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TRACE METAL LEVELS IN SOILS AND AXONOPUS COMPRESSUS WITHIN AN ABANDONED STEEL INDUSTRY ENVIRONMENT

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ABSTRACT

This research work is carried out to investigate the levels of some trace metals in soils and *Axonopus Compressus* within the abandoned Qua-Steel Industry environment. Ten metals (Fe, Ni, Mn, Zn, Al, Co, Pb, Cd, Cr, and Cu) were analysed using Unicam Solar 969 Atomic Absorption Spectrophotometer (A.A.S). Levels of these trace metals in the industrial environment were generally higher than those from the control site, suggesting that the activities of steel production and other manufacturing processes which took place when the industry was operational, contributed to the observed higher levels in the industrial environment. The average concentrations of Fe, Ni, Mn, Zn, Al, Co, Pb, Cd, Cr and Cu, in the plant samples were 257.31+40.75 mg/kg; 8.53+3.62 mg/kg; 2.41+1.18 mg/kg; 60.80+19.18 mg/kg; 21.85+15.40 mg/kg; 1.73+1.20 mg/kg; 0.25+0.24 mg/kg; 2.39+2.01 mg/kg; 33.74 20.28 mg/kg; and 130.89+33.72 mg/kg, respectively. In soil samples, the average levels were: Fe(206.48+25.32 mg/kg), Ni(24.01+5.11 mg/kg), Mn(25.55+5.23 mg/kg), Zn(69.71+17.12 mg/kg), Al(32.54+6.42 mg/kg), Co(7.72+3.68 mg/kg), Pb(3.68+2.55 mg/kg), Cd(7.50+2.61 mg/kg), Cr(48.84+25.48 mg/kg), and Cu(92.67+28.57 mg/kg). The levels of Cd in both soils and *Axonopus compressus* and the concentrations of Co, Cr and Cu in the plant were significantly high to cause environmental concern as their concentrations exceeded the tolerable limits. Adverse effects of these trace metals in the environment are discussed. Remediation of the polluted soil and suspension of all agricultural activities in the abandoned Qua-Steel Industry environment are recommended.

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KEYWORDS: Trace Metals, Soil, *Axonopus Compressus*, Steel Industry, Pollution

INTRODUCTION

Steel is an alloy that contains more than 50% of iron and 0.03-1.5% of carbon and to obtain the properties described for different purposes, other metals are usually added (Umland and Bellama, 1996). Some of these metals include; Manganese, Zinc, Nickel, Chromium, Tin, Tungsten, and Vanadium. Manganese is the only metal without any substitute that is used as a deoxidizing and desulfuring agent in the manufacture of steel. Zinc is used in galvanizing steel to give a protective coating against corrosion. Nickel is used in making stainless steel and high temperature alloys of steel. Chromium is used also for making stainless steel. Tin is used in protective coating for steel and tungsten is used to produce very tough steel (Leet *et al.*, 1982). Vanadium used in the manufacture of steel makes the metal more ductile and resistant to shock (Anusiem, 2000). These metals can be accumulated in the soil through waste from steel production. According to Udosen *et al.*, (1990), heavy metals in soils are associated with geometrical cycles and biological processes and could be greatly influenced by industrial activities.

Plants in turn are capable of absorbing these metals from the soil (Kalulu and Abdullahi, 2004). These

metals could be leached into the soil when they undergo chemical reactions and could come in direct contact with roots of plants (Udosen, 1991). When these plants in the form of vegetables, are eaten by man, trace metals become bioaccumulated and eventually result in several ailments which may subsequently end up in death (Odiette, 1999; Udosen, 1998). Plants can accumulate some of these metals which are not injurious to them, but may be poisonous to animals grazing on the plants (Raven and Evert, 1976). *Axonopus compressus* plant was chosen for two main reasons. First, because of its abundance in the site and secondly because of its economic importance. Domestic animals feed on these plants on the site or when harvested by their owners to the domestic animals. These animals if eaten by humans, will introduce the trace elements to man through food chain. This could have adverse effect on man's health. The iron-steel environment was of concern because of its location in an area where rural populace farm. The distance of the steel industry to the water source of the community is also worrisome. Apart from the building and cemented areas, all other areas in the abandoned steel industry are now used for agricultural purposes. Some of the

wastes emanating from steel production are spread over some parts of the environment particularly on water-logged soil. Trace metals present in the waste may therefore accumulate in the soil and plants in this environment. Hence, the soil and plants in this environment are presumed to be polluted with trace metals. This study is therefore to assess the trace metal levels in soil and the plant *Axonopus compressus* within the abandoned steel industry environment. Therefore, measurement of the levels of metals in soil and plants can be useful in establishing trends in abundance and other consequences (Kalulu and Abdullahi, 2004). Again, heavy metals discharged into our environment including their distribution, reaction in the ecosystem and subsequent uptake and distribution in plants are of great concern for human health, (Udosen *et al.*, 2007). This work is aimed at investigating the levels of some trace metals in *Axonopus Compressus* and soil within an abandoned steel industry environment. This is necessary so as to compare the levels of trace metals in *Axonopus Compressus* and soil not impacted by such and industry enterprise. Specifically, the aims of the study are: (i) to determine the levels of some trace metals in soil within the abandoned steel company environment (ii) to determine the levels of some trace metals in *Axonopus Compressus* in the abandoned steel company environment. (iii) to ascertain the pollution status and the effect of the trace metals in the environment. (iv) to recommend some remedies to the pollution problem of the environment.

MATERIALS AND METHODS

Study Area: Qua-Steel Products Limited was one of the major Steel producing industries in the South-South zone of Nigeria located along Ibeno road in Eket Local Government Area of Akwa Ibom State. The industry was commissioned in 1978, and was known for the production of steel and also for other manufacturing businesses. The major raw material used by this steel industry was steel billets. Some of the wastes generated by this industry were spread in some parts of the environment to check water-logging within the premises. Because of the lack of raw materials due to the closure of Delta Steel Company (DSC) Aladja – Warri in June 1996, and non-functionality of the major plants and machineries in the industry. Qua-Steel products Limited was closed down in 1996 and has remained abandoned till now. The premises of the abandoned industry is now used for agricultural purposes.

SAMPLE COLLECTION: Soil sampling was carried out by collecting portions of soil using a soil auger of length 15 cm at each location. The samples were put into polyethylene bags, labeled and taken to the laboratory for pre-treatment and analysis. Similarly, the plant samples (*Axonopus compressus*) commonly called carpet grass from the Qua-Steel Industry environment were also taken at the same spot where the soil samples were obtained, labeled

and taken to the laboratory for further treatment and analysis. Sampling was carried out within this environment from three different locations for three consecutive months (September to November). Samples of both soils and plants (*Axonopus compressus*) were collected in triplicate from each location. Control samples were also collected about 10 kg away from the industry.

Sample Treatment and Analysis: All soil samples were air-dried at ambient laboratory temperature. Soil samples were ground using mortar and pestle and sieved to pass through 2 mm sieve and stored for chemical analysis. Each soil sample (2 g) was placed in a Teflon beaker and digestion was carried out using concentrated nitric (10 cm³) and concentrated perchloric (5 cm³) acids in the ratio of 2:1. This was allowed to cool before leaching the residue with 5 cm³ of 20% HNO₃. Digested samples were filtered and made up to 50 cm³ with deionized water. A blank determination was treated in the same method but without sample. Solution of samples were then taken and aspirated into Atomic Adsorption Spectrophotometer (Unicam Solaar A.A.S 969 model). Each plant sample was oven-dried at 50°C - 60 °C. The dry sample was ground into powder and stored. The powdered plant sample (1g) was weighed into a crucible and ashed in a furnace at 500 °C-700 °C for 4 hours. It was removed after ashing from the furnace and cooled. The sample (ash) was leached with 5 cm³ of 6 M HCl and was made to 50 cm³ of volume of deionized water. Blank determination was also carried out as in a similar way as described above except for the omission of the sample. The solutions were analyzed for metals using A. A. S (Unicam Solaar A.A.S 969 model). A calibration graph was plotted for each element using measured absorbance and the corresponding concentration. The calibration curve was used to determine the concentration of the metal.

RESULTS AND DISCUSSION

The results obtained from this study show variations in the concentrations of heavy metals in soils and the plant *Axonopus compressus*. The levels of these heavy metals were remarkably higher in soil samples than in the plant except for iron (Fe), zinc (Zn) and copper (Cu) which had higher concentrations in *Axonopus compressus* in some locations of the industrial environment than in soil. Similar results were also obtained by Kalulu and Abdullahi (2004), when they investigated the impact of municipal solid waste on trace metal concentration in herbage and in soil samples in Abuja Municipality. Udosen *et al.*, (2007) also observed higher concentrations of some heavy metals in *Sporobolus pyramidalis* in abandoned battery industry environment and attributed it to bioaccumulation.

Iron (Fe) levels in plant samples from all the locations were generally higher than Fe levels in soil samples. The mean level of Fe in the plant from all

the locations of the study area was 257.32 ± 40.75 mg/kg while the mean level of Fe in soil samples was 206.48 ± 25.32 mg/kg. Of the all the metals analyzed for this study, Fe shows the highest concentration. This could be attributed to the fact that Fe was the major raw material used in the manufacture of steel, as observed by Joesten et al., (1991) that steel is an alloy of iron. The higher concentration of Fe in plants than in soils shows the high uptake of Fe by *Axonopus compressus* from the soil. The higher level of Fe in the plant species may also be due to Fe abundance or availability in the soil of this study area and biomagnifications (Botkin and Keller, 1998). Although Fe is not generally considered as soil pollutant because of its high background levels (Huamain et al., 1999), the relatively higher Fe concentration observed in plant samples from this study area calls for concern. The low coefficient of variation of Fe in both *Axonopus compressus* and soils, 15.84% and 12.26% respectively shows that this metal is stable and will still be present in this environment for a long time.

Higher concentrations of copper were also obtained in plant with a mean value of 130.89 ± 33.72 mg/kg than in soils with a mean level of 92.67 ± 28.57 mg/kg. The higher level of Cu in the plant species than in soil could be as result of high uptake of Cu by *Axonopus compressus*, due to Cu availability in the soil. The reduced level of Cu in the soil might be due to leaching. The level of Cu observed in the plant species in this study area is above the natural limit in plant (4-15 mg/kg) (Vecera et al., 1999). The coefficient of variation of Cu observed for both plant and soil samples, 25.675 and 30.83% respectively, from this study area is evidence that Cu will persist in this environment. Excessive amount of Cu in an environment as indicated in this study area might be toxic to man and other organisms. Raven and Evert (1976) observed that high concentration of Cu is highly toxic to plants. Excess of copper in the body has been found to cause Wilson's disease (Moore et al., 2005).

Zinc was also found to be of higher levels in plants with a mean level of 69.80 ± 19.18 mg/kg than in soils with a mean level of 69.71 ± 17.12 mg/kg. The high level of Zinc observed in this environment than in control site might be due to the use of Zinc in galvanizing steel (Leet et al., 1982). Zinc although being an essential trace element in low concentration, is toxic in high concentration (Oborn et al., 2005). Ingestion of Zinc in excess of 12 mg per day may cause lung disturbance (Eka and Udotong, 2003). Apart from the use of zinc in galvanizing steel, its use as an additive in lubricating oil (Ayodele and Gaya, 1998) may also be responsible for the observed level of Zn in this environment.

The mean levels of chromium in the plant and soil samples were 33.74 ± 20.28 mg/kg and 48.84 ± 25.48 mg/kg respectively. The level of Cr in this study is

higher in soils than in plants. The observed level of Cr in plant samples is higher than the natural limit of 0.1-1 mg/kg. The presence of chromium in this environment under study might be due to its use in the steel industry. Dudka and Andiano (1997) reported high concentrations of chromium (30-4560 mg/kg) in soil from chromium smelting industry in Japan. Exposure to chromium has been found to cause dermatitis (Ayodele and Gaya, 1998), perforation of nasal septa and kidney damage among other diseases (Vincoli, 1995).

The mean level of Al in the soil of this study area was 32.54 ± 6.42 mg/kg, while that recorded in plant was 21.85 ± 15.40 mg/kg. The low coefficient of variation of aluminum (19.735) in the soil shows that Al will persist in this environment. Exposure to high concentrations of Al through repeated inhalation may result in aluminosis or lung fibrosis. Other hazards associated with exposure to Al are accumulation of aluminum particles in the kidney and Alzheimer's disease (Vincoli, 1995).

The recorded mean level of manganese obtained in this study in the soil was 25.55 ± 5.23 mg/kg, while that observed in plant was 2.41 ± 1.18 mg/kg. These levels of Mn are within the permissible limit (Vecera et al., 1999). Manganese shows low coefficient of variation in the soil of this study area (20.41%), indicating that Mn will persist in this environment. The presence of Mn in this environment might be as a result of its use in the steel industry. Exposure to manganese has been indicated to cause lack of control of the bladder (Ayodele and Gaya, 1998) and transient psychiatric disturbances, among other effects (Nelson et al., 1993)

The mean nickel levels in plant and soil of the study area were 8.53 ± 3.62 mg/kg and 24.01 ± 5.11 mg/kg respectively. This level of nickel observed was within the natural limit of 40 mg/kg in soil (Vecera et al., 1999) while the level observed for plant was above the natural limit of 0-1-5 mg/kg for plant. Ingestion of nickel may cause hyperglycemia, depression of the central nervous system and kidney damage (Vincoli, 1995). The presence of nickel in this study area might be due to its use in the steel industry. The mean concentrations of cobalt, lead and cadmium were quite low in both plant and soil samples, although the level in soil samples were higher than that of plant samples. In soil samples the mean value of Co was 7.72 ± 3.68 mg/kg, Cd was 7.50 ± 2.61 mg/kg while Pb was 3.68 ± 2.55 mg/kg. The mean concentrations of Co, Cd and Pb in the plant samples were 1.73 ± 1.20 , 2.39 ± 2.01 and 0.25 ± 0.24 mg/kg respectively. Cobalt level in the soil was within the natural soil limit of 1-40 mg/kg while the level in plant was higher than the natural limit of 0.05-0.5 mg/k. Exposure to Co may cause dermatitis and diseases of the red blood cell (Avila, 1992). The mean concentrations of Pb were within the natural limits in both soil and plant samples. The presence of

Pb in this environment may have been due to automobile emission and industrial emission (Joesten et al., 1991). Chronic exposure to lead can lead to chronic lead poisoning, which will result in memory loss and restlessness. Lead has been found to inhibit enzymatic activity (Vincoli, 1995). Cadmium levels in both plant and soil samples were higher than the natural limits of 0.1-1 mg/kg in plant and 0.01-3.0 in soil. Cadmium is therefore considered to pollute the soil and also be toxic to plants. Exposure to high cadmium levels may result in a disease known as osteoporosis (Akesson et al., 2006), cadmium is regarded as the most hazardous trace element, and its poisoning causes damage to kidney and heart, and prolonged exposure results in loss of calcium from the bone (Udoessien, 2003).

A correlation study between the metals in the plant and soil samples carried out is shown in Table 3. Among the metals that showed strong correlations were Fe and Ni ($r=0.9986$, $p<0.05$), Fe and Ni ($r=0.9261$, $p<0.05$), Ni and Ni ($r=0.9962$, $p<0.05$), Cr and Al ($r=0.9998$, $p<0.05$), Cu and Fe ($r=0.9827$, $p<0.05$). Some metals that are negatively correlated include Fe and Pb ($r=0.9947$, $p<0.05$), Fe and Cd ($r=0.9990$, $p<0.05$), Ni and Cd ($r=0.9999$, $p<0.05$), etc.

CONCLUSION

The findings of this study show that steel production contributed to the levels of trace metals as depicted by the higher trace metal concentrations in soils and plants within the abandoned Qua-Steel industry environment than at the control site. Levels of trace metals in the soils were generally higher than levels in *Axonopus compressus* except for iron, zinc and copper. The levels of cadmium in both soil and plant species and the concentrations of cobalt, chromium and copper in the plant were above permissible limits, thus the level of environmental pollution is high in this study area. The levels of trace metal obtained in this environment may affect human health since the crops grown in this environment are continuously consumed. Thus, there is need for bioremediation of this environment and the suspension of all agricultural activities in this environment to avoid transmission of these heavy metals to man through food chain.

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APPENDIX

TABLE 1. Mean concentrations of Fe, Ni, Mn, Zn, Al, Co, Pb, Cd, Cr and Cu in *Axonopus compressus* from Qua-Steel Industry Environment and control site (Mg/Kg)

| SAMPLE | Fe | Ni | Mn | Zn | Al | Co | Pb | Cd | Cr | Cu |
|----------|------------------|----------------|---------------|----------------|----------------|---------------|---------------|---------------|----------------|-----------------|
| 1 | 246.85± 33.24 | 7.74±1. 37 | 2.29±0. 39 | 62.49±3.5 1 | 34.50±5.5 0 | 1.24±0.2 4 | 0.23±0.0 8 | 0.92±0.0 9 | 55.47±1.5 3 | 144.21±6.7 7 |
| 2 | 302.27±2. 46 | 12.48± 1.63 | 3.46± 0.39 | 91.56± 7.75 | 4.70± 0.31 | 3.09± 0.32 | 0.02± 0.02 | 4.68± 0.32 | 30.42± 3.75 | 155.91± 2.92 |
| 3 | 222.81± 13.87 | 5.36± 0.83 | 1.29± 0.26 | 55.35± 1.31 | 26.34± 3.05 | 0.85± 0.23 | 0.50± 0.05 | 1.58± 0.27 | 15.32± 1.12 | 92.54± 8.28 |
| Control | 80.00± 12.68 | 0.83± 0.23 | 0.55± 0.00 | 41.09± 2.35 | 2.17± 0.49 | 0.51± 0.02 | 0.00±0.0 0 | 0.34± 0.02 | 6.52± 1.09 | 20.36± 2.91 |
| Mean | 257.31 | 8.53 | 2.41 | 69.80 | 21.85 | 1.73 | 0.25 | 2.39 | 33.74 | 130.89 |
| S. D | 40.75 | 3.62 | 1.18 | 19.18 | 15.40 | 1.20 | 0.24 | 2.01 | 20.28 | 33.72 |
| C. V (%) | 15.84 | 42.44 | 48.96 | 27.48 | 70.48 | 69.36 | 96.00 | 84.10 | 60.11 | 25.76 |

Table 2. Mean concentrations of Fe, Ni, Mn, Zn, Al, Co, Pb, Cd, Cr and Cu in soil samples obtained from Qua-Steel Industry Environment and control site (Mg/Kg).

| SAMPLE | Fe | Ni | Mn | Zn | Al | Co | Pb | Cd | Cr | Cu |
|----------|------------------|----------------|----------------|----------------|----------------|----------------|---------------|---------------|----------------|------------------|
| 1 | 211.22±1 6.78 | 22.40± 3.37 | 30.65± 6.49 | 54.58±1.9 9 | 39.47±1.9 1 | 11.76±0. 71 | 4.04±1.2 3 | 8.04±0.6 5 | 76.28±1.4 6 | 109.49±10. 20 |
| 2 | 229.10±7. 06 | 29.74± 3.67 | 30.37± 3.85 | 88.30±4.2 4 | 31.36±1.3 4 | 4.57±0.3 7 | 0.97±1.2 1 | 4.66±0.3 4 | 44.33±5.3 2 | 108.83±8.3 4 |
| 3 | 179.12±3. 82 | 19.90± 2.27 | 20.25± 4.60 | 66.25±1.2 3 | 26.80±1.0 4 | 6.82±0.3 9 | 6.06±2.6 5 | 9.80±1.3 0 | 25.92±1.4 5 | 86.68±8.80 |
| Control | 52.14±1.9 3 | 3.38±0. 89 | 6.78±1. 59 | 25.19±0.4 6 | 14.55±2.3 4 | 2.49±0.1 5 | 0.03±0.0 0 | 2.68±0.0 8 | 13.80±2.9 0 | 31.18±4.41 |
| Mean | 206.48 | 24.01 | 25.55 | 69.71 | 32.54 | 7.72 | 3.68 | 7.50 | 48.84 | 92.67 |
| S. D | 25.32 | 5.11 | 5.23 | 17.12 | 6.42 | 3.68 | 2.55 | 2.61 | 25.48 | 28.57 |
| C. V (%) | 12.26 | 21.28 | 20.47 | 24.56 | 19.73 | 47.67 | 69.29 | 34.80 | 52.17 | 30.83 |

S. D - STANDARD DEVIATION, C. V - COEFFICIENT OF VARIATION

Table 3: Correlation Matrix between Heavy Metals in plant (*Axonopus compressus*) samples from Qua-Steel Industry Environment (r at p<0.05).

| | Fe | Ni | Mn | Zn | Al | Co | Pb | Cd | Cr | Cu |
|----|--------|--------|--------|--------|--------|--------|--------|--------|-------|-------|
| Fe | 1.000 | | | | | | | | | |
| Ni | 0.999 | 1.000 | | | | | | | | |
| Mn | 0.990 | 0.995 | 1.000 | | | | | | | |
| Zn | 0.998 | 0.995 | 0.979 | 1.000 | | | | | | |
| Al | -0.843 | 0.824 | -0.761 | -0.878 | 1.000 | | | | | |
| Co | 0.991 | 0.985 | 0.963 | -0.998 | -0.908 | 1.000 | | | | |
| Pb | -0.956 | -0.966 | -0.988 | -0.934 | 0.650 | -0.908 | 1.000 | | | |
| Cd | 0.894 | 0.878 | 0.824 | 0.923 | -0.995 | 0.946 | -0.724 | 1.000 | | |
| Cr | 0.157 | 0.191 | 0.291 | 0.089 | 0.399 | 0.022 | -0.438 | -0.302 | 1.000 | |
| Cu | 0.840 | 0.859 | 0.907 | 0.801 | -0.417 | 0.759 | -0.962 | 0.508 | 0.667 | 1.000 |

Table 4. Correlation Matrix between Heavy Metals in soil samples from Qua-Steel Industry environment (r at $p < 0.05$)

| | Fe | Ni | Mn | Zn | Al | Co | Pb | Cd | Cr | Cu |
|----|--------|--------|--------|--------|--------|-------|--------|--------|-------|-------|
| Fe | 1.000 | | | | | | | | | |
| Ni | 0.905 | 1.000 | | | | | | | | |
| Mn | 0.927 | 0.679 | 1.000 | | | | | | | |
| Zn | 0.511 | 0.828 | 0.152 | 1.000 | | | | | | |
| Al | 0.502 | 0.086 | 0.790 | -0.487 | 1.000 | | | | | |
| Co | -0.148 | -0.554 | 0.234 | -0.925 | 0.781 | 1.000 | | | | |
| Pb | -0.960 | -0.988 | -0.785 | -0.732 | -0.240 | 0.419 | 1.000 | | | |
| Cd | -0.942 | -0.995 | -0.747 | -0.770 | -0.182 | 0.471 | 0.998 | 1.000 | | |
| Cr | 0.588 | 0.093 | 0.794 | -0.481 | 1.000 | 0.777 | -0.246 | -0.188 | 1.000 | |
| Cu | 0.931 | 0.688 | 1.000 | 0.1040 | 0.782 | 0.222 | -0.792 | -0.755 | 0.786 | 1.000 |

Table 5: Correlation Matrix between metals in plants (*Axonopus Compressus*) samples and metal in soil samples from Qua-Steel Industry environment (r at $p < 0.05$)

| | Fe | Ni | Mn | Zn | Al | Co | Pb | Cd | Cr | Cu |
|----|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Fe | 0.9261 | 0.9387 | 0.9693 | 0.8981 | -0.5780 | 0.8665 | -0.9959 | 0.6588 | 0.5178 | 0.9827 |
| Ni | 0.9986 | 0.9962 | 0.9818 | 0.9999 | -0.8703 | 0.9965 | -0.9398 | 0.9163 | 0.1046 | 0.8104 |
| Mn | 0.7169 | 0.7410 | 0.8063 | 0.6677 | -0.2298 | 0.6150 | -0.8892 | 0.3286 | 0.8009 | 0.9805 |
| Zn | 0.7978 | 0.7762 | 0.7070 | 0.8371 | -0.9968 | 0.8721 | -0.5871 | 0.9834 | -0.4705 | 0.3431 |
| Al | 0.0707 | 0.1733 | 0.2739 | 0.0707 | 0.4155 | 0.0033 | -0.4217 | -0.3198 | 0.9998 | 0.6537 |
| Co | -0.5099 | -0.4794 | -0.3863 | -0.5674 | 0.8924 | -0.6216 | 0.2366 | -0.8413 | 0.7698 | 0.0384 |
| Pb | -0.9947 | -0.9977 | -0.9994 | -0.9854 | 0.7835 | -0.9717 | 0.9814 | -0.8433 | -0.2573 | -0.8914 |
| Cd | -0.9990 | -0.9999 | -0.9956 | -0.9937 | 0.8186 | -0.9839 | 0.9684 | -0.8734 | 0.2001 | -0.8632 |
| Cr | 0.1449 | 0.1795 | 0.2800 | 0.0770 | 0.4097 | 0.0097 | -0.4274 | -0.3137 | 0.9999 | 0.6585 |
| Cu | 0.7253 | 0.7490 | 0.8133 | 0.6766 | 0.2415 | 0.6255 | -0.8947 | 0.3400 | 0.7936 | 0.9828 |