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Phytoremediation of Trace Metals in Shadawanka Stream of Bauchi Metropolis, Nigeria

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Abstract:

Environment has great impact on our health through the food we eat, the water we drink and the air we breathe. The number of contaminants entering the environment has increased greatly in Nigeria in recent times and this is due to increasing population, urbanization, industrialization, modern agricultural practices and transportation activities. Major among these contaminants are heavy metals which are potential health hazard to the populace and 60- 80% of heavy metal toxins found in human bodies were the results of consuming contaminated food and water rather than through air pollution. Contaminants in soil or water environment could be cleaned up using plants. The Shadawanka stream is a major stream in the heart of Bauchi metropolis, Nigeria used for domestic, irrigation and for aquatic organisms. Heavy metal accumulation studies in Nymphaea lotus (Water lily) were carried out from eight different locations along the stream using the Atomic Absorption spectrophotometric technique in the months of April-June 2003. The levels obtained for the metals were in the range of 79.80- 130.20mg/100g for Zinc, 50.19- 69.90mg/100g for Lead, 53.60- 58.20mg/100g for Iron and 7.21-8.9mg/100g for Cadmium. The results showed that the plant has high tendency to selectively bioaccumulate Zinc and Lead thus suggesting that it could be used to monitor Zinc and Lead levels in the stream. The present study indicates that the plant has high potential to selectively uptake lead and zinc faster than cadmium and iron in the stream.

1.0 Introduction:

As an emerging technology phytoremediation offer not only greater potential to remediate contaminated sites over convectional and costly methods but also offer means to use 'green' sustainable process (Pulford and Watson, 2003; Zhi-in NIU *et al*., 2007). Phytoremediation in its general sense means cleaning of contaminated sites with appropriate plants. Due to its clean up approach to decontaminate sites it is an environmentally friendly (ecofriendly), safe, cheap way to clean up contaminants. Early estimate on the costs have shown that plants could do that same job as a group engineers for one tenth of the cost (Zhou and Song; 2004; Puschenreiter *et al*.; 2001). The plants are also more pleasing to look at than many such operations are. The water or soil need not be gathered in and stored as hazardous waste, requiring amount of land, money and manpower. Plants can be planted, watered and then harvested with less manpower.

Nymphaea lotus (Water lily) is an herbaccous aquatic plant, which is widely distributed in streams, rivers and ponds. The hydrophytes, whose leaves may either float or are submerged in water, have pink, white or yellow flowers (Fayed *and* Abdel-shafy, 1985, Fulekar, 2005). Its broad leaves are ovate to heart shaped and as said above typically float just below the water surface. ``Half opened`` yellow flowers stand on the thick stems at or above the water surface. Flowers are complete with sepals, petals, stamens and carpel (Skinner, 2006). Leaves of *Nymphaea lotus* (Water lily) also called lily pads are thick and buoyant leaves that float along water surface in close proximity to the Nymphaea lotus (Fig. 1).

Photosynthesis and exchange of gases occur in the lily pads. Lily pads are thicker than other leaves and consume large area. This helps the leaves to stay above water even when frog hop on them. Many, but not all water lilies are fragrant and produce a flora or citrus smell. The stem of all *Nymphaea lotus* reach deep below water surface and onto the muck and mud of the river or pon d bottom. The stem maintain their hold even in a strong current and connect the flowering portion of the plant to thee rhizomes on the bottom, which collect nitrogen and other nutrient necessary for plant development (Fig.1). Humans have traditionally utilized the plant. Roots are cooked and eaten as greens or dried and ground in to a powder for use as a thickening agent or flour (Skinner, 2006). There are also reports of its

use as herbal astringent, to treat diarrhea, reduce swelling and arrest bleeding (Mathew *and* Donoghue, 1999; Plant for Future, 2005) The plant is valuable in human diet as the Hausa people of Nigeria and the people of Upper Guinea, Lake Chad and some parts of America eat its seeds. The Sierra Leonians prepare eye lotion from its leaf (Skinner, 2006). Since this plant forms part of the diet of most people in the neighborhood of Bauchi as well as a number of other West African countries, there is the need to ascertain its composition, by analyzing it for heavy metals and its ability to accumulate (Audu and Lawal, 2006; FAO, 2000). This is absolutely necessary because the plant grows in nutrient rich streams and ponds giving an indication of heavy metal pollution of the water body. Furthermore, findings from this study may x-ray the plant as a bioindicator of a particular or some heavy metals and could perhaps be used to clean up such metals from such water bodies. With its potential for accumulation of pollutants, Nymphaea lotus may provide important links in transfer of chemicals for its predators. Such transfer along food chains is an important aspect of ecotoxicology (Peralta *et al*, 2000; Elson and Haas, 2001). Reports have it that the main difference in the ecophysiology of metals is due to their essentiality against non-essentiality to organism, whereby nutritional meals like Zinc and Copper are regulated and xenobiotics, like Lead and Cadmium are accumulated (Shams, 2008).

The realization of the ecophysiology of metals was a strong motivating factor behind this study. Researchers have observed that some plant species are endemic to metalliferous soil and can tolerate greater than usual amount of heavy metals or other toxic compounds (Usman and Ayodele, 2002; Ramesh, *et al*, 2003;Cosio, 2004). Miller *et al* (1995) reported that alfafa had the ability of accumulating Cadmium in soil receiving high rates of sewage sludge (equivalent to 4.6KgCd/hm^2). Phytoremediation has been used in soils surrounding the United states government`s explosive storage area (Al- Salama 2002; Zhi-xin NIU, *et al*, 2007). Researchers have used Sunflower to reduce Uranium concentration in water up to 95% (Zhou and Song 2004). Lead and Zinc that was once hazard is now being recycled from the harvested plants grown in a site containing buried car batteries in New Jersey (Ramesh, *et al*, 2003; Cosio, 2004). Shams *et al.* (2008) reported that plants like *Urtca dioica* (Singing nettle) is proved to be very efficient to extract Cr from contaminated soil to as much as 16mg/Kg Phytoremediation has been used in Chemobyl with Sunflowers to remove Cesium 137 and Strontium 90. Hybrid poplars have been used in Whitewood Creek in South Dakota to absorb Arsenic from mine wastes and Aberden, Maryland to remove trichloroethylene and polycyclic aromatic compounds from ground water(Ramesh, etal, 2003; Zhou and Song, 2004; Zhi-xin NIU *et al*, 2007). The aim of the present study is to investigate selective uptake potential of Trace metals in Shadawaaka stream by *Nymphaea lotus* (Water lily).

2.0 Materials and Methods:

Nymphaea lotus, whole plant samples were uprooted and collected at random from eight different locations along Shadawanka stream in Bauchi metropolis, Nigeria (Fig.1) The samples were kept in polythene bags and later transported to the laboratory. On arrival at the laboratory, the sample were washed with distilled water to remove any adhering soil/dust particles and were further rinsed properly before drying to constant weight in an oven maintained at 105^{0}C. The samples were ground to fine powder, and made to pass through 25µm sieve. Physico-Chemical parameter of the Shadawanka stream water was conducted using Standard method given in APHA (1998).

Fig. 1: Sample plant (*Nymphae lotus*) Showing Stem, Flower and Leaves

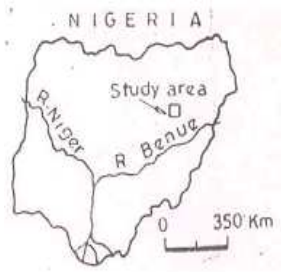

Fig. 2: Index Map of Nigeria Showing Study Area in Bauchi

3.0 Results and Discussion:

Table 1: Levels of Trace Metals in *Nymphaea lotus* (mg/100g): SEM from Shadawanka stream of Bauchi Metropolis-Nigeria

Sample Location	Pb	Cd	Fe	Zn
1	50.19 ±0.60	7.21 ±0.02	58.01 ±0.10	125.00 ±0.81
2	62.04 ±0.02	8.41 ±0.04	57.70 ±0.31	130.20 ±0.91
3	69.90 ±0.13	8.04 ±0.17	56.20 ±0.41	108.87 ±0.12
4	53.17 ±0.19	7.38 ±0.05	56.91 ±0.13	90.85 ±0.21
5	66.17 ±0.19	9.07 ±0.90	57.01 ±0.13	101.10 ±0.19
6	57.70 ±0.17	8.51 ±0.15	55.91 ±0.12	79.10 ±0.14
7	68.10 ±0.02	8.91 ±0.09	58.20 ±0.07	99.10 ±0.14
8	67.20 ±0.04	7.77 ±0.19	53.60 ±0.04	101.05 ±0.19

Table.1 represents the results of Heavy Metals (Zn, Pb, Fe and Cd) in *Nymphaea lotus* in mg/100g. Their concentration in the sample ranged between 79.80-130.20, 50.19- 69.90, 53.60- 58.20 and 7.21- 8.91 mg/100g respectively. This result shows that the sample has a greater tendency for selective accumulation of Zn and Pb than Fe and Cd. The result also indicates that the samples could serve as an important pathway for transfer of Pb and Zn to animals and humans faster than Fe and Cd. Although heavy metals accumulation in some plants such as *Nymphaea lotus* may provide an important link in the transfer of chemicals to its predators, their hazardous effects on human health, plants and animals require serious attention (Masckhel, 1981, Usman and Ayodele, 2000; Sezgin, etal, 2003). Some trace heavy metals are significant in nutrition, either for their essential or their toxicity. Metals such as lead and Cadmium are non essential with toxic effects while Iron and Zinc are essential with known biochemical functions (VanAssche and Clijsters, 1990; Li, *et al*, 2001). Metals may enter the food chain from soil through mineralization by crops or environmental contamination, as in application of agricultural inputs such as pesticides and fertilizers or in the treatment of soil with sewage sludge.

Table2: Estimated Parameters with standard Limit for Surface Water

Parameters	Mean	Standard Limit
Temperature (^{O}C)	30 ± 0.10	–
pH	7.75 ± 0.12	6.5- 8.5
Colour	16.5 ± 0.20	10
Turbidity	96 ± 0.11	–
Conductivity	350 ± 0.20	–
Total Alkalinity	61.23 ± 0.11	71.25
DO	5.66 ±0.3	6
BOD	7.33 ± 0.10	3
COD	32 ± 0.11	–
Sulphate	11.36 ± 0.2	400
Hardness	189.74 ± 0.12	300
Chloride	61.88 ± 0.20	250
Calcium	24.30 ± 0.11	80.10
Phosphate	0.021 ± 0.01	–
Magnesium	31.38 ± 0.12	24.28

All values in mg/L except pH unit less, colour l/m, turbidity in NTU and conductivity µmhos/cm

Cadmium is an ambiguitous element in biological fluid and tissues and does not possess any evidence suggesting its importance. It has been implicated in Osteoporosis with impaired general health. It is present as contaminant in food we eat. Cadmium is not required by plants. However its uptake and toxicity have been reported. Both Cadmium and Copper interact with sulfhydryl groups causing inhibition in chlorophyll biosynthesis (Onianwa, 2001). Lead is toxic to plants at concentration range of 3-20ppm depending on plant species, to animals at a concentration of 1mg/day, and human at 10g/day (Elson and Haas, 2001). Zinc is an essential element involved in metabolic functions, and is important for both man and plants health growth

(Zhou *et al*; 2004; Fulekar, 2005) although sludge treatment usually results in elevated Zinc levels, plants do not accumulate to a degree that would be toxic to animals or human. The Zinc content of normal plant tissues varies according to species, but it is usually within the range 5.300mg/Kg dry matter. High accumulation of Zn in animals have been linked to cases of throat pain and eye irritation (Adam, 1983; Zhou *et al*, 2004) while Lead have been reported in cases of damage to kidney and Central nervous system (Adam, 1983; Aziz- Abraham, *et al*, 1984; Mortor *and* Dunette, 1994; Peralta, et al, 2000). Apparently, a high accumulation of Zn and Pb was observed in this plant samples and it is possible that the Hausa people who feed on this might possibly suffer the hazardous effect of these pollutants on the long run. The Iron content of normal plants varies according to plant species but it is usually within the range 20 -200mg/Kg dry matter. Iron serves as electron carrier and constituent of a wide range of enzymes. Inhalation of Iron fumes causes Pneumonia and Siderosis, a dust disease which imparts red coloration of the lungs. Inhalation of Iron dust induces toxic effects of some carcinogenic gases like So_2. Exposure to Iron dust causes bronchitis and ventilation difficulties (Li, et al, 2001).

The high Zinc and Lead contents observed in this study points to the heavy metal accumulation of the Shadawanka stream which is located in the Commercial Nerve-Centre of Bauchi metropolis. It therefore bears the brunt of heavy traffic load. It also harbours a high density of medium- based industrial and automobile repair workshops as well as human population. It can then be inferred that run offs from the metropolis containing Lead from automobiles, discarded batteries, burnt garbage and painted wood and Zinc from automobiles repair workshops and galvanized products could account for the appreciable level of these metals at the locations sampled and this makes the study very relevant (Bowen, 1979; Karez *et al*, 1994; Burton *and* Peterson, 1979; Obodo, 2002).

Most heavy metals are toxic but the exact nature of toxicity varies considerably. For example, Cadmium, Mercury and Lead compounds are much more toxic than Iron (II) or Iron (III) compounds. Toxicity also varies with chemical forms. All toxic heavy metals can endanger human health on slight exposure; the critical organs they affect in the body differ from metal to metal. For example, the critical organ for Cd (II) and Hg (II) ions is the kidney while it is the brain for CH_3Hg. Lead affects the brain and haemotological system while arsenic appears to be specific (Zielluis, 1979; FAO, 20000; Elson and Haas, 2001). For now, there is no known reported case of Lead of Zinc poisoning resulting from the direct consumption of the seed of *Nymphaea lotus* from Shadawanka stream. However, the increase in the level of these metals could pose potential health hazard in the long run with continuous consumption of the seed by the inhabitants of Bauchi- metropolis.

Physicochemical characteristics of the collected stream water sample are given in Table 2. From the study it was found that the mean Dissolved Oxygen (DO) value was below standard limit (BIS : 6mg/L) and mean Biological Oxygen Demand (BOD) value was higher than the Standard limit (BIS : 3mglL). Also observed mean magnesium value was slightly higher than the Standard limit (BIS : 24.28mglL). The mean Colour value was higher than the prescribed Standard limit (BIS: 101 I/M). The rest parameters like temperature, pH, turbidity, conductivity, alkalinity, sulphate, hardness, calcium, phosphate, chloride etc were found below the permissible limit of the surface water (Fig.1). The levels of Trace metals and amount physicochemical parameters obtained in this study reveal the pollution status of the stream as of the time of sampling (Zhou, *et al*, 2004 and Fulekar, 2005). (Note: If DO above Standard value (6mg/L) the water quality is good. If BOD is more than 3mg/L the water quality is bad and if COD is high then the water quality is bad.

4.0 Conclusion:

Conclusively, the study showed that *Nymphaea lotus* has high potential for selective uptake of Lead and Zinc faster than for Iron and Cadmium in Shadawanka stream. For these reasons, the teeming inhabitants of Bauchi metropolis feeding on it are at a risk of potential health hazards in the long run with continuous and unabated consumption. From Physico-Chemical parameters obtained the water quality of Shadawanka stream is not suitable for domestic usage like drinking and bathing.

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