DOI: 10.1007/s10967-007-0316-9 *Journal of Radioanalytical and Nuclear Chemistry, Vol. 271, No.3 (2007) 611–619*

Analysis of some Indian medicinal herbs by INAA

A. N. Garg,[1]* A. Kumar,[1] A. G. C. Nair,[2] A. V. R. Reddy[2]

[1] *Department of Chemistry, Indian Institute of Technology, Roorkee 247 667, India*
[2] *Radiochemistry Division, Bhabha Atomic Research Centre, Trombay, Mumbai 400 085, India*

(Received April 13, 2006)

Traditional Indian medicinal herbs, used for strengthening the body immune system, are rich source of many essential nutrient elements in bioavailable form. Instrumental neutron activation analysis (INAA) employing short (5 minutes) and long (14 hours and 3 days) reactor irradiation followed by high resolution gamma-ray spectrometry has been used for the determination of Al, Au, Ba, Br, Ca, Ce, Cl, Co, Cr, Cu, Eu, Fe, K, La, Mg, Mn, Na, P, Rb, Sb, Sc, Sm, Th, V and Zn in 15 medicinal herbs commonly used in Indian household for treatment of various ailments. viz. *C. rhombifolia* (Amaltas), *W. somnifera* (Ashwagandha), *P. corylifolia* (Bakuchi), *T. cordifolia* (Guduchi), *M. fragrans* (Jaiphal), *N. jatamansi* (Jatamansi), A. *paniculata* (Kalmegh), *H. anticlysentrica* (Kutaj), *T. chebula* (Laghu Haritaki), *S. racemosa* (Lodhra), *A. indica* (Neem), *V. negundo* (Nirgundi), *H. indicus* (Sariva), *A. calamus* (Vach) and *E. ribes* (Vidang). Several of herbs are enriched in Ca, Co, Cu, Mg, P, Fe, Mn and Zn, which play a vital role in biochemical and enzymatic processes. Jatamansi, often used as antibacterial, antipyretic and heart tonic is specially enriched in Co, Cr, Cu, Na, Mn, Fe, Rb and Zn. Also Guduchi and Laghu Haritaki are enriched in Ca and Mg, respectively. An attempt has been made to correlate elemental contents with the therapeutic importance of various herbs. Also our results for the participation in an Intercomparison Study of renewal of Pine Needles (SRM-1575a) from NIST, USA are presented.

Introduction

Ayurveda, the ancient Indian system of medicine prescribes the use of various plant parts such as leaves, roots, fruits and stem for curing a variety of ailments.[1–3] Several western scholars have pursued the analysis of Indian plants and herbs for their medicinal properties.[4,5] Most studies on medicinal plants pertain to their organic constituents viz. essential oils, glycosides, alkaloids, vitamins, antioxidant compounds, and their pharmacological activity together with toxic effects.[1,6] REIF and METZER[7] determined aflatoxins by HPLC after extraction using a mixture of methanol and water. However, scanty reports are available about their minor and trace element composition or mineral contents. It is now well recognized that many trace elements play a vital role for general well being as well as in the cure of diseases.[8,9] Iron deficiency or anemia is proven to have a non-stochastic correlation with iodine deficiency whereas an excess intake of bromine may cause health problems such as mental disturbance, dilated cardiomyopathy, uremia and lymphoma.[10] However, a direct linkage between an elemental content and its curative capability is yet to be established.

The role of metals in curing ailments was first realized in Ayurveda as several metallic preparations with organic macromolecules, often referred to as bhasmas in Ayurvedic literature, are widely used for treating a variety of disorders.[11] It has been suggested that herbal preparations of Indian medicinal plants have an antioxidant activity arising from their content of antioxidants that act in a synergistic way.[4] Thus, data on major, minor and trace elements in medicinal herbs are of great importance to understand their therapeutic actions. SOLECKI et al.[12] determined radionuclides ^{90}Sr and ^{137}Cs in Polish herbal plants.

Instrumental neutron activation analysis (INAA) with thermal neutrons is a versatile multielemental technique for analyzing complex biological samples.[13] Several workers[14–21] extensively used INAA for the analysis of medicinal herbs from other parts of the world, e.g., MUKHAMMEDOV et al.[14] from former Soviet Union, KANIAS et al.[15] from Greece, FIGURA et al.[16] from Poland, CHEN et al.[17] from China, MAJID et al.[18] from Malaysia, VAZ et al.[19] from Brazil, OBIAJUNWA et al.[20] from Nigeria and SERFOR-ARMAH et al.[21] from Ghana, all have used INAA for the analysis of medicinal herbs from their respective countries. CHEN et al.[10] determined Br and I in Chinese medicinal herbs by epithermal NAA. In China, a separate discipline called Traditional Chinese Medicine (TCM) has become common. Also ABOU-ARAB et al.[22] determined heavy metals in Egyptian medicinal plants by AAS. HARADA and HATANAKA[23] measured natural levels of trace elements in Japanese wild plants. In view of the importance of medicinal herbs, a reference material Mixed Polish Herbs (MPH-2) has been proposed.[24] Some attempts have been made to analyze Indian medicinal herbs as well by INAA.[25–27] In our earlier studies we have analyzed medicinal herbs and herbal preparations.[28–30] In the present study we report our results on the determination of 25 elements in 15 medicinal herbs commonly used in Indian households by INAA. Short and long irradiations were carried out using reactor neutrons. High resolution gamma-ray spectrometry was used for assay of activation products. Nomenclature and uses of medicinal herbs analyzed in this study are listed in Table 1. Also we participated in

* E-mail: agargfcy@yahoo.com

0236–5731/USD 20.00 *Akadémiai Kiadó, Budapest*

the analysis of depleted reference material (RM) renewal Pine Needle (1575a), through the courtesy of Dr. Donald BECKER of NIST, USA.[31]

Experimental

Sample preparation

All the medicinal herbs were procured from local Ayurvedic medicine shops. Some of them were procured from Shantikunj/Yogi Pharmacy, Haridwar in powder form. All the samples were powdered in an agate mortar, passed through a 100 mesh sieve and were oven dried at 80 °C for 2 hours. Various RMs, used as comparators, were procured from NIST (USA), IAEA (Vienna) and INCT (Poland), and used as obtained. Synthetic multielemental standards were prepared by spiking 2–5 μg amounts of Au, Cr, Fe, Co, Sb and Zn in aqueous solution of their respective AR/high purity grade salts. Depleted RM Pine Needle (new 1575a) including a reference sample of Peach Leaves were sent by Dr. Donald BECKER of NIST, USA.[31] These were dried as per recommended procedure.

Irradiation and counting

About 50 mg each of powdered samples and RMs were weighed accurately and packed in polythene or aluminum foil (Superwrap) for short (5 minutes) and long (14 hours) irradiations. Irradiations were carried out in E8 position of the APSARA reactor at the Bhabha Atomic Research Centre (BARC), Trombay, Mumbai, India, at a neutron flux of $\sim 10^{11}$ n·cm^{-2}·s^{-1}. Short-lived isotopes were measured using a 80 cm^3 coaxial HP Ge detector (EG & G Ortec) and a 4k MCA at the reactor site and later at the Radiochemistry Division of BARC. Samples were also irradiated for 3 days at $\sim 10^{13}$ n·cm^{-2}·s^{-1} in the Dhruva reactor at BARC. Long irradiated samples were brought to our laboratories in Roorkee and γ-activity was measured using an HP Ge detector with an 8k MCA having the GENIE-2000 software (Canberra, USA). Counting was followed at different intervals up to 3 months. Irradiation and counting schedule followed and elements determined are same as described earlier.[30] Elemental concentrations were calculated on the basis of different irradiations and using different RMs/synthetic standards as comparators. In each batch 3 to 4 different RMs were used. Phosphorus was determined by counting β-activity of ^{32}P on an endwindow G.M. counter using a 27 mg·cm^{-2} Al filter after a cooling period of 3 weeks.[32]

Results and discussion

Elemental concentrations in 15 medicinal herbs were measured by relative method of NAA by using different RMs and multielemental standards as comparators. Only if the values for elemental concentrations in various RMs matched well within ±10% of the certified values, the values for samples were considered. These are listed in Tables 2 and 3. Also included in the same tables are our data for participation in the analysis of depleted Pine Needles (SRM 1575a) and reference sample Peach Leaves (1547). In each case triplicate analyses were made using 100 mg each. It was observed that standard deviations for most elements were small suggesting a good precision. Further, our values for most of the elements in the depleted RM Pine Needle (1575a) including that for RM 1547 agree well with the certified values.[31] On the basis of good agreement, it is presumed that our values as listed in Tables 2 and 3 should be accurate and precise within ±10%. In order to compare, mean elemental concentrations of 15 medicinal herbs for Na, K, Mg, Ca, P and Cl are plotted in Fig. 1. Also histograms showing variation in Mn, Fe and Zn and Cr, Co and Cu concentrations with their standard deviations in 15 medicinal herbs are shown in Figs 2 and 3, respectively. Further, correlations of Fe vs. Mn and Zn vs. Cr in some samples are plotted in Figs 5 and 6, respectively.

A perusal of data in Tables 2 and 3 shows that no single herb is enriched in all the elements. The electrolytic elements Na and K responsible for maintaining normal fluid balance inside and outside cells are generally found at minor and major concentration levels, respectively. All the samples have shown much higher concentration of K by up to an order of magnitude compared to that of Na. Higher concentrations of Ca and Mg present in some herbal samples might have been responsible for the absence of side effects as regards stomach lesions. Also Ca and Mg compounds are recommended in the prevention of osteoporosis.[33] Transition elements Cr, Mn, Fe, Co, Cu, and Zn were found at varying concentrations. Iron contents of all the samples are more than 200 μg/g though bakuchi seeds and jatamansi have much higher amounts of Fe, 923±123 and 1210±200 μg/g, respectively. Zinc is an important element responsible for many enzymatic processes and is involved in working of genetic materials, proteins, immune reactions, wound healing, development of the foetus, and sperm production. It has been suggested that normal levels of Zn can prevent diarrhea.[33] In all samples, Zn concentration is found to be more than 30 μg/g, being the highest in jatamansi (60.0±6.3 μg/g). Manganese is another essential element required for biochemical processes. In most of the samples, it is found to be <100 μg/g barring in vacha, dried ginger, lodhra, bakuchi and jatamansi, where concentration of Mn is more than 100 μg/g. However, Mn is the highest for jatamansi (474±5 μg/g). Thus, jatamansi is particularly enriched in Na, Cr, Mn, Fe, Cu and Zn. In Ayurvedic

literature, jatamansi is recommended as antibacterial, antipyretic and as heart tonic.[1,6] Bakuchi seeds are commonly used for many herbal preparations, which are widely recommended as appetizer, tonic with antibacterial and stimulant properties.[3,6] Many gold and vanadium compounds have been described to possess therapeutic properties. These elements could be detected in a few herbs only suggesting their special importance. The variation in elemental concentrations as observed in Tables 2 and 3 could be due to preferential uptake of the elements by the plant species from the soil. Therefore, soil characteristics together with environmental conditions may also play an important role in the elemental contents.

Correlations of elemental concentrations

Histograms of mean elemental concentrations of minor constituents (Na, K, Mg, Ca, P and Cl) are shown in Fig. 1. It is observed that, in general, all medicinal herbs are enriched in K and Ca, though P, Mg and Cl are also present in significant amounts. As mentioned earlier, Na content is the lowest whereas K content is the highest in all the cases.[27] Further, K/Na ratio is the lowest in jatamansi (5.94) and the highest for guduchi (761) though for 9 samples it is below 50. Histograms of Mn, Fe and Zn in all the medicinal herbs are shown in Fig. 2. Though Fe concentration in jatamansi and bakuchi seeds is ~1 mg/g but amaltas and laghu haritaki also exhibit significant amounts (>0.6 mg/g) whereas all others have <0.3 mg/g. Apparently Zn concentration varies in a small range of 13.5–60.0 μg/g. Similar histograms of Cr, Co and Cu in medicinal plants are shown in Fig. 3. Apparently jatamansi is most enriched in Cu (40.7 μg/g) whereas other herbs contain Cu in a much smaller range of 2.63–14.7 μg/g. Same pattern was observed for Cr concentration with jatamansi exhibiting the highest (8.19 μg/g) amount, whereas all other herbs contain <3 μg/g. In most of the herbs, Co concentration is the lowest (≤1 μg/g) but varies in a wider range (0.07–1.26 μg/g) with the highest concentration in jatamansi.

There are several literature reports suggesting interrelationship of K and P. We have plotted K/P ratio as shown in Fig. 4. Ashwagandha, kalmegh and sariva exhibit K/P ≥20 whereas in about 8 medicinal herbs the ratio is in the range of 8–10 and only two samples show K/P <5. In general, it can be said that K content in the plant samples is ≥10 times that of P content. Fe and Mn, both essential elements for biochemical processes, are correlated in medicinal plants. A plot of Fe with Mn shows poor relationship (Fig. 5) with $r = 0.645$. This poor relationship may be due to the fact that we are considering different parts such as fruit, seed, leaves, stem, and root of the herbs. Interestingly, when the values of Zn and Cr only in leaves samples of 6 medicinal herbs were considered then a near linear relationship with $r = 0.926$ was observed as shown in Fig. 6. In general, it may be mentioned that the interrelationship of several medicinal herbs suggest synergistic or antagonistic effect among the elements present, thus providing various elements to the body in a balanced manner.

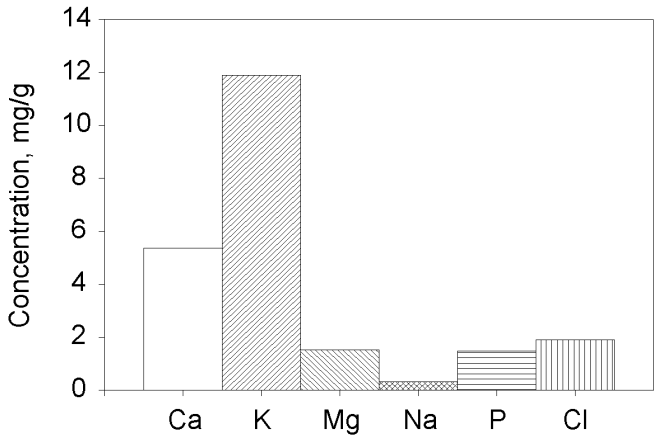

Fig. 1. Mean elemental concentration of minor elements

Table 1. Common uses of medicinal herbs as described in Ayurvedic literature

General name	English name	Family	Botanical name	Medicinal uses (Refs 1, 3, 6)
Amaltas (fruit)	Indian laburnum	Caesalpinceae	*Cassia rhombifolia*	Laxative, Anti-inflammatory, Antipyretic, Expectorant, Antileprotic, Analgesic, Cures Ringworms, Rheumatism, Constipation
Ashwagandha (leaves & root)	Winter cherry	Solanaceae	*Withania somnifera*	Aphrodisiac, Rejuvenator, Diuretic, Narcotic, Antipurgative, Nervine tonic, Anti-inflammatory, Analgesic, Antifungal, Antibacterial, Antiarthritic
Bakuchi (seeds)	Malaya tea	Leguminosae (Papilionaceae)	*Psoralea corylifolia*	Nervine tonic, Appetizer, Expectorant, Antibacterial, Stimulant, Wound healer, Anthelmintic, Laxative, Diuretic, Leprosy, Asthma, Fever
Guduchi (leaves & fruit)	Tinospora	Menispermaceae	*Tinospora cordifolia*	Astringent, Antipyretic, Rejuvenator, Blood purifier, Nervine tonic, Diuretic, Anti-dote, Anti elegric, Anti-inflammatory, Gout, Pyrexia
Jaiphal (fruit)	Nutmeg	Myristicaceae	*Myristica fragrans*	Stomachic, Astringent, Heart tonic, Carminative, Stimulant, Aphrodisiac, Appetizer, Blood purifier, Anti thirst, Intestinal trouble
Jatamansi (root)	Spikenard	Valerianaceae	*Nardostachys jatamansi*	Aromatic, Stimulant, Antispasmodic, Nervine & heart tonic, Diuretic, Laxative, Antipyretic, Arthritis, Sedative, Hypotensive, Antibacterial, used in Colic, Ulcer, Hysteria
Kalmegh (fruit)	The creat	Acanthaceae	*Andrographis paniculata*	Hepatic stimulant, Cholagogue, Antileprotic, Stomachic, Nutritive, Anorexia, Malaria, Oedema, Skin disease, Blood purifier
Kutaz (leaves)	Tellicherry	Apocynaceae	*Holarrhena antidysenterica*	Astringent, Antibillous, Digestive, Diarrhea, Haemorrhoid, Rheumatic arthritis, Skin disease, Blood purifier, Piles, Asthma
Laghu Haritaki (fruit)	Chabulic myrobalans	Combretaceae	*Terminalia chebula*	Digestive, Laxative, Stomachic, Rejuvenator, Anti-inflammatory, Tonic, Appetizer, Anti-diabetic, Malaria and eye infections
Lodhra (bark)	Symplocos bark	Symplocaceae	*Symplocos racemosa*	Astringent, Antipyretic, Blood purifier, Tonic, Piles, Anti-inflammatory, Antimucilagenous, Wound healing, Dysentery, Leucorrhoea, Liver & eye trouble, Fever, Leprosy, Ulcer
Neem (leaves)	Margosa tree	Meliaceae	*Azadirchta indica*	Astringent, Purgative, Demulcent, Anti-inflammatory, Liver stimulant, Eczema, Antiseptic, Blood purifier, Anthelmintic, and used in Fungal infections & Rheumatism
Nirgundi (leaves)	Fiveleaved chaste	Verbenaceae	*Vitex negundo*	Analgesic, Expectorant, Vermifuge, Anti-inflammatory, Stomachic, Carminative, Rejuvenator, Diuretic, Anthelmintic
Sariva (root)	Sarsaparilla	Asclepiadaceae	*Hemidesmus indicus*	Antibacterial, Antifungal, Antiviral, Diuretic, Blood purifier, Anti-inflammatory, Leucoderma, Diarrhoea, Asthma
Vacha (leaves & root)	Sweet flag	Araceae	*Acorus calamus*	Stomachic, Anticonvulcent, Antipyretic, Antibiotic, Diphoretic, Anti-inflammatory, Expectorant, Spasmolytic, Nerve tonic, Musclerelaxent
Vidang (fruit)	Barbreng	Myrsinaceae	*Embelia ribes*	Appetizer, Stomachic, Rejuvenator, Nervinetonic, Blood purifier, Tapeworms infestation, Toothache, Dentalcarries

Table 2. Elemental concentrations in some medicinal herbs

Medicinal herbs	Al, mg/g	Au, ng/g	Br, µg/g	Ca, mg/g	Cl, mg/g	K, mg/g	Mg, mg/g	Na, µg/g	P, mg/g	V, µg/g	Zn, µg/g
Amaltas	0.20 ± 0.01	0.48	4.45 ± 0.44	ND	1.41 ± 0.05	12.2 ± 0.3	0.83 ± 0.05	64.2 ± 1	3.29 ± 0.15	ND	38.9 ± 4.1
Ashwagandha	1.00 ± 0.02	ND	23.1 ± 2.6	14.9 ± 1.3	1.30 ± 0.02	14.1 ± 0.1	1.22 ± 0.06	290 ± 10	0.72 ± 0.01	ND	43.6 ± 4.2
Bakuchi	1.34 ± 0.02	ND	5.24 ± 0.41	0.73 ± 0.06	1.02 ± 0.12	13.5 ± 0.3	0.47 ± 0.03	438 ± 4	2.04 ± 0.04	1.74 ± 0.14	56.5 ± 5.9
Guduchi	0.42 ± 0.01	0.47	9.78 ± 0.8	16.3 ± 0.06	0.45 ± 0.02	18.1 ± 0.4	1.97 ± 0.06	23.8 ± 0.6	1.87 ± 0.27	ND	13.5 ± 1.9
Jaiphal	0.03 ± 0.01	1.36	0.51 ± 0.01	1.40 ± 0.05	0.23 ± 0.01	4.21 ± 0.17	1.94 ± 0.06	195 ± 5	2.03 ± 0.05	ND	40.0 ± 0.5
Jatamansi	1.70 ± 0.03	ND	7.28 ± 0.57	1.63 ± 0.12	1.19 ± 0.08	8.85 ± 0.2	0.47 ± 0.04	1490 ± 13	1.35 ± 0.06	ND	60.0 ± 6.3
Kalmegh	2.47 ± 0.24	ND	8.45 ± 0.39	2.29 ± 0.14	2.46 ± 0.22	18.6 ± 0.9	1.88 ± 0.06	443 ± 135	0.90 ± 0.05	1.44 ± 0.06	30.9 ± 1.4
Kutaz	1.04 ± 0.06	ND	23.9 ± 1.1	5.30 ± 0.07	2.34 ± 0.24	6.75 ± 0.3	2.12 ± 0.31	255 ± 78	0.70 ± 0.06	ND	27.5 ± 1.3
Laghu Haritaki	0.73 ± 0.01	ND	3.39 ± 0.19	3.88 ± 0.14	3.52 ± 0.16	11.2 ± 0.3	2.63 ± 0.03	81.3 ± 1	0.64 ± 0.04	1.70 ± 0.15	35.1 ± 3.7
Lodhra	1.08 ± 0.02	ND	13.6 ± 0.6	0.89 ± 0.06	1.91 ± 0.36	6.24 ± 0.3	2.45 ± 0.20	240 ± 74	0.91 ± 0.02	3.04 ± 0.06	26.7 ± 1.7
Neem	0.96 ± 0.02	3.84	28.8 ± 1.4	3.59 ± 0.10	2.01 ± 0.24	10.7 ± 0.6	0.90 ± 0.07	262 ± 80	1.33 ± 0.01	1.19 ± 0.08	34.8 ± 1.6
Nirgundi	1.91 ± 0.07	1.15	0.88 ± 0.03	6.48 ± 0.56	0.37 ± 0.01	13.1 ± 0.5	1.74 ± 0.05	35.5 ± 0.9	1.87 ± 0.27	ND	13.8 ± 1.7
Sariva	0.25 ± 0.03	0.38	1.73 ± 0.16	11.0 ± 0.8	2.40 ± 0.01	9.45 ± 0.44	1.32 ± 0.03	195 ± 2	0.39 ± 0.02	ND	41.1 ± 0.5
Vacha	1.36 ± 0.16	0.18	9.78 ± 0.8	4.25 ± 0.53	1.93 ± 0.08	14.1 ± 0.7	1.55 ± 0.04	466 ± 10	2.78 ± 0.06	0.66 ± 0.02	37.9 ± 0.4
Vidang	1.24 ± 0.15	0.26	15.0 ± 1.2	2.46 ± 0.11	5.94 ± 0.09	17.6 ± 0.8	1.65 ± 0.05	457 ± 8	1.43 ± 0.03	3.55 ± 0.08	37.7 ± 1.0
SRMs											
Pine Needles	0.60 ± 0.02	1.51 ± 0.3	3.08 ± 0.15	2.82 ± 0.21	0.462± 0.051	4.31 ± 0.44	1.01 ± 0.02	111 ± 34	1.12 ± 0.08	ND	36.2 ± 3.2
(SRM-1575a)	(0.58 ± 0.03)	(–)	(–)	(2.50 ± 0.10)	(0.421± 0.007)	(4.17 ± 0.07)	{1.06± 0.17}	{63 ± 1}	(1.07 ± 0.08)	(–)	(38 ± 2)
Peach Leaves	0.28 ± 0.03	1.50 ± 0.01	12.3 ± 0.3	17.5 ± 1.5	0.340± 0.020	26.5 ± 2.0	4.15 ± 0.35	22.6 ± 1.6	1.32 ± 0.13	0.52 ± 0.05	20.5 ± 1.5
(SRM-1547)	(0.25 ± 0.008)	(–)	{11}	(15.6 ± 0.20)	(0.360± 0.019)	(24.3 ± 1.0)	{4.32± 0.08}	(24 ± 2)	(1.37 ± 0.07)	(0.37 ± 0.03)	(17.9 ± 0.4)

ND: Not detected.
{ } Information values.
( ) Certified values.[31]

Table 3. Elemental concentrations in some medicinal herbs

Medicinal herbs	Ba, µg/g	Ce, µg/g	Co, µg/g	Cr, µg/g	Cu, µg/g	Fe, µg/g	Eu, ng/g	La, µg/g	Mn, µg/g	Rb, µg/g	Sb, ng/g	Sc, ng/g	Sm, ng/g	Th, ng/g
Amaltas	ND	1.29 ± 0.28	0.55 ± 0.09	1.47 ± 0.01	2.63 ± 0.24	697 ± 113	7.91 ± 1.4	1.69 ± 0.05	6.44 ± 0.06	18.1 ± 0.7	196	9.30 ± 1.10	133 ± 10	493
Ashwagandha	12.5 ± 2.3	1.11 ± 0.5	0.07 ± 0.01	1.86 ± 0.37	9.50 ± 1.7	221 ± 11	33.2 ± 1.2	0.93 ± 0.01	17.4 ± 1.0	15.5 ± 1.5	155 ± 12	44.9 ± 2.2	150 ± 11	158 ± 12
Bakuchi	28.7 ± 2.5	3.10 ± 0.7	0.86 ± 0.15	1.97 ± 0.01	12.2 ± 1.1	923 ± 150	40.5 ± 6.9	2.65 ± 0.08	161 ± 2	12.1 ± 0.5	252	54.4 ± 6.6	336 ± 30	157
Guduchi	ND	1.09	0.07 ± 0.01	0.961	4.22	277 ± 8	41.2 ± 5.6	2.38 ± 0.08	47.3 ± 1.9	14.7 ± 0.3	14.7 ± 1.8	39.0 ± 4.8	218 ± 16	28.5
Jaiphal	ND	0.92 ± 0.20	0.19 ± 0.02	1.91 ± 0.07	4.74 ± 1.1	63.2 ± 1.5	145 ± 19	0.48 ± 0.08	43.6 ± 1.7	6.64 ± 0.39	82.6 ± 2.7	93.5 ± 6.5	87.6 ± 2.2	135 ± 20
Jatamansi	17.0 ± 1.8	1.40 ± 0.3	1.26 ± 0.22	8.19 ± 0.04	40.7 ± 3.7	1210 ± 200	273 ± 47	6.19	474 ± 5	52.7 ± 2.1	310	1420 ± 20	1051 ± 170	2604 ± 64
Kalmegh	16.9 ± 1.3	0.38 ± 0.1	0.16 ± 0.01	1.11 ± 0.24	11.4 ± 1.8	250 ± 52	10.3 ± 1.8	1.00	51.3 ± 3.7	21.1 ± 2.0	ND	190 ± 10	125 ± 20	428 ± 26
Kutaz	12.5 ± 0.78	ND	0.14 ± 0.01	1.30 ± 0.23	4.05 ± 0.63	255 ± 52	7.89 ± 1.4	0.80	34.1 ± 2.4	ND	ND	180 ± 10	112 ± 18	422 ± 26
Laghu Haritaki	14.4 ± 1.7	1.00 ± 0.2	0.54 ± 0.09	1.28 ± 0.01	5.60 ± 1.44	656 ± 107	12.6 ± 2.2	0.81 ± 0.08	12.2 ± 0.3	14.8 ± 0.6	133	290 ± 20	103 ± 8	202 ± 5
Lodhra	24.4 ± 1.4	1.55 ± 0.4	0.15 ± 0.01	1.20 ± 0.24	4.10 ± 0.64	233 ± 49	8.10 ± 1.4	0.82	191 ± 13	13.9 ± 1.2	ND	220 ± 20	155 ± 25	2154 ± 90
Neem	21.7 ± 2.5	0.50 ± 0.1	0.12 ± 0.01	1.47 ± 0.26	6.49 ± 1.0	256 ± 52	11.4 ± 2.0	0.68 ± 0.01	46.4 ± 3.3	17.6 ± 1.5	ND	185 ± 10	99.0 ± 7.0	366 ± 23
Nirgundi	ND	2.52	0.07 ± 0.01	1.07	3.65	263 ± 5	59.8 ± 7.6	3.08 ± 0.09	44.2 ± 1.7	21.1 ± 0.5	22.1 ± 2.8	63.3 ± 7.7	341 ± 25	57.1
Sariva	72.0 ± 3.6	0.94 ± 0.12	0.19 ± 0.02	2.00 ± 0.07	ND	64.5 ± 0.8	771 ± 100	0.62 ± 0.12	19.1 ± 0.9	7.56 ± 0.44	84.1 ± 2.9	104 ± 10	95.0 ± 2.0	162 ± 25
Vacha	43.2 ± 2.2	1.55 ± 0.18	0.19 ± 0.02	2.01 ± 0.07	6.40	80.2 ± 1.7	21.6 ± 2.9	0.63 ± 0.12	121 ± 6	6.69 ± 0.39	56.3 ± 1.9	154 ± 13	121 ± 6	180 ± 25
Vidang	ND	1.58 ± 0.18	0.23 ± 0.02	3.02 ± 0.10	14.7	78.1 ± 1.6	57.3 ± 7.5	0.65 ± 0.12	50.2 ± 2.9	7.93 ± 0.46	49.9 ± 1.7	297 ± 30	126 ± 2	160 ± 24
SRMs														
Pine Needles	7.60 ± 0.54	0.75 ± 0.08	0.50 ± 0.03	1.33 ± 0.1	3.26 ± 0.40	192 ± 17	ND	0.34 ± 0.01	506 ± 40	16.4 ± 0.4	33.0 ± 6.0	96.7 ± 4.5	41.6 ± 2.6	205 ± 26
(SRM-1575a)	(6.0 ± 0.2)	(–)	{0.06 ± 0.01}	(–)	(2.8 ± 0.2)	(46 ± 2)	(–)	(–)	{488 ± 12}	(16.5 ± 0.9)	(–)	{101 ± 3}	(–)	(–)
Peach Leaves	116 ± 4	10.2 ± 0.2	0.05 ± 0.01	1.27 ± 0.19	3.00 ± 0.4	182 ± 16	190	9.37 ± 0.60	106 ± 6	19.2 ± 0.1	71.0 ± 2.0	114 ± 4	890 ± 20	60.2 ± 5.0
(SRM-1547)	(124 ± 3)	{10}	{0.07}	{1}	(3.7 ± 0.4)	(218 ± 6)	{170}	{9}	(98 ± 3)	{19.7}	{20}	{40}	{1000}	{50}

ND: Not detected.
{ } Information values.
( ) Certified values.[31]

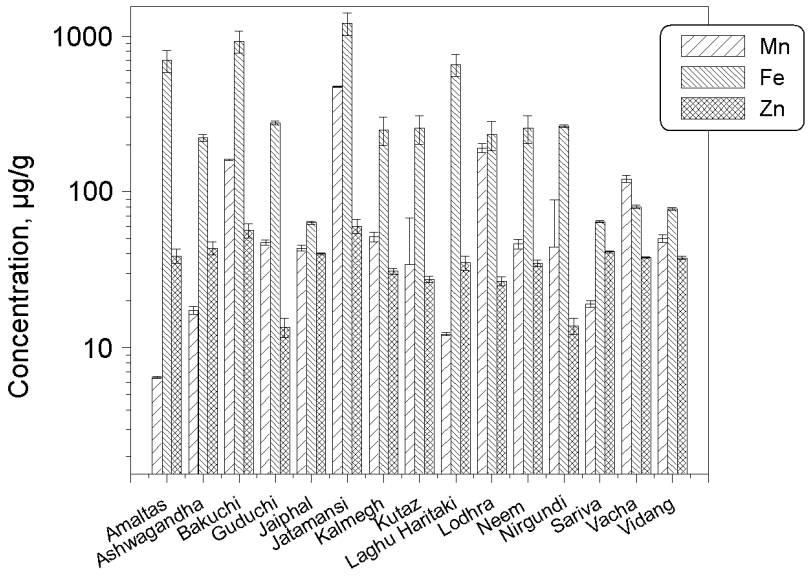

Fig. 2. Variation in concentrations of Mn, Fe and Zn in medicinal herbs with ±1σ as error bars

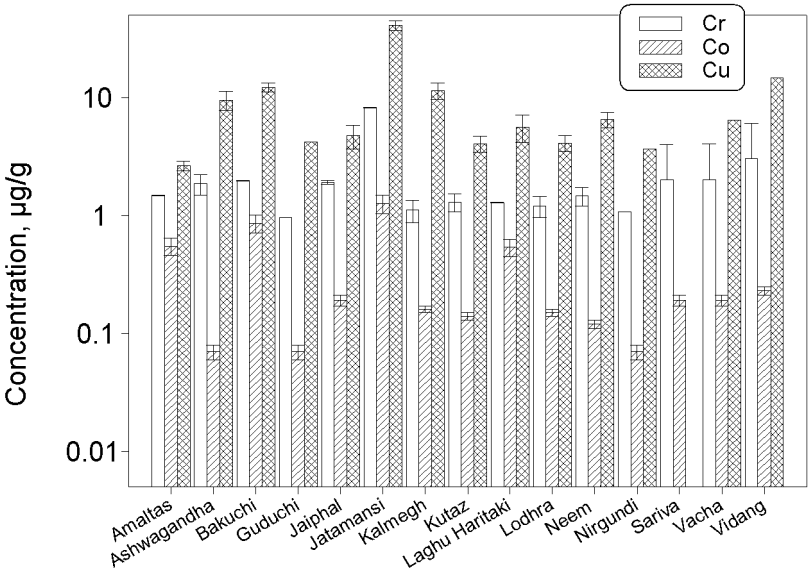

Fig. 3. Concentration of Cr, Co and Cu in medicinal herbs

These crude drugs used over centuries might have been acting like multi-drug therapy in restoring the ionic balance and as the trace element fortification in its natural form. Although little is known about the precise molecular mechanism of the trace element contents in medicinal herbs, the sustained use of these medicinal herbs by the patients and the relief in the curing suggests that these herbs provide trace elements in bioavailable/assimilable form that might be responsible for the pharmacological action. The elucidation of elemental speciation in medicinal herbs will help interpret the therapeutic action and in designing chemically pure medications. It has been well demonstrated that INAA, with the multi elemental capability over a wide range of concentrations, its blank free nature and minimum sample preparation is unique for such studies.

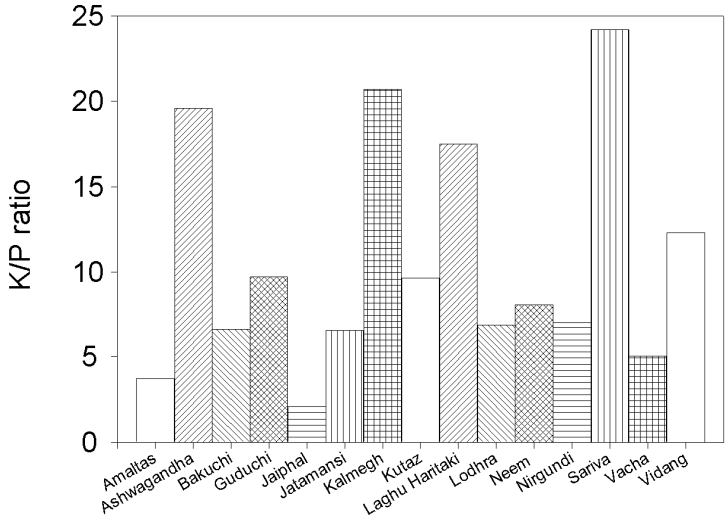

Fig. 4. Variation of K/P ratio in medicinal herbs

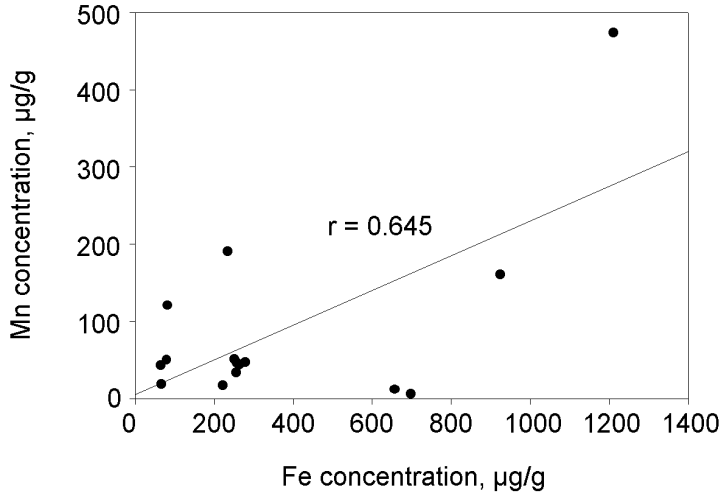

Fig. 5. Variation of Fe with Mn in different medicinal herbs

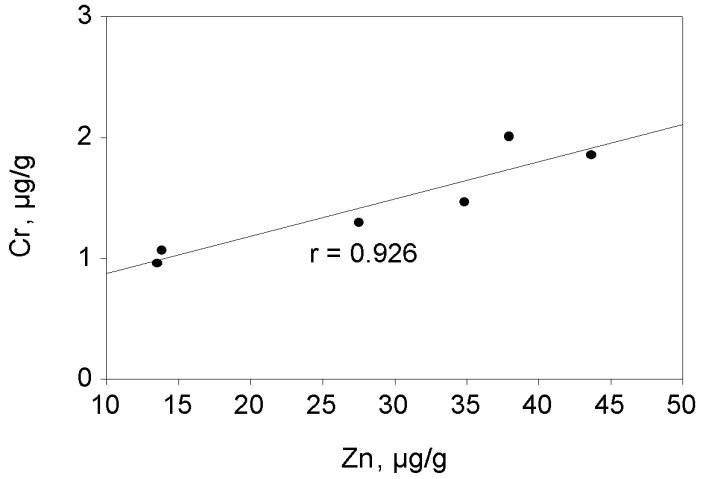

Fig. 6. Plot of Zn vs. Cr in six leave samples of medicinal plants

Conclusions

Using INAA with short and long irradiation followed by high-resolution gamma-ray spectrometry has been used for the determination of 25 elements in 15 medicinal herbs commonly used in Indian households. Wide variations in elemental concentrations have been observed. It has been observed that jatamansi is most enriched in Mn, Fe, Cu, Cr, Co and Zn. K/P ratio changes in a wide range of 2.07–24.2. Poor correlation was observed between Fe and Mn in all the samples and good correlation between Zn and Cr in leaves parts of medicinal herbs was observed.

*

Grateful thanks are due to the Board of Research in Nuclear Sciences (BRNS), Department of Atomic Energy, Government of India for financial assistance under Grant No. 2000/37/5/BRNS/520. Sincere thanks are due to Dr. V. K. MANCHANDA, Head, Radiochemistry Division, BARC, Mumbai for permission to use their experimental facilities.

References

1. P. V. SHARMA, Dravyaguna Vigyan, Vols 1 and 2, Chaukhamba Bharti Academy, Varanasi, 1971.
2. R. P. RASTOGI, B. N. MEHROTRA, Compendium of Indian Medicinal Plants, Vols 1–6, Central Drug Research Institute, Lucknow and National Institute of Science Communication, New Delhi, 1999.
3. V. V. SHIVARAJAN, I. BALACHANDRAN, Ayurvedic Drugs and their Plant Sources, Oxford & IBH Publishing Co., Pvt. Ltd., New Delhi, 1994, p. 570.
4. P. SCARTEZZINI, E. SPERONI, J. Ethnopharmacology, 71 (2000) 23.
5. R. P. STEINER, Folk Medicine: The Art and the Science, American Chemical Society, Washington, D.C. 1986, p. 223.
6. P. PARANNJPE, Indian Medicinal Plants, Forgotten Healers, Chaukhamba Sanskrit Pratisthan, Delhi, 2001, p. 316.
7. K. REIF, W. METZER, J. Chromatography, A662 (1995) 131.
8. A. S. PRASAD, Essential and Toxic Elements in Human Health and Disease: An Update, Wiley-Liss, New York, 1993, p. 661.
9. B. L. O'DELL, R. A. SUNDE (Eds), Handbook of Nutritionally Essential Mineral Elements, Marcell Dekker Inc., New York, 1997, p. 681.
10. C. Y. CHEN, Y. Y. WEI, S. P. CHANG LAI, L. K. PAN, J. Radioanal. Nucl. Chem., 257 (2003) 405.
11. N. G. PATEL, in: Folk Medicine: The Art and the Science, R. P. STEINER (Ed.), American Chemical Society, Washington, 1986, p. 41.
12. J. SOLECKI, M. RESZKA, S. CHIBOWSKI, J. Radioanal. Nucl. Chem., 257 (2003) 261.
13. G. V. IYENGAR, Elemental Analysis of Biological Systems-Biomedical, Environmental, Compositional and Methodological Aspects of Trace Elements, Vol. 1, CRC Press, Boca Raton, Fl. 1989, p. 242.
14. S. MUKHAMMEDOV, KH. TILLAEVA, N. B. BADLOV, At. Energy, 61 (1986) 446.
15. G. D. KANIAS, E. TSITSA, A. LOUKIS, V. KILKOLOU, J. Radioanal. Nucl. Chem., 169 (1993) 483.
16. B. FIGURA, J. BARBARA, L. WENDT, K. LORENZ, Farm. Pol., 41 (1985) 89.
17. K. S. CHEN, C. L. TSENG, T. H. LIN, J. Radioanal, Nucl. Chem., 170 (1993) 265.
18. A. A. MAJID, S. SARMANI, N. L. YUSOFF, Y. K. WEI, F. HAMZAH, J. Radioanal. Nucl. Chem., 195 (1995) 173.
19. S. M. VAZ, M. SAIKI, M. B. A. VASCONCELLOS, J. A. A. SERTIE, J. Radioanal. Nucl. Chem., 195 (1995) 185.
20. E. I. OBIAJUNWA, A. C. ADEBAJO, O. R. OMOBUWAJO, J. Radioanal. Nucl. Chem., 252 (2002) 473.
21. Y. SERFOR-ARMAH, E. H. K. AKAHO, B. J. B. NYARKO, A. W. K. KYERE, K. OPPON-BOACHIE, J. Radioonal. Nucl. Chem., 257 (2003) 125.
22. A. A. K. ABOU-ARAB, M. A. ABOU DONIA, J. Agric. Food Chem., 48 (2000) 2300.
23. H. HARADA, Y. HATANAKA, Soil Sci. Plant Nutr., 46 (2000) 117.
24. R. DYBCZNSKI, B. DANKO, K. KULISA, E. MALESZEWSKA, H. POLKOWSKA-MOTRENKO, Z. SAMCZYNSKI, Z. SZOPA, Preparation and Certification of the Polish Reference Material: Mixed Polish Herbs (INCT–MPH–2) for Inorganic Trace Analysis, Report Sr No. 4/2002, Institute of Nuclear Chemistry and Technology, Warsaw, 2002.
25. N. S. RAJURKAR, M. M. DAMANE, Appl. Radiation Isotopes, 49 (1998) 773.
26. G. R. K. NAIDU, H. O. DENSLAG, E. MAUERHOFER, N. PORITE, T. BALAJI, Appl. Radiation Isotopes, 50 (1999) 947.
27. T. BALAJI, R. N. ACHARYA, A. G. C. NAIR, A. V. R. REDDY, K. S. RAO, G. R. K. NAIDU, S. B. MANOHAR, J. Radioanal. Nucl. Chem., 243 (2000) 783.
28. D. L. SAMUDRALWAR, A. N. GARG, Biol. Trace Element Res., 54 (1996) 113.
29. V. SINGH, A. N. GARG, Appl. Radiation Isotopes, 48 (1997) 97.
30. A. N. GARG, A. KUMAR, A. V. R. REDDY, A. G. C. NAIR, J. Radioanal. Nucl. Chem., 263 (2005) 751.
31. D. A. BECKER, E. A. MACKEY, Final Report: Results of the ASTM Interlaboratory Comparison Exercise for the Determination of the Elemental Content of Pine Needles, NIST, USA, 2004.
32. R. G. WEGINWAR, D. L. SAMUDRALWAR, A. N. GARG, J. Radioanal. Nucl. Chem., 133 (1989) 317.
33. E. M. N. HAMILTON, E. N. WHITNEY, F. S. SIZER, Nutrition: Concepts and Controversies, 4th ed. West Publishing Co., St. Paul, MN, USA, 1988, p. 232.