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Full Length Research Paper

Utilizing Agama Lizards for Environmental Monitoring: A Study on Heavy Metal Pollution

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In this study, the suitability of *Agama* lizard as a biomarker in assessing environmental pollution levels of arsenium (As), barium (Ba), cadmium (Cd), copper (Cu), manganese (Mn), lead (Pb) and zinc (Zn) was investigated. Samples of top soil and agama lizards were taken from five sites within a university community in Nigeria for the study. Soil samples, livers and kidneys from the lizards were subjected to wet acid digestion and levels of heavy metals in the digested samples were determined using an atomic absorption spectrophotometer (AAS). Results of the study showed that the levels of the metals ranged from Cd, 20.4 ± 2.6 µg/g to Zn, 978.6 ± 2.2 µg/g in soil; Cd, not detected to Zn, 42.2 ± 0.3 µg/g in liver; As and Ba, not detected to 47.6 ± 1.0 µg/g Zn in kidney. The inter matrices correlation coefficient values obtained for the heavy metals showed that the kidney of lizards would be more relevant in assessing soil levels of such heavy metals as As, Ba, Cd, Mn and Pb among others.

Key words: Agama lizard, environmental pollution, soil, heavy metals, liver, kidney.

INTRODUCTION

Interest in the environmental levels of heavy metals is a global one because of the potential hazards of these metals to the health of animals, humans and plants when they exist at elevated levels. Heavy metals are dangerous because they bioaccumulate (Goyer, 1991; Sawyer et al., 2006) and interfere with the biochemical processes in the living tissues (Alloway and Ayres, 1995). High levels of heavy metals in soil, water and atmosphere vis-à-vis the biota are often related to industrial activities, burning of fossil fuels, chemical dumping, application of agro-allied chemicals such as fertilizers and certain pesticides. Knowledge of the levels of heavy metals in our environment is required for the purposes of setting background values of these metals, monitoring their accumulation in the biota from time to time and estimating the amounts of the metals that may possibly get translocated across the compartments in the entire ecosystem. With the increasing industrial activities, what were once pristine habitats of organisms are being encroached upon making natural populations of organisms becoming increasingly exposed to environmental pollution by heavy metals particularly and other xenobiotics generally. It can be argued that all soils in urbanized areas have been polluted to varying degrees with many trace substances including heavy metals like cadmium (Cd), lead (Pb), arsenium (As), chromium (Cr), and so on (Harrison, 1996).

Environmental monitoring and assessment have become vitally important in detecting where insidious pollution is occurring, the pollutants involved and the sources from which they came (McBee and Bickham, 1990; Propst et al., 1999). Analyses have been done using arboreal species like rat as a bio-indicator of environmental pollution. This is because the concentration of a chemical species like heavy metals in an organism found within a locality can be used to monitor pollution trends following anthropogenic activities in that locality (Burger and Gochfeld, 1995; Lam et al., 2006). The use of laboratory animals and conditions to establish assays that detect pollution-induced changes in body systems, immune responses and in identifying relevant contaminants and potential harmful threshold levels of exposure has been a powerful tool in that direction. However, it is not a sufficient tool in studying actual environmental pollution levels of contaminants

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relative to animal tissues obtained from natural populations exposed to typical environmental contaminant mixture and levels. For the purpose of environmental pollution studies, an animal species intended for environmental heavy metal exposure monitoring should (i) have a wide geographical distribution so it can be found in areas with a range of contaminant profiles to facilitate comparisons (Loubourdis, 1997; Burger et al., 2005); (ii) exist in large populations that can be easily sampled (Lambert, 1999);
(iii) be a species on which information on basic life history is available (Selcer, 2006); (iv) exhibit high site fidelity to maximize exposure (Campbell and Campbell, 2000; Fletcher et al., 2006).

Despite the considerable weight of evidence that exists in favour of the bioaccumulation tendencies of heavy metals by living things, data supporting the use of lizards in monitoring pollution trends in the Nigerian environment are limited although the advantages are overwhelming. Jenkins (1981) advanced four reasons why animals like lizards are suitable biomarkers in assessing the levels of heavy metal pollution in an environment: they are ubiquitous, abundant and are available everywhere in the environment; they are found both in natural and polluted environments; they are intermediate between the primary producers and various types of consumers and they are being eaten in some parts of the world. Generally, the advantages for using Agama lizard tissues in environmental pollution analysis may include the fact that
(i) tissue analysis can increase the probability of detecting trace amounts of some contaminants that tend to bioaccumulate in tissue; (ii) tissues provide a time – averaged assessment of the presence of contaminants in the environment; (iii) tissue analysis provides direct measurements of bioavailability of contaminants to other living organisms; (iv) by integrating tissue and soil trace metal analysis, complementary or multiple lines of evidence are provided to assist in the understanding of contaminant fate and distribution; (v) the results of the tissues analysis are likely to be true reflection of the environmental contamination or pollution status of where they live because red-headed Agama lizards (used in this study) habitually maintain a territorial system of living; (vi) by feeding directly on insects, worms, maggots, leaves of shrubs and food crumbs that fall to the ground mostly within their territory, lizards interact more or less directly with the soil; and (vii) being cold-blooded animals, the weather conditions of Nigeria (a tropical country) is conducive for their round the year existence and availability (their thriving period is not restricted to a particular season).

In the present study, heavy metal levels in lizard tissues or organs were correlated with those in the soil environment from where the lizards were sampled in order to evaluate the suitability of agama lizard tissues or organs for assessing the environmental heavy metal levels.

METHODOLOGY

Purification of apparatus and chemicals

The apparatus used included refluxing kits, polythene sample bottles, beakers, a dissecting set and polythene bags. All sample bottles, refluxing kits, and beakers were washed with detergent solution and rinsed in doubly distilled water. They were then soaked in 10% trioxonitrate (V) acid (HNO_3) for 48 h followed by thorough rinsing with doubly distilled water. The stainless steel materials in the dissecting set were wiped free of particles loosely bound to their surfaces using acetone. Reagents used for digestion were HNO_3, $HClO_4$ and HF (obtained from Sigma - Aldrich, Germany).

Sample collection and preparation

Soil and red-headed *agama* lizard samples were collected from New Bukateria (Bukateria is a slum English for Cafeteria), Old Bukateria, Halls of Residence, Staff Quarters and Church/Mosque areas within the campus of the Obafemi Awolowo University, Ile-Ife, Nigeria. These sites, to a large extent, represent the areas of vigorous human activities within the campus community having an average population of about 25,000 people. Since anthropogenic metals in soil reside substantially within the top layer between 0 to 15 cm depth depending on the soil types, top soil samples from a site were collected by selecting a representative 5 g top soil from the bulk at intervals of about 20 m apart in five locations within a sampling site.

The collected soil samples from a given sampling site were constituted into a composite sample. Each composite sample was properly air-dried in an aerated cupboard to avoid cross-contamination, mixed and then sieved to remove unwanted particles such as pebbles and humus. The sieved soil was ground to fine powder. About 1 g of each soil sample was selected by coning and quartering method and kept in a desiccator for subsequent digestion. Also, a minimum of five matured red-headed agama lizards from each of the five sampling areas were trapped, immediately transported to the laboratory and killed. Organs of interest (livers and kidneys) were promptly removed from the lizards using instruments from a dissecting set as soon as the lizards were killed. Livers from the lizards in a particular area were put together in a pestle and mortar and homogenized properly before 1 g was weighed for digestion. The kidneys of the lizards were similarly treated and selected for digestion.

Digestion of soil sample

Accurately weighed 0.2 g of the 1 g selected soil sample was placed in the refluxing flask. The sample was digested by refluxing for 2 h with 5 ml HNO_3 at a temperature of 130 ± 1°C using a thermostated heating mantle. The digestion was further done with 2 ml 1:1 v/v HNO_3 and $HClO_4$ for further 1 h. Finally, further digestion with 1ml HF was done until the colour of the digested sample became clear. Digestion by refluxing was necessitated to prevent loss of volatile metallic compounds at the stage of digestion. The digested sample was allowed to cool down before it was quantitatively poured into a 25 ml volumetric flask. The solution in the volumetric flask was made up to the 25 ml mark with doubly distilled water. A blank was also prepared along side.

Digestion of tissue samples

The homogenized and accurately weighed 1 g of the tissue sample was digested by refluxing using 5 ml 70% HNO_3 in the hood for 2 h at a temperature of 120°C using a thermostated heating mantle.

Table 1. AAS measuring parameters, detection limits and percentage recoveries of metals in the samples.

Element	Wavelength, λ(nm)	Detection limit (µg/g)*	Percentage recovery, %R, of metals in		
			Soil	Liver	Kidney
As	193	0.08 (0.11)	97±4	98±3	87±6
Ba	554	0.17 (0.21)	93±4	88±3	98±5
Cd	228	0.01 (0.02)	89±1	92±4	93±4
Cu	247	0.005 (0.006)	98±3	79±5	92±4
Mn	279	0.01 (0.02)	92±5	90±4	80±5
Pb	283	0.08 (0.09)	86±4	81±3	89±3
Zn	240	0.005 (0.005)	98±4	94±2	95±5

*Values in parenthesis were experimentally determined

After about 1½ h, a clear solution was obtained and 1 ml $HClO_4$ was added and further digestion was carried out for another 30 min. This was done to release any metal complexing with HNO_3 and to make all metals exist in their highest oxidation states. Thereafter, the refluxing beaker was brought down to simmer. The content of the Teflon beaker was quantitatively poured into a 25-ml volumetric flask and made up to the mark with doubly distilled water. A blank was also prepared along side.

Quality control measures adopted

Recovery analysis

The extractive concentration method was evaluated for the quality assurance of tissue and soil samples. This was done by recovery work to ascertain the efficiency of the analytical procedures describe in this study since standard reference materials were not available for our use as at the time of this study. Two equal samples each of soil and tissues were used. One sample was spiked at fortification levels of 10 mg/L with mixtures of As, Ba, Cd, Cu, Mn, Pb and Zn, while the other was left unspiked. Both samples in each case were digested using the procedure earlier described. The entire procedure was done in triplicates. The worked up samples were analyzed for heavy metal content using the Bulk Scientific Maker Model 200A Atomic Absorption Spectrophotometer (AAS) available at the Central Laboratory, Obafemi Awolowo University, Ile-Ife, Nigeria. Percentage recoveries (%R) were estimated from the relationship:

$$\%R = \frac{\text{Levels in spiked sample - Levels in unspiked sample}}{\text{Amount of metals used for spiking}} \times 100$$

Determination of limit of detection

This was done by serially diluting 20 µg/ml of the solution of each of the metal ions to obtain 15, 10, 5, 2.5 and 1.0 µg/ml solutions. These solutions were subjected to AAS analysis. Their absorbance versus concentration values were used to compute the detection limits following the definition of Miller and Miller (2000).

Determination of heavy metals in the samples

The Bulk Scientific Maker Model 200A AAS with detection limits (µg/ml) of 0.08, 0.17, 0.01, 0.005 0.01, 0.08 and 0.005 for As, Ba, Cd, Cu, Mn, Pb and Zn, respectively, available at the Central Laboratory, Obafemi Awolowo University, Ile-Ife, was used for the heavy metal determination. The instrument was operated as per manufacturer's manual.

RESULTS AND DISCUSSION

Table 1 contains AAS measuring parameters, limit of detection and the percentage recoveries of the elements in the samples. The detection limit is a measure of the sensitivity of the instrument (AAS) with respect to the metals. The detection limits are relatively low for Cu and Zn, and hence, detecting them at ultra-trace levels is possible. However, metals like Ba, As and Pb may not be detected easily if they exist at levels lower than 10^{-2} µg/g. This probably explains why some metals were not detected in some of the matrices investigated.

The soil levels of heavy metals at each site are outlined in Table 2. Compared with the reported background levels of heavy metals in unpolluted soils (Pais and Jones, 1997), the metals showed elevated values for all the seven metals determined. Arsenic had the highest value in samples from the Quarters (79.5 ± 0.3 µg/g); Ba in New Bukateria (94.5 ± 0.4 µg/g); Cd in Hall (57.2 ± 1.3 µg/g); Cu in Quarters (106.9 ± 0.5 µg/g); Mn in Old Bukateria (814.2 ± 2.7 µg/g); Pb in Hall (286.2 ± 3.1 µg/g); and Zn in New Bukateria (1487.9 ± 3.6 µg/g). Apart from lithogenic factors, the high levels of As at the Quarters might be as a result of past applications of arsenic-containing pesticides around the houses and to farmlands close to living areas. The high levels of Ba, Cd, Cu, Mn and Zn where they existed could also be as a result of deposits from or corrosion of alloyed rims and other utensils, discarded batteries and cans, in addition to other geological factors such as the lithogenic make up of the soil and weathering of base rocks within the vicinity over the years. In addition, the high levels of lead could be as a result of burning of leaded gasoline in automobiles in the past, which resulted in the deposits of lead-ladden particulates on the soil.

The values (µg/g) of mean load of heavy metals per sampling site in Table 2 showed the order: Cd (35.53 ± 14.3) < As (46.7 ± 22.4) < Ba (61.8 ± 24.8) < Cu (75.4 ± 21.7) < Pb (205.2 ± 64.9) < Zn (662.9 ± 221.5) < Mn

Table 2. Levels (µg/g)* of heavy metals in soil.

Element	Study sites					Mean load of heavy metals (µg/g)
	Hall (n = 5)	Old Bukateria (n= 7)	New Bukateria (n = 6)	Quarters (n = 8)	Church/Mosque area (n = 5)	
As	45.6 ± 0.3	28.2 ± 0.3	55.8 ± 1.1	79.5 ± 0.3	24.1 ± 0.1	46.7 ± 22.4
Ba	49.9 ± 0.2	73.7 ± 1.0	94.5 ± 0.4	62.1 ± 0.4	28.6 ± 0.2	61.8 ± 24.8
Cd	57.2 ± 1.3	34.6 ± 0.4	20.4 ± 2.6	39.8 ± 1.0	25.6 ± 0.3	35.5 ± 14.3
Cu	59.1 ± 0.4	87.3 ± 0.3	69.4 ± 0.7	106.9 ± 0.5	54.3 ± 1.0	75.4 ± 21.7
Mn	727.5 ± 1.5	814.2 ± 2.7	803.2 ± 3.2	648.6 ± 5.3	396.3 ± 2.9	678.0 ± 170.9
Pb	286.2 ± 3.1	208.6 ± 1.0	179.7 ± 4.3	238.6 ± 3.4	113.0 ± 1.6	205.2 ± 64.9
Zn	978.6 ± 2.2	451.7 ± 1.4	1487.9 ± 3.6	795.2 ± 2.8	601.3 ± 2.3	662.9 ± 221.5
Total load per site ± s.d.	2204.0 ± 9.0	1698.4 ± 7.2	1710.8 ± 14.7	1970.7 ± 13.6	1243.2 ± 8.3	1765.4 ± 52.7

n=Number of lizards captured and used. *Value = mean of triplicate analysis ± s.d.

Table 3. Levels (µg/g)* of heavy metals in *Agama* lizard liver.

Element	Study sites					Mean load of heavy metals (µg/g)
	Hall (n = 5)	Old Bukateria (n= 7)	New Bukateria (n = 6)	Quarters (n = 8)	Church/Mosque area (n = 5)	
As	4.5 ± 0.2	3.9 ± 0.1	3.3 ± 0.1	2.1 ± 0.1	3.0 ± 0.2	3.4 ± 0.9
Ba	4.0 ± 0.3	2.7 ± 0.1	4.1 ± 0.2	2.0 ± 0.1	4.2 ± 0.2	3.4 ± 1.0
Cd	ND	1.6 ± 0.1	1.6 ± 0.0	ND	ND	0.6 ± 0.9
Cu	3.3 ± 0.1	5.4 ± 0.2	3.1 ± 0.1	3.6 ± 0.2	6.3 ± 0.1	4.3 ± 1.5
Mn	8.9 ± 0.1	5.9 ± 0.2	2.7 ± 0.2	2.3 ± 0.2	3.6 ± 0.1	4.7 ± 2.7
Pb	3.9 ± 0.1	3.1 ± 0.0	3.3 ± 0.1	3.0 ± 0.1	4.5 ± 0.6	3.6 ± 0.6
Zn	42.2 ± 0.3	32.0 ± 0.2	26.7 ± 0.3	37.3 ± 0.2	24.1 ± 0.2	32.5 ± 7.4
Total metal burden in the liver ± s.d.	66.8 ± 1.2	54.5 ± 1.0	44.7 ± 1.1	50.3 ± 0.8	45.8 ± 1.3	52.4 ± 8.9

n= Number of lizards captured and used. *Values are mean of triplicate analysis ± standard deviation (s.d.).

(678.0 ± 170.9). These elevated values of the heavy metals generally attested to possible anthropogenic input of heavy metals from various sources as earlier pointed out. The total load of heavy metals per site indicated that the levels (µg/g) were of the order: Hall (2204.0 ± 9.0) > Quarters (1970.7 ± 13.6) > New Bukateria (1710.8 ± 14.7) > Old Bukateria (1698.4 ± 7.2) > Church/Mosque area (1243.2 ± 8.3). The order here conforms, to a large extent, to the levels of activities going on around each of the sampling sites. For example, activities such as driving in and out go on round the year around the Quarters while at the Church/Mosque area, activities are confined to worship days of Fridays and Sundays in most cases.

The liver levels of heavy metals are listed in Table 3. Arsenic has the highest value in the livers of lizards from the Hall area (4.5 ± 0.2 µg/g); Ba in those from the Church/ Mosque area (4.2 ± 0.2 µg/g); Cd in those from the New Bukateria area (1.6 ± 0.0 µg/g); Cu in those from the Church / Mosque area (6.3 ± 0.1 µg/g); Mn in those from Hall area (8.9 ± 0.1 µg/g); Pb in the ones from Church / Mosque area (4.5 ± 0.2 µg/g); and Zn in those from Hall area(42.2 ± 0.3 µg/g). Zn level in the liver was the highest of all the metals considered at all the sites. It appeared that the liver of red-headed agama lizards has a high tendency of bioaccumulating Zn. Cd was not detected in the livers of lizards from the Hall, Quarters and Church / Mosque areas. This is probably because the limit of detection is above the contents of Cd in the liver of lizards. Levels of Pb was high (4.5 ± 0.6) in the liver of lizards in Church / Mosque area. The reason for this might be because the lizards around the Church/Mosque area depend more on the leaves of grasses and insects for food than those around the residential areas where the lizards feed on food crump from dwellers in addition to leaves and insects. The leaves of grasses and insects feeding on them have the

Table 4. Levels (µg/g)* of heavy metals in *Agama* lizard kidney.

Element	Study sites					Mean load of heavy metals (µg/g)
	Hall (n = 5)	Old Bukateria (n = 7)	New Bukateria (n = 6)	Quarters (n = 8)	Church/Mosque area (n = 5)	
As	8.1 ± 0.1	6.1 ± 0.2	4.4 ± 0.2	5.7 ± 0.4	ND	4.9± 3.0
Ba	5.6 ± 0.2	5.0 ± 0.1	3.7 ± 0.2	5.1 ± 0.2	ND	3.9± 2.3
Cd	2.5 ± 0.1	3.3 ± 0.1	3.4 ± 0.1	3.8 ± 0.1	2.9 ± 0.1	3.2± 0.5
Cu	6.9 ± 0.3	14.4 ± 0.1	6.1 ± 0.3	9.5 ± 0.2	6.5 ± 0.1	8.7± 3.5
Mn	9.4 ± 0.0	10.5 ± 0.2	9.9 ± 0.4	8.9 ± 0.2	5.8 ± 0.6	8.9± 1.8
Pb	3.1 ± 0.1	1.7 ± 0.1	3.1 ± 0.1	1.9 ± 0.1	2.2 ± 0.2	2.4± 0.7
Zn	25.6 ± 0.2	17.2 ± 0.5	47.6 ± 1.0	31.6 ± 0.6	14.4 ± 0.2	27.3± 13.3
Total metal burden in the kidney ± s.d.	61.3 ± 0.9	58.2 ± 1.3	78.3 ± 2.3	66.4 ± 1.7	31.7 ± 1.3	59.2± 15.3

n=Number of lizards captured and used. *Values are mean of triplicate analysis ± standard deviation (s.d.).

tendency of harbouring metals from the exhaust fumes and soil tremendously. Thus, any animal depending on them as sole sources of food may bioaccumulate more metals. The mean load of heavy metals (µg/g) in the liver was of the order: Cd (0.6 ± 0.9) < As (3.4 ± 0.9) < Ba (3.4 ± 1.0) < Pb (3.6 ± 0.6) < Cu (4.3 ± 1.5) < Mn (4.7 ± 2.7) < Zn (32.5 ± 7.4). Total load (µg/g) of heavy metals in the liver showed that the values in samples from the Hall (66.76 ± 1.15) > Old Bukateria (54.5 ± 1.0) > Quarters (50.3 ± 0.8) > Church/Mosque (45.8 ± 1.3) > New Bukateria (44.7 ± 1.1). Other than the values obtained in the liver of lizard samples from the Hall, this order did not conform to the pattern seen in the soil samples.

Table 4 is a list of the kidney levels of heavy metals. Arsenic has the highest value in the Hall area (8.1 ± 0.1); Ba in the Hall area (5.6 ± 0.2); Cd in Quarters area (3.8 ± 0.1); Cu in Old Bukateria area (14.4 ± 0.1); Mn in Old Bukateria (10.5 ± 0.2); Pb in Hall (3.1 ± 0.1); and Zn in New Bukateria area (47.6 ± 1.0). Arsenic and Ba were not detected in the kidneys of lizards from the Church / Mosque area. In the kidney, the mean load of heavy metals (µg/g) followed the pattern: Pb (2.4 ± 0.7) < Cd (3.2 ± 0.5) < Ba (3.9 ± 2.3) < As (4.9 ± 3.0) < Cu (8.7 ± 3.5) < Mn (8.9 ± 1.8) < Zn (27.3 ± 13.3). Values of total load (µg/g) of heavy metals in the kidney were of the order: New Bukateria (78.3 ± 2.3) > Quarters (66.4 ± 1.7) > Hall (61.3 ± 0.9) > Old Bukateria (58.2 ± 1.3) > Church/Mosque (31.7 ± 1.3). The values of total load of heavy metals in the kidney in samples from the Quarters, Old Bukateria and Church/Mosque areas agreed with the pollution trends observed in soil samples from these areas. In summary, the values of the mean load of heavy metals in Tables 3 and 4 showed that the bioaccumulation capacity of heavy metals by the kidney (59.2 ± 15.3 µg/g) was significantly higher than that of the liver (52.4 ± 8.9 µg/g) at 0.05 level of confidence.

However, the liver samples in lizards from the Hall and Church/Mosque areas showed higher total load of heavy metals than the kidney samples in lizards from the same sites.

In Table 5, the matrix of correlation of levels of heavy metals in the soil against the levels in the liver is shown. Six pairs of heavy metals (constituting 12.2% of all the cases compared) gave positive significant correlation coefficients. These are Ba/Cd, Mn/Cd, Cd/Mn, Cd/Zn, Pb/Zn and Zn/Zn. Only in these cases could the levels of heavy metals in the liver be used to predict an increase in the soil levels of the heavy metals studied, where such metals occur simultaneously. Similarly, as indicated in Table 6, eighteen pairs of the heavy metals studied showed positive significant correlation coefficients of the levels in the soil against the levels in the kidney. These are As/Ba, As/Cd, As/Zn, Ba/Ba, Ba/Mn, Ba/Zn, Cd/As, Cd/Ba, Cu/Ba, Cu/Cd, Cu/Cu, Mn/As, Mn/Ba, Mn/Mn, Mn/Zn, Pb/Ba, Pb/Mn and Pb/As. This implies that in 36.7% of the cases, levels of heavy metals in the kidney can be used to predict an increase in the soil levels of the heavy metals studied. From the results of this study, it appears that the kidney of Agama lizard is more reliable in monitoring the environmental levels of heavy metals such as Pb/As, Pb/Ba, Cu/Cd and Mn/Mn pairs in which the correlation coefficients were not less than 0.850.

Conclusion

This study has proved that the liver and kidney of *Agama* lizards could serve as reliable diagnostic tools for the study of levels of some heavy metal contaminants present in soil samples within the natural habitats of the lizards. The liver of *Agama* lizards was particularly useful in this direction with respect to such heavy metals as Cd

Table 5. Correlation coefficients of levels of heavy metals in soil against levels of heavy metals in the liver of lizard.

Liver →		As	Ba	Cd	Cu	Mn	Pb	Zn
	As	-0.551*	-0.509*	-0.189	-0.768*	-0.402	-0.598	0.439
	Ba	0.025	-0.196	0.820*	-0.576*	-0.243	-0.789*	-0.041
	Cd	0.448	-0.192	-0.513*	-0.336	0.772*	0.000	0.946*
Soil	Cu	-0.556*	-0.968*	0.124	-0.224	-0.398	-0.858*	0.309
	Mn	0.419	-0.239	0.698*	-0.608	0.268	-0.757*	0.376
	Pb	0.368	-0.358	-0.156	-0.688*	0.586*	-0.444	0.966*
	Zn	0.139	-0.022	-0.746*	-0.438	0.483	0.211	0.809*

*****Values are significant at $P \leq 0.05$, n = 33.

Table 6. Correlation coefficients of levels of heavy metals in soil against levels of heavy metals in the kidney of lizard.

Kidney →		As	Ba	Cd	Cu	Mn	Pb	Zn
	As	0.393	0.501*	0.610*	-0.165	0.298	0.112	0.678*
	Ba	0.410	0.514*	0.532*	0.226	0.819*	0.194	0.757*
	Cd	0.740*	0.635*	-0.449	0.103	0.239	0.134	-0.249
Soil	Cu	0.357	0.539*	0.850*	0.614*	0.442	-0.617	0.168
	Mn	0.782*	0.816*	0.209	0.404	0.991*	0.216	0.507*
	Pb	0.961*	0.923*	-0.107	0.189	0.644*	0.222	0.187
	Zn	0.467	0.366	-0.407	-0.351	-0.101	0.328	-0.050

*****Values are significant at $P \leq 0.05$, n = 33.

and Zn, while the kidney could find wider relevance in the environmental diagnostic levels of As, Ba, Cd, Mn and Pb among others. There is the need, however, to collect more data in future studies from different socio-cultural areas so as to be able to determine possible relationships, differences and generalizations peculiar to each area in terms of heavy metal distributions in soil and body parts of animals within the vicinity.

REFERENCES

Alloway BJ, Ayres DC (1997). Chemical Principles of Environmental Pollution, 2nd Edition, Chapman and Hall, p. 395.

Burger J, Gochfeld M (1995). Heavy metal and selenium concentration in eggs of herring gulls (*Larus argentatus*): Temporal differences from 1989 to 1994. Arch. Environ. Contam. Toxicol. 29:192-197.

Burger J, Campbell KR, Campbell TS, Shukla T, Jeitner T, Gochfeld M (2005). Use of skin and blood as nonlethal indicators of heavy metal contamination in Northern Water Snakes (*Nerodia sipedon*). Arch. Environ. Contam. Toxicol. 49:232-238.

Campbell KR, Campbell TS (2000). Lizard contaminant data for ecological risk assessment. Rev. Environ. Contam. Toxicol. 165:39-116.

Fletcher DE, Hopkins WA, Saldana T, Baionno JA, Arribas C, Standora MM, Fernandez-Delgado C (2006). Geckos as indicators of mining pollution. Environ. Toxicol. Chem. 25:2432-2445.

Goyer RA (1991). Toxic effects of metals. In: Amdur MO, Doull J, Klaassen CD (eds). Caserett and Doull's Toxicology: The Basic Science of Poisons, McGraw-Hill Book Company, New York, pp. 623-680.

Harrison RM (1996). Pollution: Causes, Effects and Control, 3rd Edition, The Royal Society of Chemistry, London.

Jenkins DW (1981). Biological Monitoring of Toxic Trace Elements, United State Environmental Protection Agency, USEPA. 6001- 53-80-090, Washington D. C., p. 10.

Lam JCW, Tanabe S, Chan SKF, Lam MHW, Martin M, Lam PKS (2006). Levels of trace elements in green turtle eggs collected from Hog Kong: Evidence of risk due to selenium and nickel. Environ. Pollut. 144:790 - 801

Lambert MRK (1999). Lizards as bioindicators. Biologist 46:12-16.

Loumbourdis NS (1997). Heavy metal concentration in a lizard, *Agama stellio stellio*, compared in urban, high altitude and agricultural, low altitude areas of north Greece. Bull. Environ. Contam. Toxicol. 58:945-952.

McBee K, Bickham KW (1990). Mammals as Bioindicators of Environmental Toxicity. In: Genoways HH (ed): Current Mammalogy, Vol. 2, Plenum Press, New York. pp. 37-88.

Miller JN, Miller JC (2000). Statistics and Chemometrics for Analytical Chemistry, 4th Edition, Pearson Education Limited. p. 271.

Propst TL, Lochmiller RL, Qualls CW , McBee K (1999). *In situ* assessment of immunotoxicity risks to small mammals inhabiting petrochemical waste sites. Chemosphere 38:1049-1067.

Sawyer CN, McCarty PL, Parkin GF (2006). Chemistry for Environmental Engineering and Science, 5th Edition, Tata McGraw-Hill Publishing Company, New Delhi.

Selcer KW (2006). Reptile Ecotoxicology: Studying effects of contaminants on populations. pp. 267-297 In: Gardner S, Oberdorster E (Eds.). Toxicology of Reptiles. Taylor and Francis Group, Boca Raton, Florida, USA.