

Research Paper

Markers of Environmental Health: Nickel and Chromium Levels in Soil and Vegetation around a Steel Recycling Facility in Southwest Nigeria

ABSTRACT

Aims: Nickel and Chromium levels in the soil and leaves of *Chromolaena odorata* were used to mark the environmental health status in the vicinity of a steel recycling facility.

Methodology: Conventional methods were used to determine some soil parameters while metal content were analysed using the Atomic Absorption Spectrophotometer.

Results: The results of the soil within the factory showed pH values of 7.50 – 8.80 and reduced organic matter content indicating alkaline conditions and low microbiological activities. Electrical conductivity values were comparatively higher within the factory (423 – 1550 $\mu\text{S/m}$) than soils outside the factory showing presence of some soluble salts in the soil. Ni concentrations were increasing up to 200 m and then decreased as the distance from the factory further increased in all the four cardinal directions. Similar trends occurred for Cr in the eastern side of the factory where the detectable concentrations ($2.29 \pm 0.05 - 33.26 \pm 0.02 \text{ mgkg}^{-1}$) was observed. The Nickel content in the soil around the factory ranged from: North ($0.76 \pm 0.01 - 1.46 \pm 0.06 \text{ mgkg}^{-1}$); East ($0.19 \pm 0.05 - 2.68 \pm 0.04 \text{ mgkg}^{-1}$); West ($0.21 \pm 0.01 - 1.46 \pm 0.07 \text{ mgkg}^{-1}$) and South ($0.22 \pm 0.02 - 1.89 \pm 0.01 \text{ mgkg}^{-1}$). Within the factory however, the scrap yard contained high concentration of Cr $24.15 \pm 0.04 \text{ mgkg}^{-1}$ while the soils from the dumpsite for sorted wastes contained elevated concentrations of Ni ($73.17 \pm 0.02 \text{ mgkg}^{-1}$). Nickel and chromium content in the plant leaves in this study ranged from 1.40 – 3.60 mgkg^{-1} and 0.40 – 1.5 mgkg^{-1} .

Conclusion: Further increase in the Cr and Ni levels in the soil and plants of the study site poses a potential health hazard to animals that graze the area and man through consumption of forage and agronomic crops cultivated around the factory by peasant farmers.

Keywords: Environmental health; Nickel; Chromium; steel recycling

1. INTRODUCTION

Nickel is a member of the elements of group 10 (previously group VIII) of the periodic table with density of 8.90 g/kg^3 . Compounds of nickel are utilized as dyes in the manufacture of glass and ceramic, and in batteries containing Nickel–Cadmium compounds. About 68 % of nickel is also used as an alloy of several tools used in medicine, food technology or as kitchen equipment [1]. Therefore, nickel is a serious pollutant that is released from metal recycling plants. The Ni distribution in soil profiles is related to organic content of the soil and clay fractions [2], depending on the soil type. There is no evidence of an essential role of Ni in plant metabolism and studies of the uptake and chemical behavior of Ni in plants are related mainly to its toxicity having possible implications with respect to animals and human. Gray-green leaves and restricted growths of plants caused by an excess of Ni were observed to be effects of Ni toxicity in some cereals [3]. Chromium is a trace metal belonging to group 6 (formerly group VIb) of the periodic table with density of 7.19 g/cm^3 . The main

industrial use of Cr is in the metallurgical, refractory and chemical industries. Cr is used primarily in the manufacture of green tints for paints, varnishes, glazes, inks; in leather tanning, chromate plating, in metal finishing, and as wood preservatives [4]. Therefore, many municipal and industrial wastes from various sources may contain elevated amounts of Cr and lack of appropriate disposal facilities can lead to serious groundwater and soil pollution [5]. Although many different oxidation states of chromium exist in the environment, only the trivalent (III) and hexavalent (VI) forms are considered to be of biological importance. Soils surrounding a Cr smelter in Albania contain Cr at average of 3117 mg/kg, whereas its highest concentration, up to 20,300 mg/kg was reported in soils close to the slags [6]. The most available to plants is Cr^{6+} , which is the very unstable form under normal soil conditions [7] and its availability depends on soils properties, and especially on soil texture and pH. Cr^{3+} is rather benign to most plants and binds strongly to soil solids. There is no evidence of an essential role of Cr in plant metabolism. The forms and transformation of Cr in soils have great environmental and health implications. Therefore, most remediation treatments of Cr-contaminated soils is the conversion of easily mobile Cr^{6+} to Cr^{3+} and thus mitigates effects of Cr toxicity in plants [8]. However, although Cr^{3+} is considered an essential food nutrient, very large doses is reported to be harmful [9]. Also, occupational exposure to Cr^{6+} containing compounds is known damage to the kidney and liver [9] and to induce increased incidence of respiratory-system cancers [10].

The main goal of the present study was to assess the environmental health status of a steel recycling facility with specific focus on the distribution and concentration of two associated metals in soil and leaves of *Chromolaena odorata* around the factory with no other apparent source of industrial pollution in the area.

2. MATERIAL AND METHODS

2.1 Sample Collection

Sixty four soil samples were collected randomly using Dutch soil auger from the upper 15 cm of the selected sites within and around the factory. Fifty four samples in duplicates were collected from each of the twenty seven $10 \times 10 \text{ m}^2$ sampling plots covering a distance of 350 m at 50 m interval from the walls of the recycling factory site in the four cardinal directions, eight from four selected sites within the factory and two composite soil samples at 2,000 m away in the western side of the factory to serve as control. The four selected sites within the factory include location A (the scrap yard), location B (the slag area), location C (dumpsite for sorted wastes) and location D (the soil around the furnace area). The samples were collected before the raining season of the year 2012 due to the fact that research has shown that the concentrations of these metals in soil are higher in the dry season than in the rainy season [11]. This could be due to absence of surface run-off and leaching.

2.2 Soil Analysis Collection

The soils were dried for 8 days, ground using agate mortar and sieved with a 2 mm mesh size. Air-dried soil samples (10 g each) were accurately weighed into series of 250 ml conical flasks and 100 mls of 0.1 N HCl was added into each of the flasks containing the soil samples. These were shaken properly for 30 minutes. The contents were filtered through Whatman's No.42 filter paper. The metals were analyzed with PG 990 series model of Flame Atomic Absorption Spectrophotometer. A reagent blank sample was taken through the method, analyzed and subtracted from the samples to correct for reagent impurities and other sources of errors. Other parameters determined on the soil samples included: pH in 1:1 soil:deionized water; percentage organic carbon; particle size analysis and electrical conductivity.

2.3 Plant Analysis

Leaves of *Chromolaena odorata* were collected only around the factory, because no plants grew on top of the slag piles and on the other wastes sites within the factory. Plants samples were cleaned, rinsed once with tap water and twice with deionized water, and dried in the oven at 70°C for 48 hours. Two gram of the dried samples ground using a stainless steel hammer mill was weighed into a 50 ml Pyrex volumetric flask and 2 ml concentrated H₂SO₄ acid was added and heated on a hot plate at a temperature of 450°C. Drops of hydrogen peroxide were added from time to time as the oxidizing agent until the sample becomes clear and was left to cool and made up to volume with distilled water. The concentrate was analyzed for Chromium (Cr) and Nickel (Ni) using the Atomic Absorption Spectrophotometer.

2.4 Data Analysis

The data from soil and plants tissue analyses of the sampled plots were subjected to descriptive and one-way analyses of variance.

3. RESULTS AND DISCUSSION

Results should be clearly described in a concise manner. Results for different parameters should be described under subheadings or in separate paragraph. Table or figure numbers should be mentioned in parentheses for better understanding.

3.1 Soil Parameters

All the soil samples from the four cardinal directions of the factory were moderately to slightly acidic pH conditions (Table 1). This is typical of most African soils. The pH of the soils from the sites within the factory however, ranged from moderately alkaline (7.50 – 7.80) to strongly alkaline (8.80). High soil pH have also been reported in heavy metal contaminated soils [12,13,14,15]. The alkaline condition of the soils within the factory may be due to the some crumbs of some carbonate materials used in the production processes and the basic slag which are high in pH and often used as liming materials in agricultural soils. At high pH values, the availability of Phosphorus and most micronutrients as well as anaerobic conditions of soil tend to decrease. Except in the northern side of the factory where the soil was sandy clay loam, similar textural composition of the soils observed within and around the factory was sandy loam. However, there was a marked significant variation in the organic carbon content of the soils within the factory (Table 2). Low organic carbon content at the slag area and soils around the furnace could be attributed to the removal of topsoil and vegetation within the factory. Population and activities of soil microorganisms tends to decrease in heavy metal contaminated sites with low organic matter content (Huang *et al.*, 2009). Results of the electrical conductivity were very high within the factory (Table 2) with values ranging from 423 – 1550 µs/m. These values were higher than those reported by [13]. This may be due to the presence of some soluble salts in the top soil within the factory. However, these conductivity values were comparatively lower than those around the factory which ranged from 146 – 226 µs/m in the soil samples.

127 **Table 1: Soil properties of the study sites from the four cardinal directions of the**
128 **factory**

Soil Property	North	East	West	South	Non-polluted soil
pH (H ₂ O)	5.57	6.46	5.89	6.16	6.20
Organic Carbon (%)	2.53	2.72	1.75	1.75	2.81
Electrical Conductivity (µs/m)	221	226	170	146	115
Sand (%)	55.17	67.86	70.14	70.00	67.00
Silt (%)	18.17	14.86	14.43	16.14	16.00
Clay (%)	26.83	17.29	15.43	13.86	17.00
Textural Class	Sandy clay loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam

129

130 **Table 2: Soil properties from the study sites within the metal recycling factory**

Soil Property	A	B	C	D	E
pH (H ₂ O)	7.60	7.50	7.80	8.80	6.20
Organic Carbon (%)	2.18	0.94	1.76	0.43	2.81
Electrical Conductivity (µs/m)	1335	423	1550	877	115
Sand (%)	70	75	73	59	67
Silt (%)	10	16	14	36	16
Clay (%)	20	9	13	5	17
Textural Class	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam

131 A – Scrap yard; B – Slag area; C – Dumpsite for sorted wastes; D – Soil around the furnaces;
132 E – Non-polluted soil

133

134

135 3.2 Ni and Cr content in the Soil around the factory

136 The results from this study showed that Nickel and Chromium concentrations in the soils of
137 the study area were generally low. The same trend occurred in all the sides of the factory
138 where Ni concentrations first increased up to 150 m and 200 m and then decreased as the
139 distance from the factory further increased. These confirmed the observations of [16,17] that
140 the soils closest to the factory contained elevated concentrations of the element than
141 distances further away from the factory. The Cr concentration ($2.29 \pm 0.05 - 33.26 \pm 0.02$) of
142 the eastern side of the factory (Table 3) followed similar trends with that of Ni. The Nickel
143 content in the soil around the factory (Table 4) ranged from 0.76 ± 0.01 to 1.46 ± 0.06 mgkg⁻¹
144 ⁻¹ in the north; 0.19 ± 0.05 to 2.68 ± 0.04 mgkg⁻¹ in the east, 0.21 ± 0.01 to 1.46 ± 0.07
145 mgkg⁻¹ in the west and 0.22 ± 0.02 to 1.89 ± 0.01 mgkg⁻¹ in the southern side of the
146 factory. Although the Ni values were within the normal soil concentration of 15 mgkg⁻¹ [18],
147 the levels were higher than those recorded in the control site proving that the presence and
148 activities of the factory influenced the content of the soils around the factory. Conversely, the
149 chromium concentrations in the soils were below detectable limits in the northern, western
150 and southern side of the factory (Table 3) probably because of wind direction which was
151 majorly southwesterly. These metals originating from activities of the factory are distributed
152 in soil by the atmosphere within a distance that depends on the size of particles. The
153 concentration of these metals in soil can vary greatly according to the strength and direction

of wind, type of soil, and pH. The low and non-detection of chromium in some sites could be attributed to the fact that most of the paints in the scraps have peeled off before they were brought to the factory for recycling or used in the recycling process. It may also be due possible conversion to the non available form (Cr^{6+}) due to the presence of organic matter content in the study site.

Table 3: Chromium concentrations (mgkg^{-1}) from the soil samples around the factory

Distances (m)	North	East	West	South
50	nd	nd	nd	nd
100	nd	2.29 ± 0.05	nd	nd
150	nd	21.97 ± 0.00	nd	nd
200	nd	22.48 ± 0.03	nd	nd
250	nd	33.26 ± 0.02	nd	nd
300	nd	15.57 ± 0.03	nd	nd
350	nd	nd	nd	nd
Non-polluted soil	0.53 ± 0.03	0.53 ± 0.03	0.53 ± 0.03	0.53 ± 0.03

nd = not detected

Table 4: Nickel concentrations (mgkg^{-1}) from the soil samples around the factory

Distances (m)	North	East	West	South
50	nd	0.19 ± 0.05	0.21 ± 0.01	0.22 ± 0.02
100	0.76 ± 0.01	0.58 ± 0.02	0.46 ± 0.06	1.24 ± 0.04
150	1.36 ± 0.02	0.87 ± 0.02	0.78 ± 0.03	1.89 ± 0.01
200	1.18 ± 0.03	2.68 ± 0.04	1.46 ± 0.07	1.02 ± 0.02
250	1.02 ± 0.02	nd	0.87 ± 0.10	0.77 ± 0.02
300	1.16 ± 0.00	0.74 ± 0.01	0.85 ± 0.97	0.77 ± 0.56
350	1.46 ± 0.06	0.69 ± 0.01	0.30 ± 0.50	0.76 ± 0.50
Non-polluted soil	0.17 ± 0.02	0.17 ± 0.02	0.17 ± 0.02	0.17 ± 0.02

nd = not detected

3.3 Ni and Cr content in the Soil within the factory

Metal concentrations in the soils within the factory were very variable depending on the location (Table 5). The scrap yard contained high concentration of Cr $24.15 \pm 0.04 \text{ mgkg}^{-1}$ followed by the site where the sorted wastes were dumped $19.75 \pm 0.03 \text{ mgkg}^{-1}$. These values were within the Maximum Allowable Concentration of 50 -200 mgkg^{-1} [3]. The metal levels in the soil of the scrap yard of this study were higher than those reported by [13] in soils around a metal scrap dump, Nigeria but lower than those of [19] the soils around an

iron smelter in brazil and [5] in the soils around chromium-containing slag heap of steel alloy factory. The soils from the dumpsite for sorted wastes contained elevated concentrations of Ni ($73.17 \pm 0.02 \text{ mgkg}^{-1}$) which was above the Maximum Allowable Concentration of 20 – 60 mgkg^{-1} in agricultural soil [3]. Except at location B (soil of the slag area), the Ni concentrations were significantly higher than those of chromium in all the locations within the factory. This is expected because Ni (as an alloy element) is contained in most of the scrap used. Continuous dumping of these wastes on exposed soil surface will lead to contamination of the soil and underground water sources.

183

Table 5: Concentrations of Nickel and Chromium (mgkg^{-1}) from the soil samples within the factory

Location	A	B	C	D	E
Ni	31.55 ± 0.02	11.80 ± 0.05	73.17 ± 0.02	14.64 ± 0.03	0.17 ± 0.02
Cr	24.15 ± 0.04	18.30 ± 0.02	19.75 ± 0.03	5.53 ± 0.02	0.53 ± 0.03

A – Scrap yard; B – Slag area; C – Dumpsite for sorted wastes; D – Soil around the furnaces;
E – Non-polluted soil

189

3.4 Ni and Cr content in the Plant around the factory

The chromium and nickel levels in the leaves of *Chromolaena odorata* in the four directions around the factory showed similar trends as elevated concentrations were recorded between 200 m and 250 m away from the factory. Nickel content in the plant tissue in this study ranged from 1.40 – 3.60 mgkg^{-1} while chromium content ranged from 0.40 – 1.5 mgkg^{-1} similar to those reported by [20] in the same species around Agbabu Bitumen Deposit Area, Nigeria. The Ni values in the plant leaves were within normal range of 0.10 – 5.0 mgkg^{-1} and tolerable levels of 1.0 – 10.0 mgkg^{-1} for agronomic crops [3]. The Cr concentrations however exceeded the normal range of 0.10 – 0.50 mgkg^{-1} suggested by the same author but were within the tolerable limit (2 mgkg^{-1}) for agronomic plants. Wilting and chlorosis of the young leaves and root injury are reported symptoms of Cr toxicity in plants [3]. Further increase in the Cr and Ni levels in the soil and plants of the study site poses a potential health hazard to nomadic animals and man through the consumption of forage and agronomic crops grown around the factory by some workers and peasant farmers.

204

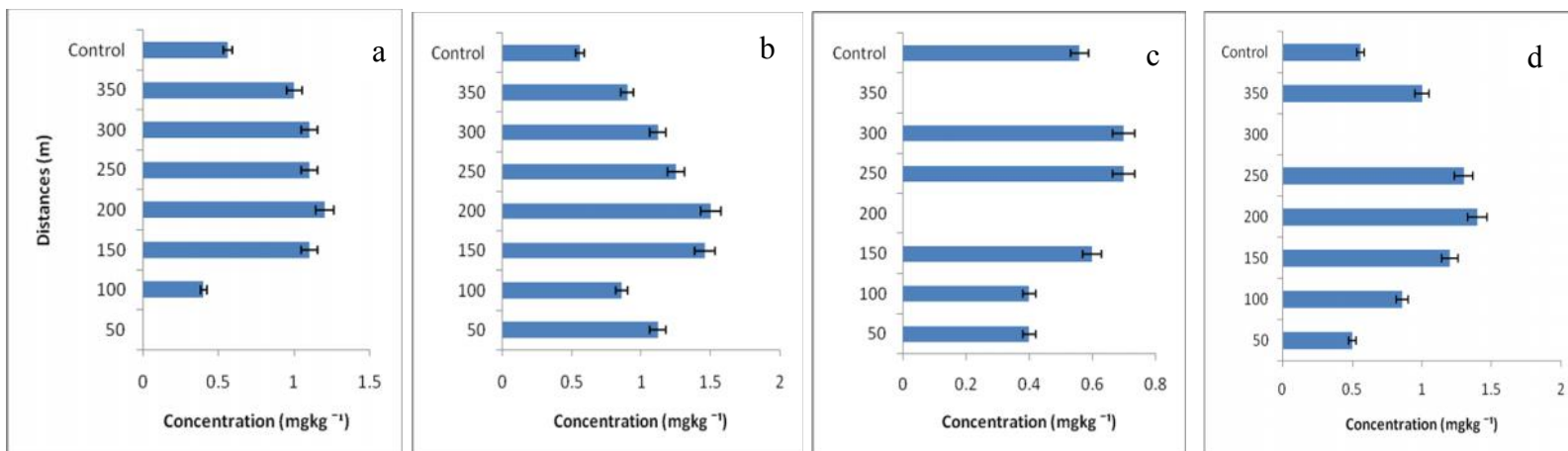


Figure 1: Chromium accumulation (mgkg⁻¹) in leaves of *Chromolaena odorata* from four cardinal sides (a) North (b) East (c) West (d) South of the factory

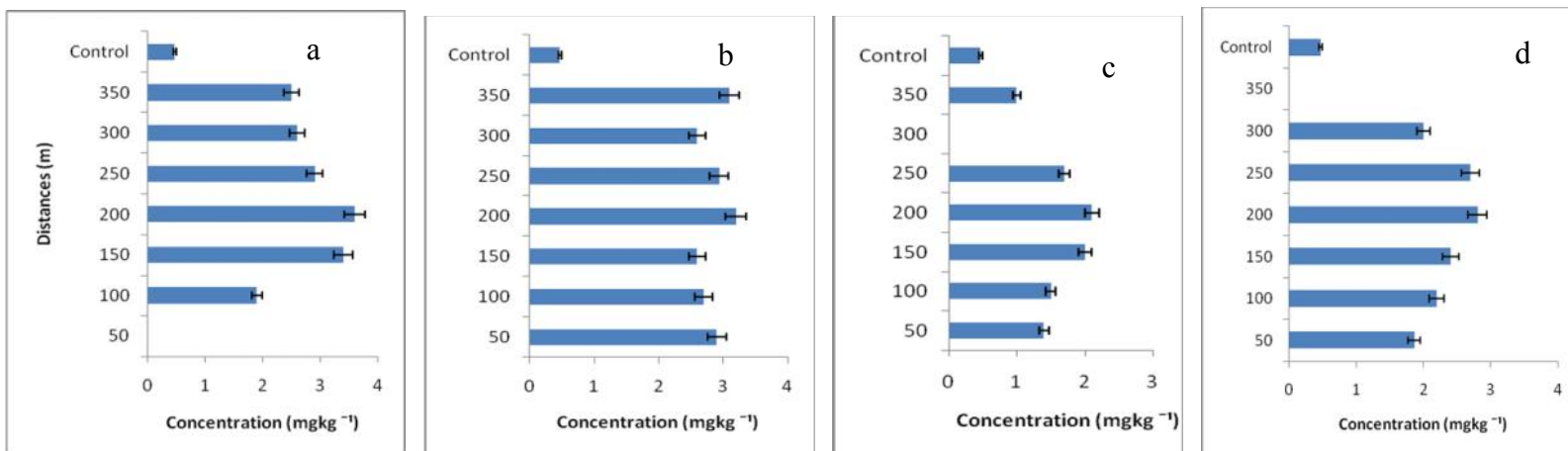


Figure 2: Nickel accumulation (mgkg⁻¹) in leaves of *Chromolaena odorata* from the four cardinal sides (a) North (b) East (c) West (d) South of the factory

4. CONCLUSION

The result obtained from this study has shown elevated levels of the metals in the soil and *Chromolaena odorata* collected from sites within and immediate surrounding of a steel recycling facility compared to an undisturbed site 2 km from the factory. Sites within the factory contained higher concentrations of the metals than those outside of the factory where some concentrations were below detectable levels. Although the values obtained at various points were within tolerable limits, further indiscriminate dumping of wastes and activities of the factory should be checked to prevent further deterioration of living systems in the factory's immediate environment.

REFERENCES

1. Reck BK, Muller DB, Rostkowski K, Graedel TE. Anthropogenic nickel cycle: insights into use, trade, and recycling. *Environ. Sci. Technol.* 2008;42:3394–3400.
2. Senwo ZN, Tazisong IA. Metal contents in soils of Alabama. *Commun. Soil Sci. Plant Anal.* 2004;35:2837–2848.
3. Kabata – Pendias A. Trace Elements in soils and plants. 4th edition. CRC press, Boca Raton, London, New York;2011.
4. Malkoc E, Nuhoglu Y, Dundar M. Adsorption of chromium(VI) on pomace—An olive oil industry waste: Batch and column studies. *Journal of Hazardous Materials* 2006;B138:142–151.
5. Huang S, Peng B, Yang Z, Chai L, Zhou L. Chromium accumulation, microorganism population and enzyme activities in soils around chromium-containing slag heap of steel alloy factory. *Trans. Nonferrous Met. Soc. China.* 2008;19: 241 - 248.
6. Shtiza A, Swennen R, Tashko A. Chromium and nickel distribution in soils, active river, overbank sediments and dust around the Burrell chromium smelter (Albania). *J. Geochem. Explor.* 2005;87:92–108.
7. Mukherjee AB. Chromium in the environment of Finland. *The Science of the Total Environment* 1998;217: 9 – 19.
8. Singh G, Brar MS, Malhi SS. Decontamination of chromium by farm yard manure application in spinach grown in two texturally different Cr-contaminated soils. *J. Plant Nutr.* 2007;30:289–308.
9. USPHS. Toxicological profile for chromium on CD-ROM. Agency for Toxic Substances and Disease Registry. U.S. Public Health Service;1997.
10. International Agency for Research on Cancer. Chromium and certain chromium compounds. In: IARC monographs on the evaluation of the carcinogenic risk of chemicals to humans. Chemicals, industrial processes and industries associated with cancer in humans. IARC monographs, Vol. 1 to 29,1998.
11. Yahaya MI, Mohammad S, Abdullahi BK. Seasonal Variations of Heavy Metals Concentration in Abattoir Dumping Site Soil in Nigeria. *J. Appl. Sci. Environ. Manage.* 2009;13(4) 9 – 13.
12. Osakwe SA, Otuya, OB. Elemental Composition of Soils in Some Mechanic Dumpsites in Agbor, Delta State, Nigeria. *Proceedings of Chemical Society of Nigeria.* 2008;557-559.
13. Akpoveta OV, Osakwe SA, Okoh BE, Otuya BO. Physicochemical Characteristics and Levels of Some Heavy Metals in Soils around Metal Scrap Dumps in Some Parts of Delta State, Nigeria. *Journal Applied Science Environmental Management* 2010;14 (4) 57 – 60.
14. Adewole MB, Adesina MA. Impact Of Marble Mining On Soil Properties In A Part Of Guinea Savanna Zone Of Southwestern Nigeria. *Ethiopian Journal of Environmental Studies and Management* 2011;4 No 2.

- 265 15. Anjaneyulu E, Ramgopal M, Narasimha G, Balaji M. Effect of Pig Iron Slag Particles on
266 Soil Physico-Chemical, Biological and Enzyme Activities. Iranica Journal of Energy and
267 Environment 2011;2 (2): 161-165.
- 268 16. Cartwright B, Merry RH, Tiller KG. Heavy metal contamination of soils around a lead
269 smelter at Port Pirie, South Australia. Australian Journal of Soil Research 1997;15(1) 69
270 – 81.
- 271 17. Al-Khashman OA, Shawabkeh RA. Metals distribution in soil around the cement factory
272 in southern Jordan. Environmental Pollution 2006;140, 387 -394.
- 273 18. Bowen HJM. Environment Chemistry of Elements, Academic Press, London;1979.
- 274 19. Brigden K, Stringer R, Labunska I. Organochlorine and heavy metal pollutants
275 associated with the Gerdau Iron smelter in Sapucaia do Sul, Brazil 2000. Greenpeace
276 Research Laboratories, Department of Biological Sciences, University of Exeter, Exeter,
277 UK. Technical Note: 2100; 2000
- 278 20. Fagbote EO, Olanipekun EO. Evaluation of the Status of Heavy Metal Pollution of Soil
279 and Plant (*Chromolaena odorata*) of Agbabu Bitumen Deposit Area, Nigeria. American-
280 Eurasian Journal of Scientific Research 2010;5 (4): 241-248.