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ASSESSMENT OF HEAVY METAL LOAD IN MEDICINAL PLANTS COLLECTED FROM A MAJOR WHOLESALE MARKET OF INDIA

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ABSTRACT

Increased usage and demand of medicinal plants (MP) in recent times has consequently resulted in increased requirement of quality raw material. Reports of heavy metal contamination of MP has been a major cause of concern in this regard. Studies to determine the source and level of metal in MP are important to assess the risk to human health. The present study was conducted to determine the metal content of MP sold in a major Indian wholesale market- Khari Baoli. Samples of fifteen widely used MP were collected and analyzed for heavy metal load using atomic absorption spectrometer. Presence of heavy metals such as Cadmium (Cd), Lead (Pb), Zinc (Zn), Nickel (Ni), Copper (Cu) and Iron (Fe) was detected in MP samples. The highest concentrations detected were of Cd in *Anacyclus pyrethrum* (0.027 ± 0.011 ppm), Pb in *Swertia chirayita* (0.090 ± 0.025 ppm), Zn in *Stevia rebaudiana* (4.41 ± 0.00 ppm), Cu in *Piper longum* (1.031 ± 0 ppm), Ni and Fe in *Nardostachys jatamansi* (0.307 ± 0.192 ppm, 8.716 ± 0.386 ppm respectively). Heavy metals detected in all the test samples were within permissible limits set by the World Health Organization, thus ascertained to be fit for consumption. Potential health risk to humans posed by these metals was calculated using estimated daily intake (EDI) and target hazard quotient (THQ), and was found to be significant for Cd metal. Amongst the plants *Eclipta sp.* was ascertained to have a significant THQ for all the metals tested. The study confirms that MP raw materials need to be monitored regularly and consumed in moderation to reduce toxicity risk due to bioaccumulation.

KEY WORDS : AAS, Heavy metals, Medicinal Plants (MP)

INTRODUCTION

Medicinal plants (MP) represent a native rich natural heritage in India. Widely used in traditional medicinal systems like Ayurveda, Siddha and Unani, MP are also being acknowledged in recent times (Sen and Chakraborty, 2017). These are widely used in developing countries however, their popularity is rapidly growing in the west too. With an estimated domestic consumption of 80 billion annuallyand export of 110 billion (Goraya and Ved, 2017) the Indian MP market is estimated to grow at the rate of 16% annually and is estimated to reach 7 trillion by 2050 (Pandey *et al.*, 2013). In spite of huge economic relevance, trade of MP in India is disorganized, underestimated and unregulated (Semwal *et al.*, 2019). Its growth is further undermined by presence of heavy metals in the raw materials and ayurvedic products. Heavy metal contamination especially of iron, lead, mercury, arsenic, chromium and cadmium has been reported in MP (Moscow and Jothivenkatachalam, 2012; Teerthe and Kerur, 2015). This is a matter of serious concern for human health because of the associated problems of toxicity, persistence and bioaccumulation (Briffa *et al.*, 2020). On entry into the human body the metals interfere with the normal functioning of the vital organs like brain, liver, lungs, heart and kidney, and may cause diseases like hypertension, abdominal pain, cancer etc. (Ezeabara *et al.*,2014; Asiminicesei *et al.*, 2020). It becomes absolutely imperative, especially for the ayurvedic product consumers, to check for metal content in such remedies before consumption.

Presence of heavy metal in MP exports has emphasized the need to assess the possible source contamination and establish stringent standards. Contamination of MP can occur during cultivation, storage and processing. Increasing industrial and anthropogenic activities are significant contributing factors for increasing levels of heavy metals in MP (Sarma *et al.*, 2012). MP used in our Indian systems of medicine are mostly collected from the wild (Phondani *et al.*, 2016). These natural habitats are being contaminated because of increasing industrial activities and can result in accumulation of heavy metal in the tissues of MP (Asgari Lajayer *et al.*, 2017) and thereby in raw material and herbal products (Bolan *et al.*, 2017). In India, MP related trade is facing a serious challengebecause of increase in accumulation of heavy metalsin plant tissues (Tripathy *et al.*, 2015). Quality assessment of MP is a prerequisite for ensuring efficacy and safety of MP based formulations (WHO, 2003; Govindaraghavan and Sucher, 2015). In view of this, random assessment of the raw materials can help to identify the contaminated sites and would help to isolate the raw material generated at these sites from getting into MP derived products.

In India, MP are traded on a large scale across major cities like Mumbai, Delhi, Chennai and Tuticorin. Khari Baoli market in Delhi, is one of the biggest markets in South Asia, where raw material of more than 500 species of MP are traded. It is a huge market in terms of volume as well as value of the plants traded. The raw material is collected by local villagers and vendors collect it from villagers and is taken to the wholesale markets. Local ayurvedic practitioners, drug manufacturing companies or pharmaceutical industries purchase it from these wholesale markets for use in herbal formulations or it is exported. The present study was conducted to ascertainheavy metal load in raw material of fifteen MPtraded in Khari Baoli market. The tested MP include *Aegle marmelos, Anacyclus pyrethrum, Asparagus racemosus, Boerhaviadiffusa, Bacopa monnieri, Convolvulus pluricaulis, Eclipta sp., Gymnemasylvestre, Nardostachys jatamansi, Ocimum sp., Piper longum, Stevia rebaudiana, Swertia chirayita, Tinospora cordifolia and Withaniasomnifera*. These plants are well known for their medicinal value and are traded locally as well as exported for use in medicinal formulations (Table 1). EDI and THQ values were calculated to determine the toxicity risk posed by consumption of these MP.

MATERIALS AND METHODS

Sample collection and processing

Raw material (whole plant, root, leaves and fruit samples) of selected medicinal plants - *Aegle marmelos, Anacyclus pyrethrum, Asparagus racemosus, Boerhaviadiffusa, Bacopa monnieri, Convolvulus pluricaulis, Eclipta sp., Gymnemasylvestre, Nardostachysjatamansi, Ocimum sp., Piper longum, Stevia rebaudiana, Swertia chirayita, Tinospora cordifolia and Withaniasomnifera*were procured from Khari Baoli market, Delhi, in the form of whole plant, roots, stem and leaf powder depending on their specific medicinal value. Samples were oven dried at 60°C for 48 h and stored in airtight containers until further analysis.

Digestion of samples

One gram of oven dried plant material was mixed with concentrated nitric acid and perchloric acid in the ratio of 3:1. Samples were heated on a hot plate until a clear solution was obtained. Subsequently, after cooling the volume was raised to 50 ml with deionized water and mixed. Samples were then filtered through filter paper (Whatman No. 42).

AAS Analysis

Heavy metals content was assessed using Atomic Absorption Spectrophotometer (AA-6800 Shimadzu). Samples were prepared from dried plant material in triplicates for accuracy and precision of results. Standard stock solutions of 1000 ppm were diluted in range (1-10 ppm) and prepared for quantitative estimation of heavy metals.

Health Risk Assessment

Estimated daily intake of heavy metals

The health risk posed by metals can be assessed by calculating the estimated daily intake (EDI) The EDI of each of the heavy metals- Cadmium (Cd), Lead (Pb), Zinc (Zn), Nickel (Ni), Copper (Cu) and Iron (Fe) was estimated using the equation recommended by US EPA (2007):

$$EDI = \frac{IRxC}{W_{AB}}$$

Where IR refers to Ingestion rate, maximum and minimum of each heavy metal (Khare, 2008), C is the estimated concentration of heavy metal in the

MP sample, W_{AB} is the average Indian body weight (Male: 63.05 kg; Female: 52.6 kg).

Target Hazard Quotient (THQ)

The level of risk posed by heavy metal exposure is characterized by THQ estimations using the following equation:

$$THQ = \frac{EDI}{RfD}$$

Where C = estimated concentration of heavy metal in the MP sample; IR = ingestion rate (kg/day or l/day); RfD = reference dose (mg/kg) used as recommended by US EPA (2007); Cd: 0.001, Pb: 0.004, Zn:0.300, Ni: 0.02, Cu: 0.04 and Fe: 0.7.

Statistical analysis

Principal component analysis (PCA) and hierarchical clustering analysis (HCA) was performed using estimated concentration of heavy metals in the MP samples. For PCA unit variance scaling is applied to rows; SVD (Singular Value Decomposition) with imputation is used to calculate principal components. X and Y axis show principal component 1 and principal component 2 that explain 93.9% and 5.7% of the total variance, respectively. N = 6 data points. This means that all variables are scaled so that they will be equally important (variance = 1) when finding the components. As a result, a difference of 1 means that the values are one standard deviation away from each other, or from the average of the row if rows are centered). In HCA,clustering distance is euclidean, complete-linkage clustering method has been applied, further tree ordering is higher median value where first arranged. Both the statistical analyses were performed using online tool Clustvis (https://biit.cs.ut.ee/clustvis/).

RESULTS AND DISCUSSION

Heavy metal concentration in MP samples

Presence of varying concentrations of heavy metals such as lead, chromium, cadmium, nickel, copper and iron were observed in MP samples (Table 2). Highest concentration of Cd was found in *Anacyclus pyrethrum* (0.027 ± 0.011 ppm) while least was found in *Stevia rebaudiana* (0.005 ± 0.002 ppm). However, in all of the samples analyzed Cd concentration was found within permissible limits, which is 0.3 ppm as recommended by WHO (2007). Presence of Cd has also been reported in medicinal plants collected from various parts of India (Kulhari *et al.*, 2013; Sadhu *et al.*, 2015; Kalpana *et al.*, 2018; Kumar *et al.*,2018). Potential sources of Cd in soil and plants include phosphate fertilizers, non-ferrous smelters, lead and zinc mines, sewage sludge and combustion of fossil fuels (Du *et al.*, 2020). Cd exposure is known to cause cardiovascular diseases and impair renal function (Gao *et al.*, 2018).

Presence of Pb has been previously reported in MP in India (Kumar *et al.*, 2018; Nath *et al.*, 2020). Pb poisoning due to consumption of contaminated ayurvedic medicines has also been reported (Mehta *et al.*, 2016). Pb is highly dangerous and toxic for plants, animals and other microorganisms and is known to accumulate in the environment due to excessive use of fertilizers, fuel consumption and deposition of sewage sludge. It enters the body through oral ingestion, inhalation and skin absorption and affects the cardiovascular, nervous, renal and reproductive systems (Kushwaha *et al.*, 2018). In the present study, Pb content was detected in the range of 0.014 ± 0.00 to 0.090 ± 0.025 ppm, which is quite low, compared to the permissible limit of 10 ppm (WHO 2007). Maximum concentration of Pbat 0.090 ± 0.025 ppm, was detected in *Swertia chirayita*.

Zn is an essential element required for normal body growth and brain development and as per the WHOguidelines, the permissible limit for Zn is 50 ppm. In all the samples tested in this study, Zn concentrations ranged from 0.469 ± 0.035 to 4.41 ± 0 ppm and were within the permissible limit. Ni is a known carcinogen that affects lungs and also causes heart disorders (Denkhaus and Salnikow, 2002). Anthropogenic activities are known sources that cause an increase in Ni concentration in plants. In our samples, the highest concentration of Ni was 0.307 ± 0.192 ppm andwas detected in *Nardostachys jatamansi*. High Cu concentration in humans can cause nausea, vomiting, liver and neurodegenerative disorder. Cu concentrations in the samples tested ranged from 0.115 ± 0.067 to 1.031 ± 0 ppm. Highest concentration was found in *Piper longum* (1.031 ± 0 ppm). However, all samples were within permissible limitsof 0.5 to 1 ppm. Fe is a constituent of enzymes and pigments, and plays an important role in metabolism in plants as well as animals. However, it can be toxic, if consumed beyond the permissible limits. All the samples tested in the present study had Fe content within the permissible limit of 15 ppm (WHO, 2007). Highest

Fe concentration was found in *Nardostachys jatamansi* (8.716 ± 0.386 ppm).

Health Risk Assessment

Estimated daily intake of heavy metals

EDI value of Cd, in *Aegle marmelos*, *Asparagus racemosus*, *Convolvulus pluricaulis*, *Gymnemasylvestre*, *Nardostachys jatamansi* and in *Gymnemasylvestre* were lower than RfD value (Table 3). In *Ecliptaspp* all the six heavy metals (Cd, Pb, Zn, Ni, Cu, and Fe) were estimated to have lower RfD. The THQ for Cd from *Aegle marmelos*, *Asparagus racemosus*, *Convolvulus pluricaulis*, *Gymnemasylvestre*, *Nardostachys jatamansi* plants indicated high health risk as the THQ value was higher than 1. Similarly, in case of Pd in *Gymnemasylvestre* and six heavy metals (Cd, Pb, Zn, Ni, Cu, and Fe) in *Eclipta* spp were estimated to have more than 1 THQ indicating health risk associated with consumption of these MP.

Multivariate analysis

Multivariate analysis such as hierarchical cluster analysis (HCA) and principal component analysis (PCA) were performed to identify the probable sources of contamination of MP raw material. Based on the clustering algorithm four clusters were identified with each cluster (group) distinct from each other and the metals (objects) within each cluster were broadly similar to each other (Fig. 1).

In HCA, five clusters were defined based on the clustering analysis. *Piper longum*, *Stevia rebaudiana* were in first cluster and second cluster had *Bacopa monnieri*, *Anacyclus pyrethrum*, *Nardostachys jatamansi*. Third cluster contained four plants - *Swertia chirayita*, *Boerhaviadiffusa*, *Eclipta* spp,

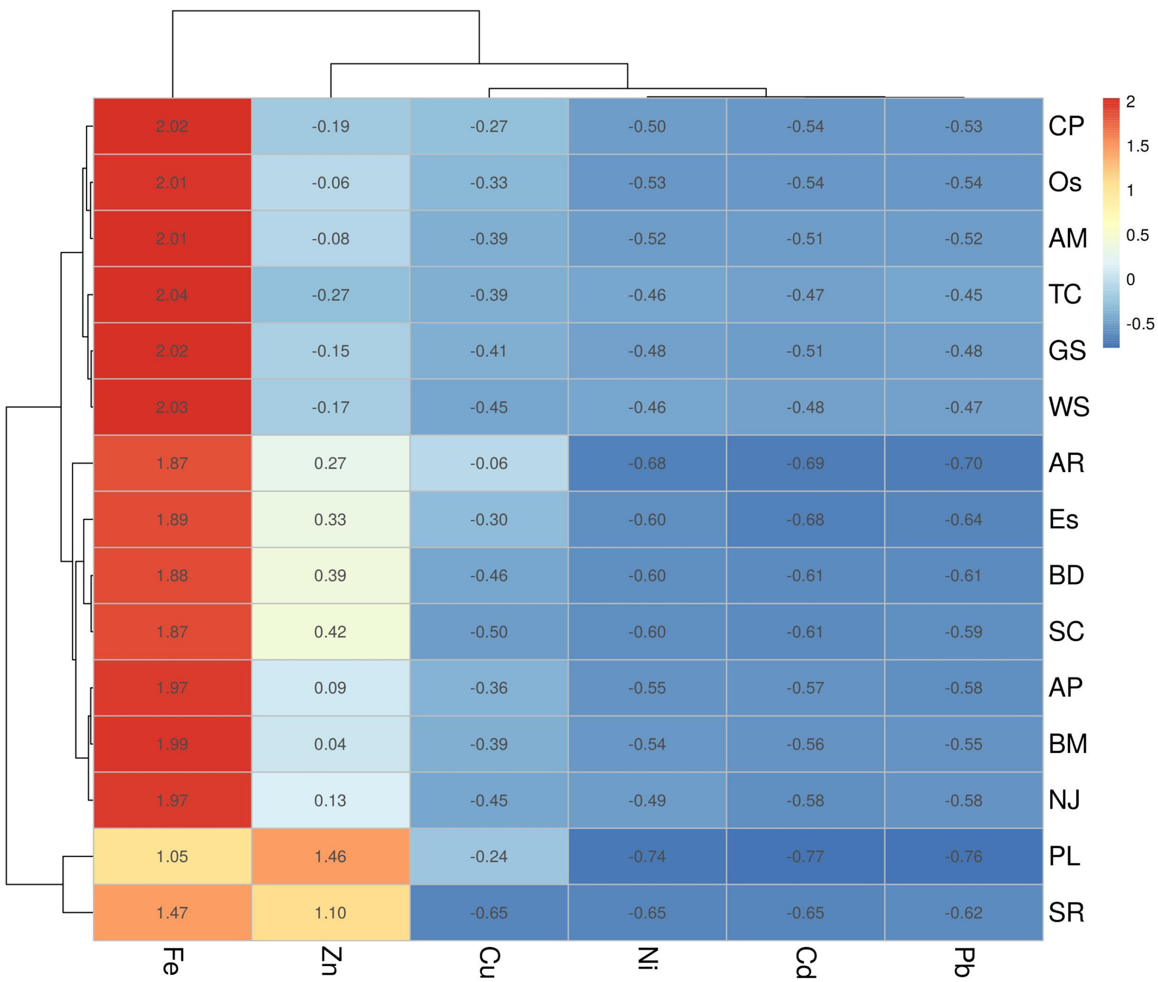

Fig. 1. Hierarchical clustering analysis (HCA), of all 15 Medicinal plants containing heavy metals. Abbreviations: *Aegle marmelos*- AM, *Anacyclus pyrethrum*- AP, *Asparagus racemosus*- AR, *Boerhaviadiffusa*- BD, *Bacopa monnieri*- BM, *Convolvulus pluricaulis*- CP, *Eclipta sp.*- Es, *Gymnemasylvestre*- GS, *Nardostachysjatamansi*- NJ, *Ocimum sp.*- Os, *Piper longum*- PL, *Stevia rebaudiana*- SR, *Swertia chirayita* - SC, *Tinospora cordifolia*- TC *and Withaniasomnifera*- WS.

Table 1. Details of medicinal plants used in the study

S. No	Scientific name	Common name	Family	Part(s) used	Medicinal properties	References
1	*Aegle marmelos*	Bael/Bel	Rutaceae	Leaves/ Fruit	Hypoglycemic, anti-inflammatory, antimicrobial, anticancer, chemoprotective, chemopreventive and anti-oxidative activity.	(Manandhar *et al.*,2018)
2	*Anacyclus pyrethrum*	Akarkara	Asteraceae	Root	Anti-rheumatic, analgesic, aphrodisiac, stimulates salivary glands, and acts as rubefacient. Anacyclin in roots acts as a stimulant of the nervous system, antibacterial and anti-inflammatory.	(Usmani *et al.*, 2016)
3	*Asparagus racemosus*	Shatavari	Liliaceae	Root (rhizome)	Antihepatotoxic, immunomodulator, immunoadjuvant, antilithiatic effect.	(Singh *et al.*, 2018)
4	*Bacopa monnieri*	Brahmi	Plantaginaceae	Whole plant, Leaves	Improves memory capacity, intellectual activity and enhances immune function	(Aguiar and Borowski, 2013)
5	*Boerhaavia-diffusa*	Punaranava	Nyctaginaceae	Whole plant	Antifibrinolytic, hepatoprotective immunomodulatory	(Murugan K *et al.* 2020)
6	*Convolvulus pluricaulis*	Shankh-pushpi	Convolvu-laceae	Whole plant Roots, Seeds,	Anti-inflammatory, anticancer, hypolipidemic, analgesic.	(Balkrishna *et al.*, 2020)
7	*Eclipta* spp	Bhringraj	Asteraceae	Whole plant, Seeds	Hepatoprotective, hypoglycaemic, anti-inflammatory, neuroprotective, antimicrobial, hypolipidemic.	(Feng *et al.*, 2019)
8	*Gymnema-sylvestre*	Gudmar	Asclepiadaceae	Whole plant	Treatment of obesity, arthritis, hyperlipidemia, parkinsonia, hyperchlorestimea. Anti-inflammatory, antimicrobial, anti-cancerous.	(Khan *et al.*, 2019)
9	*Nardostachys jatamansi*	Jatamansi	Valerianaceae	Root	Antimicrobial, antioxidant, hepatoprotective, cardioprotective, spasmolytic, bronchodilator. Treatment of insomnia, CNS disorders.	(Sahu *et al.*, 2016)
10	*Ocimum* spp.	Tulsi	Labiate	Whole plant, Leaves	Anticancer, antidiabetic, antifungal, antimicrobial, cardioprotective, analgesic, antispasmodic,anxiolytic, anti-inflammatory, immunostimulatory.	(Cohen, 2014)
11	*Piper longum*	Piplamool	Piperaceae	Root, Fruit	Anti-inflammatory, analgesic, antioxidant, antimicrobial, anticancer, antidiabetic.	(Yadav *et al.*, 2020)
12	*Stevia rebaudiana*	Sweet leaf	Asteraceae	Leaves	Sweetening agent, antioxidant, anti-inflammatory, immunodulatory, antiviral, gastroprotective, anticancerous.	(Momtazi-Borojeni *et al.*, 2017)
13	*Swertia chirayita*	Chiraita	Gentianaceae	Whole plant, Leaves, Stem,	Hepatoprotective, hypoglycemic, antimalarial, antimicrobial, cardiac stimulant, anti-inflammatory.	(Kumar and Van Staden 2016)
14	*Tinospora cordifolia*	Guduchi	Menisper-maceae	Stem	Treatment of fever, diabetes, dyspepsia, jaundice, urinary problems, skin diseases, chronic diarrhoea, dysentery, heart diseases, leprosy, helminthiasis, rheumatoid arthritis.	(Sharma *et al.*, 2019)
15	*Withanias-omnifera*	Ashwa-gandha	Solanaceae	Root	Anti-inflammatory, Antitumor, Antistress, Antioxidant, Hematopoietic effect.	(Mukherjee *et al.*, 2021)

Table 2: Heavy metals concentrations (expressed in ppm) in tested samples determined by AAS.

Plant name	Part used	Cd	Pb	Zn	Ni	Cu	Fe
Aegle marmelos	Leaves	0.018 ± 0.016	ND	0.869 ± 0.194	ND	0.250 ± 0.007	4.974 ± 3.151
Anacyclus pyrethrum	Stem	0.027 ± 0.011	ND	2.067 ± 1.276	0.094 ± 0.060	0.692 ± 0.169	7.876 ± 0.348
Asparagus racemosus	Root	0.024 ± 0.007	0.014 ± 0.00	0.852 ± 0.219	0.031 ± 0.026	0.568 ± 0.00	2.231 ± 1.292
Bacopa monnieri	Whole plant	0.007 ± 0.003	0.020 ± 0.006	1.850 ± 0.117	0.071 ± ± 0.037	0.533 ± 0.066	7.839 ± 2.607
Boerhaviadiffusa	Root	0.024 ± 0.009	0.027 ± 0.00	1.934 ± 0.755	0.053 ± 0.011	0.321 ± 0.161	4.804 ± 1.867
Convolvulus pluricaulis	Whole plant	0.018 ± 0.006	0.027 ± 0.006	0.469 ± 0.035	0.070 ± 0.044	0.357 ± 0.047	3.299± 0.777
Ecliptaspp	Whole plant	0.023 ± 0.005	0.065 ± 0.024	1.305 ± 0.052	0.121 ± 0.019	0.503 ± 0.022	3.284 ± 1.400
Gymnemasylvestre	Leaves	0.015 ± 0.008	0.064 ± 0.043	0.777 ± 0.110	0.072 ± 0.022	0.229 ± 0.029	5.401 ± 0.446
Nardostachysjatamansi	Root	0.023 ± 0.009	0.024 ± 0.007	2.429 ± 0.933	0.307 ± 0.192	0.457 ± 0.104	8.716 ± 0.386
Ocimumspp	Leaves	0.02 ± 0.009	ND	1.192 ± 0.108	0.036 ± 0.006	0.522± 0.029	6.319 ± 0.771
Piper longum	Stem	0.017 ± 0.007	0.044 ± 0.017	4.235 ± 0.671	0.078 ± 0.044	1.031± 0.00	3.461 ± 0.045
Stevia rebaudiana	Leaves	0.005 ± 0.002	0.088 ± 0.00	4.41 ± 0.00	ND	ND	5.338 ± 0.848
Swertia chirayita	Whole plant	0.016 ± 0.008	0.090 ± 0.025	3.077 ± 0.598	0.068 ± 0.021	0.364 ± 0.129	7.384 ± 2.193
Tinospora cordifolia	Whole plant	0.011 ± 0.002	0.065 ± 0.005	0.663 ± 0.020	0.047 ± 0.006	0.270 ± 0.185	8.193 ± 0.742
Withaniasomnifera	Powder	0.006 ± 0.005	0.028 ± 0.009	0.969 ± 0.243	0.077 ± 0.029	0.115 ± 0.067	7.729 ± 3.547

Results are mean of three replicates ± standard deviation; i,e n = 3 ± SD; ND = Non Detectable

Asparagus racemosus. While *Withaniasomnifera, Gymnemasylvestre, Tinospora cordifolia* were present in fourth cluster, fifth cluster contained *Convolvulus pluricaulis, Ocimum* sp. and *Aegle marmelos.* Among all the metals, concentration of Fe was highest among all the plants. However, its concentrations in cluster 1 were comparatively lower than other clusters. On the contrary, contraction of Zn was highest in the members of cluster 1 as compared to other clusters. Concentration of other metals like Cd, Pb, Ni or Cu did not show any bias among different plants. Cluster 3rdhad lower Fe concentration than 2nd, 4th and 5th cluster while Cluster 4th had the highest Fe concentration than all the other clusters.

All the clusters had higher concentration of Fe metals in them. Cluster 2nd shows slightly lower concentration of Fe as compared to other clusters. Cluster 2nd was enriched in Zn, whereas Ni,Cd, and Pd had lowest concentration in cluster 3rd. Cluster 4th had higher Fe, moderate Zn, and lower concentration of Ni, Cd and Pd metals. PCA analysis revealed two principal components viz. PCA 1 had Fe and PCA 2 Ni, Cd and Pb (Fig. 2). Fe metal falls apart from other components (metals) or we can have the highest percentage variance, as compared to other metals. Ni, Cd, and Pd metals show least percentage variance among themselves.

Heavy metals were present in raw material of MPcollected from Khari Baoli market, however, these were within the prescribed limits of WHO and therefore deemed safe for consumption. Our study confirms that raw materials of MP available in the market have a low metal load. However, a significant THQ in some samples suggests potential health risk due to possibility of bioaccumulation and

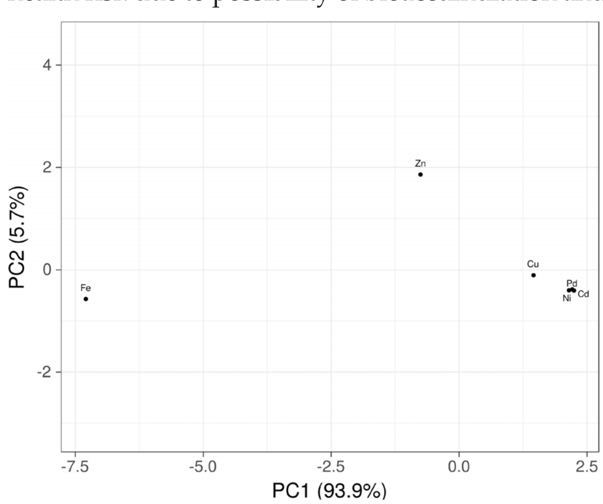

Fig. 2. Principal component analysis (PCA), to measure the variance of heavy metals were calculated.

Table 3. Average EDI (Male, female, and IR) and Average THQ (Male, female, and IR)of heavy metals through the consumption of MP in Indian population. The samples with THQ higher than 1 have been highlighted.

		Cd		Pd		Zn		Ni		Cu		Fe	
S.No	Plant name	EDI-Avg	THQ-Avg	EDI-Avg	THQ-Avg	EDI-Avg	THQ-Avg	EDI-Avg	THQ-Avg	EDI-Avg	THQ-Avg	EDI-Avg	THQ-Avg
1	*Aegle marmelos*	0.0014	1.4123	0	0	0.068	0.2273	0	0	0.02	0.49	0.39	0.5575
2	*Anacyclus pyrethrum*	0.0004	0.3531	0	0	0.027	0.0901	0.001	0.0615	0.009	0.226	0.1	0.1471
3	*Asparagus racemosus*	0.0019	1.8831	0.001	0.275	0.067	0.2228	0.002	0.1216	0.045	1.114	0.18	0.2501
4	*Bacopa monnieri*	0.0002	0.2441	7E-04	0.174	0.065	0.215	0.002	0.1238	0.019	0.465	0.27	0.3905
5	*Boerhavia diffusa*	0.0008	0.8369	9E-04	0.235	0.067	0.2248	0.002	0.0924	0.011	0.28	0.17	0.2393
6	*Convolvulus pluricaulis*	0.0014	1.4123	0.002	0.53	0.037	0.1227	0.005	0.2746	0.028	0.7	0.26	0.3698
7	*Eclipta* spp	0.0098	9.8251	0.028	6.942	0.557	1.8582	0.052	2.5844	0.215	5.372	1.4	2.0041
8	*Gymnema sylvestre*	0.001	1.0462	0.004	1.116	0.054	0.1806	0.005	0.2511	0.016	0.399	0.38	0.5381
9	*Nardostachys jatamansi*	0.001	1.0026	0.001	0.262	0.106	0.3529	0.013	0.6691	0.02	0.498	0.38	0.5428
10	*Ocimum* spp	0.0007	0.6974	0	0	0.042	0.1386	0.001	0.0628	0.018	0.455	0.22	0.3148
11	*Piper longum*	0.0006	0.5928	0.002	0.384	0.148	0.4923	0.003	0.136	0.036	0.899	0.12	0.1724
12	*Stevia rebaudiana*	0.0002	0.1744	0.003	0.767	0.154	0.5126	0	0	0	0	0.19	0.2659
13	*Swertia chirayita*	0.0006	0.5579	0.003	0.785	0.107	0.3577	0.002	0.1186	0.013	0.317	0.26	0.3678
14	*Tinospora cordifolia*	0.0009	0.8631	0.005	1.275	0.052	0.1734	0.004	0.1844	0.021	0.53	0.64	0.9183
15	*Withania somnifera*	0.0005	0.4708	0.002	0.549	0.076	0.2534	0.006	0.3021	0.009	0.226	0.61	0.8663

warrants regular monitoring and assessment.

CONCLUSION

Increasing consumption of medicinal plants-based formulations has resulted in increased demand for clean and safer MP. Consumption of heavy metal contaminated MP products affects human health and can be fatal. Therefore, it is essential to screen raw materials time to time and ascertain that heavy metal content in the raw material obtained from MP plant is under permissible limits. In the present study, content of several heavy metalswas tested in the raw materials from several plants, that were collected from a major market of Delhi was determined. Heavy metals were detected in the samples tested; however, these were within permissible limits and the samples were therefore found safe for consumption. Studies such as ours aims to ensure the confidence of the consumers and are important to ensure quality, safety and efficacy of MP.

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