

PHYTOREMEDIATION OF HEAVY AND TRACE ELEMENTS IN KHARTOUM REFINERY BY SOME PLANTS

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(Received 30th August 2021; accepted 19th October 2021)

Abstract. The study area landscape is located in the semi desert zone north of Khartoum State, Khartoum Refinery (KRC) is located north of Khartoum State, Sudan; the objective of the research to investigate the tolerance plants for treated waste water at Khartoum Refinery Inaddtion to study phytoremediation of elements in Khartoum Refinery .The determination of elements was the atomic absorption. The study area was divided into control site (merely received rain water) and treated one (received rainwater and treated water). In KR, the treated area was subdivided into four units planted with Eucalyptus camaldulensis (Ban) based on age of plantation (6, 4, 2 years and 2 weeks). The results showed that plants Ca, Na, Mg concentrations in Khartoum Refinery was high and that plants Ca, Na, Mg concentrations in plantations of was Khartoum Refinery significantly different from control. The results showed that plants K, Zn, Fe, Cu and Mn concentrations in Khartoum Refinery was low, while Cr, Co, Cd and Pb were not detected.

Keywords: *phytoremediation, heavy and trace elements, tolerance plant, treated waste water*

Introduction

Phytoremediation is evolving into a cost-effective means of managing wastes, especially excess petroleum hydrocarbons, polycyclic aromatic hydrocarbon, explosives, organic matter, and nutrients. Applications are being tested for cleaning up contaminated soil, water, and air. A number of important botanical processes have been discovered, including phytoextraction and hyperaccumulation from soil, plant-assisted microbial degradation of hydrocarbons in soil, use of specific enzymatic processes involved in created wetland treatment, and several other means of transforming and sequestering organic pollutants. Plant metabolism using sunlight energy and atmospheric carbon dioxide to produce organic matter is fundamentally different from heterotrophic microbial respiration requiring energy, carbon, and nutrients from soil or water. As a result, green plant transformation, conjugation, and sequestration are vital new tools in waste management that are categorized along with methods of vegetative control of pollutants to manage contaminated groundwater plumes and soil (Baker and Smith, 2000).

Plant tolerances to contaminants

Substantial amounts of aqueous effluents contaminated with various types of toxic trace elements and heavy metals are produced every day by several anthropological activities (e.g., agricultural and industrial). These polluted aqueous discharges pose a tremendous hazard to wildlife and to mankind. Treatment technologies for such wastewaters, which are based on physical and/or electrochemical treatments, are expensive and insufficiently effective. In addition, they commonly produce hazardous by-products that must be shipped to landfill. Recently, there has been a worldwide

increased interest in wetland creation for wastewater treatment as an inexpensive and highly efficient alternative technology. For a long time, constructed wetlands were used to reduce the levels of contaminants in wastewaters contaminated with conventional pollutants such as nutrients (i.e., N and P), biological oxygen demand (BOD), and total suspended solids (TSS) (Johnsen et al., 2000). More recently, the interest in using constructed wetlands in the clean-up of waste waters has extended towards the remediation of waters contaminated with heavy metals and toxic trace elements. Constructed wetlands are especially advantageous in the cleanup of large volumes of waters contaminated with low levels of trace elements.

Several studies have shown that constructed wetlands are very effective in removing heavy metals from polluted wastewaters (McFarlane et al., 2002). Wetland vegetation plays a major role in the removal of toxic trace elements from waters passing through the wetland. Wetland plants remove trace elements by several processes: (i) uptake and accumulation in their tissues; (ii) phytostabilization of the element into unavailable form; (iii) phytostimulation of rhizosphere microorganisms that mineralize, sequester, and stabilize the element; and (iv) phytovolatilization of volatilizable elements (e.g., Se, Hg) into the atmosphere (McCutcheon and Schnoor, 2004). Different wetland plant species differ, however, in their abilities to take up and accumulate various trace elements in their tissues (McCutcheon and Schnoor (2004). Therefore, a judicious selection of plant species to be planted in a constructed wetland treatment system must be made so that the capacity of wetlands to remove potentially toxic trace elements from wastewaters can be maximized. Recently, wetland plant species with abnormally high capacities of trace element removal from water were identified (Siciliano and Germida, 1998); duckweed (*Lemna minor* L.) and water hyacinth [*Eichhornia crassipes* (Mart.) Solms-Laubach] were excellent accumulators of Cd, Se, and Cu.

There is considerable interest in developing cost effective and environmentally friendly technologies for the remediation of soils and wastewaters polluted with toxic trace elements. Some plants have a natural ability to absorb and hyper accumulate trace elements in their tissues (McCutcheon and Schnoor, 2004). This ability is being harnessed to remove toxic heavy metals and trace elements from contaminated soils and waters in a process referred to as phytoremediation. Several terrestrial plants that are highly effective in absorbing and accumulating various toxic trace elements have been identified in the last two decades and are being evaluated for the phytoremediation of soils polluted with trace elements (Baker et al., 1996). Wetland plants may also be used in phytoremediation (Bansal and Caudle, 1999). demonstrated that water hyacinth can remove and recover silver from industrial waste water with high efficiency in a fairly short time. They, also, demonstrated that the accumulation of some other heavy metals and trace elements (i.e., Zn, Cu, Pb, Cd) by several species of wetland plants.

The main objectives of this study are: (1) to study phytoremediation of elements in Khartoum Refinery, and (2) to investigate the tolerance plants for waste water at Khartoum Refinery.

Materials and Methods

The study area landscape is located in the semi desert zone north of Khartoum State, Sudan at latitude of 16.4023N to 16.1157N; as well as longitude of 32.4609E to 32.2086E. According to Andrews (1948), the area is the semi desert grassland on sand in places with a thin scatter of *Acacia raddiana*, *A. mellifera* and *Commiphora* spp

Sampling

The plant samples were collected from the two different sites of Khartoum refinery, where 6 species are selected at different the grown study area. The study areas were divided into control area in which the plants were irrigated by rain, and treatments in which the plants were irrigated by treated waste water. The rain irrigated plant specimens were collected from *Eucalyptus camaldulensis* forest plantations (6, 4 and 2 years old) in Khartoum refinery (Table 1). In addition to the natural flora, the *Aerva javanica* (Burm.f.) Juss.ex Schult, *Tamarix senegalensis* DC, *Acacia tortillis* sp *spirocarpa* Hochst, *Corochorus depressus* (L.) Christens, and *Senna alexandrina* Mill in Khartoum refinery were also spotted and used in this study. All samples were replicated three times for accurate results.

Table 1. Plant sampling at Khartoum Refinery.

No	Plant species	Category	Label
1	<i>Aerva javanica</i>	Control	S1
		6 years	S2
2	<i>Tamarix senegalensis</i>	Control	S3
		6 years	S4
		2 years	S5
3	<i>Eucalyptus camaldulensis</i>	6 years	S6
		4 years	S7
4	<i>Acacia tortillis</i> SP <i>spirocarpa</i>	Control	S8
		6 years	S9
5	<i>Crochours depressus</i>	6 years	S10
		2 years	S11
6	<i>Senna alexandrina</i>	6 years	S12
		2 years	S13

Determination of elements composition of plant leaves

The method was used of determination of elements by atomic absorption (Perkin, 1994) was used. 1 g of an air dried plants leaves and sieved plants samples were placed in into the furnace for 4 hours for dry ashing. The ash was kept in an Erlenmeyer flask extracting solution 5ml (1M HCl) were added and the mixture was then placed in a filter paper into a 50 ml with extracting solution.

Results and Discussion

Plant minerals

The results showed that plants Ca, Na, Mg concentrations in Khartoum Refinery was high and that plants Ca, Na, Mg concentrations in plantations of was Khartoum Refinery significantly different from control table. The results showed that plants K, Zn, Fe, Cu and Mn concentrations in Khartoum Refinery was low, while Cr, Co, Cd and Pb were not detected (Table 2). Transformation is often essential to detoxification and phytoremediation of organic contaminants. For example, parrot feather (*Myriophyllum aquaticum*) is capable of quickly transforming trinitrotoluene at concentrations that could otherwise result in the death of this aquatic plant. Hybrid poplar (*Populus deltoides* X *Populus nigrd*) continues to transform chlorinated solvents and explosives

even as transpiration rates decline. Contaminant stress usually leads to metabolic changes in the plants and the expression of unique biochemicals. Understanding plant responses to contaminant stress defines whether a plant has the potential to transform and tolerate a wide range of organic chemicals, which would enhance phytoremediation. The fundamental mechanisms of plant tolerance and resistance to xenobiotic chemicals are related to the phytotoxicity of two major classes of contaminants chlorinated aliphatic compounds and explosives.

Table 2. Minerals concentrations in plants irrigated with treated water plus rain versus the control (rain fed) in Khartoum Refinery.

Label	Minerals concentrations (mg/L)							
	Ca	K	Zn	Fe	Cu	Na	Mn	Mg
S1	33.593C	1.4200E	0.2567FG	1.3677DE	0.4070CD	10.280CD	0.6514C	56.800A
S2	36.582B	1.5360D	0.2667FG	1.2227F	0.4527C	9.895E	1.6253A	57.250A
S3	2.696J	2.6380A	0.2277G	0.3917I	0.3360EF	10.658CD	0.6573C	56.400AB
S4	30.548D	1.3020F	0.4780DE	1.3223EF	0.3390EFG	10.750BC	0.3877D	56.523AB
S5	25.151F	1.0373I	0.2920G	1.0230G	0.6447B	11.453A	0.7253C	54.990DE
S6	28.441E	1.2017G	0.4620E	1.6217C	0.3553E	11.119AB	0.9603B	55.417CDE
S7	18.673H	0.7610L	0.2247G	0.3277I	0.3273EFG	11.262A	0.9627B	54.537DE
S8	19.334H	0.8120K	0.3117F	1.0670G	0.2717H	7.199F	0.1320E	54.457E
S9	15.201I	0.6260M	0.5310CD	0.5807H	0.2867FGH	2.380F	0.2163E	54.473E
S10	22.011G	0.9790J	0.6037B	0.6337S10H	0.2837GH	1.716G	0.1813E	54.950DE
S11	27.311E	1.1370H	0.4933CDE	4.3227A	0.3663DE	2.301G	0.3567D	54.783DE
S12	45.420A	1.9410B	0.7270A	2.1973B	0.7773A	10.106DE	0.2227E	55.190DE
S13	35.582B	1.5360C	0.5570BC	1.4843D	0.6420B	7.534E	0.1383E	55.557BCD
P	≤0.0754	≤0.00020	≤0.0037	≤0.0016	≤0.136	≤0.0083	≤0.0016	≤0.0026
SE	±0.3341	±1.788	±0.0130	±0.0371	±0.0100	±0.0172	±0.0259	±0.2074
CV	2.21	0.24	5.45	3.35	4.11	1.63	8.8	0.65

The relation to phytotoxicity provides a practical understanding of how tolerance and resistance may affect phytoremediation applications (Siciliano and Germida, 1998). The understanding of tolerance and plant stress is important in applying green plants to control or treat hazardous wastes. Phytoremediation often involves high contaminant concentrations that may cause stress or toxicity beyond natural or background levels. All these stresses play a role in assessing whether application of phytoremediation is successful or not. Plant stress has been defined as environmental constraints, shortages and excesses in the supply of solar energy, water, and mineral nutrients including also sub-or-supraoptimal temperatures and growth inhibiting toxins. Two factors in the ambient environment capable of creating stress are pollutants, especially environmental toxins and excessive micronutrients. As primary stressors, toxins and nutrients can interact with other stressors including biotic stress from competition, predation, parasitism, and related stresses, altering the susceptibility of the affected organisms. For chemicals in the environment, as for several other factors, there is a range that allows growth of all individuals within a species without injurious effects, and a range that does not allow growth of any individuals. Between healthy conditions and death is a range of effects and injuries over which not all individuals are affected to the same degree (McCutcheon and Schnoor, 2004).

Plant species of Khartoum refinery (KRC) in this study are different and belong to different species and families, and with different ages, in addition to some species are native to same environmental conditions. So they vary in their characteristics in response to their phytoaccumulation of metals, genetic components and their ambient environment. The results show that the best plant species for the accumulation of Ca in (KRC) is *Senna alexandrina* 6years, *Aerva javanica* 6years and *Tamarix senegalensis* Control. The best plant species for the accumulation of K in (KRC) was *Senna*

alexandrina 6 years and *Aerva javanica*. The best plant species for the accumulation of Zn in (KRC) was *Senna alexandrina* 6years, *Crochours depressus* 6years and *Senna alexandrina* 2 years. Best plant species for accumulation of Fe in (KRC) is *Senna alexandrina* 6years and *Eucalyptus camaldulensis* 6 years. The best plant species for accumulation of Cu in (KRC) is *Senna alexandrina* 6 years, *Eucalyptus camaldulensis* 2years and *Senna alexandrina* 2 years. The best plant species for accumulation of Na in (KRC) is *Eucalyptus camaldulensis* 4 years, *Eucalyptus camaldulensis* 6 years and *Eucalyptus camaldulensis* 2 years. The best plant species for accumulation of Mn in (KRC) is *Aerva javanica* 6years, *Eucalyptus camaldulensis* 6years, *Eucalyptus camaldulensis* 4 years and *Eucalyptus camaldulensis* 2 years. Best plant species for accumulation of Mg in (KRC) is *Aerva javanica* (Burm.F.) 6 years, *Tamarix senegalensis* 6 years and *Senna alexandrina* Mill 2 years.

Conclusion

In conclusion, the stimulation usually occurs on some aspects of performance at the individual level and does not affect the population. It has been suggested that organisms become adapted to many deleterious xenobiotic compounds because these chemicals are similar to natural molecules, and that homeostatic mechanisms can respond by changing the rate of uptake, exclusion, transformation, segregation, and other metabolic process that have evolved. Therefore, hormesis could be the by-product of normal responses in counteracting the effects of inhibitors. Effects on general fitness have not been described, and therefore hormesis may have no consequences on population dynamics and evolution (McCutcheon and Schnoor, 2004). By reversible changes in physiological processes and metabolic reactions, plant populations of the same genotype can express different phenotypes in response to different environmental insults. Examples of phenotypic plasticity involve several aspects of plant life, such as closure of stomata, development of roots, shoots, and leaves; flowering; and changes in metabolic rates. Excessive alkali or metal content in soils, and nutrient depletion can induce similar modifications (McCutcheon and Schnoor, 2004). Because phenotypic plasticity is due to genetic variation in species and populations, natural selection can cause changes in plasticity levels. Generally, high levels of plasticity are associated with low levels of stress resistance in individuals, and with low levels of genetic variation in populations (McCutcheon and Schnoor, 2004). Plastic responses are not very common if the stress is persistent, as is the case with most contaminants, unless a single individual encounters micro spatial variation in soil concentrations. Therefore, the occurrence of anthropogenic contamination is more likely to select for resistant genetic variants. Another phenomenon linked to stress is hormesis, defined as the stimulatory effect on organism performance occurring in response to low levels of exposure to agents that are harmful at high levels of exposure (McCutcheon and Schnoor, 2004). This phenomenon has been demonstrated for several contaminants and several species, especially TNT and parrot feather (*Myriophyllum aquaticum*).

Acknowledgement

This research is self-funded.

Conflict of interest

The author confirm that there are no conflict of interest involve with any parties in this research study.

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