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Review Paper on Phytoremediation: A Green Technology

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ABSTRACT

The contamination from industrial, research experiments, military, and agricultural activities either due to ignorance, lack of vision, carelessness, or high cost of waste disposal and treatment affects the land, surface waters, and ground water worldwide. The rapid build-up of toxic pollutants (metals, radionuclide, and organic contaminants in soil, surface water, and ground water) not only affects natural resources, but also causes major strains on ecosystems. Interest in phytoremediation as a method to solve environmental contamination has been growing rapidly in recent years. Phytoremediation involves growing plants in a contaminated matrix to remove environmental contaminants by facilitating sequestration and degradation (detoxification) of the pollutants. The costs of using plants along with other concerns like climatic restrictions that may limit growing of plants and slow speed in comparison with conventional methods (i.e., physical and chemical treatment) for bioremediation must be considered carefully. The long-term implication of green plant technology in eliminating or sequestering environmental contaminations must be addressed thoroughly. While adopting the new technology, we have to proceed with caution.

Keywords*: *Phytoremediation, Green Technology, Pollutants,, Contaminants, Toxic Metals

I. INTRODUCTION

Unnecessary consumption and wastage of water will lead to the water shortage in India and will be a key issue for its sustainable development in the future. Conventional sources of water i.e. groundwater and surface water sources are becoming increasingly vulnerable to industrial and natural pollution. International Water Management Institute (IWMI) predicts that by 2025, one in three Indians will live in conditions of absolute water scarcity. If wastewater is treated properly before discharging in the surface waters, it can control the water pollution. Various physical, chemical and biological treatments are given to wastewater. Physical treatment includes screening, sedimentation, filtration. Chemical treatment includes chemical precipitation, coagulation and flocculation, chemical adsorption. Biological treatment includes rotating biological contactor (RBC), sequencing batch reactor (SBR), anaerobic sludge blanket (UASB), constructed wetland (CW) and membrane bioreactors (MBR), have been applied for grey water treatment. The biological processes were often preceded by a physical pre-treatment step such as sedimentation, usage of septic tanks or screens. Phytoremediation is one of the biological treatment which can be adopted for all types of wastewater./

II. PHYTOREMEDIATION

Phytoremediation is a technology that uses plants to clean up contaminated sites. Phytostabilization which is ` enhances the soil fertility. But there are some disadvantages like a) The contaminants are left in place, so the site need stabilization for sometimes b) Elevated, toxic effects may prevent plants from growing. c) If soil additives are used, they may need to be periodically reapplied to maintain the effectiveness of the immobilization etc.

Phytoremediation is an emerging cost effective, non-intrusive, aesthetically pleasing, and low cost technology using the remarkable ability of plants to metabolize various elements and compounds from the environment in their tissues. Phytoremediation technology is applicable to a broad range of contaminants, including metals and radionuclides, as well as organic compounds like chlorinated solvents, polychlori- biphenyls, polycyclic aromatic hydrocarbons, pesticides/insecticides, explosives and surfactants. Phytoremediation is the direct use of green plants to degrade, contain, or render harmless various environmental contaminants, including recalcitrant organic compounds or heavy metals. Plants are especially useful in the process of bioremediation because they prevent erosion and leaching that can spread the toxic substances to surrounding areas. Several types of phytoremediation are being used today. One is phytoextraction, which relies on a plant's natural ability to take up certain substances (such as heavy metals) from the environment and sequester them in their cells until the plant can be harvested. Another is phytodegradation in which plants convert organic pollutants into a non-toxic form. Next is phytostabilization, which makes plants release certain chemicals that bind with the contaminant to make it less bio available and less mobile in the surrounding environment. Last is phytovolitization, a process through which plants extract pollutants from the soil and then convert them into a gas that can be safely released into the atmosphere. Rhizofiltration is a similar concept to phytoextraction, but mainly use with the remediation of contaminated groundwater rather than the remediation of polluted soils. The contaminants are either absorbed onto the root surface or are absorb by the plant roots. Plants used for rhizofiltration are not planted directly in situ, but are acclimated with the pollutant first. Until a large root system has developed, plants are hydroponically grown in clean water rather than in soil. Once a large root system is in place, the water supply is substituted for polluted water supply to acclimate the plant. After the plants become acclimatized, they are planted in the polluted area. As the roots become saturated, they are harvested and disposed of safely.

III. PLANTS USED FOR PHYTOREMEDIATION:

The principal application of phytoremediation is for lightly contaminated soils and waters where the material to be treated is at a shallow or medium depth and the area to be treated is large. Plants that are able to decontaminate soils does one or more of the following: 1) plant uptake of contaminant from soil particles or soil liquid into their roots; 2) bind the contaminant into their root tissue, physically or chemically; and 3) transport the contaminant from their roots into growing shoots and prevent or inhibit the contaminant from leaching out of the soil.

Moreover, the plants should not only accumulate, degrade or volatilize the contaminants, but should also grow quickly in a range of different conditions and lend themselves to easy harvesting. If the plants are left to die in situ, the contaminants will return to the soil. So, for complete removal of contaminants from an area, the plants must be cut and disposed of elsewhere in a non-polluting way. Some examples of plants used in phytoremediation practices are the following: water hyacinths (Eichorniacrassipes); poplar trees (Populus spp.); forage kochia (Kochia spp); alfalfa (Medicagosativa); Kentucky bluegrass (Poapratensis); Scirpusspp, coontail (Ceratophyllumdemersum L.); American pondweed (Potamogetonnodosus); and the emergent common arrowhead (Sagittarialatifolia).

3.1 EichorniaCrassipes (Water Hyacinth):

The water hyacinth is an invasive plant that is native of the Amazon and whose capacity for growth and propagation causes major conservation problems. It is a species of great ornamental value used in gardening because of the beauty of its foliage and flowers. Most of the problems associated with E. crassipes are due to its rapid growth rate, its ability to successfully compete with other aquatic plants, and its ease of propagation. These characteristics give rise to enormous amounts of biomass that cover the water surface of a great variety of habitats often interfering with the use and management of water resources. It is said that it grows double in 5 to 15 days. Some of the principal problems are its interference with navigation, water flow, and the recreational use of aquatic systems, as well as the risk it poses of mechanical damage to hydroelectric systems. The impact of E. crassipes on the physico-chemical characteristics of the water in general are declines biological oxygen demand (organic load), and nutrient levels. This makes them suitable for the treatment of wastewater. Optimal water pH for growth of this aquatic plant is neutral but it can tolerate pH values from 4 to 10.

3.2 Pistia Stratiotes (Water Lettuce):

Pistia stratiotes, also known as 'Jal kumbhi', water cabbage, water lettuce, Nile cabbage, or shellflower is a free floating aquatic plant of streams, lakes and ponds. As a floating weed it forms dense mats on surface of water bodies, disrupting aquatic flora and fauna underneath and thus adversely affects the water ecosystem and hinders water flow, fishing, swimming, boating, water sports and navigation. Lettuce doubles its biomass in just over 5 days; triples it in 10 days, quadruples in 20 days and has its original biomass multiplied by a factor of 9 in less than one month. However, water lettuce is capable to remove nutrients and heavy metals from the sewage sludge and drainage ditches. The physicochemical parameters reduce progressively from the influent to effluent ponds like turbidity, phosphates, total iron, sulphates and suspended solids. Hence it is the most suitable plant for waste phytoremediation in tropical areas. Water lettuce contain alkaloids, glycosides, flavonoids, and steroids, vitamin A, B and C, proteins, essential amino acids, and minerals. Its leaves are used in traditional medicine for treatment of ringworm, syphilis, skin infections, boils, wounds, fever, tuberculosis and dysentery in many countries of the world.

IV. GRASSES AS POTENTIAL PHYTOREMEDIATORS:

4.1 Vetiver Grass (Vetiveriazizanioides L.) belongs to the same grass family as maize, sorghum, sugarcane, and lemon grass. It has several unique characteristic as reported by the National Research Council. Vetiver grass is a perennial grass growing two meters high, and three meters deep in the ground. It has a strong dense and vertical root system. It grows both in hydrophilic and xerophytic conditions. The leaves sprout from the bottom of the clumps and each blade is narrow, long and coarse. The leaf is 45 - 100 cm long and 6 - 12 cm wide. Vetiver grass is highly suitable for phytoremedial application due to its extraordinary features. These include a massive and deep root system, tolerance to extreme climatic variations such as prolonged drought, flood, submergence, fire, frost, and heat waves. It is also tolerant to a wide range of soil acidity, alkalinity, salinity, solidity, elevated levels of Al, Mn, and heavy metals such as As, Cr, Ni, Pb, Zn, Hg, Se, and Cu in soils. Vetiver grass can be used for rehabilitation of mine tailings, garbage landfills, and industrial waste dumps which are often extremely acidic or alkaline, high in heavy metals, and low in plant nutrients.

4.2 Cogon Grass (Imperatacylindrica L.): Cogon grass, generally occurs on light textured acid soils with clay subsoil, and can tolerate a wide range of soil pH ranging from strongly acidic to slightly alkaline. It is hardy species, tolerant those experiencing disturbances. It is a perennial grass up to 120 cm high with narrow and rigid leaf-blades of shade, high salinity, and drought. It can be found in virtually any ecosystem, especially

4.3 Carabao Grass (Paspalumconjugatum L.): Carabao grass is a vigorous, creeping perennial grass with long stolons and rooting at nodes. Its culms can ascend to about 40 to 100 cm tall, branching, solid, and slightly compressed where new shoots can develop at every rooted node. It is adapted to humid climates and found growing gregariously under plantation crops and also along stream banks, roadsides, and in disturbed areas. This grass can adapt easily to a wide range of soils.

V. CASE STUDY

5.1 Role of various plants in treatment of wastewater:

Qin et al, conducted experiments to explore the potential of the alien plants water hyacinth (Eichorniacrassipes) and water lettuce (Pistia stratiotes) as phytoremediation aquatic macrophytes for nutrients (nitrogen and phosphorus) removal and algal interception from open pond contaminated with domestic sewage. Water hyacinth, which exhibited hyperactive accumulating capacity for nitrogen (58.64% of total reductions), was more suitable than water lettuce for the intensive purification of domestic sewage with high nitrogen concentrations. This result may be attributed to the larger total root surface, active absorption area and leaf area and higher root activity, root biomass and net photosynthetic rate of water hyacinth than those of water lettuce.(1)

Akinbile and Yusoff, analyzed water hyacinth (Eichorniacrassipes) and water lettuce (Pistia stratiotes) to determine their effectiveness in aquaculture wastewater treatment in Malaysia. Wastewater from fish farm in Semanggol Perak, Malaysia was sampled and the parameters determined included, the pH, turbidity, dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), phosphate (PO_4^{3-}), nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3), and total kjeldahl nitrogen (TKN). Also, hydroponics system was set up and was added with fresh plants weights of 150 ± 20 grams Eichorniacrassipes and 50 ± 10 grams Pistia stratiotes during the 30 days experiment. Considerable percentage reduction was observed in all the parameters treated with the phytoremediators. Percentage reduction of turbidity for Eichorniacrassipes was 85.26% and 87.05% while Pistia stratiotes were 92.70% and 93.69% respectively. Similar reductions were observed in COD, TKN, NO_3^-, NH_3, and PO_4^{3-}. The capability of these plants in removing nutrients was established from the study. (2)

Sivasankari and Ravindran, conducted experiments on water hyacinth and water lettuce and showed that these two macrophytes can be readily degraded under anaerobic condition to yield significant quantities of hydrogen. Anaerobic digestion provides a feasible technology to harness the chemical energy stored in these weeds. Water hyacinth and water lettuce were evaluated in this study as substrates for bio hydrogen production. The result showed that aquatic plants are a promising biomass for bio hydrogen production. Bio hydrogen will play a major role in future because it can utilize renewable sources of energy. (3)

Awuah et al., performed a bench-scale continuous-flow wastewater treatment system comprising three parallel lines using duckweed (Spirodelapolyrhiza), water lettuce (Pistia stratiotes), and algae (natural colonization) as treatment agents to determine environmental conditions, fecal coliform profiles and general treatment performance. Each line consisted of four ponds connected in series fed by diluted sewage. Influent and effluent parameters measured included environmental conditions, turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate, nitrite, ammonia, total phosphorus. BOD removal was highest in the duckweed system, followed by pistia and algae at 95%, 93%, and 25%, respectively. COD removals were 65% and 59%, respectively, for duckweed and pistia, while COD increased in algal ponds by 56%. Nitrate removals were 72%, 70%, and 36%, respectively for duckweed, pistia, and algal ponds. Total phosphorus removals were 33% and 9% for pistia and duckweed systems, while an increase of 19% was observed in the algal treatment system. Ammonia removals were 95% in both pistia and duckweed and 93% in algal systems. Removals of total dissolved solids (TDS) were 70% for pistia, 15% for duckweed, and 9% for algae. (4)

Dixit et al., studied the effect of sewage effluent on growth of five aquatic species Eichorniacrassipes, Alternantheraphiloxeroides, Egeria densa, Najasflexilis and Potamogetoncrispus, 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. 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. (5)

Awuah et al. used lettuce in their study of bench-scale continuous-flow wastewater treatment system with feed of sewage. They observed that lettuce removed TDS by 70%, fecal coliform by 99%, BOD by 93%, COD by 59%, nitrate by 70%, total phosphorus by 33% and ammonia by 95%. Water lettuce is reported to reduce the ammonium ions from the water as it utilizes ammonium (NH4-N) prior to nitrate (NO3-N) as nitrogen source and does not switch on the utilization of NO3-N until NH4-N gets consumed entirely. (6)

Ingersoll and Baker reported nitrate removal efficiency of water lettuce ranged from 31 to 51%. According to Aoi and Hayashi, at an initial nitrate concentration of 5.5 mg/L, water lettuce had a similar nitrate removal capacity to water hyacinth in batch culture experiments. It has been extensively used to remove metals like Zn, Ni, and Cd from the water column. However, at 20 mg/L Cr, plants of lettuce showed 100% death after three days.(7)

Girija et al. stated that the higher temperature favours their growth and multiplication. Low values of pH become almost neutral after one month of its planting. EC of polluted water is directly proportional to its dissolved mineral matter content and after planting vetiver, the EC decreased to a very low value.(8)

Mane et al. found that shoot length of vetiver grass was increased by 18.6% at 200 mM NaCl concentration whereas; increase in root length about 24.8% was observed at 50 mM NaCl. The average leaf area also increased under saline conditions. Dry weight and fresh weight biomass was less effective under salinity stress. They also observed increased levels of polyphenols at elevated salinity due to the accumulation of secondary metabolites. Linear increase in the EC and TDS of the soil was found at increasing salinity and the vetiver is tolerant up to 100 mM of salinity because of increase in growth and photosynthetic parameter. (9)

Wagner et al. found that both N and P supplies increased vetiver growth significantly level of N supplied. However, very little growth response occurred at rates higher than 6000 kg/ha/year although rates up to 10,000 kg/ha of N did not adversely affect vetiver growth. Vetiver requirement for P was not as high as for N, and no growth response occurred at rates higher than 250 kg/ha/year. However, its growth was not adversely affected at P up to 1000 kg/ha/year. (10)

Anon and Zheng et al. found 98% removal for total P in 4 weeks and 74% for total N after 5 weeks in polluted river water.(11)

Truong and Hart used vetiver for domestic effluent treatment for 4 days and the removal in total nitrogen was 94%, total P was 90%, EC by 50%, change in pH was (from 7.26 to 5.98), faecal coliform changes were 44% and E. coli changes were 91%. Therefore, vetiver has high potential to be used for industrial wastewater treatment. (12)

VI. CONCLUSION

Phytoremediation using "green plants" has potential benefits in restoring a balance in stressed environment. It is an emerging low cost technology, non-intrusive, and aesthetically pleasing using the remarkable ability of green plants to metabolize various elements and compounds from the environment in their tissues. It has been observed that phytoremediation of wastewater using the floating plant system is a predominant method which is economic to construct requires little maintenance and increase the biodiversity. Many researchers have used water hyacinth, water lettuce and vetiver grass for the removal of water contaminants. The treatment capacity of the plants is depends on different factors like climate, contaminants of different concentrations, temperature, etc. The removal efficiency of contaminants like TSS, TDS, BOD, COD, EC, hardness, heavy metals, etc varies from plant to plant. Plant growth rate and hydraulic retention time can influence the reduction of contaminants.

Many studies are reported on the use of water hyacinth and water lettuce in phytoremediation to remove different contaminants. Hence these plants can be used effectively for the treatment of wastewater provided their growth is properly controlled. Therefore, an available technology for removal of water contaminants and advances in waste water treatment can be helpful to assess and control water pollution.

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