Rejuvenation of Lakes

Insights from the success story of Jakkur Lake

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Wetlands include a wide range of aquatic habitats such as marsh, fen, peat land/open water, estuaries, flowing water (rivers and streams), or static (lakes and ponds). These ecosystems, being the transition zone between land and water, are ecologically important in relation to the stability and biodiversity of a region and in terms of energy and material flow, evident from the recharge of groundwater aquifers and the stabilisation of shorelines. These ecotonal regions are repositories of rich biodiversity and support the food chain while performing a vital function of uptake of nutrients and bioremediation of heavy metals, volatile organics, and other xenobiotic compounds and are aptly known as "Kidneys of the landscape." Wetlands act as giant sponges, which help to retard runoff, lower flood heights, and reduce shoreline and stream bank erosion. The functional ability of wetlands depends on the type of trophic structure and material exchange. Algae, the primary producers, synthesise carbohydrates during photosynthesis and give out oxygen and produce other essential metabolites. The bulk of the CO^2 gets sequestered into algal biomass in these wetlands systems that aid in combating global warming through reductions of GHG (Greenhouse gases) in the environment. However, the functional aspects of wetlands are tied to the trade-off between the ecosystem function and anthropogenic impacts, including encroachment, altering the catchment (changes in land cover), solid waste disposal in lake beds, the sustained inflow

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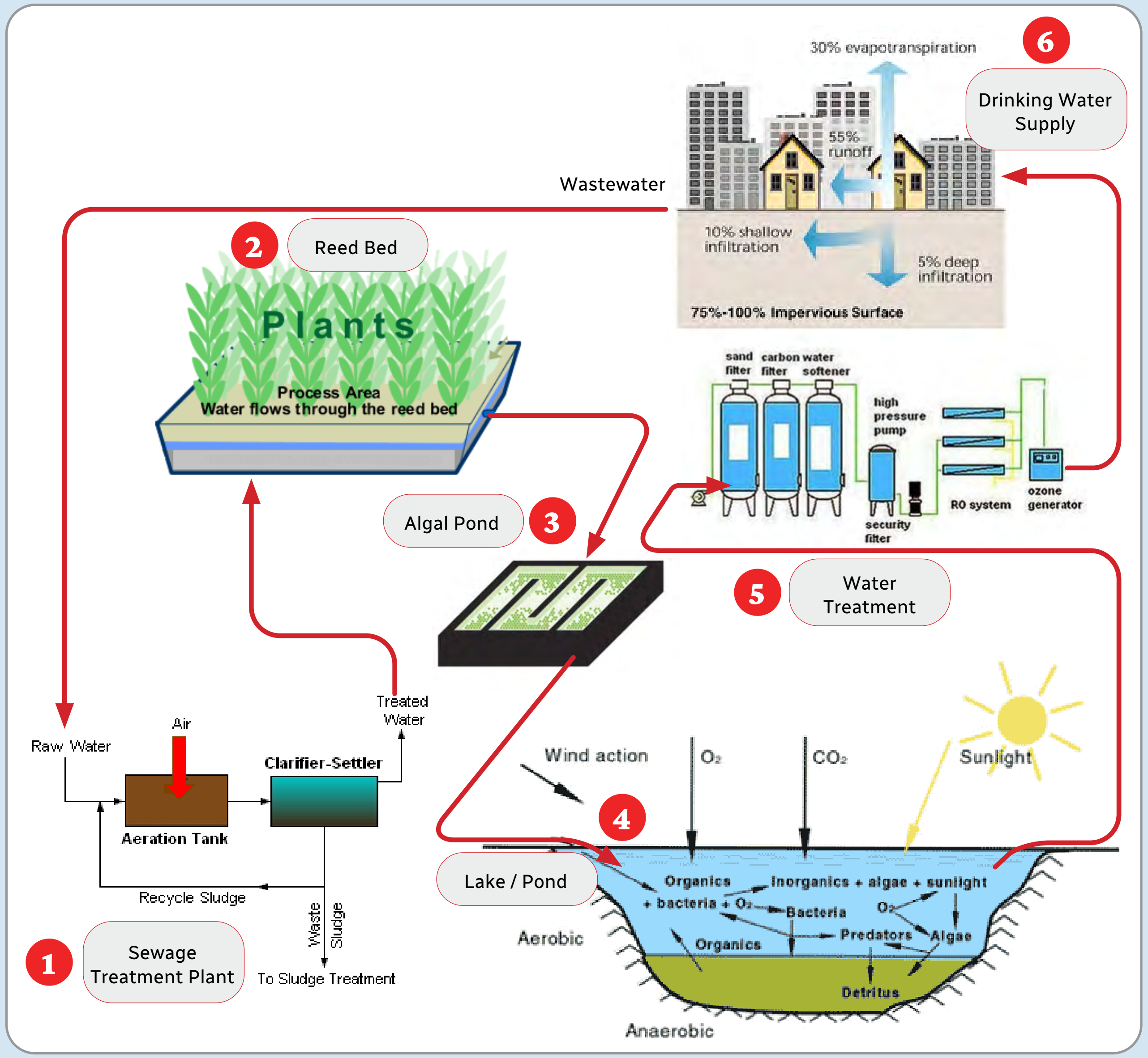
of untreated sewage from the neighbourhood, etc.

Jakkur Lake was constructed about 200 years ago to meet the domestic and irrigation water requirement of Jakkur village, Bangalore Urban District, throughout the year and has been a source of livelihood to farmers, fishing, and *dhobi* (laundryman) communities. During potential fish growing seasons, fish catch crosses 500 kg per day. Twelve to fifteen *dhobi* families depend on the lake for washing cloth daily. In the command area of the lake, agriculture and horticulture (coconut, banana, and mango plantations) were practised, and remnants of these plantations are present even today in the region. Rapid urbanisation leading to large-scale land use changes has increased paved surfaces and declined groundwater recharge.

The lake was rejuvenated in 2010 with the removal of accumulated silt (desilting) and implemention of an integrated wetland system consisting of a secondary sewage treatment plant (STP), constructed wetlands, and algal ponds. Treated water from the integrated wetland system reaches the lake after final polishing (consisting of floating wetland species).

Conventional wastewater treatment options are energy and capital-intensive, apart from their inability to remove nutrients altogether and generate concentrated waste streams necessitating environmentally sound disposal. Compared to this, an integrated wetland system (Figure 1) would help in the cost-effective tertiary treatment (removal of N, P, and heavy metals), which prevents contamination of lake water and groundwater resources. Algae grow rapidly and uptakes nutrients (C, N, and P) available in the wastewater. Algae convert nitrate into organic compounds (proteins, lipids) through photosynthesis. Algae exhibit higher growth rates than other plants due to their extraordinarily efficient light and nutrient utilization. Algal bacterial symbiosis is very effective as algae generate O_2 (during photosynthesis), which aids in the efficient oxidation of organic matter with the help of the chemo-organotrophic bacteria and provides algae with an enriched supply of CO_2, minerals, and nutrients.

The integrated wetland system (1.6 Ha) consists of Upflow Anaerobic Sludge Blanket Reactor (UASB) with an extended aeration system for 10 MLD sewage treatment. Treated effluent then gets into wetlands (settling basin) of spatial extent ~4.63 ha consisting of diverse macrophytes such as *Typha sp.*, *Cyperus sp.*, *Ludwigia sp.*, *Alternanthera sp.*, Water hyacinth, etc., in the shallow region (with an area of ~1.8 ha) followed by deeper algal basin (covering an area of about 2.8 ha). This system with macrophytes and algae jointly helps in nutrient removal and wastewater remediation. The water from the settling basin through sluices (with moderate flow) flows into Jakkur Lake, which spans over 45 ha. There was notably less occurrence of floating macrophytes, except near the outfalls (~0.5 ha) due to blockage



▲ Figure 1. Integrated wetland system

of the outflow channels by solid wastes and debris. Local fishermen are managing these macrophytes. The clear water in Jakkur Lake, with abundant phytoplankton diversity in acceptable densities, indicates a healthy trophic status.

Integration of the conventional treatment system with the constructed wetlands and the algal pond has helped cost-effectively remove nutrients and chemical ions. Emergent macrophytes (such as *typha*) act as a filter to remove suspended matter and avoid anaerobic conditions by the root zone oxidation and algae taking the dissolved nutrients. Four to five days of residence time helps remove pathogens apart from nutrients. However, the integrated system requires regular maintenance through harvesting macrophytes and algae (from algal ponds). Harvested algae would have energy value, which could be used for biofuel production. Nutrient analysis highlights nutrient removal by wetlands due to macrophytes and algae, which removes 77 % COD, ~90 % BOD, ~33 % NO_3-N, and ~75 % $PO4^{3-}$-P. The first stage comprising of emergent vegetation and an algal pond, removes ~45% COD, ~66 % BOD, ~33 % NO^{3}-N, and ~40 % $PO4^{3-}$-P. Jakkur Lake aids in the final level of treatment and removes ~ 32 % COD, ~23% BOD, ~ 0.3 % NO^{3}-N, and ~34 % $PO4^{3-}$-P. The combination of all the stages leads to the complete removal of nutrients to acceptable levels

▲ **Top:** The macrophytes in the Jakkur wetland area and at the outfalls of the lake, include *Typha augustata* species (54%) followed by *Alternanthera philoxeroides* (28%)

Bottom: Floating macrophytes Eicchornia *crassipes* (84%) were restricted to the outlet reaches

according to CPCB norms. The algal species primarily comprised of Chlorophyceae, followed by Cyanophyceae, Euglenophyceae, and Bacillariophyceae. The macrophytes in the wetland area and at the outfalls of the lake, include *Typha angustifolia* (54%) followed by *Alternanthera philoxeroides* (28%). Floating macrophytes *Eicchornia crassipes* (84%) were restricted to the outlet reaches. A nominal residence time (~5 days) would help remove pathogens apart from nutrients. However, this system requires regular maintenance of harvesting macrophytes and algae (from algal ponds). Harvested algae would have energy value, which could be used for biofuel production. Biomass productivity is ~122 mg/l/d and lipid productivity ~32 mg/l/d. Gas chromatography and mass spectrometry (GC-MS) analysis of the fatty acid methyl esters (FAME) showed a higher content of desirable fatty acids (biofuel properties) with major contributions from saturates such as palmitic acid [C_{16}:0; ~40%], stearic acid [C_{18}:0; ~34%] followed by unsaturated such as oleic acid [C_{18}:1(9); ~10%] and linoleic acid [C_{18}:2(9,12); ~5%]. This study provided vital insights into the environmentally sound option of managing wastewater while addressing the water crisis due to unscientific and chaotic urbanisation in Bangalore. Replication of this model in Bangalore would help meet the water demand and also help in recharging groundwater sources without any contamination. Measures required to mitigate the water crisis in burgeoning Bangalore are:

- Rainwater harvesting at decentralised levels through rejuvenated lakes addresses the water crisis as it helps harvest 15 TMC of rainwater generated in the Bangalore catchment.
- Rejuvenation and restoration of existing lakes are necessary to decontaminate water bodies due to the sustained inflow of untreated wastewater. Removing deposited silt would aid in eliminating nutrient-rich silt (which is useful for enriching croplands) apart from enhancing the storage capacity.
- An integrated wetlands ecosystem consisting of constructed wetlands and algal pond helps treat wastewater through bioremediation. Replicating the Jakkur Lake ecosystem would help treat water and reuse it. Rejuvenating lakes will have the added advantage of maintaining groundwater quality in the vicinity.

The integrated wetland system at Jakkur provides an opportunity to assess treatment efficacy apart from providing insights for replicating similar systems to address the impending water scarcity in the rapidly urbanising Bangalore.