKN, TN and TP from domestic wastewater by SBR process were obtained to be in the ranges of 96.8-97.7, 93.0-94.9, 96.7-99.0, 69.0-85.4, 57.9-71.4 and 55.9-68.5%, respectively.

Ethical Consideration

All Ethical issues (such as informed consent, conflict of interest, plagiarism, misconduct, co-author-

ship, double submission, etc) have been considered carefully.

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