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TRACE METAL LEVELS IN ARTHROPTERIS ORIENTALIS FROM BATTERY INDUSTRY ENVIRONMENT

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ABSTRACT

The levels of five trace metals (Pb, Sb, Cd, Cu and Co) in the aquatic plant, Arthropteris orientalis from four sites (BDP, ADP, QIR[1] and QIR[2]) within a Battery Industry environment and UPS site (regarded as the background) were determined using a Pye Unicam Absorption Spectrophotometer Model SP-9 with an air acetylene burner equipped with an automatic readout facility. The ranges in mean metal concentrations in the plant samples during wet and dry seasons were 0.94μgg^{-1} - 60.04 μgg^{-1} and 1.05 μgg^{-1} - 67.35 μgg^{-1} respectively. The coefficients of variation for the metals during wet season ranged between 5.34 % and 46.55% while the range during dry season was 5.33% to 42.47%. When resolved into two based on their concentrations, Pb and Sb had very high concentrations at ADP and QIR[1] (impacted sites) relative to UPS (background site). Results obtained when compared with background values revealed that all the elements were present in plants from sites downstream of discharge point at concentrations high enough to produce long and short term effects always associated with their presence in any environment.

KEY WORDS: Trace metals, Aquatic environment, Battery Industry.

INTRODUCTION

The quest for industrialization by the various state governments in Nigeria has led to the indiscriminate siting of industries without consideration to the environmental consequences of such industries on plant and animal population. A case in point is the siting of a battery industry in Essien Udim Local Government Area of Akwa Ibom State, Nigeria quite close to Atan stream, a tributary of Qua Iboe River (Fig. 1). This stream serves as a major source of water supply for domestic and other purposes apart from being a fishing ground for the inhabitants of the area.

When industries discharge their wastes into any aquatic and/or terrestrial environment, the wastes are transformed depending on the nature of the receiving environment and the prevailing conditions. For instance speciation of metals may occur in a reducing environment resulting in their easy absorption by plants. However, the concentration of these metals especially in vegetables and fruits depend largely on factors such as inherent qualities of the plants, trace element content of the sediment and soil, geographical location as well as the use of fertilizers and fungicides (Rao, 1980).

Since the biotic and abiotic components of any ecosystem are so delicately balanced, it is natural that the most subtle change in the biotic component would adversely affect the abiotic component(Richter et al; 1984). Trace metals added to sediments including their mobility and reactions in the sediments and the subsequent uptake and distribution in plants is therefore of critical importance in relation to man's health. Where there is pollution consciousness, efforts are often made to reduce the quantity of pollutants to permissible limits before being discharged into any natural water body such as river or stream. When the equilibrium of an ecosystem is disturbed due to the discharge of untreated waste water into it, intoxication and sometimes death of a particular species of hydrobionts result leading to a chain reaction which could depress the whole biocenosis.

By comparing the levels of these metals in plants from the industrial environment with those from a background site and results of similar work by other researchers, it was possible to deduce the effects of not only locating an industry close to a natural water course, but of continuously discharging its waste into it.

THE STUDY AREA

The Battery Industry is located at Ukana in Essien Udim Local Government Area. The liquid effluent from this industry is discharged into Atan stream, a tributary of Qua Iboe River. Atan stream is downstream of Nkap stream which takes its rise from a hill in Ikot Ekpene Local Government Area (Fig.1).

Essien Udim and Ikot Ekpene Local Government Areas, both in Akwa Ibom State are located in a typical tropical humid climate characterised by distinct wet and dry seasons. The wet season sometimes begins in March or April and is always characterised by heavy storms of short duration. The effects usually include among others, erosion

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hazards on uncovered steeply sloping lands. In the study area, heavy rainfall usually occur between June and September and sometimes spill over to October. During this period, tremendous runoff from the thinly vegetated slopes often carry with it a lot of waste including trace metals into water bodies which becomes polluted by them. The average annual rainfall in the two local government areas considered is between 2,000 and 3,000mm (Okoji, 1988). Qua Iboe River is a major river which flows through over 60% of Akwa Ibom State including Essien Udim and Ikot Ekpene. This river is therefore a major source of domestic and industrial water supply for the people.

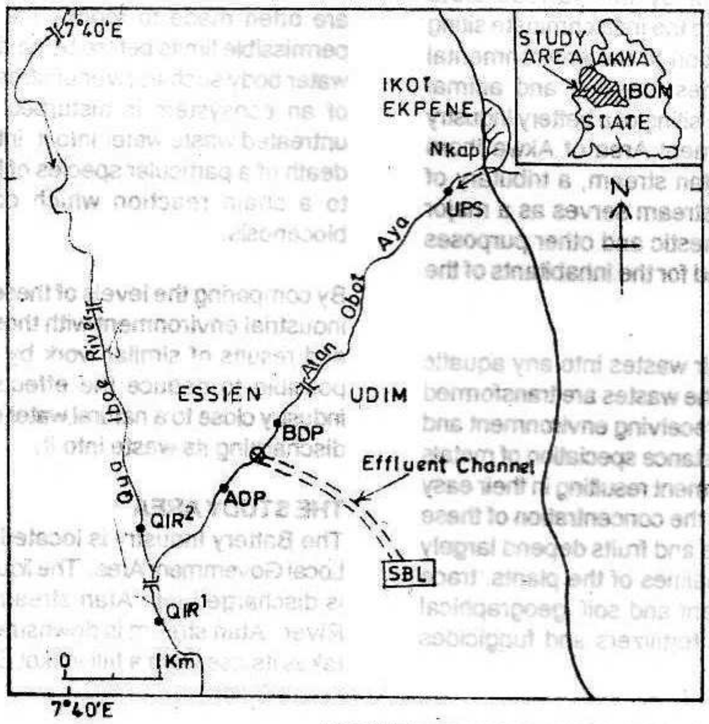
MATERIALS AND METHOD

The samples were collected at five sites viz Upstream (UPS), before effluent discharge point (BDP), after effluent discharge point (ADP), Qua Iboe River downstream (QIR[1])and Qua Iboe River Upstream QIR[2] from three stations (Nkap stream, Atan stream and Qua Iboe River (Fig. 1). Sampling was carried out at the interval of 500 metres between sites except between BDP and UPS which was 2000 metres apart. UPS is in Nkap stream and was chosen to provide the needed background information.

Since many economic plants of significance were not found at these sites during the period of investigation, a typical fresh water fern (Arthropteris orientalis) of the family Davalliaceae was sampled not only because of its prevalence and even distribution at all sites investigated but also because of its nutritive value.

Five samples were collected from each of the five sites once a month by cutting the plants withsharp, stainless steel knife. The samples were then put into brown calico bags and taken to the laboratory for treatment and analysis. Altogether, 50 plants made up of 10 plants per site were collected for ten months between July to December 1989 and January to April 1990.

The plant leaves (5.0g) were oven-dried at 105°C and ashed at 450°C. This was cooled and the ash dissolved with 2MHCl in a ratio of 1:5 w/v ash to acid and evaporated to dryness. The residue was redissolved with 25% HCL ($20cm^3$), transferred quantitatively and made up to 100 cm^3 with deionised water in a standard volumetric flask. The solution was then analysed for the five metals using a Pye Unicam Atomic Absorption Spectrophotometer Model SP-9 with an air-acetylene burner equipped with an automatic readout facility. Procedural blanks were also run for the metals determined. The detection limits in parts per million (ppm) were Pb (0.10), Sb (0.20), Cd (0.02), Cu (0.04) and Co (0.05). Recoveries of over 99% were obtained, thus confirming the repeatability and precision of the method employed.



LEGEND

⊗ Effuent discharge point
⟶ Direction of stream flow
• Sampling points
UPS= Upstream regarded as background site
BDP= Before Effluent Discharge point
ADP= After Effluent Discharge point
QIR[2]= Qua Iboe River upstream of QIR[1]
QIR[1]= Qua Iboe River downstream of discharge
SBL= Sunshine Batteries, Ltd.

Fig. 1: Qua Iboe River and Atan Obot Aya showing the sampling sites, location of the Sunshine Battery Factory and insert of Akwa Ibom State indicating the study area.

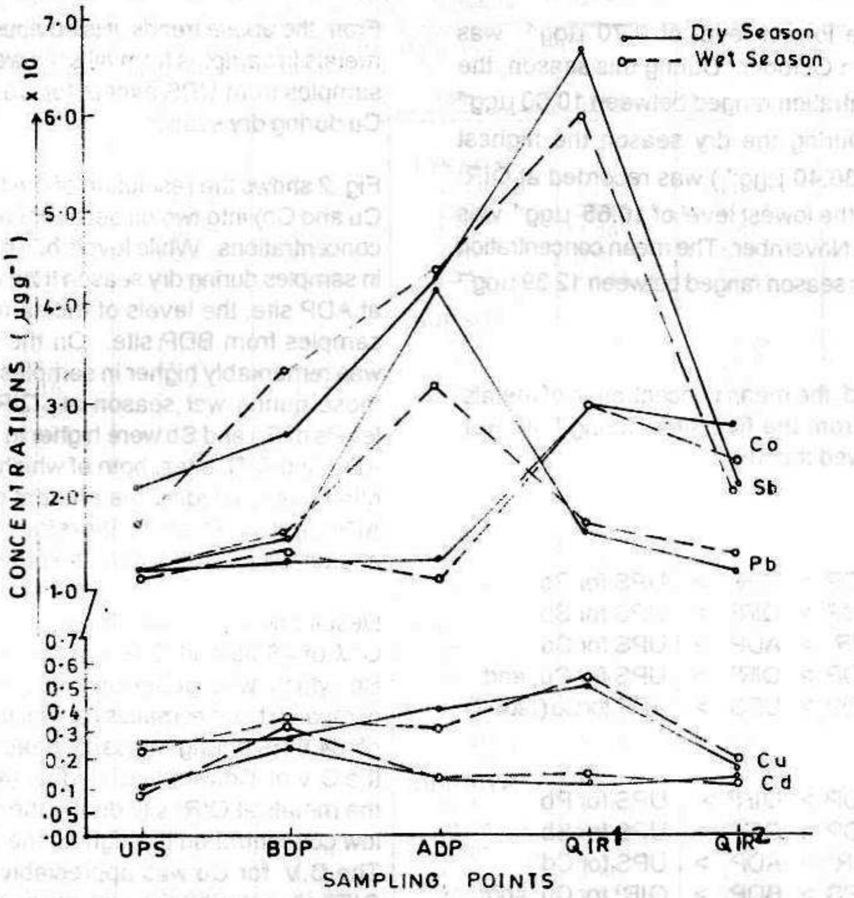


Fig. 2: Temporal seasonal variations (µgg⁻¹) of Co, Sb, Pb, Cu and Cd in Arthropteris orientalis in battery industry environment.

RESULTS AND DISCUSSION

The monthly concentrations of trace metals in the plant Arthropteris orientalis from four sites (BDP, ADP, QIR[1] and QIR[2]) within a Battery Industry environment and a background sites (UPS) as well as the mean levels and coefficients of variation in wet and dry seasons are given in Tables 1 and 2 respectively. A summary of the mean seasonal levels of these metals on site basis is given in Table 3 while a comparison of the mean concentrations in the samples between site pairs using student's t-test is given in Table 4.

During wet season the highest Pb level of 37.40 μgg^{-1} was recorded at ADP in October while the least level of 9.20 μgg^{-1} was recorded at QIR[2] in October. The mean monthly concentration of Pb during this season ranged between 11.40 μgg^{-1} and 32.39 μgg^{-1} : The highest Pb level of 53.34 μgg^{-1} during the dry season was recorded in February at ADP site while the lowest level of 10.00 μgg^{-1} was recorded in November at QIR[2] site during the same season. The mean monthly level ranged between 11.52 μgg^{-1} and 42.32 μgg^{-1} during this season. For Sb, the highest concentration of 73.80 μgg^{-1} was recorded at QIR[1] site in September during wet season while the lowest level of 14.20 μgg^{-1} was recorded at QIR[2] site in October. During the season the mean monthly concentration ranged between 17.17 μgg^{-1} and 60.04 μgg^{-1} . On the otherhand, the highest level of 80.00 μgg^{-1} was recorded at QIR[1] site in February during the dry season while the lowest level of 1.05 μgg^{-1} was recorded at UPS in November. The mean monthly concentration of Sb in dry season ranged between 20.94 μgg^{-1} and 67.35 μgg^{-1} . The highest Cd level of 4.72 μgg^{-1} was recorded at BPD in July during the wet season while the lowest level of 0.70 μgg^{-1} was recorded at QIR[2] site in October. The mean monthly concentration of Cd during wet season ranged between 0.94 μgg^{-1} and 3.19 μgg^{-1} . During the dry season the highest Cd level of 4.70 μgg^{-1} was recorded at BDP site in March and the lowest concentration of 0.80 μgg^{-1} recorded at QIR[2] in February and November (Table 2). The mean monthly level of Cd during dry season ranged between 1.05 μgg^{-1} and 2.99 μgg^{-1} . The highest Cu level of 6.05 μgg^{-1} was recorded at QIR[1] site in October during the wet season while the lowest concentration of 1.00 μgg^{-1} was recorded at QIR[2] site in the same month. The mean monthly concentration during the season ranged between 2.22 μgg^{-1} and 5.69 μgg^{-1} . During the dry season, the highest Cu level of 5.60 μgg^{-1} was recorded at QIR[1] site in February while the lowest level of 1.00 μgg^{-1} was recorded at QIR[2] site in January. The mean monthly level ranged between 1.46 μgg^{-1} and 5.05 μgg^{-1} . The highest Co level of 36.50 μgg^{-1} was recorded at QIR[1] site in September during the

wet season while the lowest level of 9.70 μgg^{-1} was recordedat ADP site in October. During this season, the mean monthly concentration ranged between 10.80 μgg^{-1} and 30.62 μgg^{-1}. During the dry season the highest monthly level of Co (36.40 μgg^{-1}) was recorded at QIR[1] site in February while the lowest level of 10.65 μgg^{-1} was recorded at ADP site in November. The mean concentration of this metal during this season ranged between 12.39 μgg^{-1} and 30.42 μgg^{-1}.

In the plant investigated, the mean concentration of metals in samples collected from the five sites during both wet and dry seasons followed the trend:

WET SEASON:

ADP > QIR[1] > BDP > QIR[2] > UPS for Pb
QIR[1] > ADP > BDP > QIR[2] > UPS for Sb
BDP > QIR[2] > QIR[1] > ADP > UPS for Cd
QIR[1] > BDP > ADP > QIR[2] > UPS for Cu, and
QIR[1] > QIR[2] > BDP > UPS > ADP for Co (Table 1)

DRY SEASON:

ADP > QIR[1] > BDP > QIR[2] > UPS for Pb
QIR[1] > ADP > BDP > QIR[2] > UPS for Sb
BDP > QIR[2] > QIR[1] > ADP > UPS for Cd
QIR[1] > ADP > UPS > BDP > QIR[2] for Cu, and
QIR[1] > QIR[2] > BDP > ADP > UPS for Co (Table 2).

From the above trends, it is obvious that the levels of these metals in samples from all sites were higher than levels in samples from UPS except for Co during wet season and Cu during dry season.

Fig. 2 shows the resolution of the five metals (Pb, Sb, Cd, Cu and Co) into two on seasonal basis depending on their concentrations. While levels of Pb, Cu and Co were higher in samples during dry season than those during wet season at ADP site, the levels of the same metals were lower in samples from BDP site. On the otherhand, level of Sb was remarkably higher in samples during dry season than those during wet season at QIR[1] site. On the whole, levels of Pb and Sb were higher in samples collected from ADP and QIR[1] sites, both of which are downstream of the other sites including the effluent discharge point (Fig.1). ADP and QIR[1] could therefore be considered as the impacted sites relative to the other sites.

Despite its low levels (Table 1), Cd had a relatively high C.V. of 46.55% at QIR[1] site during the wet season while Sb which was generally high throughout the season compared to other metals had uncorrespondingly lower C.V. of 34.64% during the same season (Table 1). Similarly the C.V of Cd was much higher (41.86%) than the rest of the metals at QIR[2] site during the dry season inspite of its low concentration throughout the period of investigation. The C.V. for Cu was appreciably high only at ADP and QIR[2] sites during the wet season while it was generally low during the dry season (Table 2). This corresponded to

Table 1. Monthly concentrations of metals in Arthropteris orientalis during wet Season

	SAMPLING PERIODS/SAMPLES AND CONCENTRATIONS μg/g								
S/N	METAL	APR.	JUL	AUG.	SEP.	OCT	$\overline{X}$	SX	C.V.(%)
					UPS SITE				
1.	Pb	10.10	13.00	11.20	10.50	12.20	11.40	1.20	10.53
2.	Sb	18.18	15.25	20.11	16.30	16.00	17.17	1.97	11.47
3.	Cd	0.83	0.9	0.96	1.03	1.00	0.94	0.08	8.51
4.	Cu	3.60	1.50	1.52	1.70	2.80	2.22	0.94	42.34
5.	Co	11.95	10.45	10.00	11.50	12.30	11.24	0.98	8.72
					BDP SITE				
1.	Pb	17.55	17.78	16.00	17.00	14.00	16.47	1.54	9.35
2.	Sb	38.10	40.00	38.00	25.90	30.00	34.40	6.12	17.79
3.	Cd	3.80	4.72	1.85	2.10	3.50	3.19	1.20	37.62
4.	Cu	2.70	4.00	4.10	3.60	4.05	3.69	0.59	15.99
5,	Co	13.25	14.60	13.80	14.00	12.70	13.64	0.73	5.34
					ADP SITE				
1.	Pb	35.25	31.20	30.60	28.10	37.40	32.39	3.83	11.82
2.	Sb	37.10	46.50	60.00	36.20	41.25	44.21	9.70	21.99
3.	Cd	1.30	0.95	1.00	1.00	0.80	1.01	1.18	17.82
4.	Cu	4.50	2.50	2.00	4.25	2.80	3.21	1.10	34.26
5.	Co	14.15	10.35	10.10	10.00	9.70	10.86	1.85	17.03
					QIR[1] SITE				
1.	Pb	16.50	17.00	17.50	14.95	17.78	16.75	1.12	6.69
2.	Sb	58.75	50.65	50.40	73.80	66.60	60.04	10.19	16.97
3.	Cd	0.98	2.00	1.80	1.30	1.20	1.46	1.46	16.97
4.	Cu	5.50	6.00	5.70	5.20	6.05	5.69	0.35	6.15
5.	Co	32.75	31.25	25.00	36.50	27.60	30.62	4.48	14.63
					QIR[2] SITE				
1.	Pb	12.50	15.30	16.50	14.55	9.20	13.61	2.86	21.01
2.	Sb	15.80	31.00	25.10	17.10	14.64	20.64	7.15	34.64
3.	Cd	0.75	2.00	0.95	1.40	0.70	1.16	0.54	46.55
4.	Cu	2.10	3.50	2.00	3.00	1.00	2.32	0.97	41.81
5.	Co	25.35	21.10	30.60	20.00	23.80	24.17	4.17	17.25

Table 2. Monthly concentrations of metals in Arthropteris orientalis During Dry Season

	SAMPLING PERIODS/SAMPLES AND CONCENTRATIONS µg/g								
S/N	METAL	NOV.	DEC.	JAN	FEB	MAR.	$\bar{X}$	SX	C.V.%
					UPS SITE				
1.	Pb	10.25	10.80	13.00	13.20	10.35	11.52	1.46	12.67
2.	Sb	15.05	18.50	20.80	25.20	25.15	20.94	4.37	20.87
3.	Cd	1.05	0.91	1.00	1.00	1.20	1.05	0.11	10.48
4.	Cu	1.88	2.20	2.10	3.80	3.00	2.60	0.80	30.77
5.	Co	11.60	12.00	12.50	12.50	13.35	12.39	0.66	5.33
					BDP SITE				
1.	Pb	15.30	15.00	16.50	16.30	15.20	15.28	1.28	8.38
2.	Sb	28.25	35.35	17.00	17.50	35.50	26.72	9.13	34.17
3.	Cd	2.10	2.15	4.00	2.00	4.70	2.99	1.27	42.47
4.	Cu	2.50	2.15	3.50	2.00	1.90	2.14	0.65	26.97
5.	Co	14.35	13.00	12.50	11.00	15.00	13.17	1.58	12.00
					ADP SITE				
1.	Pb	27.60	40.00	40.30	53.34	50.35	42.32	10.15	23.98
2.	Sb	38.90	35.05	50.35	50.84	40.80	43.19	7.07	16.37
3.	Cd	0.88	1.10	1.20	1.18	1.05	1.08	0.13	12.04
4.	Cu	3.50	5.00	4.10	4.50	3.55	4.13	0.64	15.50
5.	Co	10.65	13.00	13.90	14.60	12.00	12.83	1.56	12.16
					QIR[1] SITE				
1.	Pb	15.50	16.00	14.82	17.78	17.80	16.38	1.35	8.24
2.	Sb	60.00	70.35	55.10	80.00	71.30	67.35	9.86	12.64
3.	Cd	0.88	1.15	1.00	1.20	1.50	1.15	0.23	20.00
4.	Cu	4.90	4.41	5.35	5.60	5.00	5.05	0.45	8.91
5.	Co	28.35	30.45	26.90	36.40	30.00	30.42	3.63	11.93
					QIR[2] SITE				
1.	Pb	10.00	10.50	11.20	13.50	13.00	11.64	1.54	13.23
2	Sb	30.40	22.00	15.50	25.50	18.20	22.32	5.89	26.39
3.	Cd	0.80	2.10	1.50	0.80	1.25	1.29	0.54	41.86
4.	Cu	2.00	1.20	1.00	1.50	1.60	1.46	0.38	26.03
5.	Co	35.50	27.50	31.00	20.50	22.70	27.44	6.09	22.19

the general low trend of the metal during dry season. On the whole, the mean C.Vs. for all the metals considered during wet season ranged between 5.34% and 46.55% while the range during dry season was between 5.33% and 42.47%. Peak mean levels of Sb, Co and Cu collected during both seasons occurred at QIR[1] site (below confluence) while that of Pb occurred at ADP site and Cd at BDP site (Fig. 2). Site pair comparisons of mean metal concentrations in Arthropteris orientalis (Table 4), indicate that mean levels of Pb and Sb at UPS site were significantly lower than their levels at the other three sites.

The concentrations Pb in plants from all sites (except BDP) were higher in dry season than in wet season while concentrations of Sb in plants collected from all the sites (except ADP and QIR[2]) were lower in dry season than in wet season (Tables 1 and 2). Similarly the concentrations of Cd in samples collected from all sites (except UPS and BDP) were lower in dry season than in wet season while the concentrations of Cu at all sites (except BDP and QIR[1]) were higher in samples collected during dry season than during wet season. Co recorded higher concentrations in UPS, ADP and QIR[1] sites during the wet season compared to levels of these metals in samples from the same sites during dry season. According to Udosen (1994), levels of metals in one stratum such as soil or sediment could influence the levels of the same metals in other strata as well as the biological species such as plants found within these strata depending on the environmental factors. Moreover, all elements including the essential ones are toxic at high concentrations and their toxicities often depend on the chemical nature of the species containing the element concerned (Bowen, 1979).

A comparison of the mean metal concentrations in the plants between site pairs using student's t-test (Table 4) gave the following trend: BDP>UPS ($P<0.001$); ADP > UPS ($P<0.001$); QIR[1]>UPS ($P<0.001$) and QIR[2] = UPS ($P>0.05$) for each of Pb and Sb. Pb and Sb levels were higher in plants from all sites (except QIR[2]) than UPS which is upstream of BDP and ADP. UPS was not directly affected by the discharged industrial effluent and was therefore chosen to serve as the background site. Similarly QIR[2] which is upstream of QIR[1] site was not directly affected by this effluent. Cd levels between site pairs using student's t-test gave the following trend: BDP>UPS ($P<0.001$); ADP = UPS ($P>0.05$); QIR[1]>UPS ($P<0.05$) and QIR[2] = UPS ($P>0.05$).

The trend for Cu levels in the plants between site pairs using student's t-test was BDP = UPS ($P>0.05$); ADP > UPS ($P<0.01$); QIR[1]>UPS ($P<0.001$) and QIR[2] = UPS ($P>0.05$). A comparison of mean cobalt levels in the plants between site pairs (Table 4) showed that BDP>UPS ($P<0.01$); ADP = UPS ($P>0.05$); QIR[1]>UPS ($P<0.05$) and QIR[2] > UPS ($P<0.001$).

Stream sediments are gigantic traps and sinks for trace metals. Generally, the degree of contamination of an aquatic plant depends to a large extent on the degree of contamination of the dediment on which the plant grows and on the sources of the contaminants. For example, a

Table 3: Mean metal levels (µgg) in Arthropteris orientalis on Site Basis From Battery Industry Environment during Wet and Dry Seasons

			SITE/ CONCENTRATION				
S/N	METALS	SEASON	UPS	BDP	ADP	QIR¹	QIR²
1.	LEAD (Pb)	WET	11.40	16.46	32.39	16.75	13.61
		DRY	11.52	15.28	42.32	16.38	11.64
2.	ANTIMONY (Sb)	WET	17.17	34.40	44.21	60.04	20.64
		DRY	20.94	26.72	43.19	67.35	22.32
3.	CADMIUM (Cd)	WET	0.94	3.19	1.01	1.46	1.16
		DRY	1.05	2.99	1.08	1.15	1.29
4.	COPPER (Cu)	WET	2.22	3.69	3.21	5.69	2.32
		DRY	2.60	2.41	4.13	5.05	1.46
5.	COBALT (Co)	WET	11.24	13.67	10.86	30.62	24.17
		DRY	12.39	13.17	12.83	30.42	27.44

UPS = Upstream (regarded as background)
BDP = Before Effluent Discharge Point
ADP = After Effluent Discharge Point
QIR¹ = Qua Iboe River down stream of discharge point
QIR² = Qua Iboe River upstream of QIR¹

level as high as 2370µgg⁻¹ of Pb was recorded by Warren (1981) in a river passing through a mineralized catchment area against a background value of 160µgg⁻¹ of Pb in an unmineralized tributary. Olade et al (1979) also recorded levels of between 10.00 ppm and 999.00 ppm of Pb in the Zn - belt of Benue trough in Nigeria. It has been confirmed from studies that toxicants including trace metals could move up into any plant depending on factors such as solubility of the toxicants, pH of the medium, genetic tolerance, stage of growth of the plant, age and kind of tissue as well as exposure of the plant to the toxicants (Beavington, 1975).

The high Pb and Sb levels in the plants from ADP and QIR¹ sites throughout the period of investigation compared to values obtained in plants from the other sites reveal that these metals were considerably present in the discharge industrial effluent. Similarly, the very high mean level of Co in QIR¹ samples throughout the period of study could be attributed to the contribution of this metal by the industrial battery effluent and runoff through the neighbouring agricultural farms while that at QIR² may have been contributed by the runoff through Essien Udim Local Government Headquarters and the neighbouring farmlands. The mean seasonal concentrations of all the metals (except Co at ADP site during wet season) throughout the period were significantly higher at ADP and QIR¹ sites. Since ADP and QIR¹ are sites downstream of the effluent discharge point, the high levels must have been due to contribution by the industrial effluent which contained a lot of metal ions principally those of Pb and Sb. That the mean levelsof Pb and Sb were higher in plants from both the ADP and QIR¹ sites than BDP and UPS sites could be explained by the fact that ADP and QIR¹ being sites downstream of the other two sites and the discharge point (Fig. 1) must have received discharges and runoff from both the battery industry and surrounding environments. The levels of Sb and QIR¹ samples were higher than those in ADP samples because of additional contributions made by QIR² site (Fig. 1) which receives runoff from Essien Udim Local government Headquarters. Although mean concentration of Pb was not significantly different between UPS and BDP sites, they were remarkably different between UPS and ADP sites, an indication of pollution by external sources. The same trend was observed for Sb between UPS and ADP sites. These remarkable differences in levels of Pb and Sb in plants downstream of effluent discharge point presupposes contribution of these metals to ADP site by the industrial effluent since Pb and Sb levels could be traced to the use of antimonial lead and pure lead in the manufacturing of battery. For instance, while antimonial lead is used in making grids of various specifications and small parts such as terminals and connectors, pure lead is used in making Pb0 power paste needed for plate formation.

Although Pb is generally accepted as being unappreciably absorbed by roots of plants owing to its low solubility potential in water (Udosen 1994), yet high levels of this metal in the plants suggests possible absorption of this metal from the sediments on which the plants grew. Moreover, the presence of about 0.1 ppm reduces heterotrophic activity in microflora which may in turn enhance bioaccumulation of Pb in plants. Consumption of such plants could therefore lead to brain damage, convulsion, behavioural disorders and death since Pb is a neurotoxin (Yen, 1975; Goldsmith & Hildyard, 1988). Although there has not been any authentic record of the effects of Sb on plant, investigation on the effect of this metal on animal showed that the lifespan of rats and mice were shortened when they were fed with Sb - contaminated feeds Oxides of Sb have also been shown to cause

Table 4. Comparison of mean metal concentrations between site pairs in Arthropteris orientalis from Battery Industry Environment using students' t-test.

METALS	SITE PAIR	LEVEL OF SIGNIFICANCE	DIFFERENCE BETWEEN SITES
Lead (Pb)	UPS and BPD	$p < 0.001$	BPD > UPS
	" " APD	$p < 0.001$	APD > UPS
	" " QIR[1]	$p < 0.001$	QIR[1] > UPS.
	" " QIR[2]	$p > 0.05$ *	QIR[2] = UPS
Antimony (Sb)	UPS and UPS	$p < 0.001$	BPD > UPS
	" " APD	$p < 0.001$	APD > UPS
	" " QIR[1]	$p < 0.001$	QIR[1] > UPS
	" " QIR[2]	$p > 0.05$ *	QIR[2] = UPS
Cadmium (Cd)	UPS and BPD	p < 001	BPD > UPS
	" " APD	$p > 0.05$*	UPS = APD
	" " QIR[1]	$p < 0.05$	QIR[1] > UPS.
	" " QIR[2]	$p > 0.05$ *	QIR[2] = UPS
Copper (Cu)	UPS and BPD	$p > 0.05$ *	UPS = BPD
	" " APD	$p < 0.01$	ADP > UPS
	" " QIR[1]	$p < 0.01$	QIR[1] > UPS.
	" " QIR[2]	$p > 0.05$*	QIR[2] = UPS
Cobalt (Co)	UPS and BPD	$p < 0.05$	BPD > UPS
	" " APD	$p > 0.05$*	UPS = APD
	" " QIR[1]	$p < 0.05$	QIR[1] > UPS
	" " QIR[2]	$p < 0.001$	QIR[2] > UPS

* Not significant

pneumonitis and heart damage to animals including man (Schroeder, 1974).

The high levels of Cd in plants from BDP site during both seasons relative to UPS and other sites could be traced to runoff through already polluted areas into the stream. The high levels of Cd throughout the period of investigation before effluent discharge point (BDP) (Tables 1 and 2), is an indication that the battery effluent contributed little or no Cd metal to the receiving stream. Due to its various applications, Cd is found in every environmental compartment such as soil, groundwater and air. Although there was no significant concentration of Cd in these plants, they should not be consumed by man since this metal, being a cumulative poison could become bioconcentrated and subsequently transferred to man with the attendant adverse health effects such as pulmonary emphysema, hypertension, kidney damage and cardiovascular disease. Worse still, a concentration of 0.03 - 3.5 mg/m^3 could significantly reduce children's weight (Schroeder, 1974). Cd also interferes with Zn and Cu metabolism. Lee (1977) discovered that the presence of Cd in any environment could lead to stunted growth of plants. Similarly, Page et al (1972) asserted that leaves accumulate excessive amounts when solutions contain a few µg/ml of Cd. Unlike most of the other trace metals, Cd can be taken up easily by many plants because at low pH and high temperature it exists in its stable form, Cd^{2+} (a relatively soluble ion that behaves like Ca^{2+}) (Voogt et al, 1980). This makes this metal readily available to plants and therefore capable of accumulating in any food chain (Udosen 1994).

The levels of Cu in plants from QIR[1] site were generally higher than the levels from QIR[2] site because, unlike QIR[1] site which received drainage from UPS, BDP, ADP and QIR[2] sites, QIR[2] is not influenced by any of the other sites (Fig. 1). Although Cu is an essential trace element, the body hardly tolerates a high concentration of it. Cu must have been contributed to the batteryeffluent by the Quality Control Laboratory. Generally, the presence of Cu, especially its salts are poisonous (Buser & Efimov, 1984). Moreover, Cu is very toxic to most plants, highly toxic to invertebrates and moderately toxic to mammals (Hellawell, 1988). About 0.05M Cu^{2+} inhibits root growth while 0.1M stops the germinalion of plants (Jones, 1972, Mukherji & Gupta, 1972). Ingestion of Cu could also cause hermochromatosis, lung and liver injury.

Cobalt could be introduced anthropogenically into the environment through its application in agriculture as a microfertilizer. While the concentrations of Co in plants from QIR[1] and QIR[2] sites were significantly different from that of UPS site, the difference in Co levels between plants from BDP and ADP sites and those from UPS site was not significant at all (Table 4). The essentiality of Co in plant is not established. However, although Co in trace quantity is essential to man, effects of high dose of this metal in man include polycythaemia, bone hyperplasia, metaplasia in spleen, liver and kidneys as well as hyperglycemia due to reversible pancreatic damage. Direct human effects of this metal include dermatitis, heart attack as well as liver and kidney damage (Schroeder, 1974).

CONCLUSION

The study has shown that pollutants, including trace metals dumped into any water course could eventually get trapped by sediments, become slowly absorbed and transported through the roots of any plant to other parts of the plant including the foliage which serves as food for some animals and human beings. ADP and QIR[1] which are sites below the effluent discharge point are also downstream of UPS in Nkap stream which flows through the Government Residential Area (GRA) in Ikot Ekpene Local Government Area. It is therefore not unlikely that runoff from the town and the GRA must have carried some metal-laden wastes from these areas into UPS which flowed through BDP and ADP into QIR[1]. Consequently the high levels of Pb and Sb in plants from ADP and QIR[1] sites in contrast to those from UPS site must have resulted from a contribution by the factory effluent and the town runoff. Moreover, the study has revealed that whenever industrial effluents are discharged into any water course the quality of water downstream is not only tampered with but aquatic plants and animals become contaminated by toxicants present in the effluents.

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