





also detected in some of the medicinal plant species (44%) whilst majority were below the detection limit (0.002) representing 56%. Aluminum (Al) was found in all of the plant species, except two (4%). Mercury and arsenic in all the plant species were below the detection limit (0.001), representing 100% [Tables 2-5].

## DISCUSSION

According to the world health organization (WHO),<sup>[1]</sup> about 80% of the world population use plant-based medicines. Most of these plants are collected in the wild, only few are cultivated. A number of mineral elements important to nutrition accumulate in these plants. Other elements such

as Cd, Co, and Pb, which are not used directly by the plant and are detrimental to human health, also accumulate in these plants.<sup>[5,6]</sup> The environmental impact of these metals as well as their health effects has been a source of major concern.<sup>[7]</sup> Their accumulation in plants highly depends on the availability in the soil.<sup>[7]</sup> Heavy metal contamination of medicinal herbal products occurs during cultivation, cross-contamination during processing or their deliberate introduction as therapeutic ingredients. Cultivation in soils containing high concentrations of heavy metals is one mechanism by which heavy metal contamination of herbal products has been documented.<sup>[8]</sup>

Medicinal plants have been cited as a potential source of heavy metal toxicity to both man and animals.<sup>[9]</sup> The

**Table 2: Concentration of heavy metals (µg/g) in *Cassia alata* and *Cassia occidentalis***

Minerals	<i>Cassia alata</i>					<i>Cassia occidentalis</i>				
	RD	AC	RS	FO	PG	RD	AC	RS	FO	PG
Lead	4.450	8.200	17.650	7.450	5.900	4.350	7.850	6.400	7.700	6.000
Cadmium	<0.002	<0.002	0.900	0.150	0.950	<0.002	<0.002	0.350	<0.002	13.700
Aluminum	65.900	100.45	8.950	14.250	106.3	67.150	98.750	4.800	20.650	96.275
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	<0.001	0.001	0.002	<0.001	<0.001	<0.001	0.001	<0.001	0.001	<0.001

RD=Refuse dump; AC=Around campus; RS=Roadside; FO=Forest; PG=Physique garden values with<=below detection limit of the spectrophotometer

**Table 3: Concentration of heavy metals (µg/g) in *Rauwolfia vomitoria* and *Paulinia pinnata***

Minerals	<i>Rauwolfia vomitoria</i>					<i>Paulinia pinnata</i>				
	RD	AC	RS	FO	PG	RD	AC	RS	FO	PG
Lead	1.550	9.250	7.750	4.600	4.750	2.700	8.450	4.950	9.050	6.700
Cadmium	<0.002	0.850	<0.002	<0.002	<0.002	<0.002	0.650	<0.002	<0.002	<0.002
Aluminum	82.650	101.800	23.350	23.200	105.525	76.650	104.25	23.800	15.850	12.400
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	<0.001	0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001	<0.001

RD=Refuse dump; AC=Around Campus; RS=Roadside; FO=Forest; PG=Physique Garden values with<=below detection limit of the spectrophotometer

**Table 4: Concentration of heavy metals (µg/g) in *Moringa oleifera* and *Taraxacum officinale***

Minerals	<i>Moringa oleifera</i>					<i>Taraxacum officinale</i>				
	RD	AC	RS	FO	PG	RD	AC	RS	FO	PG
Lead	5.350	3.250	3.400	6.400	3.900	6.250	1.650	4.650	7.250	4.800
Cadmium	0.550	0.500	0.650	0.350	<0.002	14.050	<0.002	1.500	<0.002	0.950
Aluminum	77.150	110.475	33.850	20.750	16.450	94.375	105.85	28.400	11.500	21.450
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001

RD=Refuse dump; AC=Around campus; RS=Roadside; FO=Forest; PG=Physique garden values with<=below detection limit of the spectrophotometer

**Table 5: Concentration of heavy metals (µg/g) in *Ocimum gratissimum* and *Alstonia boonei***

Minerals	<i>Ocimum gratissimum</i>					<i>Alstonia boonei</i>				
	RD	AC	RS	FO	PG	RD	AC	RS	FO	PG
Lead	4.600	<0.010	6.650	3.250	5.550	6.400	4.950	8.350	4.900	8.650
Cadmium	<0.002	<0.002	1.800	<0.002	2.250	<0.002	<0.002	1.450	<0.002	1.800
Aluminum	94.275	107.60	25.950	31.650	3.550	94.425	105.800	24.700	36.000	<0.030
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001

RD=Refuse dump; AC=Around campus; RS=Roadside; FO=Forest; PG=Physique garden values with<=below detection limit of the spectrophotometer

most common heavy metals implicated in human toxicity include lead, mercury, arsenic, and cadmium, although aluminum and cobalt may also cause toxicity. Therefore, the world health organization recommends that medicinal plants, which form the raw materials for most herbal remedies, should be checked for the presence of heavy metals. However, majority of people, living in areas where these plants grow, harvest them locally for personal or family use without checking for heavy metal accumulation. The general notion that medicinal plants are safe and devoid of heavy metal toxicity could be misconstrued. From the study, the levels of these metals differed in the same plant collected from different geographical locations. For example, the levels of lead in *Cassia alata* varied from 17.7 to 4.45 µg/g for the 5 collection sites [Table 2]. That for *Cassia occidentalis* and *Rauwolfia vomitoria* varied between 7.85-4.35 and 9.25-1.55 µg/g, respectively (Table 2 and 3). Similarly, that of aluminum varied between 105.53-23.3 for *Rauwolfia vomitoria* and 104.25-12.4 µg/g for *Paullinia pinnata* [Table 3]. The levels of heavy metals also varied for different plants collected from the same location. Uptake of metals by plants is influenced by a number of factors including metal concentrations in soils, cation exchange capacity, soil pH, organic matter content, types and varieties of plants, and plant age. However, the prevailing factor is the concentration of the metal in the soil<sup>[10]</sup> and thus the existing environmental conditions.

Lead is considered very harmful for plants, animals, and particularly for microorganisms.<sup>[7]</sup> It has no physiologic role. The highest level of lead occurred in *Cassia alata* harvested from the roadside (17.65 µg/g) [Figure 2]. This exceeded the WHO standard of 10 µg/g for lead in raw materials for herbal medicines.<sup>[1]</sup> This could possibly be due to its accumulation in the soil from vehicular exhaust fumes. In a large number of the samples, the level of lead was just below the allowable limit, suggesting that toxicity could arise from long term use of these plants. Levels of lead beyond the permissible values or long term use of these plants could lead to toxicity characterized by colic, anemia, headache, convulsions and chronic nephritis of the kidneys, brain damage, and central nervous system disorders.<sup>[7,11]</sup>

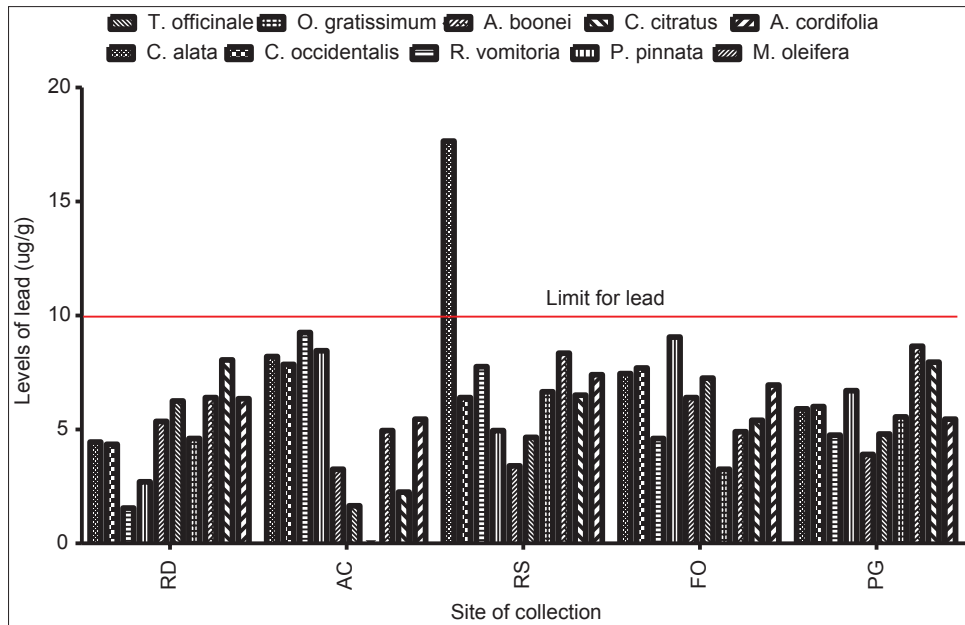
The levels of mercury and arsenic, in all the medicinal plant samples in different geographical locations, were found to be below the minimum detectable limit (<0.001 µg/g) [Table 2 and 6]. All values were below the permissible values of 5 and 0.2 µg/g for arsenic and mercury, respectively.<sup>[1]</sup> Thus, human activities in the areas, where these plants were collected, do not lead to the accumulation of arsenic and mercury in the soils. Mercury levels in humans above the allowable values have been associated with male infertility, inhibition of endogenous antioxidant enzymes, and brain damage among others.<sup>[12]</sup> Supraoptimal levels of arsenic are often fatal. Other toxic symptoms include peripheral polyneuropathy, liver cirrhosis, visual disturbance, and blindness.<sup>[13]</sup> Similarly, aluminum levels in all plant samples from the same area in different geographical locations varied from 4.8 to 108 µg/g [Tables 2-6]. All values were within allowable limits for aluminum, which is not used in any biochemical process in living systems. It accumulates in the brain and, to a lesser extent, in the bones.<sup>[14]</sup> The levels of aluminum in medicinal plants in different geographical locations must be checked as long term use could lead to toxicity.

The level of cadmium, in all 10 plant samples, exceeded the WHO recommended value of 0.3 µg/g for some geographical locations, whereas for other collection sites, the levels were below the minimum detectable values (<0.001 µg/g) [Figure 3]. The levels of cadmium from plant samples collected from the roadside exceeded the maximum safety limit, indicated by the red line in Figure 3, possibly due to contamination from vehicular activities. Also, most medicinal plants collected around the university campus and the physic garden accumulated cadmium above the recommended levels in medicinal plants [Figure 3] with the highest occurring in *C. occidentalis* (13.7 µg/g). About 70% of medicinal plants harvested from the physic garden (within KNUST campus) exceeded the maximum safety limit for cadmium. The most common sources for cadmium in soil and plants are phosphate fertilizers, sewage sludge application, and combustion of fossil fuels. Thus, there is the need for a proper and efficient waste disposal system in and around the university community as cadmium levels above permissible values may result in irreversible kidney damage.<sup>[15]</sup>

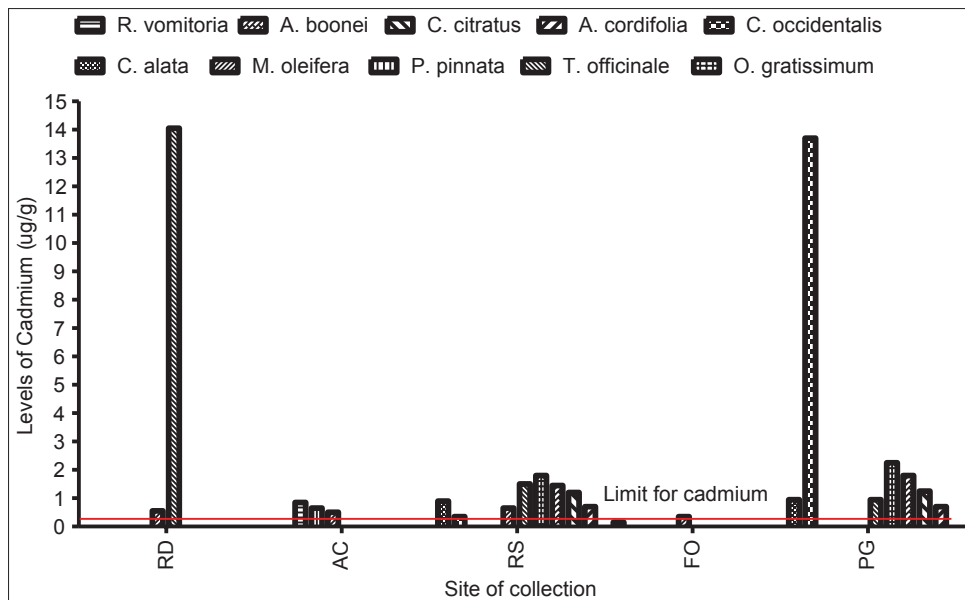
**Table 6: Concentration of heavy metals (µg/g) in *Cymbopogon citratus* and *Alchornia cordifolia***

Minerals	Cymbopogon citratus					Alchornia cordifolia				
	RD	AC	RS	FO	PG	RD	AC	RS	FO	PG
Lead	8.050	2.250	6.500	5.400	7.950	6.350	5.450	7.400	6.950	5.450
Cadmium	<0.002	<0.002	1.200	<0.002	1.250	<0.002	<0.002	0.700	<0.002	0.700
Aluminum	89.575	108.075	44.400	26.350	<0.030	100.275	97.150	38.850	15.950	10.300
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001

RD=Refuse dump; AC=Around campus; RS=Roadside; FO=Forest; PG=Physique garden values with<=below detection limit of the spectrophotometer



**Figure 2:** Levels of lead in plant samples in different geographical locations. RD = Refuse dump, AC = Around campus, RS = Roadside, FO = Forest, PG = Physique garden values with  $\leq$  below detection limit of the spectrophotometer



**Figure 3:** Levels of cadmium in plant samples in different geographical locations. RD=Refuse dump, AC=Around xampus, RS=Roadside, FO=Forest, PG=Physique garden values with  $\leq$  below detection limit of the spectrophotomete

## CONCLUSION

Our study has shown that same species of medicinal plants, growing in different geographical locations, cumulates different levels of heavy metals. Concentration of heavy metals also differed for different plant species collected from the same geographical location. Amounts of heavy metals detected in plants collected from the Bobiri forest reserve were within permissible limits, whereas the levels

in other geographical locations exceeded the recommended values. Thus, medicinal plants for the formulation of herbal remedies should be harvested from pollution-free natural habitat. Our findings further indicate that the medicinal plants, used for local or pharmaceutical purposes, should be collected from areas not contaminated with heavy metals. It is, therefore, advised that the metal content in medicinal plants be checked for levels of heavy metals before their use for local and pharmaceutical purposes.

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