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THEME 2 : WHAT POTENTIAL FOR WASTEWATER USE IN AGRICULTURE?

Assessing the performance of free water surface constructed wetlands in treating domestic WASTEWATER: A POTENTIAL ALTERNATIVE FOR IRRIGATION

ÉVALUATION DE LA PERFORMANCE DE LA SURFACE DE L'EAU LIBRE DES ZONES HUMIDES CONSTRUIT DANS LE TRAITEMENT INTERNE

EAUX USÉES : UNE ALTERNATIVE POTENTIEL D'IRRIGATION

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ABSTRACT

The irrigation water scarcity in the drylands of the world is an emerging global challenge. Thereis an urgent need to raise awareness as well as provide economical solutions to abate the risk ofraw wastewater irrigation, an emerging practice mainly in the peri-urban areas. The present studyfocuses on exploring the potential of free surface constructed wetland in treating domesticwastewater. Performances of field scale (treatment capacity 2.8 m3 day-1 each) constructedwetlands operating under identical hydraulic loading and wastewater source were investigated.The study involves two free water surface constructed wetlands vegetated with combination oftypha (Typha latifolia) + water hyacinth (Eichhorniacrassipes) and typha + water lettuce(Pistia stratiotes). Exploration and optimization of the nutrient removal potentials of these plantspecies on a practical and quantitative scale has been attempted in this study. The wastewatertreatment process shows higher efficiency for total suspended solids (98%), chemical oxygendemand (68%) and coliforms (99%). High nitrogen uptake has been detected for all three plantspecies, whereas highest uptakes of phosphate and sulfate have been observed in water hyacinthand typha, respectively. Higher sulfate to sulfur ratio was observed in the rhizosphere of typha.The absence of significant sodium removal necessitates the strategic investigation for thereduction of water salinity required for irrigation.

RÉSUMÉ

La rareté de l'eaud'irrigationdans les zones arides du monde est un défimondialémergent. Ilya un besoin urgent de sensibiliserainsi que de fournir des solutions économiques pour réduire le risque de crue irrigation des eauxusées, unepratiqueémergenteprincipalementdans les zones péri-urbaines. La présenteétude se concentre sur l'exploration du potentiel de surface libremaraisartificieldans le traitement des eauxuséesdomestiques. Performances de l'échelle du champ (d'unecapacité de traitement de 2,8 m3 par jour-1 chacun) zones humidesconstruitopérant sous source hydrauliqueidentique de chargement et des eauxuséesontétéétudiés. L'étudecomportedeux surface construite zones humidesd'eaulibre de végétation avec la combinaison de Typha (Typha latifolia) + jacinthed'eau (Eichhorniacrassipes) etyphalaitue + de l'eau (Pistia stratiotes). Exploration etl'optimisation des potentielsd'élimination des nutriments de cesespècesvégétales sur uneéchellepratique et quantitative a ététentédanscetteétude. Le processus de traitement des eauxuséesreprésenteunrendement plus élevé pour les matièresen suspension (98%), la demandechimiqueenoxygène (68%) et les coliformes (99%). Forte absorption d'azoteaétédétectée pour les troisespèces de plantes, tandisque les plus

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élevés absorptions de phosphate et de sulfate ontétéobservéesdans la jacinthed'eau et typha, respectivement. Sulfate supérieur au rapport de soufreaétéobservéedans la rhizosphère de typha. L'absenced'uneéliminationsignificative de sodium nécessitel'investigationstratégique pour la réduction de la salinité de l'eaunécessaire pour l'irrigation.

Keywords:constructed wetland, wastewater treatment, *Typha latifolia*,*Eichhornia crassipes*, *Pistiastratiotes*

1. Treated domestic wastewater irrigation

1.1 Potentials and challenges

Scarcity of irrigation water is an emerging global trend of the last decade which has fanned the rampant (and often uncontrolled) use of raw wastewater for irrigation practices. According to a recent study conducted by the Institute for Global Environmental Strategies, a Japan-based research organization, 20 million hectares of land in 50 countries was being irrigated with raw or partially treated wastewater in 2000.According to a research by People in Centre Consulting, an Ahmedabad-based consultancy, about 73,000 ha of peri-urban agriculture in India is dependent on wastewater for irrigation. There is an urgent need to understand the potentials as well as challenges associated with wastewater irrigation. Often the farmers as well as the consumers remain unaware of the health risks of raw wastewater irrigation and the plough to plate relation of contaminants such as heavy metals, nematodes etc.

1.1.1 Present scenario

In developing countries like India, each year significant amount of rural population comprising marginalised farmers as well as the economically uplifted ones. While the later one increases the population density of the existing city, the economically weak and marginalised fraction settles in new peri-urban clusters near the city peripheries. The volume of wastewater generated in most major cities in the developing nations out-competes the increase in wastewater treatment capacity. This surplus volume of untreated wastewater often ends up in the city periphery in hitherto wastelands. Peri-urban agriculture using raw wastewater in the barren lands by the migrant and marginalised rural settlers has grown tremendously over the last few decades in India. The livelihood of a large number of marginalised people, anemerging health concern for the farmers as well as the consumers, rapid degradation of soil quality and the surplus wastewater volume together makes the challenge bigger than it initially appears.

1.1.2. Easy availability and low input cost

It is safe to predict considering the increasing water stress situation particularly in the semi-arid tropics that the practice of wastewater irrigation will continue. Apart from being perennial in nature the nutrient content of the wastewater reduces the input cost of fertilizer. The availability at the ground level and near the fields reduces the cost of pumping compared to ground water wells or freshwater sources. The proximity to the urban market in combination with the above makes raw wastewater irrigation in the peri-urban area a lucrative option for this marginalized population.

1.1.3. Perceptions, risks and sustainability

The perennial availability of large volume of nutrient rich surplus wastewater has changed the perception from that of a waste to resource over the last few decades in the SAT. However, use of raw wastewater tends to deteriorate the soil due to salt accumulation. Moreover, such practices tend to give an entry to the food chain for heavy metals if present in the wastewater. Some degree of treatment using low cost techniques like CWs can increase the sustainability of such irrigation practices. Leafy vegetablesparticularly salad crops when grown on raw wastewater tend to compromise on hygiene with increased health risks from nematodes, coliforms and other pathogens. An increased awareness may help farmer to opt for best farm practices for wastewater irrigated fields and the consumers alert of the health threat.

1.1.4. Potential of constructed wetlands (CWs)

Energy and skill intensive wastewater treatment technologies are often not feasible alternative in areas where electricity supply is scarce and unreliable. Adeniran, 2011, observed that the water hyacinth of CW based requires only 13% of the energy as compared to conventional sewage treatment plant for the same quantity of sewage and concluded that is a viable and cost effective option for the treatment of domestic sewage in a developing economy. Phytoremediation of wastewater includes identification of efficient aquatic plant; estimation of plant uptake by the growing plants, optimization of harvesting schedule and investigation of beneficial use of the plant biomass post harvesting (Lu, 2009). Macrophytes such as water hyacinth and water lettuce grow abundantly in eutrophicated water bodies, whereas Typha is ubiquitous on the banks of eutrophicated water bodies. Phyto-remediation potential of these plants species is well known, though field scale performance assessment is scarce in literature (John et al., 2008).High photosynthetic surface area macrophytes can grow vertically as well as horizontally which increases the photosynthetic surface area, makingmakes these two macrophytes among the earth’s most productive communities (Lu, 2009).Because this plant reproduces rapidly and decays, the efficacy of the system is intimately linked to its careful management trough periodic harvesting of part of the biomass produced.

1.2 Design, operationand maintenance of the constructed wetland

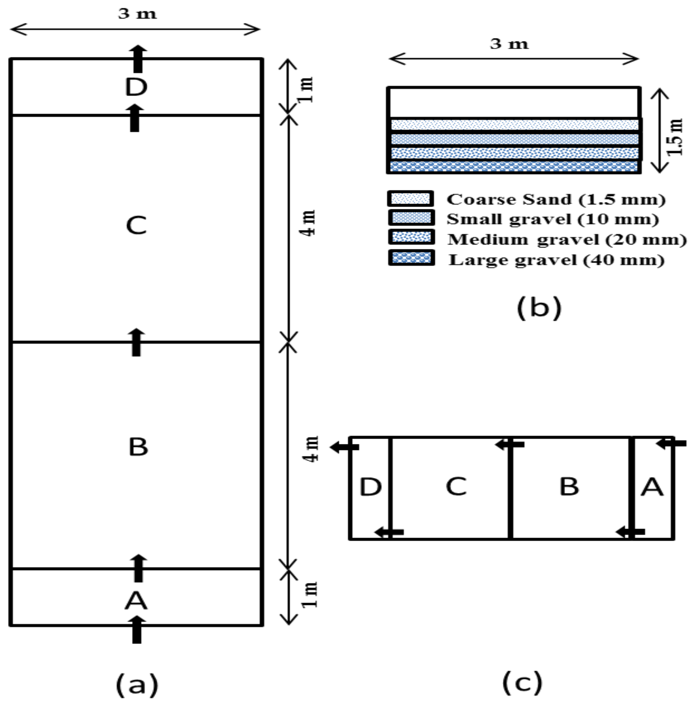

Fig 1 : Design, inner dimensions and flow regime of the CWs

The study was conducted in two identical constructed wetlands. The inner dimension and design is shown in Fig 1a. Cell A and D were the inlet and outlet tanks respectively. Cell B and C were the cells with vegetation in which phytoremediation took place. Both cell B and C were filled with multiple layers of gravel and a top layer of coarse sand, these layers acted as the filter bed providing physical screening. The media comprised of four layers each of 25 cm thickness (Fig 2b), where three gravel layers were covered with a top layer coarse river sand. The size of the gravel was followed by 10 mm gravel and 20 mm gravel layers. The bottom layer was of 40 mm gravel. The flow regime of wastewater is depicted in Fig 1c. The B cell was vegetated with typha in both the cells whereas C cells of CW-1 and CW-2 was having free floating macrophytes, water hyacinth and water lettucerespectively.The wetland inlet was fitted with flow regulator as well as flow meter while the outlets were provided with only flow meter. A U-shaped bend was provided before the flow meter in the inlet pipe to prevent excessive clogging. A wastewater flow of 2 l/m was maintained for both the CWs throughout the study period.

2.Results and discussions

2.1 Performance of the constructed wetland

2.1.1 Wastewater treatment

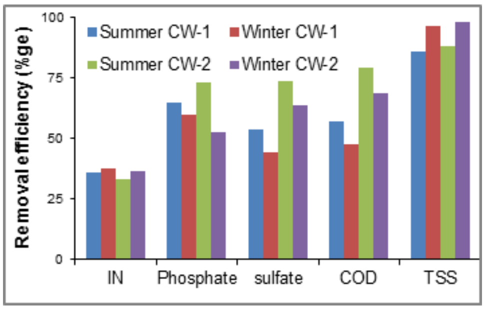

Fig 2 : Performance of CWs

The domestic wastewater of a nearby urban housing colony was treated by the two field scale CWs. The inlet and outlet wastewater analysis of both the CWs were conducted for various parameters on a weekly basis to evaluate their wastewater treatment efficiency. No major change in pH (varied between 7.8 to 8.0) or electrical conductivity (varied between 1.5 to 2.0 ms/cm) was observed between the inlet and outlet wastewater for both CWs. Significant removal efficiency was observed for five key parameters viz. inorganic nitrogen or IN (ammoniacal nitrogen as well as nitrate nitrogen), phosphate, sulphate, chemical oxygen demand or COD and total suspended solids or TSS. The removal efficiency (RE) of inorganic nitrogen varied between 33-37 % for the two CWs, moreover the RE didn't show significant seasonal change (Fig 2). A slightly higher RE (73.3 %) for phosphate was observed in CW-2 particularly during the summer month (30-43 ^{o}C), though theRE (52.6 %) dropped significantly in winter (15-20 ^{o}C) and was in fact less than the RE (60%) observed in CW-1. The sulfate removal efficiency in CW-2 was higher than CW-1 throughout the study period. In peak summer a RE of 74 % was observed while during winter months the RE dropped to 64 %. The RE for sulfate dropped to 43 % during winter in CW-1, from a peak value of 53.7 % observed during summer. The chemical oxygen demand of the inlet wastewater showed both diurnal as well as seasonal variation (64 – 252 mg/L). The COD removal efficiency of CW-2was higher than CW-2, though the performance dropped during the winter months.A drop in the microbial activity, in the root mycorrhiza as well as lower growth rate during the winter may be the reason for the reduced RE. Standard methods for water analysis were followed throughout the study (APHA, 2005). Both the field scale CWs showed consistent REs for IN, phosphate, sulfate, COD as well as TSS throughout the year demonstrating the field applicability of the technology (Fig 3). Salt removal was found to be a limitation though with the three plant species used in this study. Both CWs showed very low removal of sodium (5-8 %), calcium (3-5 %), magnesium (2-3%) as well as chloride (1-2 %) and fluoride (0-1 %). Thus the sodium adsorption ratio (SAR) of the treated wastewater was around 3.5. Thus there is a scope to evaluate the performance of plant species with high salt uptake capacity such as *Salicornia brachiata*etc. in CWs. The critical maintenance aspect was found to be optimized harvesting schedule, in the absence of which macrophytes tend to rapidly at the end of the lifecycle releasing the absorbed nutrients.

2.1.2Optimized harvesting schedule

Fig 3 : Field scale CWs at ICRISAT campus

Though lot of lab scale research with Typha, water lettuce and water hyacinth is available in the literature field scale evaluation is scarce (Mishra et al., 2008). Moreover often the work available with synthetic wastewater with chemically defined constituents may not give the accurate phytoremediation potential for real wastewater. The optimized harvesting schedule for water lettuce was found to be every 10 days during summer and every 20 days during winter. For water hyacinth the optimized harvesting schedule was found to be every 15 days during summer and every 30 days during winter. Water hyacinth was found to be more sensitive to disturbance compared to water lettuce. The dry biomass harvested during the summer months were 0.22 and 0.25 kg/m^2 for water lettuce and water hyacinth respectively.During the winter months the dry biomass yield were less at 0.14 and 0.11 kg/m^2 for waterlettuce and water hyacinth respectively. The dry biomass yield for typha during summer and winter months were 0.3 kg/m^2 and 0.15 kg/m^2 respectively.A harvesting period of 30 days were maintained for typha throughout the year, as unlike macrophytes it does not die and decay rapidly upon reaching the end of life cycle.

2.1.3. Plant nutrient uptake

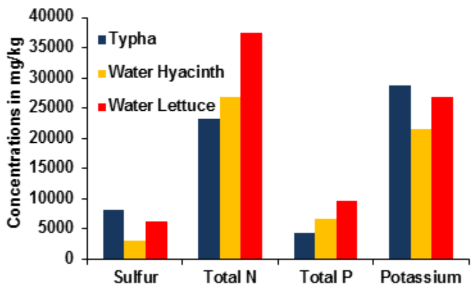

Fig 4 :Plant nutrient uptake data for the CWs

Plant samples were taken every month for nutrient analysis. The plant samples were separated into grain and straw, dried to a constant weight in oven at 65+5 ^{o}C, and then ground and analyzed for N, P, K, and B in the Charles Renard Analytical Laboratory at ICRISAT, Patancheru. Total N, P and K in plant materials were determined by digesting the samples with sulphuric acid-selenium. Nitrogen and P in the digests were analyzed using an auto-analyzer (Skalar SAN System, AA Breda, Netherlands), and K in the digests was analyzed using an atomic absorption spectrophotometer (SavantAA, GBC Scientific Equipment, Braeside, VIC, Australia) (Sahrawat et al. 2002a).Total S in plant samples were determined by inductively coupled plasma emission spectrophotometer (ICP-AES) (Prodigy High Dispersion ICP, Teledyne Leeman Labs, Hudson, New Hampshire, USA) in the digests prepared by digesting the samples with nitric acid (Mills and Jones 1996). As shown in Fig 4 the sulphur uptake capacity for both Typha as well as water lettuce was found to be much higher than that of water hyacinth. In terms of plant uptake as well as overall biomass yield throughout the year water lettuce was exhibited higher efficiency than water hyacinth. The free water surface cell with floating water lettuce however was found to be a mosquito breeding place. Growing small fishes which may feed on mosquito larvae may circumvent this problem.

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