Profile of heavy metals in some medicinal plants from Ghana commonly used as components of herbal formulations

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ABSTRACT

The levels of some heavy metals in 27 medicinal plant species from Ghana were studied in order to evaluate their health implications. These plant species, especially those used in the treatment of diseases such as hypertension, diabetes and asthma may require long term usage. The metals were copper, zinc, iron, manganese, nickel and cadmium. Atomic Absorption Spectrophotometry (wet digestion) was used for the analyses, and content of metals per sample was expressed as percent μg/g. Daily total intake of these metals is discussed based on the recommended daily intake of the medicinal plants or their corresponding formulations. From the results of the study zinc, copper and cadmium were present in all the plant species examined. Manganese was present in all species except *V. amygdalina*. Iron was found in all except five species (82%), whilst nickel was (rather rare) detected in only eight (30%) of the plant species. Significant variations in metal content existed ($P<0.05$) among the medicinal plant species with respect to the heavy metals evaluated. The concentrations of copper, zinc, cadmium and manganese were within their respective maximum permissible daily levels. However, some species, especially *Ocimum canum (8)*, *Clausena anisata* and *Rauwolfia vomitoria* had levels of iron higher than the maximum permissible level of 1000 μg/day and may require care to avoid iron toxicity. The results also highlighted the differences in contents of minerals in *Lippia multiflora* obtained from different locations in Ghana. The findings generally suggest that the use of these plant species for the management of diseases will not cause heavy metal toxicity and may be beneficial to the users in cases of micronutrient deficiency, as these metals were found to be present in readily bioavailable form.

Key words: Health implications, heavy metals, herbal formulations, medicinal plant

INTRODUCTION

Medicinal plants play a major role in the health care sector of developing nations for the management of diseases. Thus herbal medicines have a prominent role to play in the pharmaceutical markets and health care sector of the 21st century.[1] Heavy metals as micronutrients are important for the proper functioning of vital organs in the body. For example, iron is a component of hemoglobin and other compounds used in respiration. Heavy metals are widespread in soil as a result of geo-climatic conditions and environmental pollution. Therefore, their assimilation and accumulation in plants is obvious. Together with other pollutants, heavy metals are discharged into the environment through industrial activity, automobile exhaust, heavy-duty electric power generators, municipal wastes, refuse burning and pesticides used in agriculture.[2] Human beings, animals and plants take up these metals from the environment through air and water. Heavy metals have the tendency to accumulate in both plants and human organs.

Since plants and animals are essential sources of micronutrients for man, it becomes necessary to monitor the levels in biological materials that are required by man for both dietary and medicinal purposes. This is because deficiency or excess of micronutrients can be factors of disease generation.

Even though a lot of phytochemical and bioactivity studies have been carried out on a number of medicinal plants in Ghana,[3] not much has been reported on the heavy metal contents of these plants. This study therefore sought to

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establish the presence, quantity and prevalence of six heavy metals (Cu, Zn, Fe, Mn, Ni and Cd) in 27 medicinal plants commonly used for the treatment, prevention and management of diseases in Ghana.

In view of the fact that micronutrients can be good, toxic or lethal depending on the dose, the study also evaluated the health implications of the heavy metals quantified, based on the recommended daily intake of medicinal plant decoctions.[4] The use of atomic absorption spectrophotometry for determination of the amounts of heavy metals in both organic and inorganic samples has been well reported.[5]

MATERIALS AND METHODS

Plant materials

A total of 27 different medicinal plant species used in the study were collected from their natural habitat and authenticated at the Department of Botany, University of Ghana, where voucher specimen of each plant species is deposited [Table 1]. The leaves were air-dried for four days and later pulverized.

Mineral analysis

An acid digest of each plant species was prepared by oxidizing 0.2 g of the powdered plant sample with a nitric/perchloric acid (2:1) mixture (10 ml). Aliquots of the mixture were used to estimate Fe, Cu, Zn, Mn, Ni and Cd by Analyst 400 Atomic Absorption Spectrometer. Each sample was analyzed thrice, and the data were reported as mean ± SD in μg/g.

Statistical analysis

The data were based on three replicates and subjected to analysis of variance. Standard errors of each individual nutrient of the samples were computed, and variations among the species were evaluated by least significance difference (LSD) at 5% level of probability ($P = 0.05$). Data analysis was conducted using the SAS Statistical Computer Package.

RESULTS AND DISCUSSION

From the study, zinc, copper and cadmium were present in all plant species examined. Manganese was present in all species except *V. amygdalina*. Iron was found in all except five species (82%), while nickel was (rather rare) detected in only eight of the plant species (30%) [Table 2].

The iron content found in all the plant species examined was generally relatively high (20-753 μg/g), with the three highest concentrations found in *O. canum* 8, *C. anisata* and *R. vomitoria*, respectively. The maximum permissible level (MPL) of iron is 1000 μg/day.[6] In this study, however, majority of the plant species examined (60%) had iron

Table 1: List of experimental plants used and their voucher numbers

Species	Family	Common use	Formulation	Voucher number
Alchornea cordifolia	Euphorbiaceae	Septicaemia	Decoction	UGB3708
Boerhavia diffusa	Nyctaginaceae	Fevers	Infusion	UGB3808
Cassia siamea	Caesalpiniaceae	Pains	Decoction	UGB4308
Cinnamomum zeylanicum	Lauraceae	Dyspepsia	Decoction	UGB4408
Clausena anisata	Rutaceae	Diabetes	Decoction	UGB4508
Desmodium adscendens	Papilionaceae	Jaundice	Decoction	UGB4608
Gymnema sylvestre	Asclepidiaceae	Diabetes	Decoction	UGB4708
Heliotropium indicum	Boraginaceae	convulsion	Decoction	UGB5308
Jatropha gossypifolia	Euphorbiaceae	Migraine	Decoction	UGB5408
Lippia multiflora (*Attebubu*)	Verbenaceae	Hypertension	Infusion	UGB5508
Lippia multiflora (*Kasoa*)	Verbebaceae	Hypertension	Infusion	UGB6008
Lippia multiflora (*Kadjebi*)	Verbenaceae	Hypertension	Infusion	UGB6108
Ocimum basilicum (*ABF017*)	Lamiaceae	Flatulence	Infusion	UGB6208
Ocimum basilicum (*ABF042*)	Lamiaceae	Flatulence	Infusion	UGB6308
Ocimum basilicum (2)	Lamiaceae	Flatulence	Infusion	UGB6808
Ocimum canum (8)	Lamiaceae	Flatulence	Infusion	UGB6908
Ocimum gratissimum	Lamiaceae	Flatulence	Infusion	UGB7408
Ocimum sanctum (1)	Lamiaceae	Flatulence	Infusion	UGB7508
Ocimum sanctum (9)	Lamiaceae	Flatulence	Infusion	UGB7608
Pegularia daemia	Asclepiadaceae	Pneumonia	Decoction	UGB7708
Phyllanthus amarus	Euphorbiaceae	Thrush	Decoction	UGB7808
Rauwolfia vomitoria	Apocynaceae	Insomnia	Decoction	UGB7908
Turraea heterophylla	Meliaceae	Impotence	Decoction	UGB8008
Vernonia amygdalina	Asteraceae	Diabetes	Decoction	UGB8108
Vinca roseus	Apocynaceae	Jaundice	Decoction	UGB8208
Voacanga africana	Apocynaceae	Dental caries	Decoction	UGB8308
Zanthoxylum xanthoxyloides	Rutaceae	Impotence	Decoction	UGB8708

Table 2: Concentrations of heavy metals present in the medicinal plants

Species	Fe	Zn	Mn	Cu	Ni	Cd
A. cordifolia	33.0 ± 0.002	46.5 ± 0.002	645.0 ± 0.05	11.5 ± 0.000	nd	35.5 ± 0.007
B. diffusa	358.5 ± 0.024	43.5 ± 0.001	14.5 ± 0.002	10.5 ± 0.000	nd	37.5 ± 0.004
C. siamea	156.0 ± 0.005	47.0 ± 0.003	4.0 ± 0.001	11.5 ± 0.000	16.5 ± 0.005	30.0 ± 0.009
C. zeylanicum	nd	46.5 ± 0.003	233.5 ± 0.011	14.5 ± 0.000	nd	42.5 ± 0.003
C. anisata	639.5 ± 0.012	495 ± 0.002	64.5 ± 0.002	8 ± 0.001	14.0 ± 0.003	28.5 ± 0.006
D. adscendens	247.0 ± 0.008	164.5 ± 0.005	35.0 ± 0.001	63.5 ± 0.002	nd	50.0 ± 0.005
G. sylvestre	105.0 ± 0.001	65.5 ± 0.002	1190 ± 0.024	86.5 ± 0.001	25.0 ± 0.012	53.0 ± 0.003
H. indicum	220.0 ± 0.006	76.5 ± 0.001	26.0 ± 0.002	50.2 ± 0.001	13.5 ± 0.002	28.5 ± 0.009
J. gossypifolia	135.5 ± 0.003	56.0 ± 0.002	55.0 ± 0.002	3.5 ± 0.000	nd	35.5 ± 0.002
L.multiflora (Attebubu)	89.5 ± 0.002	45.0 ± 0.005	58.5 ± 0.001	13 ± 0.001	nd	58.0 ± 0.005
L. multiflora (Kasoa)	nd	45.0 ± 0.004	31.0 ± 0.202	8.5 ± 0.001	nd	59.0 ± 0.007
L.multiflora (Kadjebi)	53.0 ± 0.003	57.5 ± 0.004	30.0 ± 0.002	44 ± 0.001	14.0 ± 0.010	22.5 ± 0.004
O.basilicum (ABF017)	20.0 ± 0.005	101.5 ± 0.006	65.0 ± 0.001	24.5 ± 0.001	nd	49.5 ± 0.002
O.basilicum (ABF042)	nd	80.5 ± 0.003	14.5 ± 0.001	17 ± 0.001	nd	38.0 ± 0.005
O. basilicum2	238.5 ± 0.332	81.5 ± 0.001	74.5 ± 0.001	28 ± 0.001	36.5 ± 0.000	32.0 ± 0.004
O. canum (8)	753.0 ± 0.007	50.5 ± 0.002	49 ± 0.001	15.5 ± 0.001	nd	43.5 ± 0.003
O. gratissimum	73.5 ± 0.004	100.5 ± 0.006	33.5 ± 0.001	18 ± 0.001	23.0 ± 0.013	46.5 ± 0.011
O. sanctum (1)	nd	122.5 ± 0.004	5.0 ± 0.002	22.5 ± 0.002	nd	47.0 ± 0.011
O. sanctum (9)	148.0 ± 0.005	133 ± 0.002	27.5 ± 0.001	27 ± 0.001	nd	51.5 ± 0.001
P. daemia	470.5 ± 0.014	63.5 ± 0.005	102 ± 0.001	114.5 ± 0.008	nd	26.5 ± 0.012
P. amarus	127.5 ± 0.001	80.5 ± 0.001	49.5 ± 0.001	44.5 ± 0.001	nd	27.5 ± 0.009
R. vomitoria	574.0 ± 0.003	47.5 ± 0.001	1455 ± 0.014	9.35 ± 0.000	nd	46.5 ± 0.014
T. heterophylla	391.0 ± 0.013	66.5 ± 004	23.5 ± 0.001	15.5 ± 0.001	nd	43.5 ± 0.002
V. amygdalina (1)	130.5 ± 0.010	58.5 ± 0.002	nd	12.5 ± 0.001	nd	44.5 ± 0.008
V. rosea	84.5 ± 007	98.5 ± 0.002	28.5 ± 0.002	17.5 ± 0.001	3.5 ± 0.000	39.5 ± 0.004
V. Africana	193.0 ± 0.005	70.5 ± 0.003	556 ± 0.010	25 ± 0.000	nd	29.5 ± 0.004
Z. xanthoxyloides	nd	48.5 ± 0.002	54.5 ± 0.039	36 ± 0.00	nd	48.0 ± 0.012
LSD (0.05)	0.183	0.009	0.039	0.005	0.012	0.020

Data are Mean ± SD (μg/g) of n=3. LSD (0.05) values are indicated at the bottom; nd = below detection limit

content above the maximum permissible level per 10 g daily dose of plant material or its equivalent formulation. Iron salts have an astringent action resulting in irritation of the gastrointestinal mucosa, which gives rise to gastric discomfort, nausea, vomiting and diarrhea or constipation.[7,8] Therefore, the presence of these symptoms commonly associated with the intake of some medicinal plants may be due to iron toxicity.

Zinc content ranged from 43.5 μg/g in *B. diffusa* to 495.0 μg/g in *C. anisata*. Zinc is a component of many metalloenzymes, especially some enzymes which play a central role in nucleic acid metabolism.[9] Zinc is also a membrane stabilizer and a stimulator of the immune response.[10] Manifestations of acute zinc poisoning include nausea, vomiting, diarrhea, fever and lethargy.[7] The estimated safe and adequate daily intake of zinc is between 10,000 and 20,000 μg/day.[6] The zinc levels per 10 g of plant species were not more than 4950 μg, hence lower than the maximum permissible level and regarded as safe.

Manganese content was disproportionately very high in only a few species, including *R. vomitoria* (1455 μg/g) followed by *G. sylvestre* (1190 μg/g), *A. cordifolia* (645 μg/g) and *V. africana* (556 μg/g). The estimated safe and adequate daily dietary intake of manganese in adults is 11,000 μg/day.[11] Therefore, most of the plant species examined (93%) can be said to have acceptable manganese content. Deficiency of manganese in humans may lead to immunodeficiency disorder, rheumatic arthritis in adults, disorder of bony cartilaginous growth in infants, as well as myocardial infarction and other cardiovascular diseases.[12]

Copper content was variable among the plant species, ranging from 8.0 to 114.5 μg/g, with *G. sylvestre* recording the highest amount. Copper is essential to the human body since it forms a component of many enzyme systems, such as cytochrome oxidase, lysyl oxidase and ceruloplasmin, an iron-oxidizing enzyme in blood. The observation of anemia in copper deficiency may probably be related to its role in facilitating iron absorption and in the incorporation of iron in hemoglobin.[6] However, copper could be toxic depending on the dose and duration of exposure.[7] The maximum permissible level (MPL) of copper is 12,000 μg/day.[6] Therefore, the suggested average intake of about 10 g of plant material or its equivalent formulation gives a maximum of 1145 μg of copper per day.[4] This implies that the 27 medicinal plants evaluated contained safe levels of copper.

The MPL of nickel is 100 μg/day.[10] Although nickel was

Table 3: Comparison of the maximum permissible levels and maximum contents of the heavy metals assessed in the plant species

	Fe	Zn	Mn	Cu	Ni	Cd
MPL (μg/g)	1000	20000	11000	12000	100	30
Maximum content per daily dose (μg/g)	7530	4950	11900	1145	365	59
No. of plant species below MPL	11 (40)	27 (100)	25 (93)	27 (100)	20 (74)	5 (19)
No. of plant species above MPL	16 (60)	0 (0)	2 (7)	0 (0)	7 (26)	21 (81)

*Figures in parentheses are percentages

present in only eight species, all except *V. rosea* had nickel content higher than the permissible level. This however constitutes only 26%; the majority (74%) had nickel content within acceptable limits. Nickel exerts a potent toxic effect on peripheral tissues and on the reproductive system.[10] It also causes dose-related decreases in bone marrow cellularity and in granulocytomacrophage and pluripotent stem cell proliferative responses.

Cadmium was also found in all the plant species, and its concentration ranged from 22.5 μg/g in *L. multiflora (Kadjebi)* to 59.0 μg/g in *L. multiflora (Kasoa)*. Cadmium is a nonessential trace element with uncertain direct functions in both plants and humans.[13] It is however reported that the lowest level of cadmium which can cause yield reduction in plants is 5 to 30 μg/g, and the maximum acceptable concentration for foodstuff is about 1 μg/g.[14] The results of this study indicated that about 80% of the plant species had cadmium content above 30 μg/g, which is essential for improved yield.

The overall results indicated clearly that heavy metals are present in Ghanaian medicinal plants and that the contents of these metals except iron were within acceptable and safe limits [Table 3]. Therefore, herbal formulations of these plant species can also be beneficial sources of appropriate and essential trace elements, though care must be taken to avoid iron toxicity, especially in higher doses.

CONCLUSIONS

Most of the plant species contained safe levels of the heavy metals analyzed and hence may have no adverse effects normally associated with heavy metal toxicity on people who patronize these products for their health needs.

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