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WETLAND BIODIVERSITY FOR WATER TREATMENT

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ABSTRACT

Low cost technology approaches to the recycling of wastewater is gaining importance taking into account the global increase in inevitable wastewater produced. Wetlands with its assemblage of flora and fauna can be effectively used to remove pollutants from the aquatic environment. The present paper reviews the various components and processes of wetlands which function for the improvement of water quality.

Keywords : Biodiversity, wetland flora, fauna, microbes.

INTRODUCTION

Low cost technology approaches to the recycling of wastewater is gaining importance taking into account the global increase in inevitable wastewater produced annually. The existing treatment methods require expensive, complicated facilities and involve several after effects of chemical treatment. It has therefore become essential to look for alternative, ecologically sound methods of water treatment. The functioning systems of the ecosystem, including aquatic flora and fauna can be used to remove pollutants from the aquatic environment.

Wetlands are transitional lands between terrestrial and aquatic systems which provide habitat for a variety of flora and fauna. It includes an assemblage of habitats ranging from rivers, floodplains, rain fed lakes to mangrove swamps, estuaries and salt marshes (Gore, 1983). Wetlands perform many ecological functions.

The ability of wetlands to transform and store organic matter and nutrients has results in the wetlands often being described as the 'Kidneys of the landscape' (Mitsch and Gosselink, 1993). The use of wetland biodiversity for improving water quality is not a new invention. Ancient Chines and Egyptian cultures had been using wetlands for the disposal of wastewater. It was an acceptable solution, although the functioning of these systems in relation to wastewater treatment was not conclusively determined. Regarding the removal mechanism, a basic understanding of the role of each minor component of a wetland system is still lacking (Polprasert *et al.,* 1996).

Improvement of the quality of wastewater in wetlands depends on a large number of variables which include the hydrologic regime, nutrient concentrations in the wastewater, nutrients already present in the system, the kind of vegetation (annual or perennial, submerged or emergent), sediments (mineral and organic), and other biota.

Components of Wetlands

The major components of wetlands which function for water quality improvement include.

Soil

Types of wetland soils are organic and mineral capable of absorption/adsorption of pollutants. Organic wetlands soils are those that are made mostly of the remains of plants and animals. Wet organic soils look like black muck or black to dark brown peat. Mineral soils with little or no organic materials can be made of a wide range of materials, such as sand, silt, clay or loam.

Microbes

Microorganisms, including algae, protozoa, fungi and bacteria, enables removal of pollutants from water. The wetland optimizes the habitat for these organisms by providing a detrital layer on the wetland bottom to which millions of microbes can attach and then treat wastewater.

Bacteria inhabit microenvironments in the plant root zone and may also be dispersed throughout the water column. The bacteria most commonly seen in wetlands are species of *Vibrio, Pseudomonas, Flavobacterium, Bacillus, Escherichia* etc. *Pseudomonas putida, Arthrobacter* *viscous* and *Citrobacter sps.* remove several heavy metals. Organic carbon, typically measured as BOD_5 is utilized by bacteria as an energy source and for cell synthesis.

Yeast species such as *Debaryomyces, Torulopsis* and *Rhodotorula* are seen in wetlands. The yeast *Saccharomyces cerevisae* can accumulate uranium from dilute solutions.

Fungus species of wetlands can metabolise several pollutants (both organic and inorganic) and therefore are of importance in wetlands. *Aspergillus terreus, Curvularia lunata, Penicillium sp., Trichosporon sp.* etc. are of importance in treating domestic wastewater. *Rhizopus arrhizus, Aspergillus niger, Trichoderma harzianum, Trichoderma cutaneum, Penicillium digitatum* etc. can remove metal ions (Nandan & Raisuddin, 1996)

Algae are a diverse group of microorganisms that can perform photosynthesis and are capable of metabolising wastes. All major algal groups are represented in the wetlands although the most commonly reported groups are diatoms, green algae and cyanobacteria. The algal species such as *phormidium, Selestrum* sp. (Raj and Kavitha, 2002) *Scenedusmus* sp. (Tridci *et al.,* 1992) *Ankistrodesmus* sp. (Patil, 1991) *Spirulina* (Rose *et al.,* 1995), *Chlorella* and *Chlamydomonas* (Kawasaki *et al.,* 1982; Gordon *et al.,* 1977) have potential to remediate wastewaters.

Floating Plants

Aquatic flora in wetlands includes floating, submerged and emergent types. The roots of floating plants are good habitat for the bacteria responsible for waste stabilization. Several genera of floating macrophytes including *Eichhornia, Salvinia, Lemna, Pistia* and other plants are seen in wetlands. They are also known to absorb heavy metals and refractory organics from effluents. The plant extract of *Lemna* inhibits the growth of *Staphylococcus.*

Submerged Plants

Submerged plant species in wetlands that are able to survive in highly enriched waters includes *Potamogeton, Ceratophyllum, Hydrilla, Elodea, Myriophyllum and Najas*. Submerged plants remove soluble nutrients and provide substratum for attachment of algae, diatoms, bacteria and stalked ciliates.

Emergent Plants

The emergent macrophytes include *Typha, Juncus, Scirpus, Phragmites and Eleocharis.* Emergent macrophytes have more supportive tissue than floating macrophytes, and therefore greater potential for storing nutrients over a longer period.

Mangroves

Mangroves, the salt tolerant, intertidal wetland ecosystems of tropical and subtropical regions have the capacity to improve the water quality. The plants have peculiar adaptations such as support roots, viviparous germination, salt excreting leaves, breathing roots, knee roots etc, by which the plants are well adapted to water logged, anaerobic saline soils of coastal marine environment. Important mangrove species are *Avicennia officinalis* L., *A. marina* (Forsk.) Vierh., *Bruguiera cylindrica* (L.) Bl., *Rhizophora apiculata* Blume, *R. mucronata* Lamk., *Kandelia candel* (L.) Druce, *Sonneratia caseolaris* (L.) Engl., *Acanthus ilicifolius* L., *Acrostichum aureum,* L., *Derris trifoliata* Lour, *Aegeceras corniculatum* (L.) Blanco and *Excoecaria agallocha* L. The rhizome of *Acrostichum* as well as the leaf and stem bark of *R. mucronata* have antibacterial activity (Dagar *et al.,* 1991)

Invertebrates

A wide variety of beneficial organisms ranging from protozoa to higher animals can exist in wetland systems. Protozoa are microscopic animals, which multiply by simple fission and feed upon bacteria and organic detritus. Removal of excess bacteria and suspended organic debris serves to clarify water. The genera of protozoa which probably aid in improving the water quality include *Paramecium, Colpoda, Euplotes, Arcella, Oxytricha, Vorticella, Amoeba* and *Didinium.*

Wetlands typically support a diverse aquatic insect fauna of which chironomids are probably the most abundant, often comprising greater than 50 percent of all insects (Wrubleski, 1987) which feed on the entrapped food particles and benthic organic detritus. Copepods, cladocerans and anostracans contribute to energy dissipation through biological recycling by their consumption of algae, protozoa, bacteria and other suspended organic matter. Filter feeding cladocerans such as *Daphnia, Moina, Chydorus,* and *Bosmina*; Copepods such as *cyclops. Mesocyclops and Diapotomus* feed on bacteria and organic matter. Their thoracic legs help in filter feeding. Brine shrimps are crustaceans (anostracans), which can remove algae and other organic suspended matter from saline wastewaters (McShan *et al.,* 1974). Amphipods (*Gammarus, Hyalella*) Corixids and Odonates in wetlands are also important in waste removal (Neil & Cornwell, 1992).

Molluscs (clams, mussels, oysters and scallops) are tolerant to highly enriched waters and are capable of rapidly removing algae, phosphorous, colloidal material and fecal coliforms from water.

Vertebrates

The fishes that have the greatest potential for water purification in wetland systems are the Cyprinids (carps-minnows), Cichlids (tiapia) and Poecillids (mollies). Filter feeds, detritivores and omnivores are capable of removing wastes from water and converting it into biomass.

Wetlands provide spawning and feeding grounds for numerous higher vertebrates including water birds and mammals. These animals fulfill a number of roles in the wetland, serving as planktivores, herbivores, detritivores, promoting resuspension of sediments, providing sources and sinks for nutrients, thereby improving water quality. The details of various wetland components, their function and process involved in water quality improvement is given in Table -1.

Process of water quality improvement

The processes involved in water quality improvement vary with the components in wetlands like microbes, plants, invertebrates and vertebrates. The physicochemical and soil characteristics also contribute to the functions which lead to water purification.

Microorganisms can metabolise, absorb and adsorb pollutants in their cells/cell walls. The metabolic rates of fungi are higher (50-250 cal/kg/hour) than that of bacteria (33 cal/kg/hour). This indicates fungi can effectively biodegrade high strength wastes better than bacteria. Bacterial extracellular capsular polysaccharides as well as metabolites can non-specifically bind metal ions. Algal metabolism causes changes in water chemistry that includes oxygenation of the water column (Van) increases in pH and decreased concentration of carbon dioxide and bicarbonate (Browder). Algae contribute to wetland nutrient cycles by removing dissolved organic matter (Hall) and nitrogen fixed by cyanobacteria.

The mechanisms for the capability of plants to assimilate nutrients, including nitrates and phosphates may be complex involving physiological characteristics of the plants, biological and physicochemical reactions in the aquatic environment. Floating aquatic plants also have the capability to assimilate large quantities of trace elements, some of which are essential for plant growth, thereby improving the water quality (Reddy & De Busk, 1987). In submerged plants absorption is also facilitated by the permeability of the unthickened cellulose walls and often absence of cuticle. Even when it does occur, offers little resistance to diffusing substances (Sculthorpe, 1967)

Macrophytes aid in wastewater treatment by facilitating physical sedimentation and bacterial metabolic activity. The roots and stems provide surface for bacterial growth and are media for filtration and adsorption of solids. The stem and leaves prevent growth of suspended algae, reduce the effect of wind on water and transfer oxygen from leaves to root tips (Stowell *et al.,* 1980) Plants remove nutrients such as nitrates and phosphate by directly assimilating them into their tissue and on harvest remove them permanently from the water body. Moreover nitrogen is removed by bacterial nitrification and denitrification since aquatic plants provide surfaces for attachment of nitrifying bacteria in aquatic system (Reed *et al.,* 1988). Phosphorous removal mechanisms in aquatic systems are plant uptake, chemical adsorption and precipitation reactions (Polpraserrt). Vegetation serves only as a short-term sink for phosphorous unless the biomass is harvested as in the case of nitrogen. The major pathway for removal of sulphates is plant uptake. Sulphate is quite rapidly taken up by roots, translocated to leaf chloroplast where it is reduced and thus incorporated into organic compounds or accumulated in the vacuoles. Plant uptake of calcium and magnesium reduces its concentration, as well as the total hardness of water in aquatic systems.

An anatomical adaptation of aquatic plants is the development of aerenchyma cell structure which facilitates the exchange of oxygen from aerial tissue into the root zone (Moorhead and Reddy, 1988 and Armstrong, 1964). This oxygen if not consumed during root respiration can enter the water column and be utilized by the aerobic bacteria for oxidation of organic carbon (Reddy and De Busk, 1987)

Suspended and colloidal solids are removed as a result of collisions (Inertial and Brownian) with an adsorption to plant parts such as stem and roots (Stowell *et al.,* 1980). Particulates are filtered mechanically as water passes through the roots. Ultimate removal of suspended solids will

Table 1 : Some Wetland Components and Their Function in Wastewater Treatment

No.	Wetland Component	Characteristic	Family	Part responsible for treatment	Process of water quality improvement
Flora					
1.	*Salvinia molesta*	Floating	Salviniaceae	Root	
2.	*Pistia stratiotes*	Floating	Araceae	Root	
3.	*Eichhornia crassipes*	Floating	Pontederiaceae	Root	
4.	*Lemna sp.*	Floating	Lemnaceae	Root	Adsorption,
5.	*Azolla sp.*	Floating	Azollaceae	Root	absorption,
6.	*Nymphea caerula*	Rooted Floating	Nymphaceae	Root	assimilation precipitation
7.	*Nelumbo nucifera*	Rooted Floating	Nymphaceae	Root	sedimentation surface for
8.	*Hydrilla verticillata*	Submerged	Hydrocharitaceae	Entire plant	bacterial growth,
9.	*Ceratophyllum demersum*	Submerged	Ceratophyllaceae	Entire plant	bioactive chemicals
10.	*Lagenandra toxicaria*	Emergent	Araceae	Root	
11.	*Typha sp*.	Emergent	Typhaceae	Root	
12.	*Alternanthera philoxeroides*	Emergent	Amaranthaceae	Root	
13.	*Rhizophora sp.*	Mangrove	Rhizophoraceae	Root	
Fauna					
1.	*Paramecium sp.*	Filter feeder	Parameciidae	Cilia	Filter feeding
2.	*Daphnia sp.*	Filter feeder	Daphnidae	Thoracic appendages	
3.	*Tilapia mossambica*	Plants, plankton detritus, invertebrates		Mouth & Gill rakers	
4.	*Catla catla*	Zooplankton and detritus	Cyprinidae	Mouth & gill rakers	Direct consumption
5.	*Labeo rohita*	Decayed vegetation, epiphytes	Cyprinidae	Mouth & gill rakers	filtering by gill rakers
6.	*Cirrhinius mrigala*	Decayed vegetation, benthic animals, epiphytic plankton	Cyprinidae	Mouth & gill rakers	
7.	*Cyprinus carpio*	Phytoplankton, zooplankton, insect larvae	Cyprinidae	Mouth & gill rakers	
8.	*Channa marulius*	Zooplankton, insect larvae	Channidae	Mouth & gill rakers	

Table 2 : Details of Antimicrobial/ Biopesticidal Properties of Wetland Plants

No.	Scientific Name	Property	Chemical constituen
1.	*Acanthus* sp.	Antimicrobial	Benzoxazolin 2-one
2.	*Derris* sp.	Pesticide	Rotenone roots
3.	*Aegiceras* sp.	Biogungicide	o-methylembelin-o-benzoquinone
4.	*Bruguiera* sp.	Antitumor activity	Brugine (Tropine 1,2-dithiolane -3-carboxylate)
5.	*Rhizophora* sp.	Antibacterial and antifungal activity	2,6,-Dimethoxy-p-benzoquinone
6.	*Acrostichum* sp.	Antibacterial activity - rhizome	
7.	Phragmites sp.	Biopesticide Treats parasitic intestinal worms	N,N-DMT, 5-Meo-DMT, bufotenine and gramine
8.	*Nelumbo* sp.	Bacteriostatic action against grame +ve & grame -ve bacteria	Nuciferine, roemerine, nornaciferine
9.	*Centella* sp.	Destroys *Bacillus* sp.	Hydrocotin
10.	*Typha* sp.	Astringent	Glucoside
11.	*Ceratophyllum* sp.	Antimicrobial	Not detected
12.	*Pistia* sp.	Antimicrobial	Not detected
13.	*Lemna* sp.	Mosquito control and Inhibits growth of *Staphylococcus*	Not detected
14.	*Acorus* sp.	Antibiotic resistance inhibitor	Benzoic acid phenylmethyl ester (benzyl benzoate)
15.	*Lagenandra* sp.	Antimicrobial	Not detected.

be by bacterial metabolism, i.e., aerobic decay of solids entangled in the surfaces of vegetation (Polprasert, 1996).

Aquatic systems offer a unique combination of physical, chemical and biological factors that contribute to inactivation and removal of both pathogenic viruses and bacteria. In addition to filtration through the root substrate and attached biofilm, physical removal factors include sedimentation, aggregation and inactivation by UV radiation. Chemical factors include oxidation, exposure to biocides which may be excreted by plants (Polprasert, 1996) and adsorption to organic matter (Wood, 1990). Anaerobic metabolites, alkaloids, phenolics, terpenoids and steroids are bioactive chemicals abundant in roots and rhizospheres of plants in wetlands. Bioactivities include allelopathy, growth regulation, extraorganisimal enzymatic activities, metal manipulation by phytosiderophores and phyochelatins, various pest control effects and poisoning. Ingestion by nematodes or ciliates, attack by lytic bacteria are other causes (Gersberg *et al.,* 1987). Aquatic macrophytes such as water hyacinth, *Pistia, Lagenandra* and *Ceratophyllum* have antimicrobial properties (Agarwal, 1997) and this could aid in reducing bacterial counts. Table 2 gives details of selected wetland plant species with antimicrobial, biopesticidal and other treatment potentials.

Conclusion

Wetlands contain an assemblage of flora and fauna with various characteristics for wastewater treatment. The properties of animal and plant varieties for waste removal includes adsorption, absorption, filtration, antibacterial, disinfecting, fungicidal, pesticidal, coagulative/ flocculative effects. The alkaloids and chemical ingredients like benzoxazolin, brugine, bufotenine, hydrocotin, methylembelin etc. are found to have high disinfective and pesticidal effects removing pathogens and controlling breeding of vectors of waterborne and related diseases. The use of these animals and plants as well as microbial species will be effective in constructed wetlands, biotreatment plants and related processes. Proper designing, standardization and modeling of the systems with this highly beneficial wetland species could be promising for pollution abatement.

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