Abstract

Upflow anaerobic sludge blanket (UASB) is one of the anaerobic systems which is known for its low construction, operation and maintenance cost, high efficiency in removal of organic material, small land requirement, low operation and maintenance cost as well as low sludge production. Nevertheless, UASB is known for low efficiency in nitrogen (N) and phosphorus (P) removal. However, nitrogen is a major nutrient in wastewater that must be reduced to acceptable levels because the uncontrolled release of nitrogen to the environment is known to cause serious problems such as infant methaemoglobinaemia and eutrophication. Therefore, an appropriate post-treatment unit has to be installed after UASB to comply with effluent guidelines for reuse. Waste stabilization ponds (WSP) which are also considered as low cost system, are able to meet effluent standards for reuse. However, these systems are characterized by high land requirement.

Duckweed-based ponds (DBPs) are at their core, modified type of WSP. Furthermore, the WSP are not only a low cost and easy to build and operate, but they also produce tertiary quality effluents and offer the possibility of resource recovery by producing high quality duckweed protein, which can be of further use. DBPs as well as WSP systems are efficient as post-treatment units after UASB system. Moreover, land requirement for WSP and DBPs systems can be considerably reduced when influent sewage is pretreated by UASB. Nevertheless, the use of DBPs is more promising because of the aforementioned cost recovery. Moreover, land requirement and hence cost can be further reduced by using deeper pond systems. However, the effect of depth on ponds performance especially in nitrogen removal has so far not been investigated especially under Palestinian conditions.

The main objective of this thesis was to investigate the effect of depth variation on DBPs and ABPs performance and nitrogen removal efficiency. In order to perform this study, a pilot-scale treatment plant was constructed at Al-Bireh Wastewater Treatment Plant site (AWWTP), 15 Km northeast of Jerusalem-Palestine. The pilot plant consisted of a UASB-septic tank operated under hydraulic retention time (HRT) of 4 days. It was followed by three parallel lines of stabilization ponds with three equal ponds each of similar total HRT of 28 day per line. The depth of the ponds in the first, second and third lines were respectively 90, 60 and 30 cm. The study was divided into two periods; the first period was conducted between May, 2, 2004 and August, 18, 2004 to investigate the effect of depth variation in DBPs. As the growth of duckweed and hence the duckweed cover was not maintained due to unfavorable conditions of treated sewage, the

same as the first period was investigated for algae based ponds (ABPs) in the period between August, 18, 2004 and November, 1, 2004.

The pilot plant was operated for six months, the average ambient temperature throughout the experimental period was 24.5 ^oC, while the average water temperature in the first and second periods were 23.6 and 22.9 ^oC, respectively. Influent total COD to the system was 1275 ± 84 mg/L, while average COD concentration in DBPs and ABPs period was 701.6 ±241.5 and 330.9 ± 69 mg/L, respectively. The corresponding volumetric loading rates were 25.0 and 11.8 g COD/m^3.d, respectively. The results of this research revealed that total COD, TP and N removal efficiencies were inversely proportioned to depth when equal total HRT was applied for the three lines. COD removal efficiency for the shallowest and deepest DBPs were 75.4 ± 4.1%, 62.5 ± 5.7%, while its removal efficiency in the shallowest and deepest ABPs was 54 ± 1.1%, and 51.6 ± 3.2%, respectively. Moreover, total phosphorus (TP) removal in DBPs and ABPs increased by the decrease in depth. The removal efficiencies of TP in the shallowest and deepest DBPs were 48.5 ± 9.2% and 38.5 ± 4%, respectively. While TP removal efficiencies in the shallowest and deepest ABPs were 57.6 ± 5.6% and 37.6 ± 6.4%, respectively. Furthermore, total suspended solids (TSS) removal efficiency was higher for deeper DBPs; it was 64.4 ± 11.8%, and 58 ± 11.2% in shallowest DBPs, however negative removal efficiency was achieved in ABPs due to algal growth. Higher ammonium (NH_4^+) removal efficiencies were achieved in the shallowest compared to deepest DBPs were 46.6 ± 5.2% , 30.9 ± 1.6%, while, in the shallowest and deepest ABPs, they were 64.5 ± 2.8% and 51.2 ± 1.9%, respectively. Furthermore, the removal efficiencies of total Kjeldahl nitrogen (TKN) in the shallowest and deepest DBPs were 44.5 ± 6.3% and 29.4 ± 6.8%, respectively. While they were in the shallowest and deepest ABPs 45.4 ± 3.1% and 61.1 ± 4.5%, respectively. Significantly higher value of sedimentation (higher contribution to treatment) was found in ABPs compared to DBPs. Finally, even though better removal efficiency was achieved in shallowest ponds for most of the tested parameters, however, they showed higher land requirement (11.7 m^2/capita and 7.8 m^2/capita in DBPs and ABPs, respectively) compared to deepest ponds (6.9 m^2/capita and 3.9 m^2/capita in DBPs and ABPs, respectively) to comply with WHO guidelines for restricted irrigation.