International Journal of Chemical Science
www.chemicaljournals.com
Online ISSN: 2523-2843, Print ISSN: 2523-6075
Received: 13-07-2021, Accepted: 27-07-2021, Published: 14-08-2021
Volume 5, Issue 4, 2021, Page No. 39-43

Evaluation of the phytoremediation potential of *Sacciolepis africana* in the treatment of Ni-contaminated aqueous system

Odediran Oluwagbemisola, Lajide Labunmi
Chemistry department, Federal University of Technology Akure, Nigeria

Abstract
Purple swamp grass (*Sacciolepis africana)* was evaluated to determine its effectiveness in the treatment of nickel-contaminated aqueous system. A phytotoxicity test was conducted with *Sacciolepis africana* grown in sediments to which varied dilute concentrations of 100 mg/l, 200 mg/l, and 300 mg/l were added and a control set-up without nickel solution in simulation of the natural habitat. Samples were taken at 3 days interval for 15 days. Ni concentration in water, sand medium and plant tissues were determined using Atomic Absorption Spectrophotometer (AAS). The hydrophytes by physical observation were seen to show chlorosis and necrosis as a result of the high concentration of Ni possibly interfering with iron uptake. The results showed that as at day 3, 90.732%, 81.824% and 78.778% of Ni had been removed from the water medium and Ni concentration at the end of the experiment finally decreased up to 99.823%, 99.752%, 99.683% for 100 mg/l, 200 mg/l and 300 mg/l respectively with the residual concentration 0.177±0.04 mg/l, 0.497±0.05 mg/l, 0.952±0.03 mg/l. The results showed significant difference ($P<0.05$) with that of the control. The sediment adsorbed high amount of Ni, this can be related to its high electrical conductivity value. Correlations between the concentration in the water medium and the plant stem and leaves were obtained. There was also correlation between nickel concentration in the sediment and roots. Bioconcentration factors were greater than 1 but less than 1000 and translocation factors were less than 1 indicating that the hydrophyte was not bio accumulative, it excluded the metal from its tissues but preferentially accumulated them in the root compartment, thus suggesting it to be good for phyto stabilization purposes.

Keywords: bio concentration factor, translocation factor, bio accumulative, hydrophyte, phyto stabilization

Introduction

Heavy metals are naturally occurring in the environment in moderate quantities but the industrial revolution brought about their elevated concentrations in the environment. Heavy metals can be classified according to the roles they play in biological systems as essential and non-essential. The essential heavy metals are those involved in physiological and biochemical functions, they are iron, manganese, copper, zinc and nickel [1, 7]. On the other hand, non-essential heavy metals are those that are not needed by living organisms for any physiological and biological functions. Examples are cadmium, lead, arsenic, mercury, and chromium [3]. The essential metals even though they are needed in the body can become toxic if it exceeds the allowable limit causing acute and chronic diseases. Plants have the ability to accumulate these metals in their growth matrix as they take up nutrients. Having them in elevated concentrations lead to enhanced plant uptake and resultantly a negative effect on the plant growth [17]. The literature survey available suggests nickel as an essential element in the development of many species of plants and animals, it interacts with iron found in haemoglobin and helps in oxygen transport, stimulate the metabolism and also it is regarded as a key metal in several plants and animals enzymes systems [15, 22].

Water is essential for life and it is capable of dissolving many contaminants hence, it ends up as a sink for heavy metal pollution. It has been discovered that when an environment becomes unsupportive for the existence of man because of pollution, certain animals and plants develop adaptive features for such an environment. This has been the basis for researches on bioremediation and phytoremediation. Several researches have been conducted in search for hyperaccumulators of heavy metals hence, the purpose of this research to determine the effectiveness of *Sacciolepis africana* as a phytoremediator of nickel-contaminated aqueous system. *Sacciolepis africana* is widely available and is not readily consumed by people in South West Nigeria, this makes it economically suitable for this research and since phytoremediation has proven to be cheap and environmentally friendly.

Materials and method

Material collection and Pre-analysis

The hydrophytes of similar shoot height were collected from a pond along Ilesha-Akure expressway in Akure, Ondo State, Nigeria. Sediments were also collected from the ponds. Pre-analysis of the plants and sediments were carried out for residual nickel ions by acid digestion and instrumental analysis using Buck Scientific Atomic Absorption Spectrophotometer according to the method of Fabunmi *et al*., 2014 [5]. The slurry method of pH determination of sediment was done according to the method of Kalra, 1995 [9]. The hydrometer method was used to determine the particle size distribution according to Ibitoye, 2015.

Organic matter content of the sediment was also determined using the method of Ibitoye, 2015 and the electrical conductivity according to Thiagalingam, 2000 [19]. The results are presented in tables 1 and 2.

Pot Experiment

About 12 medium sized hydrophytes were transplanted per pot into 4 pots having 10 kg of sediments in a greenhouse illuminated with natural light. The hydrophytes were allowed to get rooted and get adjusted to the new environment for 10 days. They were watered with borehole water till they got stabilized. Nickel solution in the form of nickel sulphate hexahydrate ($NiSO_4.6H_2O$) with varied concentration of 100 mg/l, 200 mg/l, and 300 mg/l were introduced to the set of hydrophytes leaving one pot as the control. The pH was adjusted to the range of 6-6.5 using 0.1 M HCl and 0.1 M NaOH. The hydrophytes, sediment and water were collected at 3 days intervals for 15 days in order to determine the nickel ions uptake or adsorbed by the sediment. Physical observation was conducted to know the effect of nickel contamination on the hydrophyte. There was no nutrient added during the test.

Sample Collection and Preparation

The hydrophytes, sediments and water were collected at 3 days intervals for 15 days. The hydrophytes were washed to remove attached sediments with borehole water and then distilled water. They were air dried for 48 hours. The hydrophytes were separated into roots, stem and leaves and further oven dried at 80^oC for 24 hours before being ground with mortar and pestle and further milled with an electric powered blender (Saisho blender, Model S-T4PN). The sediments were air dried and evenly mixed for proper analysis. The water samples were acidified immediately after collection with 2-3 drops of concentrated HNO_3 to preserve the sample before digestion.

Reagent Preparation

Stock nickel solution of 1000 mg/l was prepared using Nickel Sulphate Hexahydrate ($NiSO_4.6H_2O$) from which varied concentration of 100 mg/l, 200 mg/l and 300 mg/l was prepared by dilution.

Aqua regia reagent was used for the acid digestion of the samples and it was prepared by mixing three parts by volume of concentrated hydrochloric acid (HCl) with one part of concentrated nitric acid (HNO_3) in the ratio 3:1 respectively.

Digestion of Water Samples and Analysis

The water samples were digested according to EPA method 3005A, Revision 1 (1992). 10 ml of the samples were taken in a volumetric flask, 0.2 ml of concentrated HNO_3 and 0.5 ml of concentrated HCl were added to the samples. The samples were digested by heating on a hot plate under a fume hood. The digests were allowed to cool, filtered and the filtrates were made up to 10 ml with distilled water using a 10 ml standard flask. The prepared samples were then analysed using Buck Scientific Atomic Absorption Spectrophotometer (AAS) Model 210.

Digestion of plants, Sediment Samples and Analysis

The ground plant parts and sediment samples were digested using wet digestion. Di-acid digestion of a combination of conc. HCl and conc. HNO_3 (aqua regia 3:1) was used. 0.5g each of the plant parts and sediment samples were taken and 10 ml of the aqua regia was added [5, 21]. The samples were digested by heating on a hot plate under a fume hood. The digests were allowed to cool, filtered and the filtrates were made up to 25 ml with distilled water using a 25 ml standard flask. The prepared samples were then analysed using Buck Scientific Atomic Absorption Spectrophotometer (AAS) Model 210.

Results and Discussion

Sacciolepis africana without the introduction of nickel solution was found to be high in nutrients (table 1) and the nutrients were well translocated to the shoots having their highest concentrations in the leaves except for nickel that was highest in the roots.

Table 1: Mineral composition of *Sacciolepis Africana*

	Ca (mg/kg)	Mg (mg/kg)	K (mg/kg)	Na (mg/kg)	Mn (mg/kg)	Fe (mg/kg)	Ni (mg/kg)
Root	5251.0	502.5	2106.0	847.0	97.0	2107.0	58.6
Stem	34379.5	2005.5	9501.0	861.5	183.5	734.0	48.0
Leaf	47757.0	4167.5	8312.0	878.0	1782.0	11957.0	51.5

Table 2: Characterization of Sediment used in the study

pH	Texture (%)			OM (%)	EC (µS/cm)	Ni (mg/kg)
	Sand	Clay	Silt			
7.60	62.90	15.75	21.35	6.07	161	6.80 ± 2.11

By physical observation, the three set-ups contaminated with nickel solution all showed signs of chlorosis and necrosis while the control set-up showed no sign indicating that the chlorosis and necrosis was as a result of nickel toxicity, possibly interfering with certain essential elements like iron, calcium, magnesium uptake and metabolism [16, 2].

Rapid removal of Ni from the water occurred within the first 3 days and decreased continuously till the last day of observation.

The mean concentrations were significantly different from the control ($P<0.05$) and denoted by the superscripts a, b, c, d in an increasing order in table 3. The percent removal in the water medium was calculated using the mathematical expression:

$$\% \, Removal = \frac{C_i - C_f}{C_i} \times 100$$

C_i = Initial Ni concentration

C_f = Final Ni concentration

The results are presented in the figure 1 below. Considering the SON/NIS drinking water standard for Ni (0.02 mg/l), all the final concentrations were above the permissible limit (SON, 2007) but for FEPA standard for irrigation water (0.2 mg/l), That of 100 mg/l set-up was lower. Eskandari and Alizadeh (2016) reported that for higher concentrations of Ni to be removed from the environment, more time would be required and that the ability of Ni phytoremediation is dependent on the concentration.

Table 3: Ni concentration in the water medium

Day	Control (mg/l)	100 mg/l	200 mg/l	300 mg/l
3	0.200^a ±0.04	9.268^b ±0.62	36.352^c ±1.62	63.667^d ±6.58
6	0.074^a ±0.06	0.852^b ±0.06	3.524^c ±0.02	15.135^d ±0.73
9	0.030^a ±0.05	0.595^b ±0.07	1.230^c ±0.02	5.164^d ±0.40
12	0.035^a ±0.06	0.290^b ±0.11	0.589^c ±0.05	1.476^d ±0.15
15	0.043^a ±0.04	0.177^b ±0.04	0.497^c ±0.05	0.952^d ±0.03

Number of replicates = 3; Mean concentration (mg/l) ± S.D; Mean with different superscripts across rows are significantly different at ($P<0.05$)

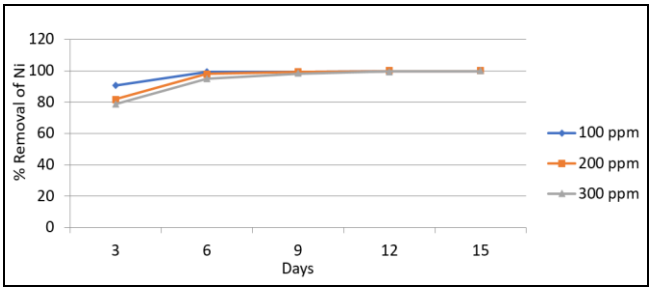

Fig 1: Percentage removal of Ni from water

In the sand medium, there was continuous adsorption of the metal till it got to a peak and then began to desorb but more time is required for the complete desorption. The results are presented in table 4. In the plant, nickel was generally highest in the roots with little translocation to the stem and leaves (Table 5). This pattern is similar to a study done by Narendra *et al*., 2012 for the phytoremediation potential of some macrophytes in accumulation of metals from drain water and tannery effluent.

Table 4: Nickel concentration in sand medium

Day	Control	100 mg/l	200 mg/l	300 mg/l
3	11.480 ^{a} ±0.47	33.170 ^{a} ±4.62	104.630 ^{b} ±24.38	170.080 ^{c} ±6.33
6	9.025 ^{a} ±0.63	148.217 ^{b} ±7.43	165.467 ^{b} ±37.41	462.033 ^{c} ±55.03
9	12.450 ^{a} ±3.25	132.183 ^{b} ±8.85	202.780 ^{c} ±12.48	535.725 ^{d} ±21.03
12	9.825 ^{a} ±0.68	99.200 ^{b} ±7.67	213.350 ^{c} ±19.13	372.017 ^{d} ±4.19
15	7.950 ^{a} ±0.84	98.875 ^{b} ±1.93	207.033 ^{c} ±8.60	346.333 ^{d} ±34.17

Number of replicates = 3; Mean concentration (mg/kg) ± S.D; Mean with different superscripts across rows are significantly different at (P<0.05)

Table 5: Nickel concentration in the plant tissues

Day	Plant tissue	Control	100 mg/l	200 mg/l	300 mg/l
3	Root (mg/kg)	45.234^{a}±0.97	104.958^{b}±0.74	44.282^{a}±7.15	49.896^{a}±9.05
	Stem (mg/kg)	30.350^{b}±7.67	6.570^{a}±0.79	9.281^{a}±0.13	212.375^{c}±10.38
	Leaf (mg/kg)	27.464^{a}±20.61	9.606^{a}±0.62	11.968^{a}±0.05	469.499^{b}±8.01
6	Root (mg/kg)	0.000^{a}±0.00	45.740^{b}±0.26	79.410^{c}±2.24	176.610^{d}±20.79
	Stem (mg/kg)	1.920^{a}±3.33	7.280^{a}±0.08	6.730^{a}±0.63	22.070^{b}±4.31
	Leaf (mg/kg)	7.174^{a}±1.40	6.000^{a}±0.18	12.391^{b}±1.22	79.944^{c}±1.14
9	Root (mg/kg)	5.293^{a}±2.107	53.363^{b}±3.74	153.714^{d}±18.38	82.596^{c}±12.61
	Stem (mg/kg)	4.040^{a}±0.17	6.564^{b}±1.80	27.288^{d}±0.20	9.657^{c}±1.48
	Leaf (mg/kg)	6.453^{a}±0.37	5.940^{a}±0.74	22.308^{b}±1.33	52.353^{c}±2.11
12	Root (mg/kg)	3.083^{a}±0.21	41.203^{b}±4.95	102.695^{c}±5.40	41.324^{b}±13.24
	Stem (mg/kg)	0.000^{a}±0.00	7.910^{b}±0.66	4.760^{b}±1.03	22.000^{c}±3.85
	Leaf (mg/kg)	4.790^{a}±0.97	7.400^{a}±0.20	4.470^{a}±1.71	43.310^{b}±4.44
15	Root (mg/kg)	5.280^{a}±0.28	22.900^{b}±1.25	233.000^{d}±2.00	79.500^{c}±0.45
	Stem (mg/kg)	0.000^{a}±0.00	0.000^{a}±0.00	16.410^{c}±3.42	12.220^{b}±1.38
	Leaf (mg/kg)	1.550^{a}±2.69	4.200^{a}±7.28	85.830^{b}±6.78	8.640^{a}±0.46

Number of replicates = 3; Mean concentration (mg/kg) ± S.D; Mean with different superscripts across rows are significantly different at (P<0.05)

Using the paired sample test, the contaminated water, soil and plants with that of the control set-up, there was significant difference except for the stem and leaves of 100 mg/l and 200 mg/l. The stem and leaves of 300 mg/l showed significant difference which indicates that only at high concentration will there be translocation to the stem and leaves. This is shown in table 6 below.

Table 6: Paired Samples Test at 95% Confidence Interval (P<0.05)

	Concentration (mg/l)	Mean±S.D	T	Df	Sig. (2-tailed)	Remark
Water	0 - 100	-2.160±3.59	-2.329	14	0.035	S
	0 - 200	-8.362±14.44	-2.243	14	0.042	S
	0 - 300	-17.203±24.64	-2.704	14	0.017	S
Soil	0 - 100	-92.182±41.64	8.574	14	0.000	S
	0 - 200	-168.503±46.63	-13.994	14	0.000	S
	0 - 300	-365.490±129.60	-10.952	14	0.000	S
Root	0 - 100	-41.855±14.73	-11.009	14	0.000	S
	0 - 200	-110.844±78.81	-5.447	14	0.000	S
	0 - 300	-74.208±60.79	-4.728	14	0.000	S
Stem	0 - 100	1.597±12.17	0.508	14	0.619	NS
	0 - 200	-5.630±16.02	-1.361	14	0.195	NS
	0 - 300	-48.401±69.49	-2.698	14	0.017	S
Leaf	0 - 100	2.857±11.60	0.953	14	0.357	NS
	0 - 200	-17.907±36.94	-1.877	14	0.081	NS
	0 - 300	-120.663±167.71	-2.786	14	0.015	S

S = Significant; NS = Not Significant

As could be seen on table 7, the bioconcentration factors were high in the 100 mg/l and 200 mg/l set-up but was low in the 300 mg/l. We can therefore infer that higher concentration of nickel may limit its bioconcentration in the plants, this is in agreement with a report by Panwar *et al*. 2002 [12]. Mohammad and Faezeh, 2011[10] also reported that bioconcentration factors decreases with increasing soil metal concentration. The hydrophyte was able to deplete metal from the solution, it showed accumulation of substantial quantity of Ni as BCF was mostly more than 1

but did not behave as a hyperaccumulator. For a plant to be considered as a hyperaccumulator, the BCF value must be greater than 1000 [14]. Most of the translocation factors as seen in table 8 were less than 1 indicating that the hydrophyte excluded the metal from its tissues but accumulated them in the roots, thus suggesting that the plant will be effective for phytostabilization purposes [13].

Table 7: Bio Concentration factors (BCF) at the varied concentrations of Nickel

Day	100 mg/l	200 mg/l	300 mg/l
3	11.00	1.22	0.78
6	53.69	22.53	11.67
9	89.69	124.97	15.99
12	142.08	174.35	28.00
15	129.38	468.81	83.51

$$BCF = \frac{C_{root}}{C_{water}}$$

BCF = Bioconcentration factor
C_{root} = Ni concentration in the roots
C_{water} = Ni concentration in water

Table 8: Translocation factors (TF) of the varied concentrations of Ni

Day	100 mg/l		200 mg/l		300 mg/l	
	Stem	Leaf	Stem	Leaf	Stem	Leaf
3	0.06	1.46	0.21	1.29	4.26	2.21
6	0.16	0.82	0.08	1.84	0.12	3.62
9	0.12	0.90	0.17	0.82	0.27	2.35
12	0.19	0.94	0.04	0.94	0.53	1.97
15	0	0	0.07	5.23	0.15	0.71

$$TF_{stem} = \frac{C_{stem}}{C_{root}}$$

$$TF_{leaf} = \frac{C_{leaf}}{C_{stem}}$$

TF = Translocation factor
C_{root} = Ni concentration in the roots
C_{stem} = Ni concentration in stem
C_{leaf} = Ni concentration in the leaf

Conclusion

The percentage removal of nickel from the water medium at the end of the experiment was 99.823%, 99.752%, 99.683% for the 100mg/l, 200mg/l and 300mg/l respectively. The sand medium was seen to partake in the removal of nickel from the water medium since large amount of nickel got adsorbed to it before it gradually began to desorb. Longer time is therefore needed for complete desorption of the sand medium. The hydrophyte will be good for immobilizing nickel in contaminated aqueous system in a process called phytostabilization since it preferentially stored nickel in its roots.

References

1. Cempel M, Nikel G. Nickel: a review of its sources and environmental toxicology. Polish Journal of Environmental Studies,2006:15:375-382.
2. Cuiyun C, Dejun H, Jianquan L. A review on Functions and Toxicity of Nickel in Plants: Recent Advances and Future Prospects. Clean,2009,37(4-5):304-313.
3. Daboonne S, Koffi B, Kouadio E, Koffi A, Due E, Kouame L. Traditional utensils: Potential sources of poisoning of heavy metals. British Journal of Pharmacology and Toxicology,2010:1:90-92.
4. Eskandari E, Alizadeh AA. Ability of some crops for phytoremediation of nickel and zinc heavy metals from contaminated soils. Journal of Advance Environmental Health Resources, 2016:4(4):234-239.
5. Fabunmi I, Olumodeji O, Uyimadu JP, Adeleye A. Evaluation of the Effectiveness of Different Acid Digestion on Sediments. IOSR Journal of Applied Chemistry. e-ISSN: 2278-5736,2014,7(12):39-47.
6. Federal Environmental Protection Agency (FEPA) Act. Guidelines and standards for Industrial effluent, gaseous emissions and hazardous waste management in Nigeria. Supplement to Official Gazette Extraordinary – Part B, 991:78(42):B15-31.
7. Göhre V, Paszkowski U. Contribution of the arbuscular mycorrhizal symbiosis to heavy metal phytoremediation. Planta,2006:223:1115-1122.
8. Ibitoye AA. Practical Manual on Basic Soil and Fertilizer Analysis,28-32.
9. Kalra YP. Determination of pH of Soils by Different Methods: Collaborative Study. Journal of AOAC International,1995:78:310-324.
10. Mohammad R, Faezeh Z. Bioaccumulation and translocation factors of cadmium and lead in Aeluropus littoralis. Australian Journal of Agricultural Engineering,2011:2(4):114-119.
11. Narendra K, Kuldeep B, Neetu D, Barman SC, Singh DP. Accumulation of metals in selected macrophytes grown in drain water and tannery effluent and their phytoremediation potential. Journal of Environmental Biology,2012:33:923-927.
12. Panwar BS, Ahmed KS, Mittal SB. Phytoremediation of Nickel-Contaminated Soils by Brassica Species. Environment Development and Sustainablity,2002:4(1):1-6.
13. Pignatteli S, Colzi I, Buccianti A, Cecchi L, Arnetoli M, Monnanni R, *et al*. Exploring element accumulation patterns of a metal excluder plant naturally colonizing a highly contaminated soil. Journal of Hazardous Material,2012:227-228:362-369.
14. Razinger J, Dermastia M, Drinovec L, Drobne D, Zrimec A, Koce JD. Antioxidative responses of duckweed (Lemna minor L.) toshort term copper exposure. Environmental Science and Pollution Research,2007:14:194-201.
15. Samal L, Mishra C. Significance of Nickel in Livestock Health and Production. International Journal of Agro Vetenary and Medical Sciences,2011:5(3):349-361.
16. Satish AB, Amit SS, Anukthi CP. Toxicity of Nickel in Plants. International Journal of Pure and Applied Bioscience,2015:3(2):345-355.
17. Schmidt U. Enhancing Phytoextraction: The effects of chemical soil manipulation on mobility, plant accumulation and leaching of heavy metals. Journal of Environmental Quality,2003:32:1939-1954.
18. Standard Organization of Nigeria. Nigeria Standards for drinking water quality ICS 13.060.20. Price group D. NIS 554:2007.
19. Thiagalingam K. Soil and plant sample collection,

preparation and. interpretation of chemical analysis. A training manual and guide. Australian Contribution to National Agricultural Research System in PNG. Prepared by AACM International Project Managers and Consultants Adelaide, Australia, 2000.
20. Uddin AH, Khalid RS, Alaama M, Abdulkadar AM, Kasmuri A, Abbas SA. Comparative study of three digestion methods for elemental analysis in traditional medicine products using atomic absorption spectrometry. Journal of Analytical Science and Technology, 2016m, 7:6.
21. Zdrojewicz Z, Popowicz E, Winiarski J. Nickel-role in human organism and toxic effects. Polish Medical Journal,2016:41(242):115-118.