

Original Article

## QUALITY ASSESSMENT FOR THE PRESENCE OF HEAVY METALS IN HERBAL MATERIALS FROM THE MARKETS OF CHENNAI, INDIA

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### ABSTRACT

**Objective:** To assess the quality of herbal materials for the presence of heavy metals.

**Methods:** Herbal materials of around 49 samples from Chennai markets were procured and analysed for the presence of metals like Copper (Cu), Calcium (Ca), Cobalt (Co), Sodium (Na), Nickel (Ni), Magnesium (Mg), Manganese (Mn), Iron (Fe), Chromium (Cr) and Lead (Pb) using AAS, Shimadzu, AA 7000, Japan.

**Results:** The raw materials of the commercial herbal products were found to contain Manganese, Calcium and Magnesium at greater concentrations, when compared with the other elements analyzed.

**Conclusion:** The presence of the metals analyzed were found to be within permissible limits in accordance to the American Herbal Products Association (AHPA) and WHO standards. Although the study implies consumption of herbal materials are safe, periodical monitoring of the quality of the herbal materials is recommended.

**Keywords:** Herbal materials, Heavy metals, Quality Assessment, Atomic Absorption Spectroscopy.

### INTRODUCTION

Utilization of plants in medicine is widely followed throughout the world. Traditional medicine which includes Siddha, Ayurveda, Unani, Tibetan and Chinese medicine, use plants to control human ailments. India is not remorse in using plants in her medicinal system [1]. Over 2000 plants have been recommended by World Health Organization (WHO), based on their medicinal attributes [2]. India has officially recognized over 3000 plants for their medicinal value and nearly 6000 plants are used in India's traditional medical system [3]. However, the concern is about the safety of herbal drugs or raw materials which are freely available in the markets as over the counter (OTC) medicines.

The contaminants of the herbal raw materials or the finished products are widely reported as the major reason to lose the international market, thus affecting the economy. The safety concern is mostly due to the natural contaminants like microbes and heavy metals present in the environment which in turn find their way into the herbal materials. Herbal materials are defined as either whole plants or parts of medicinal plants in the crude state which include herbs, gums, resins and dry powders of herbs [4].

Earlier reports have indicated that herbal medicines contain toxic heavy metals as contaminants which can cause adverse effects like cancer, liver dysfunction, skin eruptions, lung disease, cerebral haemorrhage, alopecia etc. WHO has emphasized to ensure the quality control and safety of herbal products [5].

Metals such as iron, calcium, manganese, cobalt, copper, zinc, nickel, in trace amounts, are essential for human life, as growth supplements. However, large amount of heavy metal accumulation in human body get absorbed and form complexes with proteins, eventually leading to malfunctioning or death of the cells [6].

Non-essential metals such as lead, cadmium are toxic even in trace amounts while few metals (like Chromium and Arsenic) are considered as potential contaminants [7]. The aim of the present study is to ascertain the quality of herbal materials towards the presence of toxic or heavy metals sold in open markets of Chennai, India.

### MATERIALS AND METHODS

#### Sample Collection

A total of 49 raw materials of herbal products were procured from the local markets of Chennai, Tamil Nadu. The samples, belonging to 34 different families, were digested by wet digestion method. The procured material list consisting of vernacular name of the plant and the plant part used in the system of Siddha medicine in India along with its botanical name and family are provided in Table 1.

#### Analysis of Heavy metals

About 1 g of the sample was accurately weighed and dried in hot air oven at 120° C so as to remove the moisture content. The dried products were digested with Nitric acid (1%) and left at room temperature for 24 h. The digested samples were filtered through Whatman filter paper. The filtrate was used for the experiment [8].

The digested samples were analysed for the quantification of elements like Copper (Cu), Calcium (Ca), Cobalt (Co), Sodium (Na), Nickel (Ni), Magnesium (Mg), Manganese (Mn), Iron (Fe), Chromium (Cr) and Lead (Pb) using AAS, Shimadzu, AA 7000, Japan. Standard solutions of the respective metallic salts (1000 ppm) were used to obtain calibration curve. The operation condition for the acetylene gas flow rate was set to 1.5 L/min and vacuum pressure to 3.5 bar. The quantity of elements present in the herbal drugs was expressed as mean of the elemental concentration  $\pm$  S.D of three replicates.

### RESULTS AND DISCUSSION

A major part of total population in developing countries still uses folklore medicine obtained from plant resources due to its cost effectiveness and accessibility [1]. The safety and quality of herbal drugs have become a major distress for pharmaceutical industries [4]. The phytomedicines of plant species used in homeopathic system have been traced with the presence of Ca, Cr, Cu, Fe, Mg, Ca, K and Zn [9].

The raw materials of the herbal products studied showed the presence of the metals- manganese, calcium, magnesium, copper, lead, iron, nickel, chromium, cobalt and sodium.

The raw materials of the commercial herbal products were found to contain Manganese, Calcium and Magnesium at greater concentrations, when compared with the other elements analysed. The highest concentration of Mn was recorded in *Zingiber officinale*

(499.597±0.0062 ppm/g) while the lowest was recorded in *Tribulus terrestris* (0.8309±0.0006 ppm/g). Mn deficiency in human causes cardiovascular diseases, immunodeficiency disorders and rheumatic arthritis in adults [10].

**Table 1: List of Herbal materials, the part used in medicine, their scientific name and family**

S. No.	Vernacular name of the plant/ Part used in Siddha medicine	Botanical name	Family
1	Aadhathoda (leaf)	<i>Adhatoda vasica</i>	Acanthaceae
2	Aaduthinnapai (leaf)	<i>Aristolochia bracteolata</i>	Aristolochiaceae
3	Aalam pattai (bark)	<i>Arenga wightii</i>	Arecaceae
4	Amukkara (leaf)	<i>Withania somnifera</i>	Solanaceae
5	Arugampul (leaf)	<i>Cynodon dactylon</i>	Poaceae
6	Ashoka pattai (bark)	<i>Saraca asoca</i>	Fabaceae
7	Avarampoo (flower)	<i>Cassia auriculata</i>	Fabaceae
8	Boomi sakkarai kizhangu (tuber)	<i>Maerua arenaria</i>	Capparaceae
9	Chiriyangai (leaf)	<i>Andrographis paniculata</i> (a)	Acanthaceae
10	Chittharathai (rhizome)	<i>Alpinia galanga</i>	Zingiberaceae
11	Elumbu otti (leaf)	<i>Blepharis maderaspatensis</i>	Acanthaceae
12	Jaathikai (fruit)	<i>Myristica fragrans</i>	Myristicaceae
13	Kaasini keerai (leaf)	<i>Cichorium intybus</i>	Asteraceae
14	Kadukai (fruit)	<i>Terminalia chebula</i>	Combretaceae
15	Kandang kathiri (leaf)	<i>Solanum xanthocarpum</i>	Solanaceae
16	Karisalanganni (leaf)	<i>Eclipta prostrata</i>	Asteraceae
17	Karivepilai (leaf)	<i>Murraya koenigii</i>	Rutaceae
18	Kichili kizhangu (tuber)	<i>Kaempferia galanga</i>	Zingiberaceae
19	Korai kizhangu (tuber)	<i>Cyperus rotundus</i>	Cyperaceae
20	Kuppaimeni (whole plant)	<i>Acalypha indica</i>	Euphorbiaceae
21	Maasikai (gall)	<i>Quercus infectoria</i>	Fagaceae
22	Mudakarthan(leaf)	<i>Cardiospermum halicacabum</i>	Sapindaceae
23	Mukkaratai (leaf)	<i>Boerhavia diffusa</i>	Nyctaginaceae
24	Murungai pisin (gum)	<i>Moringa oleifera</i>	Moringaceae
25	Musumusukkai (leaf)	<i>Mukia maderaspatana</i>	Cucurbitaceae
26	Nannari (root)	<i>Hemidesmus indicus</i>	Asclepiadaceae
27	Veppilai (leaf)	<i>Azadirachta indica</i>	Meliaceae
28	Neermulli (leaf)	<i>Hygrophila auriculata</i>	Acanthaceae
29	Nerunjil (fruit)	<i>Tribulus terrestris</i>	Zygophyllaceae
30	Nilapanai kizhangu (tuber)	<i>Curculigo orchoides</i>	Hypoxidaceae
31	Nilavembu (leaf)	<i>Andrographis paniculata</i> (b)	Acanthaceae
32	Orithazh thamarai (whole plant)	<i>Viola odorata</i>	Violaceae
33	Pakarkai (fruit)	<i>Momordica charantia</i>	Cucurbitaceae
34	Poduthalai (whole plant)	<i>Phyllanthus nodiflora</i>	Verbanaceae
35	Punaikalli (leaf)	<i>Mucuna pruriens</i>	Fabaceae
36	Roja malar (corolla)	<i>Rosa L.</i>	Rosaceae
37	Seenthil (leaf)	<i>Tinospora cordifolia</i>	Menispermaceae
38	Sirukurinjan (leaf)	<i>Gymnema sylvestris</i>	Asclepiadaceae
39	Sukku (rhizome)	<i>Zingiber officinale</i>	Zingiberaceae
40	Thandrikkai (fruit)	<i>Terminalia bellerica</i>	Combretaceae
41	Thanneervittan kizhangu (tuber)	<i>Asparagus racemosus</i>	Asparagaceae
42	Thulasi (leaf)	<i>Ocimum sanctum</i>	Lamiaceae
43	Thumbai (whole plant)	<i>Leucas aspera</i>	Lamiaceae
44	Thuthuvalai (leaf)	<i>Solanum trilobatum</i>	Solanaceae
45	Vaazhai thandu (pith)	<i>Musa paradisiaca</i>	Musaceae
46	Vallarai (leaf)	<i>Centella asiatica</i>	Apiaceae
47	Vendayam (seed)	<i>Trigonella feonum graecum</i>	Fabaceae
48	Vettiver (root)	<i>Chrysopogon zizanioides</i>	Poaceae
49	Vishnu kiranti (whole plant)	<i>Evolvulus alsinoides</i>	Convolvulaceae

**Table 2: Presence of heavy metals in Herbal materials (In ppm/g)**

Species	Cobalt	Lead	Nickel	Sodium	Chromium
<i>Acalypha indica</i>	0.1467±0.01528	0.3891±0.0097	0.2703±0.0031	0.1929±0.0009	1.0276±0.0045
<i>Adhatoda vasica</i>	0.4753±0.00061	0.4159±0.0052	0.0543±0.004	0.0212±0.0005	1.1776±0.0043
<i>Alpinia galanga</i>	0.075±0.0002	0.239±0.0096	0.2695±0.0045	0.3003±0.001	0.0776±0.004
<i>Andrographis paniculata</i> (a)	0.1064±0.00564	0.4589±0.0096	0.2683±0.0019	0.0459±0.0008	1.278±0.0038
<i>Andrographis paniculata</i> (b)	0.0743±0.00503	0.459±0.0096	0.0348±0.0014	0.0151±0.0006	1.1754±0.0005
<i>Arenga wightii</i>	0.476±0.00656	0.4791±0.0098	0.3044±0.0046	0.0118±0.0008	1.1768±0.0025
<i>Aristolochia bracteolata</i>	0.1754±0.00055	0.129±0.0096	1.6862±0.0047	0.2824±0.0014	0.8275±0.0041
<i>Asparagus racemosus</i>	0.5774±0.00257	0.4092±0.0099	0.4234±0.0191	0.1962±0.0007	1.2038±0.0036
<i>Azadirachta indica</i>	0.2504±0.00072	0.239±0.0095	0.0532±0.0046	0.0697±0.0019	0
<i>Blepharis maderaspatensis</i>	0.0755±0.00333	0.4787±0.0097	0	0.1488±0.0011	0.9046±0.0041

<i>Boerhavia diffusa</i>	0.1499±0.00021	0.3324±0.0151	0.0861±0.0044	0.0135±0.0011	0.3526±0.0038
<i>Cardiospermum halicacabum</i>	0.1268±0.00197	0.469±0.0099	0.0334±0.0005	0.1327±0.0007	1.1031±0.0048
<i>Cassia auriculata</i>	0.0498±0.00027	0.159±0.0096	0.3697±0.0048	0.0792±0.0001	0
<i>Centella asiatica</i>	0.2253±0.00058	0.3587±0.0091	0.0371±0.0061	0.044±0.0011	0.7028±0.0036
<i>Chrysopogon zizanioides</i>	0.2052±0.00501	0.4694±0.0096	0.4208±0.0046	0.0182±0.0012	1.3521±0.0031
<i>Cichorium intybus</i>	0.1497±0.0007	0.2464±0.0057	0.0535±0.0044	0.0759±0.0011	0.1268±0.0027
<i>Curculigo orchioides</i>	0.4251±0.0022	0.4578±0.0078	0.3877±0.0045	0.0202±0.0008	1.2517±0.0025
<i>Cynodon dactylon</i>	0.4763±0.00513	0.4755±0.0049	0.1208±0.0046	0.0066±0.0006	1.1772±0.003
<i>Cyperus rotundus</i>	0.225±0.003	0.3674±0.0071	0.5016±0.0023	0.0732±0.001	0.5275±0.0038
<i>Eclipta prostrata</i>	0.1746±0.0024	0.007±0.0066	0.1698±0.0041	0.1861±0.0013	0.0274±0.0039
<i>Evolvulus alsinoides</i>	0.3371±0.01269	0.429±0.0095	0.4182±0.0016	0.0421±0.0005	1.2554±0.0047
<i>Gymnema sylvestre</i>	0.5756±0.0006	0.4289±0.0096	0.2172±0.0005	0.2779±0.0008	0.6778±0.0043
<i>Hemidesmu indicus</i>	0.3303±0.00551	0.4586±0.0096	0.0833±0.0034	0.3026±0.0008	1.2531±0.0048
<i>Hygrophila auriculata</i>	0.125±0.00025	0.2987±0.0091	0.2702±0.0052	0.1336±0.001	0.2058±0.0052
<i>Kaempferia galanga</i>	0.6057±0.00603	0.3984±0.0086	0.1413±0.0104	0.0363±0.0005	1.1529±0.0041
<i>Leucas aspera</i>	0.103±0.00608	6.049±0.0096	0.3359±0.0047	0.0343±0.0002	0.1767±0.002
<i>Maerua arenaria</i>	0.1747±0.00461	0.4692±0.0099	0.6537±0.0039	0.1021±0.0007	0.5772±0.003
<i>Momordica charantia</i>	0.1052±0.00473	0.4491±0.0097	0.0866±0.0033	0.1149±0.0009	1.3046±0.0042
<i>Moringa oleifera</i>	0.6256±0.00053	0.4489±0.0094	0.1593±0.0121	0.1386±0.0006	0.7062±0.0054
<i>Mucuna pruriens</i>	0.0523±0.00252	0.3966±0.0061	0.6349±0.0021	0.0987±0.0005	0.9273±0.004
<i>Mukia madarespatana</i>	0.0513±0.00325	0.2784±0.0086	0.1195±0.0043	0.1891±0.0015	0.4525±0.0038
<i>Murraya koenigii</i>	0.4068±0.00589	0.4488±0.0097	0.2073±0.0119	0.0858±0.0007	1.2776±0.004
<i>Musa paradisiaca</i>	0.2075±0.00736	0.4089±0.0096	0.3374±0.0036	0.2362±0.0005	1.2276±0.0042
<i>Myristica fragrans</i>	0.2052±0.00501	0.509±0.0096	0.0687±0.0017	0.0269±0.001	1.2552±0.005
<i>Ocimum sanctum</i>	0.4787±0.00403	0.4588±0.0097	0.2048±0.005	0.2015±0.0011	1.0775±0.0041
<i>Phylla nodiflora</i>	0.2567±0.00651	0.4094±0.0101	0.0361±0.003	0.1518±0.0006	1.152±0.0031
<i>Quercus infectoria</i>	0.1756±0.00072	0.4557±0.0049	0.1036±0.0031	0.1485±0.0005	1.0777±0.0042
<i>Rosa L.</i>	0.5001±0.00061	0.309±0.0096	0.1865±0.0056	0.1533±0.0004	1.2776±0.004
<i>Saraca asoca</i>	0.5778±0.00314	0.4489±0.0098	0.4843±0.0049	0.0197±0.0006	1.2277±0.0043
<i>Solanum trilobatum</i>	0.3295±0.00409	0.4393±0.01	0.237±0.0061	0.1257±0.0005	1.2775±0.0041
<i>Solanum xanthocarpum</i>	0.125±0.00015	0.2894±0.0096	0.0168±0.0003	0.1001±0.0009	0.1553±0.0046
<i>Terminalia belerica</i>	0.0261±0.00211	0.5288±0.0097	0.2373±0.0045	0.0898±0.0006	0.1281±0.0016
<i>Terminalia chebula</i>	0.1064±0.00553	0.449±0.0099	0.3201±0.0057	0.2446±0.0008	1.352±0.0032
<i>Tinospora cordifolia</i>	0.5514±0.00145	0.4089±0.0098	0.1343±0.0021	0.0437±0.0006	1.3055±0.0049
<i>Tribulus terrestris</i>	0.5254±0.00069	0.1892±0.0098	0.053±0.0027	0.0565±0.0008	0.9785±0.0053
<i>Trigonella feonum graecum</i>	0.0756±0.00125	0.4786±0.0089	0.0844±0.0031	0.0212±0.0006	1.1234±0.003
<i>Viola odorata</i>	0.2039±0.00699	0.4787±0.0097	0.0677±0.0011	0.1839±0.001	1.2521±0.0031
<i>Withania somnifera</i>	0.1093±0.00815	0.469±0.0096	0.3207±0.0047	0.096±0.0005	1.2522±0.003
<i>Zingiber officinale</i>	0.0742±0.00312	0.4488±0.0095	0.3097±0.0176	0.0081±0.0005	1.3272±0.003
<b>Permissible limits (AHPA/WHO)</b>	Yet to be established	10	10	-	2

Table 2 Continued

Species	Calcium	Copper	Iron	Magnesium	Manganese
<i>Acalypha indica</i>	285.474±0.005	47.651±0.0019	0.5834±0.0011	106.179±0.0008	5.00093±0.001
<i>Adhatoda vasica</i>	218.4032±0.0045	37.601±0.0017	0.9732±0.0008	107.969±0.0012	12.754±0.0007
<i>Alpinia galanga</i>	187.8591±0.003	0.7840±0.0017	0.9962±0.0009	106.0949±0.001	294.90±0.0008
<i>Andrographis paniculata (a)</i>	151.2051±0.0048	0.7678±0.0014	3.5413±0.0005	107.0791±0.001	82.296±0.0079
<i>Andrographis paniculata (b)</i>	132.7456±0.0039	35.502±0.0027	0.2364±0.0017	106.648±0.0011	4.6005±0.0011
<i>Arenga wightii</i>	152.66±0.0045	25.934±0.0017	1.0251±0.0009	106.985±0.0011	1.285±0.0005
<i>Aristolochia bracteolata</i>	164.5598±0.0042	0.2341±0.001	2.4868±0.0007	106.1583±0.0007	105.7011±0.0009
<i>Asparagus racemosus</i>	252.9877±0.004	2.9013±0.0016	0.8784±0.0011	108.653±0.0009	4.1007±0.0011
<i>Azadirachta indica</i>	125.4165±0.0033	2.1340±0.0016	2.339±0.0011	106.506±0.0009	53.301±0.0009
<i>Blepharis maderaspatensis</i>	266.1362±0.2284	7.6347±0.0013	0.9417±0.0012	105.432±0.0009	57.601±0.0009
<i>Boerhavia diffusa</i>	269.3731±0.0025	1.0846±0.0013	1.2569±0.001	108.068±0.0009	51.904±0.0066
<i>Cardiospermum halicacabum</i>	31.80263±0.0039	1.8345±0.0013	2.151±0.0011	107.206±0.0012	80.701±0.0009
<i>Cassia auriculata</i>	50.91603±0.0025	2.0677±0.0014	1.4119±0.0011	105.516±0.0008	88.600±0.0007
<i>Centella asiatica</i>	211.1446±0.0025	3.1674±0.0008	1.7347±0.0006	110.004±0.0005	151.60±0.0008
<i>Chrysopogon zizanioides</i>	211.8745±0.0047	1.8673±0.0018	4.1393±0.0013	108.137±0.0012	76.200±0.0016
<i>Cichorium intybus</i>	202.988±0.0032	1.5340±0.0008	2.7255±0.0006	112.011±0.0006	83.501±0.0009
<i>Curculigo orchioides</i>	245.6691±1.1526	51.351±0.0014	0.0416±0.0011	108.495±0.0016	1.3315±0.0009
<i>Cynodon dactylon</i>	92.6739±0.0046	1.8011±0.0018	0.0851±0.0008	109.337±0.0012	1.3468±0.0006
<i>Cyperus rotundus</i>	284.9887±0.0045	28.201±0.0015	0.2194±0.0009	108.411±0.0011	0.993±0.0006
<i>Eclipta prostrata</i>	298.7874±0.0025	1.7340±0.0008	3.4685±0.0008	111.305±0.0006	190.10±0.0008
<i>Evolvulus alsinoides</i>	236.5878±0.003	0.9178±0.0014	2.3801±0.0014	108.3164±0.001	142.20±0.0009
<i>Gymnema sylvestre</i>	124.5312±0.005	32.351±0.0018	0.532±0.0014	106.532±0.0009	2.68546±0.001
<i>Hemidesmus indicus</i>	217.4548±0.0046	1.9014±0.0016	2.0313±0.0011	107.595±0.0006	9.2312±0.0014
<i>Hygrophila auriculata</i>	216.0732±0.0024	0.6507±0.0006	0.546±0.0006	105.921±0.0008	53.1011±0.001
<i>Kaempferia galanga</i>	283.2172±0.0043	73.017±0.0013	0.4026±0.0009	103.474±0.0014	1.9387±0.0009
<i>Leucas aspera</i>	227.1456±0.0042	1.1511±0.0013	4.2348±0.0006	105.674±0.0008	110.70±0.0007
<i>Maerua arenaria</i>	69.7743±0.0049	27.303±0.0046	1.1418±0.0012	105.737±0.0011	45.200±0.0013
<i>Momordica charantia</i>	162.8173±0.0048	0.6676±0.0015	2.4917±0.0013	107.6483±0.001	51.600±0.0012

<i>Moringa oleifera</i>	77.5598±0.0045	37.501±0.0014	1.0496±0.001	107.322±0.001	13.739±0.0007
<i>Mucuna pruriens</i>	46.58817±0.0047	32.351±0.0015	0.1076±0.0008	107.484±0.0013	3.7078±0.0008
<i>Mukia madarespatana</i>	0.1733±0.0028	1.4670±0.0012	2.1729±0.001	112.105±0.0008	128.40±0.0007
<i>Murraya koenigii</i>	187.7744±0.0048	6.2511±0.0014	0.9532±0.0011	106.648±0.0008	62.900±0.0011
<i>Musa paradisiaca</i>	262.5032±0.0045	0.3547±0.0057	0.7204±0.0012	106.884±0.0011	26.0317±0.001
<i>Myristica fragrans</i>	55.08867±0.0048	5.1167±0.0027	0.4213±0.0012	105.074±0.0009	56.101±0.0009
<i>Ocimum sanctum</i>	199.702±0.0031	1.2034±0.0038	1.3942±0.0011	108.432±0.0009	149.500±0.001
<i>Phyla nodiflora</i>	224.5312±0.005	2.6345±0.0017	1.3585±0.0012	108.206±0.0009	2.016±0.0013
<i>Quercus infectoria</i>	21.70497±0.0043	34.351±0.0013	0.0074±0.001	108.474±0.0012	1.90787±0.001
<i>Rosa L.</i>	61.11713±0.0048	34.054±0.0051	0.926±0.0014	109.374±0.0011	1.5467±0.0013
<i>Saraca asoca</i>	167.9454±0.0036	2.9511±0.0017	0.2961±0.0013	46.2896±0.0016	3.0467±0.0013
<i>Solanum trilobatum</i>	84.21627±0.0031	10.017±0.0281	2.5189±0.0013	107.121±0.0008	125.40±0.0007
<i>Solanum xanthocarpum</i>	191.3164±0.003	1.3674±0.0017	1.0757±0.0007	105.568±0.0008	43.699±0.0017
<i>Terminalia bellerica</i>	245.2312±0.0039	44.1023±0.002	0.1919±0.0008	107.184±0.0017	3.4777±0.0009
<i>Terminalia chebula</i>	187.9597±0.004	3.3021±0.0019	0.7485±0.0016	108.105±0.0014	41.1012±0.001
<i>Tinospora cordifolia</i>	162.7734±0.004	0.93413±0.002	0.4508±0.0011	108.069±0.0009	2.7007±0.0011
<i>Tribulus terrestris</i>	123.4314±0.0044	37.784±0.0016	0.2044±0.0013	106.521±0.0013	0.8390±0.0006
<i>Trigonella feonum graecum</i>	200.517±0.0049	39.018±0.0016	2.8623±0.0015	108.507±0.0023	5.4546±0.0011
<i>Viola odorata</i>	215.2168±0.004	37.101±0.0013	0.5988±0.0009	106.984±0.0014	4.43140±0.001
<i>Withania somnifera</i>	237.6034±0.0036	34.817±0.0014	0.6819±0.0012	106.168±0.0015	12.985±0.0012
<i>Zingiber officinale</i>	203.8876±0.0031	0.9844±0.0014	0.8373±0.0012	107.542±0.0008	499.59±0.0062
<b>Permissible limits (AHPA/ WHO)</b>	-	40	Essential nutrients	-	Yet to be established

\*The results are expressed as mean±SD (ppm/g)'

Higher concentrations of Ca were recorded in *Eclipta prostrata* (298.7874±0.0025 ppm/g), *Acalypha indica* (285.4740±0.005 ppm/g) and *Cyperus rotundus* (284.9887±0.0045 ppm/g). The lowest concentration of Ca metal was detected in *Mukia madarespatana* (0.1733±0.0028 ppm/g). Ca accumulation in body helps in the metabolism of bones, blood clotting and muscle contraction [11]. *Mukia madarespatana* had the highest concentration of Mg with 112.056±0.0008 ppm/g and the lowest concentration was in that of *Saraca asoca* (46.2896±0.0016 ppm/g). This element helps in activation of the enzyme system in citric acid cycle [12]. Similarly, earlier reports related to metal analysis in the herbal cosmetic products showed Mg (2963±90 ppm/g) and Ca (2626±52.37 ppm/g) at maximum levels [13].

The maximum level of Cu metal was present in *Kaempferia galanga* (73.0178±0.0013 ppm/g). Symptoms of acute copper poisoning include salivation, epigastric pain, nausea, vomiting and diarrhoea, all of which are probably due to the irritant effect of copper on the gastrointestinal mucosa [14]. Jabeen et al [15], reported the range of copper content as 17.6 - 57.3 ppm content in 50 medicinal materials from India. The maximum concentrations of Pb and Fe were detected in *Leucas aspera* with 6.0490±0.0096 ppm/g and 4.2348±0.0006 ppm/g respectively. Lead is a toxic element to the human system [16] and it causes both acute and chronic poisoning in kidney, liver, vascular and immune system [15]. Haemoglobin possessing iron, enables the transport of oxygen from the lungs to tissues [17], the deficiency of which causes anemia in human beings. Similar results on the presence of Pb and Fe were reported in Nigerian herbal products [18]. *Aristolochia bracteolata* (1.6862±0.0047 ppm/g) has recorded the highest concentration of Ni. Excessive intake of Ni causes severe allergic reaction, bronchial asthma, dermatitis and eczema [20]. The maximum concentration of Cr was detected in *Chrysopogon zizanioides* (1.3521±0.0031 ppm/g). Trivalent Chromium plays a vital role in metabolic functions of the body while the hexavalent form is harmful to the human body [19]. The highest concentration of Co (0.6256±0.00053 ppm/g) was recorded in *Moringa oleifera*. According to Jabeen et al [15], Co was detected at concentration ranging from 3.41±0.60 µg/g to 11.26±0.30 µg/g for some herbal plants found in Pakistan. *Hemidesmus indicus* had the highest concentration of Na (0.3026±0.0008 ppm/g). However, complete absence of Cr was recorded in *Azadirachta indica* and *Cassia auriculata* whereas *Blepharis maderaspatensis* was devoid of Ni. The concentrations of different elements recorded in different herbal materials are listed in Table 2. The limitations on prescribed level of heavy metals in herbal material from different countries like Canada, China, Singapore, Malaysia, Korea and Thailand are already listed by WHO, 2007.

The accumulation of heavy metals in medicinal plants has been reported to be based on various factors such as climatic factors, plant species and air pollution, apart from other environmental factors [21]. The presence of metals in herbal drugs might also be due to phyto-accumulation [22] and other processes involved in formulation and storage of products.

#### CONCLUSION

Commercially available raw material of the herbal products is used in home remedies for common ailments, worldwide. In the present investigation, greater levels of Mn, Ca and Mg were detected when compared to the other elements. However, the presence of metals analysed were found to be within the permissible limits in accordance to the American Herbal Products Association (AHPA) and WHO standards. Although the study implies consumption of herbal materials are safe, periodical monitoring of the quality of the herbal materials is recommended.

#### CONFLICT OF INTEREST

No Conflict of Interest lies between Authors.

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