Study on Mineral content of Some Ayurvedic Indian Medicinal Plants by Instrumental Neutron Activation Analysis and AAS Techniques

Ram Lokhande[1], Pravin Singare[2], Mahadeo Andhale[1]

1. Department of Chemistry, University of Mumbai, Vidyanagari, Santacruz, Mumbai-400 098
2. Department of Chemistry, Bhavan's College, Andheri, Mumbai – 400058

Abstract

Background: One of the main problems of ethnomedicine, Ayurvedic system is lack of solid scientific evidence regarding safety, efficacy, quality of practices and their precise molecular mechanisms. However, many Ayurvedic preparations appear to demonstrate significant success in treatment and cure of complex diseases.
Purpose: In order to develop a stronger basis for appreciating the curative effects of Ayurvedic medicinal plants, the aim of the present study was to investigate their elemental composition, which is very often overlooked in biochemical assays.
Sample and Method: In the present study is applied one of the sensitive analytical techniques such as instrumental neutron activation analysis (INAA) and atomic absorption spectroscopy *(AAS)* to study the essential elemental content in different parts of six different Indian medicinal plants. The samples were irradiated with thermal neutrons in a nuclear reactor and the induced activities were counted by γ -ray spectrometry using efficiency calibrated high resolution High Purity Germanium (HPGe) detector.
Results: The results were discussed with careful reference to established role of essential elements in the physiology and pathology of human life. The overall impact of these essential trace elements on human health is also discussed.
Conclusion: The data obtained on elemental concentration of the medicinal plants studied will be useful in deciding the dosage of the Ayurvedic drugs prepared from these plant materials. The results of the present research work will be helpful to Ayurvedic clinicians and scientists who would like to pursue further research in the areas of Ayurvedic and alternative medicines.

Keywords: Instrumental neutron activation analysis, atomic absorption spectroscopy, medicinal plants, trace elemental analysis, Inter-elemental correlations

Corresponding author:

Pravin Singare
Department of Chemistry, Bhavan's College,
Munshi Nagar, Andheri, Mumbai – 400058, India
Tel: + 91 22 26256451/ 52 (O)
+ 91 251-2882452 (R)
E-mail: pravinsingare@vsnl.net

Introduction

There are many references to the curative properties of several herbs in the ancient Indian literature, *Rigveda*, though a more detailed account is found in the *Atharvaveda* from where *Ayurveda*, the Indian traditional health care system (*ayus* = life, *veda* = knowledge, meaning science of life) originated. Fairly comprehensive information about herbs has been recorded in two treatises *Charak Samhita* and *Shusruta Samhita*—a base for Ayurvedic system of medicine[1,2]. These herbs are now being increasingly used in cosmetics, food as well as alternative medicine[3]. Some of the ingredients of allopathic and most of the Ayurvedic and Homeopathy medicines are derived from plants. Traditional Indian medical herbs used for strengthening the body immune system are known to have many essential and nutritional elements. Their excess or deficiency may disturb normal biochemical functions of the body[4]. Some western scholars have pursued the analysis of various Indian plants and herbs for their medicinal properties[5]. Most studies on such medicinal plants pertain to their organic contents, viz. essential oils, glycosides, vitamins, alkaloids and other active components and their pharmacological / therapeutic effects. Besides several organic compounds, it is now well established that many trace elements play a vital role in general well-being as well as in the cure of diseases[6, 7]. Several studies have reported elemental contents in plant extracts, which are consumed by us either as a herbal health drink or medicine [8-10]. These elements are present at varying concentrations in different parts of the plants, especially in roots, seeds and leaves which are used as a dietary item as well as ingredient in the Ayurvedic medicinal preparation. The leaves of the plants are still used in some countries, as for instance, in Malaysia[11], Greece[12] and India[13] particularly for their therapeutic effects. Since these trace elements constitute a minute fraction in different parts of the medicinal plants, a sensitive and reliable analytical technique is a prerequisite for obtaining precise and accurate data.

Considering the importance of trace elements in various human metabolic processes and also considering their curative properties, in the present investigation we have applied one of the sensitive analytical techniques like INAA to study the essential elemental content in different parts of Indian medicinal plants and herbs. The overall impact of these essential trace elements on human health is also discussed. Due to increasing industrialization and environmental pollution, the study was also extended to estimate the level of toxic elements present in these medicinal plant samples. Even though the direct link between the essential elemental content and their curative capacity is not yet established, the experimental data of the present work will be of immense importance in the synthesis of new Ayurvedic formulations. Also, it will help in deciding the proportion of various active constituents and managing dose of a particular formulation.

Experimental

Sampling

The various medicinal plants (Table 1) in the form of leaves and roots were collected from and around the Keshav Shrushti, Bhayander and Narsing K. Dube College, Nalasopara, Maharashtra, India. Surface contaminants of the plant samples were removed by washing with deionized water twice and then with deionized double distilled water. The leaves were air dried in a clean drying chamber and then dried at 80 ^{o} C for overnight in an oven. The samples were powdered in agate mortar and passed through 100-mesh sieve. Sampling was done from this powder. Biological reference material namely CTA VTL-2 (IJCT Poland) was used as a reference multielemental standard. The concentrations of all the elements investigated in this study are well certified in the reference material.

Irradiation and counting

About 50-80 mg of each sample was sealed in a polyethylene cover. Samples and reference standard were packed together and irradiated in the E8 position of the Apsara reactor, BARC. Irradiation time was varied between 30 min and 7 h depending on the half lives of the activation products. The sub-cadmium neutron flux in this position is in the order of $1x10^{12}$ cm^{-2} s^{-1}. The samples were also irradiated at Dhruva reactor for 1 d in order to determine the elemental concentration of the long-lived radionuclides, such as Fe. The short irradiation and counting were conducted at the reactor site followed by spectra unfolding at the Radiochemistry Division of BARC, Mumbai. The radionuclides used for the analysis and their γ-energies are given in Table-2. All the samples and SRMs were counted at a calibrated sample-detector distance from a HPGe detector (Ortec) with 25% relative efficiency and 2.1 keV resolution at 1332.5 keV of ^{60}Co line, which was connected, to an IBM PC XT computer system. A ^{152} Eu γ-standard was used for efficiency calibration of the detector at different distances (8-15 cm) between sample and detector, in a stable source to detector geometry. Care has been taken to account for the counting losses by keeping the dead time around 5% at the start of the measurement. This has been maintained by choosing suitable duration of irradiation, 30 s to 1 minute in the case of pneumatic irradiation and keeping the sample to detector distance of 12-15 cm during measurement. Most of the short lived isotopes contributing to the dead time belong to the elements present in major Ca and minor Al levels.The presence of different elements analyzed in various medicinal plants was confirmed by measuring their characteristic γ-ray energy as well as half lives which are in good agreement with the literature values. Radioactivity measuring times were chosen not to exceed 0.2 times the half lives of the radionuclide of interest. Long irradiated samples were brought to Radiochemistry Laboratory at Mumbai University and γ-activity was measured. Counting was followed for 1, 2, 6 and 12 h at different intervals up to 3 m. Care was taken to obtain maximum elemental information from more than one counting and the reproducibility of data was checked. Elemental concentrations of various Ayurvedic medicinal plants were calculated by relative method using control and reference multielemental standard as comparators.

Atomic absorption spectrometer (AAS) measurement

The samples in the powdered form were accurately weighed and digested in (5:1) mixture of nitric acid and perchloric acid[14]. After digestion few drops of concentrated HCl was added. The solution was heated gently and then filtered. The residue was again subjected to digestion and filtrate was collected. The entire filtrate was diluted suitably with distilled deionized water. The dilute filtrate solution was used for analysis of elements of interest (Cr, Ca, Cd, Ni, Pb and Hg) by AAS (Perkin Elmer 3100 model) using suitable hollow cathode lamps. The concentration of various elements was determined by relative method using A.R. grade solutions of elements of interest. The standard conditions for atomic absorption measurement are represented in Table 3

Table 1: Medicinal plant samples selected for the study

Sample Number	Local Name	Botanical Name (English Name)	Parts of plants: Medicinal use
1	Panfuti	Bryophyllum pinnatum (Sprout leaf plant)	Leaf: Bleeding, Bruises, boils, wounds, insect bites
2	Ashwagandha	Withania somnifera (Winter cherry)	Root: It has been used in diseases such as rheumatism, leprosy, arthritis and intestinal infections. Used to treat general debility, arthritis, depression, chronic fatigue, insomnia, anxiety, depressed immunity, infertility and memory loss. It is used as a general tonic, Blood purifier, increases the iron content in the blood. It is official Indian Pharmacopoeia popularly known as Indian Ginseng. It is useful in sexual & general weakness. It gives vitality and vigour and helps in building greater endurance. It is diuretic, i.e. it promotes urination, and removes functional obstruction of the body.
3	Sarpgandha	Rauwolfia serpentine (Indian snake root / Serpentine root)	Root: It is used for Insanity, schizophrenia, epilepsy, blood pressure, snake bite, insomnia. It is Anti-hypertensive, hypnotic, sedative. It increases uterine contractions in labour.
4	Vala	Vetiveria Zizanoides (Vetiver / Khas -khas grass)	Root: Fever, pain, diuretic, stimulant and tonic
5	Anant mool	Hemidesmus indicus (Indian sarasaparilla / Country sarasaparilla)	Root: Pain, swelling, vomiting, nutritional disorders, stomach diseases, skin diseases, fever, loss of appetite, syphilis, leucorrhoea. The drug is used largely as the blood purifier, rheumatism and treatment of gravel and other urinary diseases. Root is cooling, aphrodisiac, antipyretic, antidiarrhoeal, astringent to bowels and useful in treatment of asthma, bronchitis, leucorrhoea, dysentery, thirst, burning sensation, piles, and eye troubles.
6	Shweta musli	Chlorophytum Borivilianum (safed musli)	Root: For treatment of kidney stones, diarrhoea, and senile debility. It is used for diabetes, arthritis, curative for natal & post-natal problems, rheumatism and joint pains, powerful uterine stimulant, for the preparation of nutritive tonic used in general sexual weakness. Its powder increases lactation in feeding mothers and lactating cows.

Table 2: Radionuclides Used for the Analysis and their γ- Energies

Nuclide	γ- ray energy in keV
^{42}K	1524
^{56}Mn	847
^{24}Na	1368
^{59}Fe	1099
^{65}Zn	1115
^{64}Cu	1040
^{60}Co	1332
^{82}Br	776
^{153}Sm,	103
^{38}Cl	1642
^{140}La	1596
^{28}Al	1779

Thermal Neutron flux: $10^{12} – 10^{13}$ n cm^{-2} s^{-1}

Table 3: Standard Conditions for Atomic Absorption Measurement

Element	Wavelength nm	Slit width nm	Sensitivity check ppm	Lamp current mA
Cr	357.9	0.2	4.0	7
Ca	422.9	0.5	4.0	10
Cd	228.8	0.5	1.5	4
Ni	232.0	0.5	7.0	4
Pb	283.6	0.5	20.0	5
Hg	253.7	0.5	200.0	4

Results and Discussion

The SRM of biological origin was analyzed for quality control and method validation. It was observed that most elemental contents are within ± 10% of the certified values. Standard deviations were also relatively small. The values listed in the Table 4 (which are averages of three independent measurements) are having the precision of ~ ± 2 to 10%.

An examination of the data from Table - 4 shows that different medicinal plants contain elements like K, Mn, Na, Fe, Zn, Cu, Co, Br, Sm, Cl, La, Al, Cr, Ca, Cd, Ni, Pb and Hg in various proportions. The presence of these elements in different plants was confirmed by measuring the half life of the corresponding radioisotope formed as well as their γ-energies. The elements Cr, Ca, Cd, Ni, Pb and Hg were analyzed by AAS technique by measuring the absorbance of the species at its resonance wavelength. The variation in elemental concentration is mainly attributed to the differences in botanical structure, as well as in the mineral composition of the soil in which the plants are cultivated. Other factors responsible for a variation in elemental content are preferential absorbability of the plant, use of fertilizers, irrigation water and climatological conditions[15]. The active constituents of the medicinal plants are the metabolic products of the plant cells. A number of trace elements play an important role in the metabolism. These elements are called essential. An element is considered essential for a plant if the plant fails to grow normally and complete its life cycle in a medium adequately removed from the element whereas in the presence of the suitable chosen concentration of that element it grows and reproduces normally. An examination of the data from Table 4

shows that K content is high in roots of Ashwagandha (22.30 mg/g), while roots of Anant mool contain high Na content (3.11 mg/g). The Na content is low in roots of Vala (0.05 mg/g). It is important here to note that the regulation of potassium is intimately involved with that of sodium and the two are largely interdependent. Sodium is essential for regulation of osmotic pressure of the body and helps to maintain acid-base and water balance of the body. Its deficiency causes loss of body weight and nerves disorder. Potassium is accumulated within human cells by the action of the Na^+, K^+-ATPase (sodium pump) and it is an activator of some enzymes; in particular co-enzyme for normal growth and muscle function[16]. It helps in the protein and carbohydrate metabolism. It is the principle cation of the intracellular fluid, but it is also a very important constituent of the extracellular fluid because it influences muscle activity particularly the cardiac muscle. Potassium deficiency causes nervous disorder, diabetes, and poor muscular control resulting in paralysis. The calcium content in various medicinal plants analyzed varies from 0.41 mg/g in leaves of Panfuti to 7.55 mg/g in Sarpgandha roots. Calcium is essential for healthy bones, teeth and blood[17,18]. The health of the muscles and nerves depends on calcium. It is required for the absorption of dietary vitamin B, for the synthesis of the neurotransmitter acetylcholine, for the activation of enzymes such as the pancreatic lypase. It helps to regulate the activity of skeletal muscle, heart and many other tissues. Deficiency of calcium causes rickets, osteomalacia and scurvy. The recommended daily dietary allowance of Ca for children is between 500 and 1000 mg and 800 mg for adults. The higher Ca content in roots of Sarpgandha suggests its possible use to overcome deficiency of Ca. The elements like Zn, Fe and Cr are essential trace elements (micro nutrients) for living organisms. Zinc is relatively non-toxic[19]. Zinc deficiency is characterized by recurrent infections, lack of immunity and poor growth. Growth retardation, male hypogonadism, skin changes, poor appetite and mental lethargy are some of the manifestations of chronically zinc-deficient human subjects[19]. Zinc is necessary for the growth and multiplication of cells (enzymes responsible for DNA and RNA synthesis), for skin integrity, bone metabolism and functioning of taste and eyesight[20]. It is a constituent of many enzymes and insulin. Zinc deficiency causes weight loss. Pregnant and lactating women require 20 to 25 mg, while normal adult require 15 mg of zinc every day. From the results obtained, it is observed that the concentration of Zn ranges from 13.0 µg/g in roots of Shweta musli to 47.5 µg/g in Panfuti leaves. The high concentration of zinc in leaves of Panfuti suggests its use in treatment of bleeding, boils, wounds, insect bites, and skin disease. The concentration of zinc is also appreciably high in roots of Ashwagandha (39.50 µg/g), which suggest its use in treatment of infertility, and uremic patients. Iron occupies a unique role in the metabolic process. The role of iron in the body is clearly associated with hemoglobin and the transfer of oxygen from lungs to the tissue cells[21]. Iron deficiency is the most prevalent nutritional deficiency in humans[22] and is commonly caused by insufficient dietary intake, excessive menstrual flow or multiple births. In this case, it results especially an anemia. In various medicinal plants samples analyzed, the Fe content was observed maximum in roots of Ashwagandha (324 µg/g) and minimum in Anant mool (207 µg/g). Hence the use of Ashwagandha roots in general tonic preparation may be advised to compensate for an iron deficiency. Chromium is essential in carbohydrate metabolism. It also functions in protein and cholesterol synthesis. Deficiency of chromium causes glucose intolerance, impaired growth and decreased respiratory quotient. It plays an important role diabetes treatment. It is an important element required for the maintenance of normal glucose metabolism. The function of chromium is directly related to the function of insulin, which plays a very important role in diabetes. Chromium is found in the pancreas, which produces insulin. One usable

form of chromium is the Glucose Tolerance Factor (GTF) [23], an inorganic compound containing glutamic acid, cysteine and niacin. The absorption of the trivalent chromium in GTF is about 10 to 25%. It enhances the removal of glucose from the blood. The important constituent of GTF is Cr which helps in the potentiating of insulin[24].Chromium also acts as an activator of several enzymes. Deficiency of chromium decreases the efficiency of insulin and increases sugar and cholesterol in the blood. Chromium deficiency can cause an insulin resistance, impair in glucose tolerance and may be a risk factor in artherosclerotic disease[25]. From the results obtained, it is observed that Cr content is high in roots of Anant mool (56.70 µg/g). Hence the use of this medicinal plant may be advised for the treatment and control of diabetics. The high Cr content in roots of Anant mool suggests its possible use in heart tonic preparations. In experiments conducted by Anke et al.[26] with growing, gravid and lactating goats, a poor Br-nutrition (<1 mg/g dry matter) led to a significantly reduced growth, a worse conception rate, reduced milk fat production and decreased hemoglobin content. The high concentration of Br along with Fe in Ashwagandha, Sarpgandha, Anant mool and Shwetamusli, suggests there possible use in preparation of the drugs for curing natural diuretic, phlegm eliminating and stomach invigorating diseases[27] and purifying breast milk. However, further investigations regarding possible essentiality of Br are necessary due to the fact that Br accumulates well in plants due to the application of agricultural chemicals such as methyl bromide as fumigant. The higher Mn content was observed in roots of Vala (407.0 µg/g), Anant mool (385.0 µg/g), and Shweta musli (214.0 µg/g). It is important here to note that Mn is an essential element required for various biochemical processes[28]. The kidney and liver are the main storage places for the manganese in the body. Mn is essential for normal bone structure, reproduction and the normal functioning of the central nervous system. Its deficiency causes reproductive failure in both male and female. Mn is also important for several enzymatic processes. It helps in eliminating fatigue and reduces nervous irritability[7, 29, 30]. Hence use of Vala, Anant mool, and Shweta musli roots in medicinal preparations may help to supplement Mn for various body functions. Cobalt is an essential element for the plants having the capability to fix nitrogen in the root tubercles. Animals are able to synthesize vitamin B12, which is the main source of Co in animal foods. Nevertheless, only a part of Co in food derived from animals is present in the form of cobalamines. The recommended daily intake of vitamin B12 for adults is 3 mg (0.13 mg Co), taking into account that only 50% is absorbed in the intestine[20]. Co is widely distributed throughout the body and highest concentrations are usually found in liver, kidneys and bones. Deficiency of vitamin B12 produces a genetic defect and failure of gastric mucosa. Vitamin B12 is essential for the maturation of red blood cells and normal functioning of all cells. In humans, deficiency of vitamin B12 leads to a megaloblastic anemia. Cobalt also plays an important role in thyroid metabolism in humans. The Co content was observed to be high in roots of Ashwagandha (3.91 µg/g).The higher Co and Fe content in Ashwagandha roots suggests there use in medicinal preparation for treatment of anemia. The elements like Hg, Pd, Cd and Ni are supposed to be toxic in nature and their presence in trace amount in various medicinal plant sample analyzed is due to the pollution arising from automobile and industrial activities.

Inter-elemental correlations

Several literature reports suggest interrelationship of essential elements like K, Na, Fe and Zn[6, 10, 14]. The regulation of metal ion flows, especially of K^+ and Na^+, is crucial to life and is most clearly exemplified by the ionic movements that occur in nerve cells during excitation and transmission of the action potential. The regulation of potassium is intimately involved with that of sodium and the two are largely interdependent. From the experimental

data, it is observed that K/Na ratio varies between minimum of 20.9 in Panfuti to maximum of 120.4 in Vala. The result indicates that potassium content is 20.9 times of sodium in Panfuti, and ~ 120 times in Vala. The variation of K/Na ratio for different plant samples is graphically represented in Figure 1. The transition elements Fe, Zn, and Co are well known for their role in biochemical processes[10]. Iron deficiency is common in uremic patients, it causes substantial blood losses. Some reports indicate that dysgeusia, poor food intake, and impaired sexual function, which are common problems of uremic patients, may be improved by zinc supplements[31]. In blood, about 85% of the zinc combines with protein for transport after its absorption, and its turnover is rapid in the pancreas. Deficiency of zinc causes diabetic hyposima, hypogeusia or coma[15]. The availability of Zn in the range of 14.8–28.4 µg/g may be beneficial for diabetic patients as its deficiency has been correlated with acute and chronic mal absorption states [30,32]. Similarly Fe is important because it eliminates phlegm and strengthens the function of stomach. Iron is found in body tissue enzymes and helps with energy metabolism. It facilitates the oxidation of carbohydrates, protein and fat to control body weight, which is very important in diabetes[15]. The requirement of Fe for an adult is 20 mg/day and for a child is 10 mg/day. From the result of medicinal plants analyzed, Fe/Zn ratio varies from 5.2 in Panfuti to 20.0 in Shweta musli (Figure 2). Cobalt in the form of Vitamin B-12 is in its physiologically active form. It is very essential to provide 3 µg per day in the form of Vitamin B-12 for a diabetic individual. A plot of Fe versus Co shows linear relationship (Figure 3) with r = 0.752, which represents somewhat poor relationship. It is possible due to the fact that all parts of the medicinal plants are different i.e. seeds and fruits as reported by Razic et.al[33]. In general, it may be mentioned that interrelationship of several elements in medicinal herbs suggest synergistic or antagonistic effects, thus providing various elements to the body in bioavailable form in a balanced manner with almost no harmful effects except some environmental contaminants. These, however, should be avoided by collecting herbs grown in a clean and well controlled environment [10].

Conclusion

Although there appears to be little knowledge of the precise molecular mechanisms, many Ayurvedic preparations nevertheless appear to demonstrate significant success in treatment of complex diseases. Presumably Ayurvedic medicines contain trace elements in a bioavailable form and their impact on the overall pharmacological action cannot be ruled out. Although the direct link between elemental content and curative capability is yet to be established, such studies are vital to understanding the pharmacological action of herbs. The data obtained in the present work will be helpful in the synthesis of new Ayurvedic drugs which can be used for the control and cure of various diseases. However, in order to develop a stronger basis for appreciating the curative effects of medicinal plants, there is a need to study the effect of soil and climatic conditions on the elemental contents of these medicinal plants. It has been demonstrated that *INAA*, with multi-elemental characterization over a wide range of concentration, its blank free-nature and minimum sample preparation is ideal for such studies.

Table 4: Elemental Analysis of some medicinal plants by NAA and AAS Techniques

Name of the medicinal plant (Botanical name)	Parts used	Elements																	
		K (mg/g)	Mn (µg/g)	Na (mg/g)	Fe (µg/g)	Zn (µg/g)	Cu (µg/g)	Co (µg/g)	Br (µg/g)	Sm (µg/g)	Cl (mg/g)	La (µg/g)	Al (mg/g)	Cr † (µg/g)	Ca † (mg/g)	Cd † (µg/g)	Ni † (µg/g)	Pb † (µg/g)	Hg † (µg/g)
Panfuti (Bryophyllum pinnatum)	*Leaves*	6.68 (±0.27)	198 (±13)	0.32 (±0.02)	248 (±11)	47.5 (±2.2)	7.54 (±0.25)	0.14 (±0.01)	0.54 (±0.02)	ND	0.50 (±0.02)	0.65 (±0.03)	2.06 (±0.12)	7.20 (±0.32)	0.41 (±0.02)	2.22 (±0.13)	3.23 (±0.24)	3.00 (±0.17)	5.00 (±0.25)
Ashwagandha (Withania somnifera)	*Roots*	22.3 (±1.6)	80 (±4)	0.30 (±0.02)	324 (±18)	39.5 (±1.8)	3.87 (±0.21)	3.91 (±0.18)	14.55 (±1.10)	0.16 (±0.01)	ND	2.11 (±0.17)	1.75 (±0.10)	12.64 (±1.07)	4.52 (±0.03)	5.40 (±0.23)	4.20 (±0.18)	ND	ND
Sarpgandha (Rauwolfia serpentine)	*Roots*	17.05 (±1.13)	167 (±10)	0.46 (±0.03)	288 (±15)	32.6 (±1.7)	1.35 (±0.10)	0.46 (±0.02)	55.62 (±2.33)	0.24 (±0.02)	4.70 (±0.22)	0.13 (±0.01)	0.26 (±0.15)	1.44 (±0.10)	7.55 (±0.31)	0.70 (±0.03)	1.80 (±0.09)	2.60 (±0.11)	4.30 (±0.21)
Vala (Vetiveria Zizanoides)	*Roots*	6.02 (±0.30)	407 (±23)	0.05 (±0.002)	221 (±13)	21.2 (±1.4)	4.44 (±0.21)	0.63 (±0.03)	7.06 (±0.31)	0.56 (±0.03)	3.23 (±0.14)	2.44 (±0.13)	1.85 (±0.09)	18.73 (±1.08)	1.78 (±0.11)	0.70 (±0.02)	4.30 (±0.21)	3.77 (±0.13)	7.52 (±0.34)
Anant mool (Hemidesmus indicus)	*Roots*	ND	385 (±26)	3.11 (±0.20)	207 (±12)	29.4 (±2.0)	9.55 (±0.42)	0.10 (±0.01)	24.9 (±1.7)	0.05 (±0.002)	6.14 (±0.25)	2.15 (±0.13)	0.54 (±0.02)	56.7 (±2.1)	1.56 (±0.10)	3.60 (±0.19)	ND	0.84 (±0.04)	4.65 (±0.24)
Shweta musli (Chlorophytum Borivilianum)	*Roots*	8.22 (±0.41)	214 (±16)	0.07 (±0.005)	260 (±21)	13.0 (±1.1)	7.30 (±0.31)	0.14 (±0.01)	11.1 (±0.9)	ND	2.55 (±0.17)	0.68 (±0.03)	0.31 (±0.01)	5.77 (±0.21)	0.79 (±0.03)	1.33 (±0.08)	ND	4.50 (±0.21)	0.73 (±0.04)
CTA VTL-2 (Virginia Tobacco Leaves)		[10.3] {10.0} (±0.09)	[79.7] {80.2} (±7.5)	[0.312] {0.308} (±0.02)	[1083] {1100} (±104)	[43.3] {44.1} (±2.7)	[18.2] {18.9} (±0.9)	[0.429] {0.445} (±0.02)	[14.3] {15.2} (±1.0)	[0.157] {0.162} (±0.01)	[7.43] {7.25} (±0.31)	[1.01] {1.07} (±0.08)	[1.682] {1.704} (±0.07)	[1.87] {1.79} (±0.09)	[36.0] {35.4} (±1.9)	[1.52] {1.53} (±0.06)	[1.98] {2.01} (±0.10)	[22.1] {22.9} (±1.1)	[0.048] {0.050} (±0.002)

† Elements detected by AAS technique (±) Standard deviation [ ] Certified Values { } Measured Values ND = Not Detected

Figure 1: Variation of K / Na ratio in different medicinal plant samples

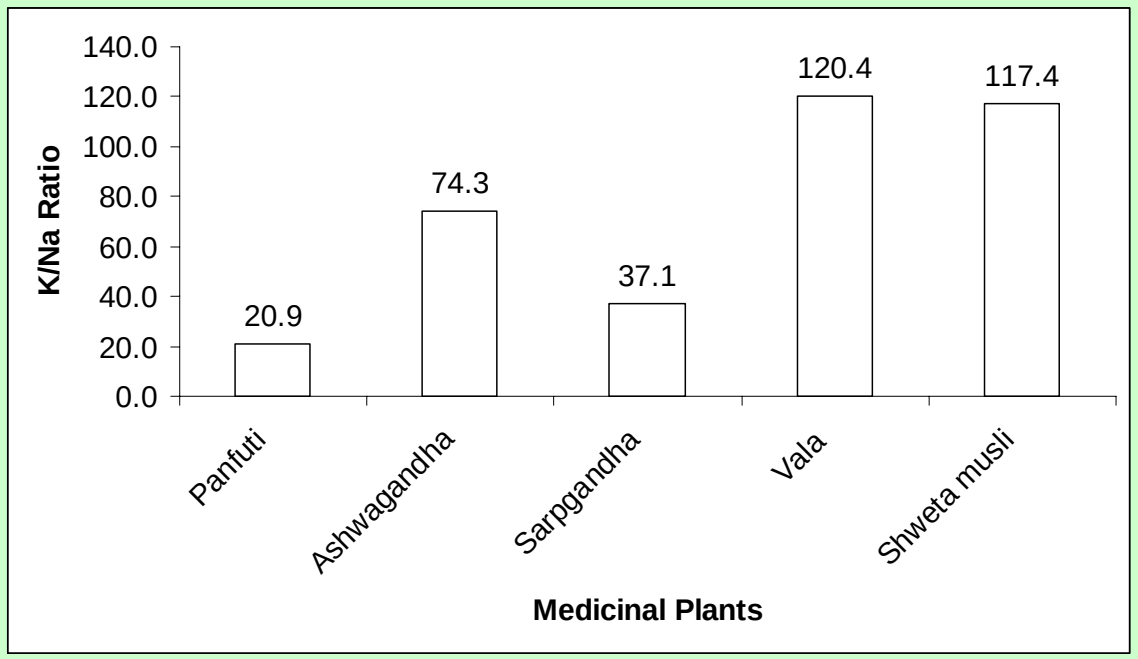


Figure 2: Variation of Fe / Zn ratio in different medicinal plant samples

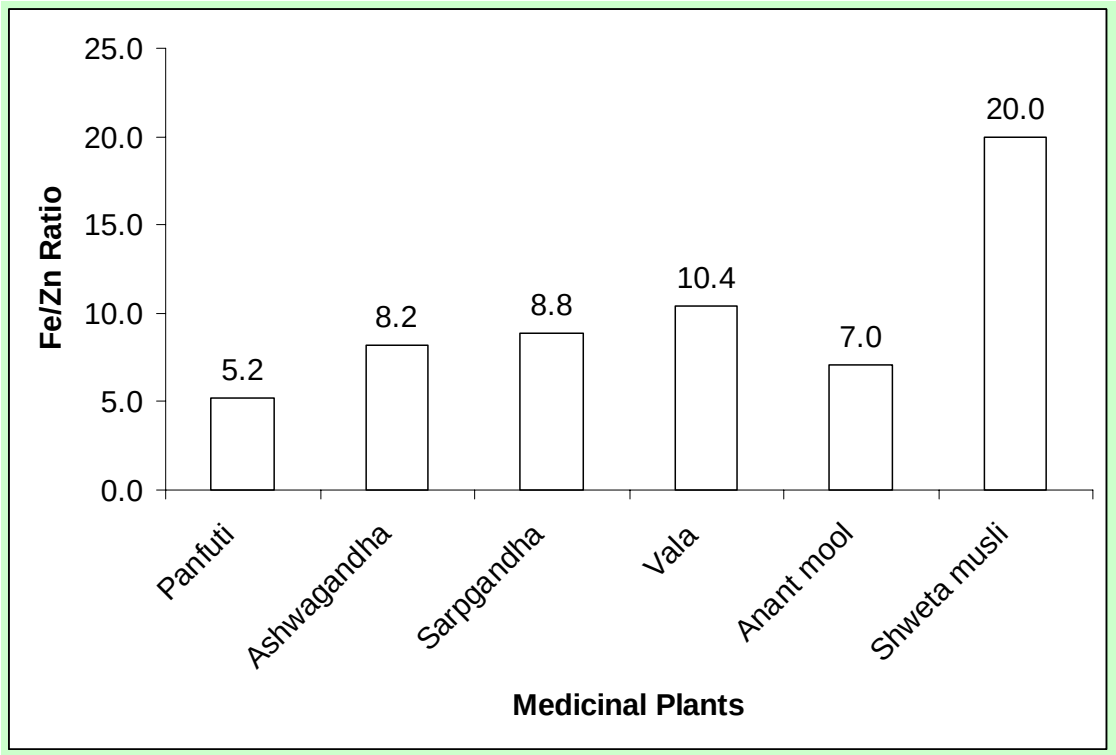
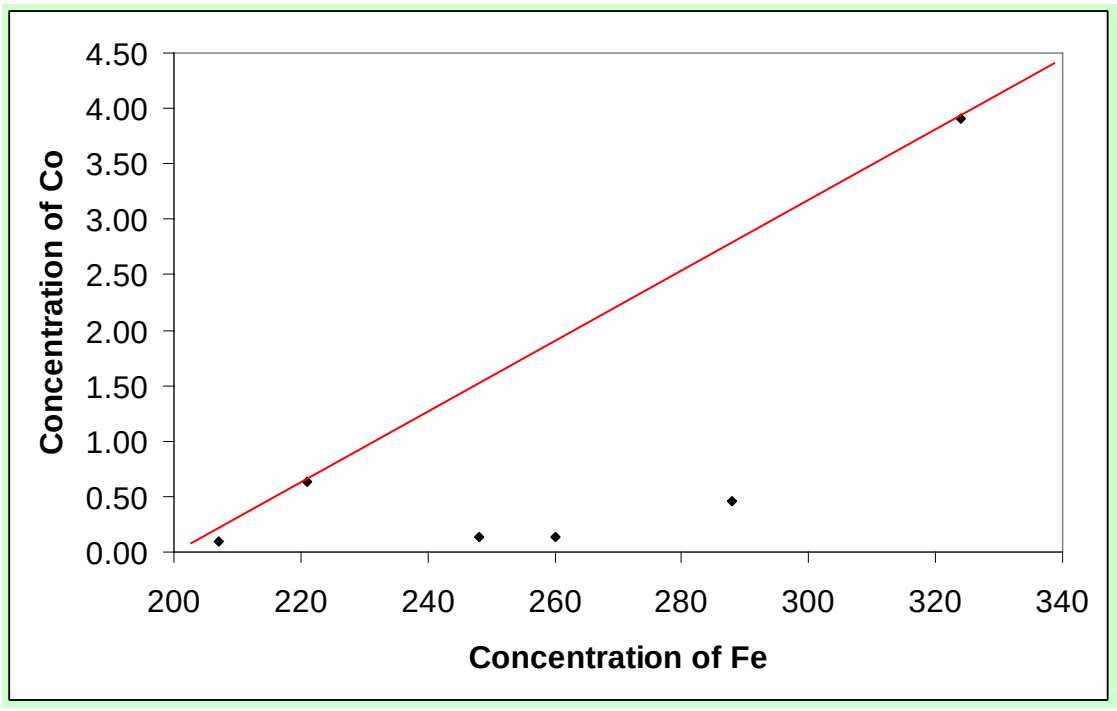


Figure 3: Correlation between Fe and Co concentrations in different medicinal plant samples



Correlation coefficient (r) = 0.752

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