TROPICAL CONSTRUCTED WETLANDS FOR EFFLUENT TREATMENT OF MUNICIPAL UASB REACTORS

By

NADEEM KHALIL

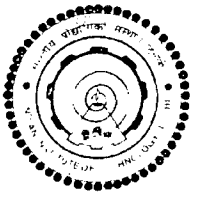
Applied Mechanics Department

Submitted

in fulfillment of the requirements of the degree of

Doctor of Philosophy

to the



INDIAN INSTITUTE OF TECHNOLOGY DELHI

New Delhi India

July 2009

Dedicated to my parents & family

Kunwer Khalil Ahmad Khan, Zeba Khalil (Parents)
Mubashra, Fadila, Firaas and Omer

CERTIFICATE

This is to certify that the thesis entitled **"Tropical Constructed Wetlands for Effluent Treatment of Municipal UASB Reactors"** submitted by Nadeem Khalil to the Indian Institute of Technology Delhi, for the award of the Degree of Doctor of Philosophy, is a record of bonafide research work carried out by him under our supervision. The thesis work, in our opinion, has reached the standards fulfilling the requirements for the degree of Doctor of Philosophy.

This is further certified that the research report and results presented in this thesis have not been submitted in part or in full to any other university or institute for the award of any degree or diploma.

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ABSTRACT

This research was started with questions about how constructed wetlands (CWs) could be used to improve the effluent quality of UASB (upflow anaerobic sludge blanket) reactors treating municipal sewage. It is hypothesized that role of local macrophytes (like *Typha latifolia, Canna flaccida, Sagittaria lancifolia, and Ipomea aquatica),* innovations in filter media, understanding of wastewater characteristics particularly toxicity from sulfides present in UASB effluent, and hydraulics can help in improving the performance of the constructed wetlands to treat the UASB effluent.

Field set-up consisted of five identical independent CWs beds/cells at pilot-scale level, installed at the full-scale 20,000 m^3/d capacity UASB sewage treatment plant. Macrophytes were planted in four beds and one bed was used as control. The performance of wetlands units was monitored for about two years at different hydraulic retention times (RT) simultaneously. These beds were initially operated as free-water surface (FWS) at 4 *days* retention time and then as sub-surface flow (SSF) conditions at 2, 4, and 8 *days* RT.

Beds planted with *canna, typha* and *ipomea* showed considerable reduction in organic matters, solids, turbidity and substantially removed nitrogen and coliforms. Study also revealed that *sagittaria* could not withstand with anaerobic effluent. However, *typha* and *canna* showed no detrimental effect.

Retention time has significant role in the removal process. Beds when operated at 4 and 8 *days* retention time produced better removal efficiency as compared to 2 *days.* Data was verified by using ANOVA and t-tests. Characteristics of the effluent from UASB reactors (feed) varied widely, which affected the quality of effluent from CWs. Overall BOD removal was 42% (*typha*), 37% (*ipomea*), 48.6% (*canna*) and 26% (control) at 4 *days* HRT under FWS flow conditions. under SSF flow conditions at 4 *days* HRT, the BOD removal efficiency increased to 53% (*typha*), 45% (*ipomea*), 60% (*canna*) and 21% (control). The study also revealed that when HRT was increased from 4 *days* to 8 *days*, efficiency increased by 5 - 10 % in different beds.

Removal of Kjeldahl nitrogen (TKN) and ammonical nitrogen (NH_3-N) are not very encouraging. Removal of TKN and NH_3 averaged 35% and 52% for *typha*, 32% and 35% for *ipomea*, 56% and 51% for *canna*, 26% and 25% for control respectively. It is observed that during initial stages, removal of TKN and NH_3 was better, but after few months of operations, efficiency decreased significantly in all the beds except *canna.*

Fate of sulphates and its conversion in UASB reactors was also studied. There is clear reduction of sulfides concentration in CWs. UASB effluent showed presence of sulfide concentration varying between 23 to 33 $mg.L^{-1}$which was reduced to less than 15 $mg.L^{-1}$. In case of *Canna,* it was even reduced to less than 5 $mg.L^{-1}$.

Tracer studies revealed that hydraulic behavior of the beds tends towards plug flow conditions. It has been determined from the data that actual hydraulic retention time (empty bed HRT) is less than half of the theoretical retention time in all the planted beds. Hydraulic efficiency was 60% for planted beds and 80% in unplanted bed.

A model has been developed to predict performance of CWs for BOD removal. This model incorporates residence time and a constant depending upon the type of vegetation. The model was validated for 62 data-set which showed good correlation with the experimental observations with the maximum deviation of 5%. This validation is in agreement with Willmott Index. The proposed model can be used for design of CWs.

Present work establishes use of constructed wetlands for the treatment of UASB effluent as an integrated sustainable approach for sewage treatment in India and in countries of tropical climates where land is cheap and easily available.

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