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LEVELS OF TOXIC METALS IN TELFAIRIA OCCIDENTALIS FROM A PAINT INDUSTRY ENVIRONMENT.

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ABSTRACT

Analyses of samples of the plant *Telfairia occidentalis* grown on soils receiving paint waste were carried out for five metals (Zn, Pb, Cd, Cu and Cr) using atomic absorption spectrophotometer (AAS). Similar analyses were carried out for the same metals in samples of the plant from background soils. The results obtained showed higher levels of Zn and Cr in samples from soils receiving paint waste than in those from background soils. On the other hand, levels of Pb and Cu were higher in samples from background soils than those from soils receiving paint waste. The possible reason for this abnormality is given in the text. The degrees of accumulation of these metals in the samples of the plant from soils receiving paint waste in relation to their background values were as follows: Zn (1.10), Pb (0.34), Cd (0.00), Cu (0.80) and Cr (2.98) respectively. The effects these metals may likely have on animals and humans have been discussed based on the results, national and international standards as well as on available literature. Recommendations on possible methods of monitoring and controlling the distribution of these metals in the environment have been made.

INTRODUCTION

As man continues to establish more industries in urban and rural areas, he contributes to the increase and distribution of heavy and toxic metals in water, land and air environments. The industrialization of these areas do not only deprive these environments of the pollution-free status they have been enjoying but could adversely affect the lives of the inhabitants. A population that benefits from the advances made by technology also bears a risk for adverse effects which can never be entirely eliminated.

In Nigeria, possible sources of industrial pollution include the manufacturing of paints, batteries, fertilizers, insecticides, plastic, textiles, papers, detergents, petrochemicals and other types of consumable chemicals. The pollutants from these industries include highly poisonous organics, inorganics and toxic metals. Hazardous waste is potentially damaging to the environment and must be regulated (FEPA, 1991).

The Peacock Paint Industry at Etinan in Akwa Ibom State produces two major classes of paints namely, the water based (emulsion) and solvent based (gloss) paints. The waste water from these two types of paint may contain substantial quantities of hazardous materials including heavy metals such as Zn, Pb, Cu, and Cr contained in pigments used in manufacturing these paints (Udosen et al 1990). When added to the soil, these metals could be leached into the soil where they undergo chemical reactions and come in direct contact with roots of plants (Udosen, 1991).

Martin *et al*. (1982) contended that environmental contamination by heavy metals such as Cd, Pb. Zn and Cu had been of great concern in the last decade because these metals can constitute a hazard to man and other organisms when accumulated within the biological system. According to them these metals are often more highly accumulated in soil compared to vegetation. Plants are therefore regarded as bioindicators for the presence of toxic pollutants in an environment (Treshow). According to Kirleis *et al* (1981) the concentration of trace metals such as Zn, Fe, Ni, Cu and Cd in plants always increases with increasing rates of sludge applied. In most of the industrial wastes, Zn is almost always present in the highest concentration while Cu is often second although Pb, Cr or Ni may exceed Cu depending on the local industry (Jones and Jarvis, 1981). On the whole plants as a rule are much more tolerable to high trace metal concentrations than animals (Bohn *et al*, 1979). Research carried out by Udosen *et al* (1990) revealed that the levels of Zn, Pb, Cu, Cd and Cr were higher in paint waste precipitates and soil receiving the wastes than in background soil samples. Although there are many paint industries operating in Nigeria, systematic environment pollution monitoring and control of wastes from these industries continue to be ignored.

There was therefore need to find out if metals contained in the soils receiving the paint wastes were easily absorbed by the plants grown on them. There was also the need to find out the effects (if any) through literature that these metals could have on man who is the ultimate consumer of plants.

MATERIALS AND METHODS

The plant samples within the artificial valley (located approximately 50 metres away from the factory site) was fluted pumpkin (*Telfairia occidentalis*). This plant was chosen because it was the only useful vegetable plant available in the environment which received the paint wastes at the period of the research.

Sampling was carried out biweekly for five months and was effected by cutting off the stem of the plant with leaves (although only the leaves were needed for analysis) using a sharp stainless steel knife.

The plant sample collected were put into brown calico cloth bags and properly labelled before taking them to the laboratory for treatment and analysis.

The oven-dried plant sample (5.0g) was ashed and cooled and the ash dissolved with 2M HCl in a ratio of 1.0g of ash to 5.0cm^3 of acid and evaporated to dryness.

The residue was redissolved in 20.0 cm^3 of 25 % $^v/_v$ HCl and transferred quantitatively into a 100 cm^3 volumetric flask. The solution was then diluted to the mark with deionised water. The solutions of the plant digest were aspirated into Atomic Absorption Spectrophotometer (Pye Unicam, model SP 9, 1981) and the absorbances obtained were used in calculating the concentrations of the metals in the different samples.

RESULTS

Table I shows that Zn and Cr levels were generally higher in PSPW samples than in PBGS samples except that there was a slight reversal of the trend in October for Zn levels. On the other hand Pb and Cu levels were generally higher in PBGS samples than in PSPW samples. Here again there was a reversal of the trend in October for Cu levels.

Table 2 contains the mean metal levels, ranges, coefficients of variation and degrees

Table 1: Mean Monthly concentrations (Ugg-1) of Metals in plants from soil receiving paint wastes (PSPW) and those from the background soil.

SAMPLES METALS	MONTHS									
	AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
	PSPW	PBGS	PSPW	PBGS	PSPW	PBGS	PSPW	PBGS	PSPW	PBGS
Zn	2.52	2.07	2.36	2.12	1.91	2.02	2.41	2.06	2.09	2.00
Pb	0.33	0.93	0.38	0.73	0.47	0.88	0.13	1.05	0.40	0.70
Cd	0.04	N. D.	0.04	N. D.	0.02	N. D	0.03	N. D.	0.04	N. D.
Cu	0.78	0.99	0.83	1.08	1.00	0.78	0.83	1.17	0.65	1.11
Cr	3.03	0.50	3.58	1.14	2.93	1.68	3.65	2.05	2.60	0.03

* *N. D. = Not detected.*

Table 2: Mean levels, Ranges, Coefficient of variation and Degree of Accumulation of Metals in Plant Samples.

METAL	SAMPLES	MEAN CONCENTRATION (Ug/g)	RANGE OF CONCENTRATION (Ug/g)	COEFFICIENT OF VARIATION	DEGREE OF ACCUMULATION
Zn	PSPW	2.26	1.53 – 2.56	15.99	1.10
	PBGS	2.05	1.88 – 2.21	4.55	–
Pb	PSPW	0.34	N. D. – 0.75	69.72	0.34
	PBGS	0.86	0.50 – 1.25	30.62	–
Cd	PSPW	0.03	N. D. – 0.06	66.70	0.00
	PBGS	N. D.	–	0.00	–
Cu	PSPW	0.82	0.50 – 1.10	24.38	0.80
	PBGS	1.02	0.75 – 1.25	14.75	–
Cr	PSPW	3.16	1.15 – 6.00	49.26	2.98
	PBGS	1.06	N. D. – 2.10	77.48	–

* *N. D. = Not Detected.*

of accumulation of the metals in plant samples in relation to their background levels.

The mean values of Zn and Cr were high compared with those of Cu, Pb and Cd with Cd having the least concentration (0.03,μgg^{-1}) for PSPW samples. For PBGS samples, the mean levels of these metals were relatively high. However, Cu and Pb levels were higher than PSPW samples (Fig. I).

The trend observed in metal levels in PSPW samples was Cr > Zn > Cu > Pb > Cd while for PBGS samples the trend was Zn > Cr > Cu > Pb > Cd (Fig. 2). The metal levels in plants from these two sites were comparatively lower than the metal levels in the corresponding soils (Udosen et al, 1990).

Pb had the highest coefficient of variation (C.V. = 69.72%) followed by Cd (C.V. = 66.72%) in PSPW. There was no evidence of the existence of Cd in PBGS Samples while Cr had the highest coefficient of variation of 77.48% followed by Pb with a coefficient of variations of 30.62% in PBGS samples (Fig. 3). On the whole Zn had the least coefficient of variation of 15.99% in PSPW samples while Cd did not vary at all in PBGS samples (C.V. = 0.00%) (Table 2).

The results indicate that Pb and Cd were less stable in PSPW samples while Zn and Cu were relatively more stable in the same samples.

Chromium exhibited an average variability. For PBGS samples, Cr exhibited the highest variability (C.V. = 77.48%) while Cd exhibited the least variability (C.V. = 0.00%).

The results further reveal that while Zn was comparatively less stable in PSPW samples than in PBGS samples, Cr was slightly stable in PBGS samples while PSPW samples exhibited high variability with C.V. = 66.72% and could be said to be unstable.

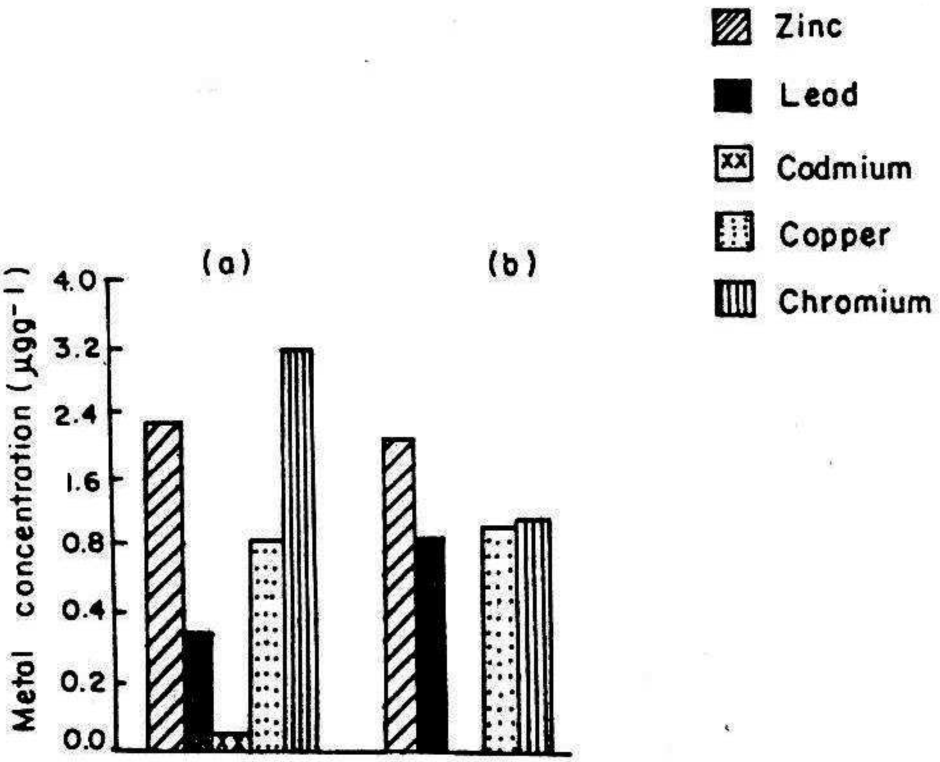

Fig. 1: Mean metal concentration in plants from (a) Soils receiving paints wastes and (b) Background soils off paints industry environment.

The computation of the degrees of accumulation of the five metals in PSPW samples in relation to their baseline values were: Zn (1.10), Pb (0.34), Cd (0.00), Cu (0.80) and Cr (2.98) respectively (Table 2).

These results show that the metals except Cd were accumulated to a reasonable extent in PSPW samples.

By comparing the results of analyses of PSPW samples with those of PBGS samples (Table 2), the following trend in metal levels emerged: Zn (PSPW > PBGS), Pb (PBGS > PSPW), Cd (PSPW > PBGS), Cu (PBGS > PSPW) and Cr (PSPW > PBGS). These show that Zn, Cd and Cr were higher in PSPW samples than in PBGS samples (Fig.2).

DISCUSSION

ZINC:

The mean level of Zn in PSPW samples (2.26μgg^{-1}) was almost the same as that of Zn in PBGS sample (2.05μgg^{-1}). Therefore based on the mean levels, it does not seem that Zn was highly absorbed by the plants. Moreover PBGS samples had a coefficient of variation of 4.55% of Zn as against those of PSPW sample (C.V. = 15.99%). Zn found in the samples may have been present in paint pigments such as $ZnCrO_4$, ZnS or ZnO in addition to natural occurrence and since soil is the ultimate sink for some metals including Zn, the retention of this metal in the soil and its subsequent uptake by plant may likely have long term pollution consequence. Although the natural levels for Zn is 1 - 300 ppm (Levinson, 1974) efforts should be intensified towards reducing the amount of Zn introduced into this environment since Zn is not a completely non toxic metal

LEAD:

PSPW samples had the least concentration of lead (0.34 μgg^{-1}). The variation in Pb

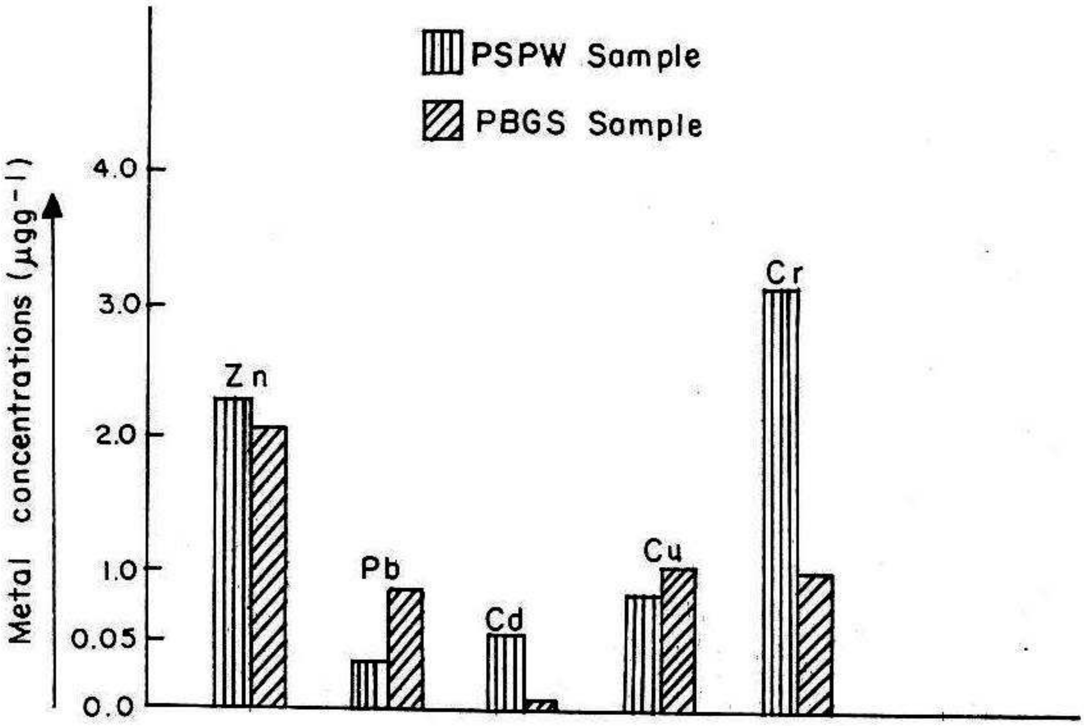

Fig. 2: Comparison of mean metal levels in plants from paint industry environment.

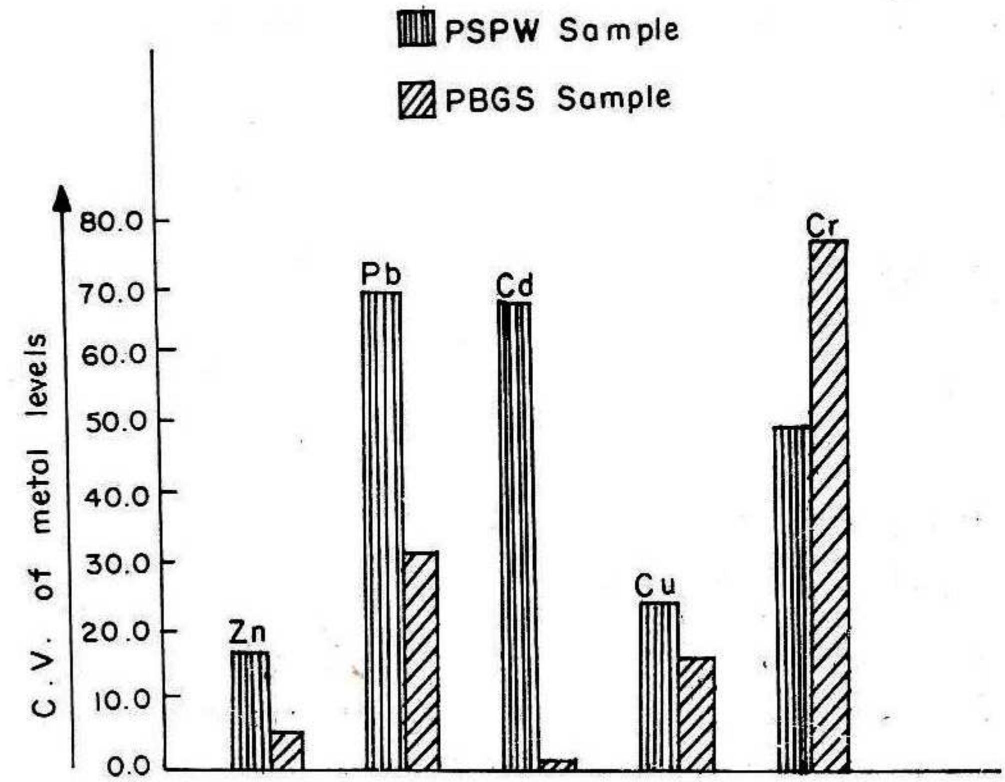

Fig. 3: The coefficients of variation of metal levels in plant samples from paint industry environment.

concentrations was also much higher in these samples than in PBGS samples (Table 2). This may have been due to lead present in pigments like $PbCrO_4$, $2PbCrO_3.Pb(OH)_2$ or $PbCrO_4.Pb(OH)_2$ as well as from aerial deposition.

Naturally there is hardly any environmental sample without lead. The high levels of Pb in PBGS compared to those in PSPW appear incomprehensible considering the fact that plant samples from soils receiving paint wastes (PSPW) contained a lot of metal ion (Udosen *et al*, 1990). However, it is now confirmed from studies that toxicants contained in any wastes can move up into any plant from the soil depending on factors such as solubility of the toxicant, pH of the soil, genetic tolerance, stage of growth of the plant and age and kind of tissue as well as exposure of the plant (Warren and Delavault, 1974; Beavington, 1975).

Lead is known to accumulate on plants growing alongside highways in proportion to the traffic density (Smith, 1976). Therefore since the background site was quite close to a highway it is not unlikely that lead-laden wastes may have been dumped there years back and the soil later reclaimed by the inhabitants for cultivation. On the other hand since lead is not easily absorbed by plants (Treshow, 1978), the high lead levels in PBGS samples must have resulted from aerial deposition on the leaves of the plant from vehicular emissions since the background site was quite close to a highway.

Although the concentrations of lead in PSPW and PBGS samples are lower than the natural level of 2 - 200 ppm in soil (Bohn *et al*, 1979), it is advisable to guard against indiscriminate discharge of Pb - laden wastes into any environment since lead is easily attracted to biological tissues once absorbed and as an accumulative toxin is capable of deadening nerve receptors in man (Bodansky and Latner, 1987).

CADMIUM:

Cadmium was not detected in PBGS samples and the natural level in soil is 0.01 - 7.0 ppm (Bohn *et al* 1979). Although the level of Cd in PSPW samples was very low, the degree of variation was quite high (66.72%). Unlike most of the other heavy metals, Cd can be taken up by many plants (Voogt *et al* 1980), because at low pH and high temperature it exists in its stable form Cd^{2+}.Cd^{2+} is a relatively soluble heavy metal ion that behaves some what like Ca^{2+}. It is readily available to plants and retention is relatively independent of pH hence its capability to accumulate in food claims.

Here lies the danger of indiscriminate discharge of Cd laden wastes into the environment. Moreover, Cd uptake is irreversible and its excretion occurs very slowly (Udosen, 1991). Above all, although Cd is very hazardous and not essential for plants, animals and human beings it often enters into many biochemical processes through the application of certain phosphate fertilizers (William & David, Korte, 1983; 1973). Once Cd has entered a system, it is capable of remaining there and at certain concentrations it causes damage to human and other living organisms especially when present as $CdC1^{+}$ or $CdC1_2$ in aqueous medium (Bryan, 1984).

Some of the effects of Cd in human beings are pulmonary disease, reduced glucose tolerance, severe kidney and liver damage and death (Voogt et al, 1980). Other effects are associated with proteinuria, glucosuria, amino acid-uria, bronchitis, pneumonitis, hypertension, anaemia and emphysema (W.H.O., 1984). These effects often increase with increased Cd concentration (Young and Blevins, 1981; W.H.O., 1984).

COPPER:

The levels of Cu in PBGS samples (1.02 μgg^{-1}) was higher than that for PsPw samples (0.80μgg^{-1}) probably due to the type of soil on which the plant was grown, geographical location, species of plant, state of maturity of the plant tissue, application of fertilizers on the soil, disposal of paints and painted materials years back as well as the presence of copper metals in different forms. On the whole the levels of Cu in these two sites were lower than the natural range of 2 - 100ppm (Bohn et al, 1979). The level of Cu in PSPW samples may have been due to the presence of pigment such as $Cu(C_8H_4N_2)_4$ only. The comparatively low level of Cu in PSPW not withstanding the discharge of waste containing Cu should be discouraged since Cu and its compounds are naturally ubiquitous in the environment and although essential to human survival could lead to severe mucosal irritation, nausea, vomiting, diarrhoea, intestinal cramps, severe gastrointestinal irritation, widespread capillary damage, hepatic and renal damage as well as irritation of nervous system, depression, necrotic changes in liver and kidney when it is present in excess (W.H.O., 1984). Moreover, Cu is very toxic to most plants, highly toxic to invertebrates and moderately toxic to mammals (Hellawell, 1988).

CHROMIUM:

The high level of Cr in PSPW ($3.16\mu gg^{-1}$) (Table I) may have been from natural occurrence as well as from the factory wastes containing pigments such as $PbCrO_4$, $PbCrO_3.Pb(OH)_2$, $PbCrO_4.Pb(OH)_2$, $Cr_2O(OH)_4$ or Cr_2O_3. PBGS had the highest coefficient of variation (77.48%) compared with that in PSPW (49.26%) (Table I). This may have been due to constant addition of Cr from the wastes to the environment.

When compared with natural levels of 5 - 1000ppm in soils (Bohn *et al*, 1979), the environment appeared not to have been polluted by Cr. This notwithstanding Cr should not be excessively added to the environment in order to avoid health effects such as liver necrosis, nephritis, irritation of gastrointestinal mucosa, digestive tract cancer, lung cancer and death often associated with the consumption of large quantity of this metal (W.H.O., 1984).

CONCLUSION

The following conclusions could be drawn from the research:

(i) Pollutants present in any soil may or may not move into the plant depending on their solubility in the soil and their absorption by the roots.

(ii) The low levels of Pb and Cu in plants grown on soils receiving paint waste (PSPW) compared to the levels in plant grown on background soils (PBGS) may be used to suggest that pigments used in making paints by this industry may have contained little or no lead and copper metals. Contrarily, the industry may have used pigments containing Zn, Cd and Cr metals as evidenced by their high levels in PSPW samples compared to PBGS samples.

(iii) The above trend confirms the findings by Treshow (1978) that lead is not absorbed by plants and that absorption of other heavy metals is normally governed by factors such as type of soil, pH, temperature, species of plants, age of plants and genetic factors.

RECOMMENDATION:

In order to prevent our environment from being unduly polluted by wastes from industries, all factory wastes including those of paint should be well treated by dewatering the wastes at the respective sites and using the resulting cakes for land filling. Moreover since paint waste is a complex heterogenous material comprising of organics and inorganics it could be converted in to usable energy (Crude oil and coal) using processes such as anaerobic digestion, incineration, gasification and pyrolysis.

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