academicJournals

Vol. 8(17), pp. 1591-1595, 9 May, 2013
DOI: 10.5897/AJAR11.1111
ISSN 1991-637X ©2013 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Review

Phytoremediation of polluted water by trees: A review

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Accepted 22 April, 2013

Presence of heavy metals and other pollutants in the aquatic systems has become a serious problem in many developing countries for environmental scientists and also for agencies engaged in environmental production. In this regard, there has been a great deal of attention given to new technologies for removal of heavy metals from contaminated water because conventional technologies to provide safe and clean water to living beings are not so far implemented. In this manner, the use of plants to remove heavy metals and other pollutants known as "phytoremediation" from the water is relatively cheaper as compared to other expensive engineering operations as plants remove pollutants from water and render them harmless. Five main subgroups of phytoremediation have been identified by the environmental scientists as "Phytoextraction, Phytodegradation, Rhizofiltration, Phytostabilisation and Phytovolatilisation". The identification and selection of plants that are suitable for successful remediation of water pollution is a matter of great concern. It is recommended that plants that have long and extensive root system should be planted at sites which are polluted due to industrial and sewage water.

Key words: Water pollution, heavy metals, phytoremediation.

INTRODUCTION

Water availability and pollution

Water is an essential element for life and is considered as most important and beneficial natural resource. According to an estimate, about 70% of the earth's surface is covered by water, approximately 97.5% of that amount is in the oceans and generally not available for daily use. Major portion of the remaining 2.5% is found in icecaps present in the Polar Regions or mountain peak and is similarly unavailable. Less than 1% of the earth's water is fresh water on the land surface, as groundwater, in the atmosphere and of this amount, only eight 10,000 of 1% is both readily available and renewable in lakes and streams for use by the earth's population (ODI, 2002). Some research studies reported that only a small percentage (0.01%) of the fresh water is only available for human use (Hinrichsen and Tacio, 2002). While this water volume remains generally constant, the population using this water continues to rise, stressing this supply more critically each year (USDA, 2000). The above mentioned water crises and availability of safe and fresh water becomes a greatest challenge for development agencies in the global world because all the ground water gets polluted due to rapid urbanization and

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industrialization revolution in the developed and developing world (World Bank, 1998). It has been reported by the press release of UNO Secretary General on world water day 2002 that about 1.1 billion people lack access to safe drinking water, 2.5 billion people have no access to proper sanitation, and more than 5 million people die each year from water-related diseases.

IMPACTS OF WATER POLLUTION

The extent of anthropogenic environmental pollution in the developing world is well documented (Mattina et al., 2003). Among overall environmental pollution, water pollution is one of the major threat to public health especially in developing and under developed countries as drinking water quality in these countries is poorly managed and monitored (Mwegoha, 2008; Azizullah et al., 2011). Both surface and ground drinking water get contaminated with coli forms, toxic metals and pesticides. About 2.3 billion peoples are suffering from water related diseases worldwide (UNESCO, 2003). The presence of heavy metals (elements with an atomic density greater than 6 g/cm^3) is one of the most persistent pollutants present in water. Unlike other pollutants, they are difficult to degrade, but can accumulate throughout the food chain, producing potential human health risks and ecological disturbances (Akpor and Muchie, 2010). In developing countries, more than 2.2 million people die every year due to drinking of contaminated water and inadequate sanitation (WHO and UNISEF, 2000). In general, water pollution has served impacts on the quality of fresh water and aquatic system. Water pollution also has negative impacts on food production, heath and social development and economic activities. Poor quality of surface and groundwater has become a threat to supplies of drinking water throughout the world (World Bank, 1998). In general, the decreasing availability of safe and healthy drinking water due to pollution, in terms of quality and quantity has been a major health concern in South Asia.

FACTORS RESPONSIBLE FOR WATER POLLUTION

There are so many factors which are responsible for water pollution, but it is most often due to human activities. Increasing population, geological factors, rapid urbanization, agricultural developments, global markets, industrial development, industrialization and poor wastewater regulation have affected the quantity and the quality of water (Saleem, 2001; Farooq et al., 2006). Besides the indiscriminate disposal of industrial, municipal and domestic wastes in water channels, rivers, streams and lakes etc. are regarded as the documented source of water pollution (Kahlown and Majeed, 2003). Kampa et al. (2001) reported that untreated domestic waste, discharges from industries, rapid deforestation and poor agricultural practices result in the soil erosion and leaching down of nutrients, pesticides and insecticides. An estimated 2 million tons of sewage and other effluents are discharged into the world's waters every day. In developing countries, the situation is worse where over 90% of raw sewage and 70% of untreated industrial wastes are dumped into surface water sources (Anonymous, 2010). Rapid industrialization in urban and Peri-urban areas and high living standards are mainly responsible for discharge of wastewater in the rivers and streams (Minareci et al., 2009). Other sources of water pollution are sewage and waste water, marine dumping, industrial waste, radioactive waste, oil pollution, underground storage leakages, atmospheric deposition, global warming and eutrophication. The Global Environmental Monitoring System (GEMS) of the United Nations Environmental Program (UNEP) have reported heavy pollution in several rivers around the World (Bichi and Anyata, 1999).

PHYTOREMEDIATION OF WATER POLLUTION

It is universally accepted that trees as a suitable vegetation cover improve the quality of life as they absorb dangerous pollutants from the environment (Aronsson and Perttu, 1994; Glimmerveen, 1996; Beckett et al., 1998; EPA, 2000). Literature shows that a healthy, well managed forest can provide many ecological benefits (Yang et al., 2005). If water flows quickly over the surface of land, many of the pollutants present on the surface, the run-off carries will reach the main body of water. If the water flows more slowly due to the presence of vegetation on land more of the pollutants will be filtered out, either by adhering to plants and soil, or by being absorbed through the root systems of plants. Trees act as water filters and improve water quality. They utilize waste water and uptake heavy metals due to their extensive root system (Bose et al., 2008).

Trees have been suggested as a low cost, sustainable and ecological sound solution to the remediation of heavy metals contaminated water as trees uptake of these metals and dangerous pollutants from soil and water. The main characteristics of trees are to make them suitable for phytoremediation by their large biomass both below and above ground (Ghosh and Singh, 2005; Coder, 1996). Salt et al. (1998) described this process to remove pollutants from environment including natural aquatic system as phytoremediation. Five main subgroups of phytoremediation have been identified:

(1) Phytoextraction: Plants remove heavy metals and other pollutants from the soil as well as groundwater and concentrate them into their harvestable parts (Kumar et al., 1995).
(2) Phytodegradation: Plants and associated microbes

degrade organic pollutants (Burken and Schnoor, 1997).
(3) Rhizofiltration: Plant roots absorb metals from waste streams (Dushenkov et al., 1995).
(4) Phytostabilisation: Plants reduce the mobility and bioavailability of pollutants in the environment either by immobilization or by prevention of migration (Vangronsveld et al., 1995).
(5) Phytovolatilisation: Volatilization of pollutants into the atmosphere via plants (Burken and Schnoor, 1999; Banuelos et al., 1997).

Plantation and vegetation can filter and immobilize sediment and other water contaminants, such as fertilizer and pesticide run-off, reducing water pollution (Schnoor, 2002). It has long been recognized that natural lands such as forests, parks and wetlands can help to slow and filter the water before it gets to rivers, reservoirs or aquifers, keeping those drinking water sources cleaner and making treatment cheaper (Crompton, 2008). Some woody species have the capacity to accumulate heavy metals as pollutants present in the ground water (Unterbrunner et al., 2007). A study of 27 water suppliers found that water treatment costs for utilities using primarily surface water supplies varied depending on the amount of forest cover in the watershed. For every 10% increase in forest cover in the source area (up to about 60% forest cover), treatment and chemical costs decreased by approximately 20%. Approximately 50 to 55% of the variation in operating treatment costs could be explained by the percent of forest cover in the source area (Ernst et al., 2007).

Plants, especially woody plants, are very good at removing nutrients (nitrates and phosphates) and contaminates (such as metals, pesticides, solvents, oils and hydrocarbons) from soil and water. These pollutants are either used for growth (nutrients) or are stored in wood. In one study, a single sugar maple growing roadside removed a considerable quantity of Cadmium, Chromium, Nickel, and Lead in a single growing season. Studies in Maryland showed reductions of up to 88% of Nitrate and 76% of Phosphorus after agricultural run-off passed through a forest buffer (Cotron n.d.). Natural forests and planted trees play an important role in protecting water quality as pointed out by many engineers, planners and community leaders as forests are the most beneficial land use for protecting water quality, due to their ability to capture, filter, and retain water (Singh et al., 2010).

Forests are also essential to the provision of clean drinking water to over 10 million residents of the watershed and provide valuable ecological services and economic benefits including carbon sequestration, flood control, wildlife habitat, and forest products. Another research study shows that trees play a crucial role in protecting water quality. Leaves and needles break the force of rain, slowing the movement of water and reducing water pollution, run-off and flooding (Kuchelmeister, 2000). Keeping in view the importance of natural and planted vegetation to remediate and restoration of hazardous polluted water due to extensive anthropogenic activities also known as phytoremediation, has gained increasing attention to environmental scientists as it is cost effective and non-intrusive means of remediation from contaminated ground water (Ouyang, 2002). It is an emerging natural and environmental friendly technology that can be considered for remediation of contaminated groundwater because of its aesthetic advantages, and long-term applicability (Chaney et al., 2005; Huang et al., 2004; Susarla et al., 2002; Pivetz, 2001). There are several advantages of phytoremediation, some of them are reported by Morikawa and Erkin (2003) as (1) it is an aesthetically gratifying, solar-energy motivated cleanup technology; (2) there is minimal environmental distraction and *in situ* treatment conserve earth; (3) it is most useful at sites with low levels of contamination; (4) it is useful for treating a broad range of environmental contaminants; and (5) it is inexpensive (60 to 80% or even less costly) than conventional physicochemical and other conventional methods (Schnoor, 1997). The use of natural and artificial planted vegetation as phytoremediation of polluted has its limitations. It is a time consuming process, and it may take at least several growing seasons to cleanup a site. Plants that absorb toxic heavy metals or persistent chemicals may pose a risk to wildlife and contaminate the food chain (Mwegoha, 2008).

In this way, the potential use and selection of suitable plant species for phytoremediation research and implementation is one of the challenges that need to be met and a pre-requisite for successful phytoremediation research. Phytoremediation of different types of contaminants requires different general plant characteristics for optimum effectiveness. Aquatic plants for example, duckweed and pennywort, also *Brassica* and sunflower remove contaminants like metals, radionuclide's, hydrophobic organics from groundwater. The cultivation of *Dalbergia sissoo* as woody species may be extended to industrial and urban areas where industrial and municipal wastewater is the only source of irrigation (Farooq et al., 2006). On the other hand, Popular and Willow trees remove inorganic, nutrients, and other chlorinated solvents present in the groundwater (Schooner, 2002). A special characteristic of Willow, which makes it a very suitable tree for use in phytoremediation, is that it can be frequently harvested by coppicing, yielding as much as 10 to 15 dry t ha^{-1} $year^{-1}$ (Riddell-Black, 1993; Punshon et al., 1995; Pulford and Watson, 2003). The concentration of heavy metal pollutants in the bark and wood of 20 different Willow varieties were determined by Pulford et al. (2002). Wetland plants generally are not "hyperaccumulator", they store metals in the below ground organ than above ground organ (Weis and Weis, 2004).

CONCLUSION AND RECOMMENDATIONS

There is a growing demand of groundwater for drinking and an irrigation purpose since it is the most readily available low cost source of water supplies to low income countries. The problem of water pollution as a result of contamination of groundwater is constantly increasing especially in developing and low income countries due to the fact that there are limited financial and technological resources to remediate polluted water sources. In this situation, the use of trees to remediate polluted water is considered as the new emerging technology which is relatively cheaper than the conventional technologies. The technology of Phytoremediation offers viable solution to water pollution. It offers restoration of sites, limited decontamination, preservation of the biological activity and physical structure of soils, and is potentially cheap, visually inconspicuous. It is also reported that trees can withstand good in heavy metal contamination than agricultural crops. The critical point in this technology is the selection of appropriate plant species that is suitable in the prevailing environmental conditions. The emphasis is given on the plantation of terrestrial plants than aquatic plants due to their larger root system. It is recommended that there must be multi disciplinary calls for collaboration between universities, research institutes and other environmental protection agencies to create voluntary teams to address questions like agronomic practices needed for successful establishment of flora; identification of locally available plant species for specific remediation requirements and expansion of these plant species at local and national level.

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