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Phytoremediation Potentials of *Cassia Occidentalis and Cassia Tora* grown in Challawa industrial area, Kano state

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Abstract

Phytoremediation refers to the use of green plants to remove, contain or render pollutants harmless. Phytoremediation is a new and emerging technology that utilizes the ability of some plants to clean contaminated soil. The technology is well known and established in the developed countries but its use in the tropics is limited. The phytoremediation potentials of two local plant species, Senna Occidentalis, and Cassia Tora was evaluated in squared plots of land experiments watered using heavy metals contaminated effluents from the Challawa Industrial area, Kano. The experiment was laid out in a completely randomised design with two plants at the Effluent and pollution monitoring centre, zawaciki Kano. Samples of plants were harvested after 30 days. The concentrations of seven heavy metals (Cd, Cr, Cu, Fe,Ni, Pb, and Zn) were analyzed in samples of the plant organs (roots, stem, leaves and whole plants) using the UV Spectrophotometer. Results obtained showed that S. Occidentalis was the best accumulator for all heavy metals (Cd, Cr, Cu, Fe,Ni, Pb, and Zn) among the two plants used for the experiment. Generally more metals were accumulated in the leaves and stem than in the roots of plants. The highest metal accumulation ratios were recorded for Fe, Cu and then Zn in the leaves of Cassia Occidentalis.

Keywords: *Phytoremediation, Cassia Occidentalis, Cassia Tora, Heavy Metals.*

INTRODUCTION

The inability of heavy metals to undergo biodegradation make them to have harmful effect on biological systems. Some toxic heavy metals such as Pb, Co, Cd cannot be biodegraded but can be accumulated in living organisms, thus, can be differentiated from other pollutants.

Phytoremediation refers to the use of green plants to remove, contain or render pollutants harmless (Braian, 2009). A weed of roadsides, waste areas, disturbed sit weeds, pastures, grasslands, open woodlands e.t.c. are considered good for phytoremediation activities A wide range of inorganic and organic compounds such as heavy metals, combustibles, and putrescible substances, hazardous waste, explosives and petroleum product, can cause contamination, major component contaminant are heavy metals, they present a different problem than other organic contaminant. Phytoremediation offers an opportunity to increase the financial possibility of phytoremediation programs, and to reduce disposal risks through the utilization of metal enriched plant biomass in energy and metal recovery with the burnt process. Some important metals, such as Ni, Se, Zn and Fe can be recovered from the phytoremediation process of phytomining and biofortification which can be done through several processes, such as agronomic practices, conventional plant breeding, and modern biotechnology. Combining biofortification with phytoremediation is a new idea to tackle malnutrition and environmental remediation (Pandey, 2013a; Pandey et al., 2016). A number of different plants have been reported and documented for phytoremediation as Ni and Zn hyperaccumulators (more than 300), as those are the most accumulated metals by different hyperaccumulator species. For example, *Alyssum lesbiacum* is an Ni hyperaccumulator (Cluis, 2004), and Arabidopsis halleri is a Zn hyperaccumulator (McNair et al., 2000). Plant selection and target metal decide the outcome and financial risks of phytoremediation programs. Jiang et al. (2015) proposed that high biomass producing plants and high value-added metals produce significantly more income (Jiang et al., 2015). Bioaccumulation factor in one of the method of assessment bioaccumulation in an organism and important for evaluating the risk the chemical possess to humans and the environment (Arnot et al; 2006). It shows the how persistent a xenobiotic is in the biological organism especially to biotransformation and subsequently to excretion.

Different approaches have been used or developed to migrate or reclaim the heavy metals polluted soils and they may be broadly classified into physicochemical and biological approaches.

The physicochemical approach includes excavation and burial of the soil at a hazardous waste site, fixation/inactivation (chemical processing of the soil to immobilize the metals), leaching by the use of of acid solutions or proprietary leachants to desorbs and leach the metal from the soil followed by the return of clean soil residue to site (Salt *et al.*, 1995). The physicochemical approaches arev generally costly and have side effects (mcGrath *et al.*, 2001).

The biological approaches of remediation included the use of microorganisms to detoxify the metal by valence transformation, extracellular chemical precipitation or volatilization (some microorganisms can enzymatically reduce variety of metals in metabolic processes that are not related to plant assimilation). The other approach involves the use of special type of plants to decontaminate soil by inactivating metals in the rhizosphere or translocating them in the arial parts. This approach is called phytoremediation, which is considered as a new and highly promising technology for the reclamation of polluted sites and cheaper than the physicochemical approaches (Garbiso and Alcona, 2001; McGrath *et al.*, 1997). Soil microorganism can degrade organic contaminant while metals need immobilization or physical removal. Although many metals are essential, all metals are toxic at higher concentrations, because they cause oxidative stress by formation of free radicals. Another reason why metals may be toxic is that they can replace essential metals in pigments or enzymes, disrupting their function, thus metal render the land unsuitable for plant growth and destroying the biodiversity. (Henry J. R. 2000)

Trace amount of some heavy metals can be detrimental to the organisms, nonessential heavy metals includes arsenic, antimony, cadmium, chromium, mercury, lead etc. These metals are of particulate concern to surface water and soil pollution (Berti *et al.*, 1996).

Heavy metals exist in colloidal, ionic particulate and dissolved phase, metals have high affinity for humid acid, organo clays and oxides coated with metallic matter (Elliot *et al.*, 1986) the solube forms are generally ions or unionized organo-metallic chelates or complexes (Cornell *et al.*, 1984).

The solubility of metals in soil and groundwater are controlled by pH, amount of metal, cation exchange capacity, organic content and the oxidation state of the mineral component and redox potential of the system (Cornell *et al.,* 1984).

In general, soil pH, seems to have greatest effect of any single factor on the solubility or retention and lower solubility of metals cation occurring at high soil pH. (Basta *et al.*, 1993).

Plants generally have three basic strategies for growth on metal contaminated soil, they include metal excluders, metal indicators and metal accumulators plant species (Raskin *et al.*, 1995).

Metal excluders prevent metals from entering thier arial part or maintain lowa and constant metal concentration over a broad range of metal concentration in soil, it mainly restrict metal in thier root, the plant may alter it membrane permeability, change metal binding capacity of the cell wall or exudes more chelating substances. (Cunningham *et al.*, 1995).

Metal indicators are plant species which actively accumualte metals in their aerial tissues and generally reflect metals level in the soil, the tolerate the existing concentration by producing intracellular metal binding compounds (Chelators), or alther metal compartmentalization pattern by storing metals in non-sensitive parts. (Cunningham *et al.*, 1995).

Metals accumulator plant species can concentrate metals in thier aerial part, to level far exceeding that of the soil.

Hyper accumulators are plant that can absorb high level of contaminant concentration either in their root, shoots and/or leave. (Ghosh and Singh, 2005).

The accumulation ratio usually indicates the accumulation capacity of plants, which is the ratio of the content of the metal in the plant or an organ of the plant to the corresponding content in cultivated solution or soil (Cheng. 2003).

The ability of *Senna occidentalis and cassia Tora* to spread in a wide range of environments indicates their weedy potentials; they can also be a weed of annual cropping systems.

BIOACCUMULATION FACTOR

Bioaccumulation refers to the process in which chemical substances is absorbed in an organism by all routes of exposure in natural environment, that is, dietary and ambient environmental sources (Arnot et al; 2003). It could also be referred to as the increase in the level of xenobiotics in a biological organism overtime especially when compared to the level of xenobiotic in the environment (Gupta et al; 2013) Bioaccumulation factor in the ratio of the concentration of a particular chemical in the organism or tissue of an organism to the concentration in the environment.

BAF = concentration of chemical in organism or tissue

Concentration of the chemical in the environment

(Jezierska and witesta; 2001)

Bioaccumulation factor in one of the method of assessment bioaccumulation in an organism and important for evaluating the risk the chemical possess to humans and the environment (Arnot et al; 2006). It shows the how persistent a xenobiotic is in the biological organism especially to biotransformation and subsequently to excretion.

METHODOLOGY

Study area: The project was carried out at Effluent and Pollution Monitoring center Zawaciki Kano, Nigerian Institute of Leather and Science Technology.

A habitat of each species was obtained using square method and was labeled as site A for *Cassia Occidentalis* and site B for *Cassia Tora*. The habitat was further sub divided into 2 equal plot of which one was used as the target plot while the other half plot was used as control. Each sub divided plot consists of about 6 individual plants with distance of about 2 meters between the two plots.

The target plot was supplied with 500ml of Effluent daily for the period of six (6) weeks while the control plot was supplied with tap water of about 500ml per day for period of six (6) weeks with proper observation.

Plant samples were harvested and washed with tap water and then with distilled water to remove debris and surface contamination. Samples were then separated into leaves, stem, flowers, buds, Roots and dried to remove excess moisture.

Dried plant samples were grinded using a porcelain mortar and pestle then sieved to attain a uniform particle size. Each sample was put in a small transparent polythene bag and labeled accordingly.

Digestion of plant samples

Digestion of plant materials in hot (110–140°C) concentrated nitric acid (HNO_3) is a common procedure for assessing their nutrient contents. In the conventional HNO_3 digestion, desired temperatures are achieved through controlled electrical heating, and digestion occurs within Pyrex test tubes. The digestion of two samples for heavy metal analysis was carried out by addition of about 5.0g of each of the dried processed plant samples to 50ml of aqua_ragia HCl/HNO_3 (3:1) on a hot plate for about 90minutes at 110°C to gentle boil until the brown fumes disappeared then 20ml of distilled water was added and heated until a colourless (transparent solution)was obtained.(Alinnor,2004,Iyaka 2007).The Concentration of heavy metals(Cd, Cu, Ni, Fe, Pb and Zn)in the solution was determined using atomic absorption spectrophotometer.(shimadzu G10).

RESULT AND DISCUSSION

Phytoremediation study of Cassia tora and cassia Occidentalis plants Concentration of Cu, Zn, Cr, Ni, Fe, Cu and Pb metals is shown in the Tables below. There is a difference in the concentration of ions in the two plants . Table 1 and 2 shows the level of heavy metals concentration and bioaccumulation of the metals In Leaf, Stem, roots, Whole Plant and Soil of *Cassia Tora*. The results shows that the whole plant has the highest metal concentrations of Cu (18.897 ± 0.2053), Cr (4.372 ± 0.0361), Cd (4.692 ± 0.00234), Fe (23.527 ± 0.1950), and Zn (35.065 ±0.1051), except for Fe which is higher in the root (25.318 ± 0.3764) while Pb concentration (1.299 ±0.0422) and Ni (1.225± 0.01214) are lower than that of soil with metals concentration of Cu (17.943 ± 0.08764), Cr (1.822 ± 0.0304), Cd (2.735 ± 0.0125), Fe (11.170 ± 0.1437), Ni (2.454 ± 0.04956), Pb (1.737 ± 0.01326), and Zn (26.237±0.2962). followed by the concentration of metals in the soil of Cu (17.943 ± 0.08764), Cd (2.735 ± 0.0125). Fe (11.170 ± 0.1437), Zn (26.237±0.2962), Ni (2.454 ± 0.04956), and Pb (1.737 ±0.01326) except for Cr which is lower than that of the leaves Cr (1.822 ±0.0304). The concentrations of metals in leaves is higher than the concentrations in the other organs of the plants Cu (13.913 ±0.1832), Cr (2.789 ±0.0312), Cd (0.9723±0.00453), Fe (), Zn (15.996 ±0.1456), Ni (0.6990 ±0.001907), and Pb (1.002 ±0.0562), except the that of Fe which is higher in the roots (25.318 ± 0.3764) . The concentration of metals in stem is higher than that of root Cu (9.592 ± 0.0975), Cr (1.746 ± 0.0239), Zn (11.063 ±0.0135), and Ni (0.5733 ± 0.008021) except Fe (5.138 ± 0.2409), and Cd (0.7960 ± 0.00306) which are lower than that in the roots. Roots has the accumulation of Cu (5.115 ± 0.06021), Cr (0.8589 ± 0.0854), Cd (1.824 ± 0.0235), Fe (25.318 ± 0.3764), Zn (5.472 ±0.1414), Ni (0.01133 ± 0.01050), and Pb (0.4947 ± 0.00551).

TABLE 1: MEAN CONCENTRATION OF HEAVY METAL AND STANDARD DEVIATION IN LEAF, STEM, WHOLE PLANT AND SOIL OF *Cassia Tora*

Sample	Cu	Cr	Cd	Fe	Zn	Ni	Pb
Leaf	13.913 ± 0.1832	2.789 ± 0.0312	0.9723 ± 0.00453	7.998 ± 0.1728	15.996 ± 0.1456	0.6990 ± 0.00190	1.002 ± 0.0562
Stem	9.592 ± 0.0975	1.746 ± 0.0239	0.7960 ± 0.00306	5.138 ± 0.2409	11.063 ± 0.0135	0.5733 ± 0.00802	0.4947 ± 0.00528
Root	5.115 ± 0.06021	0.8589 ± 0.0854	1.824 ± 0.0235	25.318 ± 0.3764	5.472 ± 0.1414	0.01133 ± 0.01050	0.4947 ± 0.00551
Whole Plant	18.897 ± 0.2053	4.372 ± 0.0361	4.692 ± 0.00234	23.527 ± 0.1950	35.065 ± 0.1051	1.225± 0.01214	1.299 ± 0.0422
Soil	17.943 ± 0.08764	1.822 ± 0.0304	2.735 ± 0.0125	11.170 ± 0.1437	26.237 ± 0.2962	2.454 ± 0.04956	1.737 ± 0.01326

Whole plant also has the highest Bioaccumulation of all the metals as Cu (1.053168), Cr (2.399561), Cu (2.708), Cd (1.715539), Fe (2.106267), Ni (0.499185), Pb (0.747841), and Zn (1.336471). Followed by the leaf with bioaccumulation of Cu (0.7754), Cr (1.530735), Cd (2.349), Fe (2.695), Ni (0.284841), Pb (0.576857), Zn (0.609673) except Cd (0.355503) which is lower than the bioaccumulation of roots. The bioaccumulation of stem is higher than that of the roots Cu (0.534582), Cr (0.958288), Zn (0.421656), Ni (0.233619), and Pb (0.284801) except Fe (0.459982)and Cd (0.291042) which are lower than that of the roots. The root has the metal bioaccumulation Cu(0.285069), Cr (0.471405), Cd (0.66691), Fe (2.266607), Ni (0.004617), Pb (0.284801), Zn (0.20856) respectively.

Table 2: Bioaccumulation Of Heavy Metal And Standard Deviation In Leaf, Stem, Whole Plant And Soil Of *Cassia Tora*

Sample	Cu	Cr	Cd	Fe	Zn	Ni	Pb
Leaf	0.7754	1.530735	0.355503	0.716025	0.609673	0.284841	0.576857
Stem	0.534582	0.958288	0.291042	0.459982	0.421656	0.233619	0.284801
Root	0.285069	0.471405	0.66691	2.266607	0.20856	0.004617	0.284801
Whole Plant	1.053168	2.399561	1.715539	2.106267	1.336471	0.499185	0.747841

Concentration of heavy metal for the *cassia Occidentalis* plant in leaf, stem, root, whole plants and Soil in sample site is shown in table 3 below. The analysis shows that the leaf has the highest Cu, Cr, and Cd concentrations of (15.410 ± 0.07581), (6.122 ± 0.1367) and (3.687 ± 0.02924) respectively, the concentrations of Fe (18.448 ± 0.0764), Zn (28.199 ± 0.04331), Ni (3.382 ± 0.09112), and Pb (2.347 ± 0.06573) are all higher in the leaves than the other organs except for the whole plants. Followed by, whole plants Cu (17.870 ± 0.0595), Cr (5.213 ±0.0321), Cd (1.895 ± 0.0027), Fe (21.056 ± 0.0643), Zn (37.247 ±0.324), Ni (3.924 ±0.1104), Pb (2.887 ± 0.0523), root Cu (13.012 ± 0.07452), Cr (3.428 ± 0.0768), Cd (2.379 ±0.2125), Fe (12.437 ± 0.1373), Zn (17.406 ±0.1204), Ni (3.121 ± 0.00510), Pb (1.986 ± 0.02456), soil Cu (10.427 ±0.04164), Cr (1.2278 ±0.02426), Cd (2.526 ±0.02637), Fe (12.735 ± 0.05398), Zn (25.735 ± 0.07757), Ni (2.883 ±0.03116), Pb (1.764 ± 0.09864)and stem which has the least mean concentration of the metals Cu (2.711 ±0.0288), Cr (5.984 ±0.03659), Cd (0.8573 ±0.01039), Fe (5.037 ± 0.05789), Zn (7.296 ± 0.07080), Ni (0.0021 ± 0.0001), Pb (0.4567 ±0.03465) .

Table 3: Mean Concentration of Heavy Metal and Standard Deviation in Leaf, Stem, Whole Plant and Soil of *Cassia Occidentalis*

Sample	Cu	Cr	Cd	Fe	Zn	Ni	Pb
LEAF	15.410 ± 0.07581	6.122 ± 0.1367	3.687 ± 0.02924	18.448 ± 0.0764	28.199 ± 0.04331	3.382 ± 0.09112	2.347 ± 0.06573
STEM	2.711 ± 0.0288	1.2278 ± 0.02426	2.526 ± 0.02637	5.037 ± 0.05789	7.296 ± 0.07080	0.0021 ± 0.0001	0.4567 ± 0.03465
ROOT	13.012 ± 0.07452	3.428 ± 0.0768	2.379 ± 0.2125	12.437 ± 0.1373	17.406 ± 0.1204	3.121 ± 0.00510	1.986 ± 0.02456
WHOLE PLANT	17.870 ± 0.0595	5.213 ± 0.0321	1.895 ± 0.0027	21.056 ± 0.0643	37.247 ± 0.324	3.924 ± 0.1104	2.887 ± 0.0523
SOIL	10.427 ± 0.04164	5.984 ± 0.03659	0.8573 ± 0.01039	12.735 ± 0.05398	25.735 ± 0.07757	2.883 ± 0.03116	1.764 ± 0.09864

The Bioaccumulation of heavy metals for the *Senna Occidentalis* plant in the sample site is presented in table 4 below. The leaves contained the highest accumulation of all the detected heavy metals with Cu (0.862339), Cr (1.174372), Cd (1.945646), Fe (0.87614), Zn (0.757081) Ni (0.861876), and Pb (0.812955). followed by the stem with the higher accumulation of four detected heavy metals than the roots of Cu (0.728148), Cd (1.255409), Ni (0.795362), and Pb (0.687911) whereby the other three detected metals are lower than in the roots Cr (0.657587), Fe (0.590663) and Zn (0.467313). For root, Cu (0.583492), Cr (1.147899), Cd (0.452401), Fe (0.604816), Zn (0.690928), Ni (0.734709), and Pb (0.611015). the Bioaccumulation of metals in whole plants for Cu, Cr, Cd, Fe, Zn, Ni and Pb are (0.151707), (0.235527),(1.332982), (0.239219), (0.195882), and (0.158192) respectively.

Table 4: Bioaccumulation Of Heavy Metal And Standard Deviation In Leaf, Stem, Whole Plant And Soil Of *Cassia Occidentalis*

Sample	Cu	Cr	Cd	Fe	Zn	Ni	Pb
Leaf	0.862339	1.174372	1.945646	0.87614	0.757081	0.861876	0.812955
Stem	0.728148	0.657587	1.255409	0.590663	0.467313	0.795362	0.687911
Root	0.583492	1.147899	0.452401	0.604816	0.690928	0.734709	0.611015
Whole Plant	0.151707	0.235527	1.332982	0.239219	0.195882	0.000535	0.158192

The general order of heavy metals bioaccumulation in various Tissue of the plant species used in this research can be represented (Table 2) as follows: Leaves > stem >roots > whole plants.

Table 5: Comparisons of Phytoremediation Potentials of *Cassia Tora* and *Cassia Occidentalis*

Plant species	Part	Heavy metal concentration (mg/kg)						
		Cu	Cr	Cd	Fe	Zn	Ni	Pb
CASSIA TORA	Leaf	0.7754	1.53073	0.35550	0.71602	0.60967	0.28484	0.57685
	Stem	0.53458	0.95828	0.29104	0.45998	0.42165	0.23361	0.28480
	Roots	0.2850	0.4714	0.6669	2.2666	0.2085	0.00461	0.28480
	Whole plants	1.0531	2.3995	1.7155	2.1062	1.3364	0.49918	0.74784
Cassia Occidentalis	Leaf	0.8623	1.1743	1.9456	0.8761	0.7570	0.86187	0.81295
	Stem	0.7281	0.6575	1.2554	0.5906	0.4673	0.79536	0.68791
	Root	0.5834	1.1478	0.4524	0.6048	0.6909	0.73470	0.61101
	Whole Plant	0.1517	0.2355	1.3329	0.2392	0.1958	0.00053	0.15819

Discussion

Heavy metal (Cu, Cr, Cd, Fe, Ni, Zn, and Pb) Bioaccumulation in plant tissues collected from the experimental areas (leaf, stem, roots and whole plants, separately) are shown in table 5. The results obtained from the UV experiments show a complicated relationship between metals. The data show that the metal contents in the plant tissues differed among species at the site indicating their different capacities for metal uptake. It is found out that plant's soil analysis of heavy metals in the sample site are contaminated with metals (Cd, Cr, Cu, Fe, Ni, Pb and Zn,) and the higher solubility of heavy metals in the soil might be due to lower pH (Malik RN, et al., 2010). The availability of certain heavy metals depends on soil properties such as soil pH and contain exchange capacity and on the distribution of metals among several soil fractions. High metal accumulation in plant parts above normal limit indicates their tolerance to the heavy metal pollution in the soil (U. Abdullahi, et al., 2016). The accumulation of all the metals in the whole plant of *Cassia Tora* in the sample site is higher than that of the *Cassia Occidentalis.* However, the absorption and accumulation is higher in the leaf, stem and root of *Cassia Occidentalis* plants. The highest concentration of Cd was accumulated by the leaves of all the plant species and is similar to the report of Sun et al., 2009. Cadmium is one of the more mobile heavy metals in the soil-plant system, easily taken up by plants and with no essential function known to date (Lehoezky E, et al., 1998). Thus, *Cassia Occidentalis* has the highest potentials of accumulating Cadmium, copper, Nickel, Lead and Zinc than *Cassia Tora* species. The cadmium and Copper and Zinc uptake by the plants indicate that the plants have highly effective cadmium, Copper or Zinc scavenging mechanisms. It is demonstrated that *Cassia Occidentalis* has high phytoremediation potential and can be adopted for remediating, cadmium, Copper, Nickel, Iron and Zinc contaminated sites. However, considering the fact that accumulation of other heavy metal of Cr, is higher in the *Cassia Tora*, it can be deduced that it has high potential of accumulating the aforementioned heavy metal than *Cassia Occidentalis* Furthermore, in all the plant parts, leaf has the highest accumulation of all the detected heavy metals with exception of Fe where the root has the highest absorption of it in *Cassia Tora plant*. This is in agreement with the findings of (Qihang et al and Islam et al.) for the two plants, the uptake of metals in the plant tissues indicates that the metals can enter into the root cytoplasm by crossing the plasma membrane of the root of the endodermal cells (Islam MM, et al., 2012). Roots did not accumulate significant amounts of metal of Cd and Ni. These results confirm the minimal values for accumulation of cadmium by different plant organs in either contaminated or non-contaminated soils. (Welch, R.M. and R.M. Norvell, 1999), who mentioned that "the uptake of Cd in the plant parts could be reduced by a competition for transport with Zn and Fe (Hussein F. F et al., 2013). Thus the higher Fe content in the studied species could be another reason for the reduced Cd content in the plant root. The data on Zn concentrations in the plant species sampled and its corresponding soil concentration reveal great variability in Zn concentrations according to plant species and sites of plant collection. There is no significance difference of concentration of Zn in plant's roots and stem in the sample site. Leaf has the highest bioaccumulation of Zn in the sample. The highest amount of Zn and Pb were detected in the leaves, followed by the stems and roots. Accumulation of Zn in the leaves might be due to its importance in biochemical reactions especially in photosynthesis (Mohd et al. 2013). This variability might be the result of varying distance of the sampling points from the polluted-related activities (Yoon et al., 2006).

Accumulation of Zinc was higher in root tissue of *Cassia Occidentalis*, perhaps the result of a tolerance mechanism developed by the plant in order to reduce heavy metal stress. Fernandez and Henriquez (1991) reported that Zinc tolerant plants prevent Zinc from reaching stems and leaves by keeping it in their roots. Limitation of transfer of Zinc to stem and leaves explained Zinc tolerance in plants (Ozounidou, 1994). Van Assche and Clijsters (1990) and Luna et al. (1994) reported that copper stopped the formation of chlorophyll and caused destruction of chlorophyll.

Chettri et al. (1998) reported a decrease in chlorophyll levels Cladonia rangiformis after dosing with Cu, Zn and Pb. Peroxidase activity and photosynthetic pigments are sensitive indicators of heavy metal stress and can be used to anticipate events on the organism level (Wu et al., 2003; Mac Farlane and Burchett, 2001.) In all cases, apart from the higher accumulation of chromium and Iron, the plants samples did not accumulate significant amounts of other heavy metals. In fact, there was an unexpected reduction of accumulation of some metals such as Ni in the sample site. Thus, the results show that in general there is not an apparent pattern of either enhanced or decreased absorption from one metal to another from the control and sample site. Moreover, apart from Cu and Fe, the samples consistently showed a poor accumulation of other metal in either the roots or leaves compared with other species.

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