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PROCESS AND PLANTS FOR WASTEWATER REMEDIATION : A REVIEW

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ABSTRACT

Increasing urbanization, industrialization and over population are the factors mainly responsible for adding hazardous components in water, which mainly constitutes heavy metals and chemicals etc. Water bodies are the main targets for disposing the pollutants directly or indirectly. This is a review paper illustrating the role of plants to assist the treatment of industrial and residential wastewater. The prevailing purification technologies used to remove the contaminants are too costly and sometimes non-eco friendly also. Therefore, the research is oriented towards low cost and eco friendly technology for waste water purification, which will be beneficial for community. The paper discusses the potential of different process and utilization of terrestrial and aquatic plants in purifying water and wastewater from different sources.

Key words: Phytoremediation, Treatment methods, Wastewater, Water pollution, Heavy metals.

INTRODUCTION

Waste-water is the combination of liquid or water-carried wastes originating in the sanitary conveniences of dwellings, commercial or industrial facilities and institutions, in addition to any ground water, surface water and storm water that may be present. Untreated wastewater generally contains high levels of organic material, numerous pathogenic microorganisms, as well as nutrients and toxic compounds. It thus entails environmental and health hazards and, consequently, must immediately be conveyed away from its generation sources and treated appropriately before final disposal. The ultimate goal of wastewater management is the protection of the environment in a manner commensurate with public health and socio-economic concerns. Wastewater treatment is becoming even more critical due to diminishing water resources, increasing wastewater disposal costs and stricter discharge regulations that have lowered permissible contaminant levels in waste streams. The municipal sector consumes significant volumes of water, and consequently generates considerable amounts of wastewater discharge. The present study comprises a comprehensive survey of the various methods and technologies currently used in wastewater treatment. The study also addresses the utilization of some eco-friendly and low cost technologies for sustainable development, with special reference to phytoremediation technology[1]. Studying the economics of different wastewater treatments is an essential pre-requisite to the identification of cost-effective solutions.

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Review work

Boyd[2] gave the method for reducing the pollution of lakes by harvesting of aquatic plants, which have withdrawn nutrients from the water. The author points out that all aquatic plants can serve this purpose but small plants, like phytoplankton, or submerged plants are more difficult and expensive to harvest than the floating and emergent vascular plants. Four species are considered suitable, *Eichhornia crassipes* (water hyacinth), *Alternanthera philoxeroides*, *Justicia americana* and *Typha latifolia*.

According to Boyd[3,4] water hyacinth, confined in barriers so that it only covers 10% of the pond, and regularly harvested, can remove sufficient nutrients to avoid excessive phytoplankton growth. Reviewing the literature, he cites three estimates of the amount of nitrogen and phosphorus that water hyacinth could be expected to extract from nutrient-rich waters under good growing conditions: (t/ha/year). Average rates of N and P removal over the entire period were 3.4 and 0.43 kg/ha/day, respectively.

Glass-house and field trials were arranged to measure the uptake of nitrogen and phosphorus by water hyacinths from water having varying concentrations of N and P by Dunigan et al.[5] The N was added as ammonium chloride and potassium nitrate. The N and P concentrations at the beginning of the trials were arranged to be 50, 100 and 250 ppm. After 21 days, all the ammonium N at the lower and medium levels, and the nitrate N at the lowest level, had been taken up. About half the P at each concentration had also been absorbed. In the field trials, the hyacinths increased the rate of loss of ammonium N, but were ineffective in removing nitrate N. The removal of P was low.

The test plants used for the study were *Ceratophyllum* sp., *Cladophora* sp., *Hydrodictyon* sp., *Aphanizomenon* sp., *Microcystis* sp., *Anabaena* sp., and *Nostoc* sp.[6] Water hyacinth was grown in the laboratory in culture solutions containing phosphorus at varying concentrations. The P concentration critical for maximum growth was 0.1 ppm. Below this level growth was limited, above it the hyacinths took up P in luxury amounts without any increase in yield[7].

Water hyacinth was grown outdoors in concrete tanks containing sewage effluent. Over a period of five weeks the uptake of P was measured as 5.5 mg/g of the dry weight of the plant. The P concentration in the effluent was 1.4 mg/litre at the start of the experiment and was reduced to 0.2 mg/litre at the end. Of this decrease 70% took place in the first two weeks and 80% by the end of three weeks. The hyacinth increase in (dry) weight was at a maximum during the first week and totaled 97 g/m^2 of water surface, which represented a 45% increase in the dry weight of the plants at the start of the experiment[8]. The authors concluded that this study indicated that water hyacinths could be used to reduce P in sewage effluent to low levels.

Wastewater treatment systems

Treatment systems

Natural systems for waste-water treatment are designed to take advantage of the physical, chemical[9,10] and biological processes[11] that occur in the natural environment when water, soil, plants, micro-organisms and the atmosphere interact natural treatment systems include land treatment, floating aquatic plants and constructed wetlands. All natural treatment[12] systems are preceded by some form of mechanical pretreatment for the removal of gross solids. Where sufficient land suitable for the purpose is available, these systems can often be the most cost-effective option in terms of both construction and operation.

Land treatment

Land treatment is the controlled application of waste-water to the land at rates compatible with the natural physical, chemical and biological processes that occur on and in the soil. The three main types of land treatment systems used are slow rate (SR), overflow (OF) and rapid infiltration (RI) systems.

Constructed wetlands

Wetlands are inundated land areas with water depths typically less than 2 ft (0.6 m) that supports the growth of emergent plants such as cattail, bulrush, reeds and sedges. The vegetation provides surfaces for the attachment of bacteria films, aids in the filtration and adsorption of waste-water constituents, transfers oxygen into the water column and controls the growth of algae by restricting the penetration of sunlight[6] Wetlands also clean the water by filtering out sedimentation, decomposing vegetative matter and converting chemicals into useable form. The ability of wetlands to recycle nutrients makes them critical in the overall functioning of earth.

Floating aquatic plants

This system is similar to the FWS system except that the plants used are of the floating type, such as hyacinths and duckweeds. Water depths are greater than in the case of wetland systems, ranging from 1.6 to 6.0 feet (0.5-1.8 m). The floating plants shield the water from sunlight and reduce the growth of algae. Systems of this kind have been effective in reducing BOD, nitrogen, metals and trace organics and in removing algae from lagoons and stabilization pond effluents. Supplementary aeration has been used with floating plant systems to increase treatment capacity and to maintain the aerobic conditions necessary for the biological control of mosquitoes.

Use of aquatic plants for water purification

Several papers did refer to the capacity of water plants to extract plant nutrients from the water in which they grew. The reason which has prompted the spate of papers within the last ten years on the nutrient extraction possibilities of aquatic plants[14] is the increasing awareness of the problems of water pollution - both fresh and salt water - as a consequence of population growth and industrial development, and the disposal of human, animal and industrial wastes into inland waters and into the sea. Many examples of the devastating consequences of the waste water on formerly clean and useful rivers and lakes have aroused public and scientific awareness of the need not only to arrest the practice of direct dumping but to try and reverse it by extracting the pollutants. The remarkable ability of aquatic plants, particularly the water hyacinth[4,5], to extract compounds and elements from water efficiently has become well recognized.

It is one of the earliest to go into the question of reducing the pollution of lakes by the harvesting of aquatic plants, which have withdrawn nutrients from the water[2]. It is pointed out that all aquatic plants can serve this purpose but small plants, like phytoplankton, or submerged plants are more difficult and expensive to harvest than the floating and emergent vascular plants. Four species are considered suitable: *Eichhornia crassipes* (water hyacinth), *Alternanthera philoxeroides*, *Justicia americana* and *Typha latifolia* (Table 1). It is stated that water hyacinth would be ideally suited for nutrient removal systems. As it floats on the surface and is not rooted, harvesting is facilitated. There would be considerable microbial activity beneath the hyacinths and nutrients would be absorbed by these organisms. In addition considerable organic matter would reach the water by the loss of root fragments and probably have a fairly high biological oxygen demand (BOD) and it might prove necessary to use conventional sewage holding ponds to reduce the BOD prior to final release.

Alternanthera philoxeroides could probably be best harvested by draining the pond and then using modified forage harvesting equipment. *Typha latifolia* as an emergent species could be grown in ponds about 1 m deep so that the water remains anaerobic, allowing bottom soils to remove P from solution. But it would be better, if space permitted, to grow the plants in water 15–20 cm deep to maximize soil absorption of P. At a stage when P equilibrium had been reached then the ponds could be dried and used for conventional crops until the P levels are reduced.

Table 1: Uptake of various elements by selected aquatic plants

	Aquatic plant species and their uptake (kg/ha/year)			
Element	*E. crassipes*	*J. americana*	*A. philoxeroides*	*T. latifolia*
N	1980	2290	1780	2630
P	320	140	200	400
S	250	200	180	250
Ca	750	1020	320	1710
Mg	790	470	320	310
K	3190	3720	3220	4570
Na	260	190	230	730
Fe	19	120	45	23
Mn	300	13	27	79
Zn	4	30	6	6
Cu	1	3	1	7

Ref. FAO Corporate Document Repository Produced by: Fisheries and Aquaculture Department (Handbook of utilization of aquatic plants)

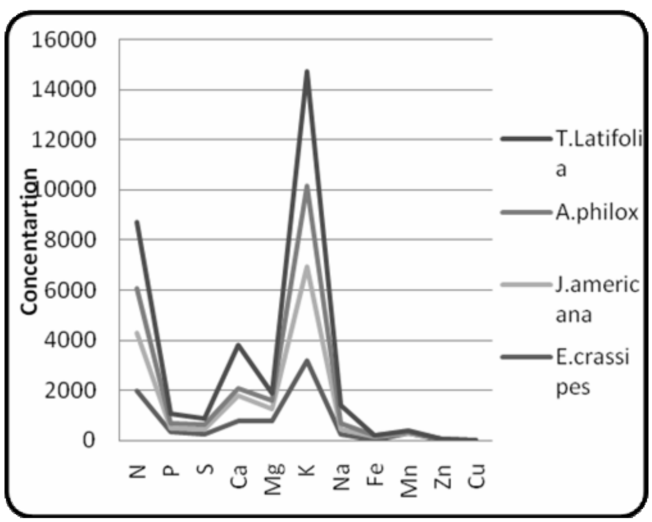

Fig. 1: Aquatic plant species and their nutrient uptake in Kg/ha/year

Nutrient removal by plants would be most effective when the nutrient is concentrated. This is typical of the effluents from feed lots of cattle. If plants were grown on the ponds holding these effluents, they could be fed to the cattle. This would be ideal because handling and transport of the plants would be kept to a minimum. Nutrient removal and plant utilization could also be handled by the same organization.

The paper reviews the potential of aquatic plants[3], for removal of nutrients from polluted water. Waste feed and the excretions of the fish lead to the development of dense blooms of phytoplankton. When the plankton dies, their decaying residues can result in oxygen depletion and fish kill. Water hyacinth, confined in barriers so that it only covers 10% of the pond and regularly harvested, can remove sufficient nutrients to avoid excessive phytoplankton growth.

A method of harvesting aquatic weeds emphasizes the usefulness of aquatic plants in purifying water[15] He comments that water plants are one of the most efficient ways of extracting nutrients from water. By releasing oxygen they also contribute to water clarity. In the field and laboratory evaluations of bioassays for nitrogen and phosphorus[8] with algae[6] and aquatic weed[16,17], technique describes the conditions of surplus, or limiting concentrations of, nitrogen and phosphorus in algae and aquatic plants. The report also discusses a simple method for measuring rates of nitrogen fixation by blue-green algae. The test plants used were *Ceratophyllum* sp., *Cladophora* sp., *Hydrodictyon* sp., *Aphanizomenon* sp., *Microcystis* sp., *Anabaen*a sp., and *Nostoc* sp. It is found that aquatic plants which have been recently exposed to a relatively high concentration of available P could absorb enough to indicate surplus P conditions by their total P content. The comparative study on nutrient content of aquatic plants from different habitats was done. In the experiment, three aquatic plants were grown in water with different degrees of pollution, from raw sewage[18] to unpolluted. The uptake of nutrients was analyzed. "Luxury consumption" of nutrients was observed from water containing large amounts of N, P and K. The authors conclude, "As the availability of the nutrient changes so does the concentration of nutrient in the plant."

The relationship of nutrients in water to algae and aquatic plants was observed. Accordingly, "The growth and development of established aquatic plants will depend on the available nutrients in the water, suitable climatic conditions and competition with other species[19]. The void created by the destruction of one type of biological growth may be filled by another and different type of biological activity". The author reviews the relationship and importance of aquatic plants to their habitat. Several aquatic plants have been found to accumulate arsenic to a level well above those associated with toxicity of this element[20].

The effect of sewage effluent on growth of five aquatic species[21,22]. *Eichhornia crassipes*, *Alternanthera philoxeroides*, *Egeria densa*, *Najas flexilis* and *Potamogeton crispus* were grown in plastic pools in well water, with or without the addition of 25% of sewage effluent. Of the five test plants, *E. crassipes* showed the maximum growth response to the sewage effluent, with *A. philoxeroides* second. In well water alone *A. philoxeroides* was the only plant to survive, indicating its ability to tolerate very low nutrient levels. The water hyacinth dominated others covering 71% of the water surface and removed 6.9 g of N, 2.9 g of P and 8.7 g of K from the sewage pools. *A. philoxeroides* did not gain N and K, instead the plants released these elements to the water; but they took up some P (0.15 mg).

Experiment[23] on the aquatic plants for the removal of mevinphos (insecticide) from the aquatic environment[24,25]. It was concluded that emergent aquatic plants may be more effective in removing mevinphos than submerged species because of the quantity of water they transpire. They also gave successful trials on Water hyacinths and alligator weeds for removal of lead and mercury from polluted waters. Following on the uptake of nickel and cadmium by water hyacinths[26,27] in the same series, the uptake of lead and mercury was carried out. The work was expanded to include also *Alternanthera philoxeroides* (alligator weed) which is known to tolerate higher levels of salinity than hyacinths. They also studied the role of water hyacinth for removal of phenol and phenolic derivatives, from polluted waters[7,25].

Similarly various other aquatic plants such as *Alternanthera philoxeroides* (alligator weeds), *Sparganium ramosum*, *S. simplex* and *Butomus umbellatus*, *Chara spp*[28]. *Myriophyllum spicatum*, duck-weed etc. were experimented for their capacity to remove nutrients from waste water.

RESULTS AND DISCUSSION

The review presented in this paper reveals that aquatic plant-based treatment systems using ponds or artificial wetlands are effective in water pollution control. Aquatic plants show promise for treating domestic wastewater, industrial effluents, and agricultural drainage water. Aquatic plants are also being considered for improving water quality of lakes and streams. Biosorption is being demonstrated as a useful alternative to conventional system for the removal of toxic metals from industrial effluents. The development of the biosorption processes requires further investigation in the direction of modeling of regeneration of biosorbent material and testing with industrial effluents. The high nutrient concentrations in water can be substantially reduced by passage of water through aquatic vegetation. The aquatic plants play a very crucial role in purification of waste water. Nutrient removal is being influenced by temperature, biological activity and flow rate. The slower the flow and the longer the retention time, the greater is the removal. It is concluded that out of various aquatic plant species *Eichhornia crassipes* (water hyacinth) can be usefully employed to extract nutrients from sewage. It is also proved useful in treating effluents polluted with toxic heavy metals. Duckweeds[27] are being tested as a means of sewage filtration during cold months when water hyacinth is temporarily inactive. *Typha latifolia* (Bulrush) is a perennial herbaceous plant which grows in temperate, subtropical and tropical areas and shows the maximum absorption of metal like Na. Thus on one hand aquatic plants show marked absorption of nutrients like N, P, S, Ca, Mg, etc. and metals like Na, Fe, Mn, Zn, Cu etc.[29] and on the other hand it is also emphasized to simultaneously harvest and remove the aquatic vegetation specially submerged plants from the lagoons otherwise they will die, decay and return their contained/absorbed nutrients to the water and thus the level of nutrients in the lake cannot be reduced to an acceptable level and will further degrade the water quality.

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