Chapter 9

SUMMARY

Constructed wetlands (also known as reed bed or root zone treatment systems) have been demonstrated as a viable technology to provide an alternative system for wastewater treatment requiring lower capital and maintenance costs, and generally, no or very little energy to operate it when compared to the advanced treatment technologies involving chemical methods. The CWs are for the same reason recommended particularly for the developing countries like India.

Although several experimental studies and small-scale field trials have been made in India to examine the potential of constructed wetland technology to treat a variety of wastewaters, the reports do not provide any information on the design criteria suitable to the Indian climatic conditions. Further, these trials have focused on treating the wastewaters with high temporal variability in their quality (BOD, salinity, nutrients, pH, etc.) and often without pre-treatment, and only *Phragmites* species has been used without testing the suitability of other indigenous species.

Thus, the need for tertiary treatment with the help of constructed wetlands was recognized for reducing substantially the BOD and nutrients, especially nitrogen and phosphorus, in secondary treated effluents from conventional treatment plants. The wastewater from milk processing plant such as the Mother Dairy at Delhi was selected for the study.

Recognizing the different factors that affect the treatment efficiency of a constructed wetland and also needed to optimize the treatment abilities, the study was segregated into four different experimental steps, based on the following objectives.

- To evaluate the efficiency of different macrophyte species in improving the water quality and the selection of the most appropriate species for the treatment of the particular wastewater.
- To evaluate the system efficiency with different flow rates and hydraulic retention time, to optimize the system for maximum removal efficiency.
Chapter 9. Summary

- To evaluate the maximum nutrient removal capacity of the system with further nutrient enrichment
- To evaluate the efficiency of the system with harvesting regime.

The study was conducted in two phases: The first phase involved evaluation of the emergent species (*Phragmites karka, Scirpus littoralis* and *Typha angustata*) for their potential efficiencies for tertiary treatment at a fixed HRT of 3 days and flow rate of 60L d⁻¹. The system comprised three treatment cells of acrylic bath tubs (1.68 x 0.76 x 0.45m). In the second phase, the species with maximum efficiency was selected for assessing the effects of (a) flow rate with different hydraulic retention time (1, 2, 3 and 4 days), (b) nutrient enrichment (only N), and (c) partial harvesting. All the experiments were conducted sequentially. Three more cells of stone slabs (2.14 x 0.76 x 0.61m) were used in this phase. The layout of the inlet and outlet pipes was such so as to ensure maximum vertical flow arrangement and the water level was maintained just below the surface of the gravel bed making it vertical subsurface flow constructed wetland. For ensuring optimum hydraulic conductivity, enough space for the growth of belowground organs, and to avoid clogging with the retention of particulate matter, two different medium size gravels (approximately 2.5 cm and 1.5cm diameter) were used as bed media that provided an estimated 30% porosity in the treatment cells.

Plants were collected locally from different places in Delhi, and grown in monocultures, to raise enough number of uniformly sized young plants. These young plants were then planted randomly in the treatment cells and periodically supplied with wastewater as a source of nutrients for the plants. In both the phases, plantation was done in the peak growth period (April-May) so as to ensure establishment of dense stands of plant species prior to the analysis of system’s treatment performance. Initially the young plants of all the three species did not tolerate the secondary-treated effluent. The plants turned yellow, started withering or drying within a week. Therefore, the wastewater was diluted with tap water and then introduced into the cells till the growth of the plants stabilized in the gravel media. It was hypothesized that the high conductivity, possibly because of high concentration of sodium that is used in the washing process, is the cause of toxicity to the plants. Also the development of vegetation stands of all the three macrophytes exhibited a particular growth pattern with more density and plant height.
towards the inlet zone as compared to the outlet zone of the bed. This behaviour, likely in response to the declining availability of nutrients in the wastewater along the gradient, has an implication for the treatment efficiency of long treatment cells in the CWs. With the establishment of dense stands in the treatment cells, inflow and outflow samples from each of the system were collected and analyzed weekly from November 2005 to October 2006, for various pollutants according to standard methods. Plant growth in terms of height, density and biomass was measured as appropriate.

The three emergent macrophytes differed in their treatment ability with Typha angustata outperforming Phragmites karka and Scirpus littoralis. Even the density and growth of the plants reveal Typha’s competitive superiority during the six months of establishment. Typha was relatively 15% to 30% more efficient than Phragmites but its efficiency was 50% more than that of Scirpus. Among the pollutants analysed, Typha showed maximum reduction in $\text{NH}_4$-N and $\text{NO}_3$-N with more than 90% removal at 3 days HRT. However Typha did not prove to be equally effective for $\text{PO}_4$-P removal (41%) from the secondary treated effluent but was still 36% more efficient than Phragmites and 69% more than Scirpus. The differences in the treatment ability of the three species may be related to their overall growth. Typha’s more aggressive growth in above and below ground organs and colonizing ability may be responsible for its better performance compared to other two species. The Indian studies have relied exclusively on Phragmites karka. Possibly, lower efficiency of this species in the present study is because a complete development of root/rhizome system of Phragmites in a constructed wetland requires 3-5 years. The uptake and accumulation of nutrients by plants in their biomass directly contributed to the improvement of wastewater quality. The present study revealed higher uptake of N and P by Typha compared to Phragmites and Scirpus, and also higher percent removal from the system.

The effect of 4 HRTs (1-4 days) was investigated for only Typha which was most efficient among the three species. The treatment cells received wastewater ranging from 300 L/d to 75 L/d according to the HRT. The applied hydraulic loads ranged between a minimum of 59.05 mm/d in the cell with 4 days HRT and a maximum of 236.22 mm/d in the cell with 1 day HRT. Typha showed even better efficiency at 4 days HRT when compared with that of at 3 days. The reduction of all pollutants (except conductivity)
increased sharply with an increase in the HRT from 1 to 3 days but improved relatively little with further increase in HRT to 4 days. The removal of organic matter (BOD and COD) was beyond 80% i.e. relatively 20-25% more than at 3 days HRT while NH4-N and NO3-N showed approximately 100% and 95% removal respectively. This signifies that 4 days is sufficient for complete removal of NH4-N from the system by Typha plants. Higher BOD removal also revealed positive relationship between microbial removal and HRT. The analysis of total coliform in wastewater showed 76% removal at HRT of 4 days.

Longer HRT had also the advantage of stabilizing the effluent quality, i.e. there was practically no variation in the treated effluent quality despite large fluctuation in the influent wastewater characteristics.

The system was loaded with urea to examine if there is any threshold N concentration beyond which the efficiency of a constructed wetland system will decline? More importantly, it appeared that the concentration of P is very high relative to that of N. The wetland cell with 1 day HRT received more additional N and the cell with 4 days HRT received relatively smaller addition. The cell with 1 day HRT responded rapidly with a sharp decline in the treatment efficiency but the cell with 4 days HRT had relatively smaller effect. The result showed only 2-4% decline in efficiency of NH4-N, NO3-N and TKN at 4 days HRT in the post enrichment period than before nutrient addition while the additional N loading did not improve the efficiency of P removal and also did not affect the tissue P concentrations that were determined from the plants harvested after the experiment with urea addition. The analysis of N and P in plant aboveground biomass after the wetland system had received extra nitrogen in form of urea for several weeks, revealed Typha with 8.45% N and 31.92% P of the total mass loading into the system at 4 days HRT. The actual mass loading of nutrients is expected to have been less than estimated because the plants were allowed to grow and establish in diluted wastewater for several days, and the wastewater quality may have fluctuated before the monitoring was started. However, the increased nutrient loading does not necessarily result in more nutrient uptake. The percent nutrient removal by the plants will therefore decline with increased loading. In CW systems, the nutrient loading is always greater at lower HRT but the nutrient removal does not increase with it. This is observed
in the present study where the nitrogen loading had been increased by additional input of urea, but the plant uptake in aboveground shoots of *Typha* accounted for a small fraction (1.39% N) of the highest nutrient load (>2400 g/m²) against a larger proportion (8.45% N) at a lower loading (470 g/m²). Similarly, the P uptake also accounted for a smaller percentage of the high loading.

The present study evaluated also the response of the CW system in terms of its treatment efficiency after *Typha angustata* shoots were harvested towards the end of the growing season. Nearly 80-90% of the plants were harvested from each cell but the rapid growth of the plants within 3 weeks reveal that the complete removal would have not affected the system. Comparison of the treatment efficiency of the system in the pre and post harvest period revealed no effect on pollutant removal at higher HRT of 4 days. Thus, *Typha* shoots can be safely harvested at least annually.

In conclusion, the present study shows that (a) *Typha angustata* is more efficient than *Phragmites karka*, in the tertiary treatment of secondary-treated effluents of the milk processing plant, and certainly so in the first year of growth, (b) the plants contributes to wastewater treatment through significant removal of nutrients, (c) the HRT has a significant effect on the treatment efficiency, and that 4 days HRT appears to be optimal for stabilizing treated effluent quality, (d) large N loadings in a P-rich system do not improve the efficiency, and (e) the plants can be harvested towards the end of the growing season without any effect on the system’s treatment efficiency.