Research Journal of Environmental Toxicology

ISSN 1819-3420

Academic Journals Inc.

www.academicjournals.com

Research Journal of Environmental Toxicology 4 (3): 178-184, 2010
ISSN 1819-3420 / DOI: 10.3923/rjet.2007.78.84

A Preliminary Study on Herbal Resources and their Contamination with Toxic Heavy Metals around Pulicat Lake, North Chennai, South East Coast of India*

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Abstract: In the present study, available herbal resources among the 96 villages around Pulicat Lake have been isolated, identified and located using global positioning system. Nearly 34 species of herbal plants belonging to 24 families have been observed in these villages. Analysis of 27 plant and 27 soil samples for concentrations of toxic heavy metals (cadmium, chromium and lead) reveals relatively higher concentrations of cadmium (4.81 μg mL^{-1}) and chromium (1.472 μg mL^{-1}) in the plants when compared with the soil samples. In addition to this, 22 water samples were collected and their physiochemical parameters like pH, salinity, chloride, carbonate and bicarbonate were analyzed. The results obtained indicate that pH and chloride do not seem to influence the bioavilability of toxic heavy metals. Further work is required to establish the relationships among physiochemical characters of the water, soil, accumulation of heavy metals in plants and their physiology.

Key words: Lake sediments, medicinal plants, Pulicat Lake, industrial pollution, toxicity, human health

INTRODUCTION

The use of herbal medicines in therapeutics as well as in dietary supplement has increased vastly in the last decades (Khan *et al*., 2001; WHO, 2002; Wojcikowski *et al*., 2004). This has rapidly increased the demand for medicinal herbs but the lack of adequate regulation laws has led to decline in the quality of herbs and increase in the marketing of contaminant herbs. Poisoning associated with the presence of toxic heavy metals in herbal medicinal products was reported in Asia and European countries (Abou-Arab *et al*., 1999; Ernst, 2002; Chan, 2003). Plants accumulate these toxic heavy metals from the soil, water and some times from air (McLaughlin *et al*., 1999). However, high concentration of toxic heavy metal can occur in medicinal products, if the plants were grown in polluted areas or when toxic heavy metals were used as active ingredients in herbal medicinal preparation. In addition, several other factors that enhance the heavy metal contamination in plants are, (I) Environmental condition in which the plants were grown (ii) Application of toxic metals-containing fertilizers, fungicides and insecticides (iii) Processing and storage conditions and (iv) Type of industrial effluents released (Abou-Arab *et al*., 1999).

Pulicat Lake is the second largest brackish water lagoon in India, which runs parallel to the Bay of Bengal, bordering the east coast in Nellore District of Andhra Pradesh, with a portion of it extending

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*Originally Published in Research Journal of Environmental Toxicology, 2007

into Thiruvallur District of Tamil Nadu. The lake is about 360 sq km and contains diverse natural resources. *Catharanthes roseus, Pedalium murex, Argemone mexicus* and other plants is the most dominant flora in the coastal regions of Pulicat Lake. The local people regularly harvest the plants and distribute them to the vendors. The improperly treated industrial effluents, including those from two coal based power plants and petrochemical industries from the Ennore Creek and Buckingham Canal, ultimately reach the Pulicat Lake through its bar mouth from the Bay of Bengal. Earlier studies in soil and sediment samples of the Lake have recorded elevated levels of heavy metal concentrations, especially cadmium, arsenic and mercury (Padma and Periakali, 1998, 1999; Periakali and Padma, 1998; Kamala Kannan and Krishnamoorthy, 2006). Hence, the present research has been undertaken to acquire information about the available herbal resources in Pulicat Lake with special emphasis on toxic heavy metals present in the plant as well as soil samples. In addition physico-chemical parameter of the water samples were also analyzed to study their influence on bioavilability of metals.

MATERIALS AND METHODS

In all, 96 villages were covered in two phases of fieldwork (November 2003 to November 2004) around Pulicat Lake and the available herbal plants in villages were isolated and identified. The exact locations were fixed with the help of a global positioning system. Twenty-two water samples were collected (15 during pre monsoon and 7 during monsoon) and analyzed for physiochemical parameters like pH, salinity, chloride, carbonate and bi-carbonate. Soil samples were taken randomly at the locations of plant sampling in 27 inner lake and outer villages.

Salinity, carbonate, bicarbonate and chloride were estimated titrimetrically following the procedure of Strickland and Parsons (1960). Dry ashing methods were followed for the digestion of plant samples (Tuzen, 2003) and the soil samples were digested according to Loring and Rantala, 1992. The toxic metals were analyzed using an Atomic Absorption Spectrophotometer (Perkin Elmer, AA 700). Instrument is calibrated with standard solutions prepared from commercial materials. Analytical blanks were run in the same way as the samples and concentrations were determined using the standard solutions prepared in the same acid matrix. The standard reference material (Merck) was used to check the accuracy of present results.

RESULTS AND DISCUSSION

Thirty-four species of herbal plants belonging to 24 families were isolated and identified from the 96 villages (Table 1). A total of 22 water samples were collected during the pre monsoon and post monsoon seasons. Among these, 11 were ground water and the other 11 backwater samples. The various physiochemical parameters analyzed in the samples are presented in the Table 2.

Bioaccumulation of heavy metals in plants depends upon several factors such as pH, chloride and other ions present in the soil. Soil pH exerts major control on the solubility and ability of the metals to form chelates in the soil. Acidic soils enhance the mobility and availability of the toxic heavy metals present in the soil (Ledin, 2000). The presence of high chloride concentration in soil or sediment, however, inhibits bioavailability by bonding with the metals (Craig and Moreton, 1985). Other ions like sulfide may also have the same effect (Gilmour and Capone, 1987). Bioavailability of metals also depends upon plant physiology, exposure time, metal concentration and species of chelators. Some times plants uptake toxic heavy metals similar to nutrients in chemical form or behavior; cadmium and arsenic enter the plant system because of their similarity to calcium and phosphate (Pierzynski *et al*., 1994). It is obvious from Table 2 that none of the ground water samples is acidic and their chloride content is also too low (maximum of 0.70 mg L^{-1}) to influence the bioavailability of heavy metals.

Three toxic heavy metals were analyzed in the soil and plant samples collected at twenty-seven sites. The entire samples exhibit a relatively high concentration of at least one of the three heavy metals

Table 1: List of available herbals around the coastal regions of Pulicat Lake

Name of the medicinal plants	Family	Medicinal use
Abutilon indicum L.	Malvaceae	Wound healing, Cough, Leprosy, Piles, Blood vomiting, etc.
Acalypha indica	Euphorbiaceae	Eczema, Rat bites, Scorpion sting, Skin ulcers, etc.
Achyranthus aspera L.	Amaranthaceae	Piles, Rabies, Snake bite, Scorpion sting, Menstrual cycle, Dysentery, etc.
Aegle marmelos	Rutaceaae	Diarrhoea, Dysentery, Dyspepsia, Uropathy Vomiting, Deafness, Seminal weakness, etc.
Argemone mexicana L.	Papaveraceae	Guinea worm infections, Skin diseases, Leprosy, Pruritis, Ulcers, Cough, Malarial fever, etc.
Cardiospermum halicacabum L.	Sapindaceae	Eczema, Arthritis, Rheumatism, Piles, Chronic Cough Nervous disorders, Skin disease, etc.
Cassia auriculata	Caesalpiniaceae	Diabetes, Jaundice, controls excessive menstrual flow, Chylous urine, etc.
Catharanthes roseus	Apocynaceae	Excess urination, Diabetes, Kidney disorders, Leukemia, Excess thirstiness, etc.
Cissus quadrangularis L.	Vitaceae	Anorexia, Dyspepsia, Flatulence, Skin diseases Leprosy, Scurvey, Burns, Hemorrhoids, etc.
Clitoria ternatea	Caesalpiniaceae	Opthalmopathy, Leprosy, Elephantiasis, Bronchitis, Pulmonary tuberculosis, etc.
Coccinia grandis	Cucurbitaceae	Vomiting, Uterine discharges, Leprosy, Skin diseases, Bronchitis, Jaundice, Ulcers, etc.
Crotalaria palida	Fabaceae	Cardiac disorders, Skin diseases, Scabies, Diarrhoea, etc.
Crotalaria retusa	Fabaceae	Cardiac disorders, Stomatopathy, Diarrhoea Scabies, Skin diseases, Leprosy, etc.
Datura metal	Solanaceae	Periodic fever, Arthritis, Malaria, Leprosy, etc.
Euphorbia hirta L.	Euphorbiaceae	Respiratory diseases, Cough, Asthma, Gonorrhoea, Venereal diseases, etc.
Eclipta prostrata	Euphorbiaceae	Jaundice, Hair tonic preparations, Eye diseases, Anemia, Dropsy, Asthma, etc.
Heliotropium curassivicum	Boraginaceae	Cough, Gonorrhoea, Rheumatism, Bronchitis, Ulcers, Sores, Wounds, Erysipelas, etc.
Hygrophila auriculata	Acanthaceae	Bright's disease, Jaundice, Arthritis, Dysentery, Anemia, Gastropathy, Gonorrhoea, etc.
Leucas aspera	Lamiaceae	Stomach disorders, Diarrhoea, Eye disorders, Indigestion, etc.
Melothria maderaspatana L.	Cucurbitaceae	Bronchitis, Chest pain, Cough, Gastropathy Dyspepsia, Wheezing, etc.
Mimosa pudica L.	Mimosaceae	Vaginopathy, Ulcers, Dysentery, Jaundice, Asthma, Hydrocele, Conjunctivitis, etc.
Ocimum tenuiflorum	Lamiaceae	Cough, Scorpion sting, Poisonous bites, Parasiticide, etc.
Opuntia dillenii	Cactaceae	Wound healing, Eye diseases, Cough, etc.
Pedalium murex L.	Pedaliaceae	Anti-inflammatory, Calculi, Ulcers, Flatulence Spermatorrhoea, Splenomegaly, etc.
Pergularia daemia	Apocynaceae	Uterine and menstrual disorders, Inflammation, Vitated conditions, Anti pyretic, etc.
Phyllanthus amarus	Euphorbiaceae	Jaundice, Cobra bite, Itching, Eczema, Anemia, Spleen and Kidney inflammation, etc.
Pistia sp.	Araceae	Asthma, Dysentery, Cough, etc.
Portulaca sp.	Portulacaceae	Stomachie, Antibacterial, Vomiting, Skin diseases, Cardio vascular diseases, etc.
Pysalis minima	Solanaceae	Vitiated conditions of pitta, Gastropathy, Ulcers, Bronchitis, Pruritis, Erysipelas, etc.
Solanum trilobatum L.	Solanaceae	Inflammation, Colic, Constipation, Stomachie, Dyspepsia, Anorexia, Leprosy, etc.
Solanum virginianum	Solanaceae	Skin disorders, Tuberculosis, Cough, Respiratory infections, Itching, etc.
Tribulus terrestris L.	Zygophyliaceae	Anorexia, Cough, Asthma, Gonorrhoea Inflammation, Epistaxis, etc.
Tridax procumbens	Asteraceae	Wound healing, Ulcer, etc.
Vitex negundo	Verbenaceae	Arthritis, Bronchitis, Malaria, Leprosy, Cholera, Cardiac diseases etc.,

Table 2: Analytical results of water samples

Site	Source	Season	Location	pH	Carbonate (mg L^{-1})	Bi-Carbonate (mg L^{-1})	Salinity (ppt)	Chloride (mg L^{-1})
Vanjivakkam	Ground water	Monsoon	13° 24' 48" 80° 15' 44"	7.5	17.7	335.5	1.3	0.7
Uppunelvayal	Ground water	Monsoon	13° 27' 20" 80°13' 05"	7.6	2.9	427	0.5	0.3
Kammala madam	Back water	Monsoon	13° 27'26" 80° 16'59"	8.0	35.4	823.5	19.4	10.7
Pakkam	Ground water	Monsoon	13° 25' 12" 80° 16' 48"	7.5	2.9	67.1	0.06	0.04
Pakkam	Back water	Monsoon	13° 25' 21" 80° 16' 35"	8.3	5.9	280.6	12.9	7.0
Avirivakam	Back water	Monsoon	13° 25' 35" 80° 16' 23"	8.5	5.6	262.3	15.9	8.7
Kammala madam	Ground water	Monsoon	13° 23' 35" 80° 16' 59"	7.6	3.0	158.6	0.34	0.2
Annamali cheri	Back water	Monsoon	13° 27' 26" 80° 15' 48"	8.2	5.6	286.7	39.6	21.6
Pulicat Lake	Back water	Monsoon	13° 24' 18" 80° 18' 01"	8.2	35.4	186	25.4	13.8
Pasiavaram	Back water	Monsoon	13° 24' 24" 80° 19' 26"	8.1	5.9	268.4	34.5	18.8
Edamani kuppam	Ground water	Monsoon	13° 24' 27" 80° 19' 08"	7.6	8.9	384.3	0.41	0.2
Kulathumedu	Back water	Monsoon	13° 24' 35" 80° 18' 27"	7.9	5.9	250.1	33.5	18.2
Satankuppam	Back water	Monsoon	13° 23' 23" 80° 19' 08"	7.9	8.9	256.2	35.8	19.6
Satankuppam	Ground water	Monsoon	13° 23' 54" 80° 19' 36"	7.5	5.9	115.9	0.7	0.4
Satankuppam	Back water	Monsoon	13° 24' 46" 80° 19' 26"	7.9	5.9	262.3	32.8	17.9
Agaram	Ground water	Post monsoon	13° 27' 07" 80° 12' 32"	7.1	5.9	140.3	0.36	0.2
Chinnanatham	Ground water	Post monsoon	13° 27' 09" 80° 08' 16"	7.0	2.9	103.7	0.11	0.05
Mettukuppam	Back water	Post monsoon	13° 29' 00" 80° 10' 51"	7.8	5.9	158.6	27.4	14.9
Periyamangodu	Ground water	Post monsoon	13° 29' 06" 80° 12' 27"	7.5	2.9	140.3	1.3	0.7
Sunnambu kulam	Back water	Post monsoon	13° 29' 33" 80° 09' 19"	8.2	14.8	122	33.8	18.4
Sennavaram	Ground water	Post monsoon	13° 27' 37" 80° 09' 60"	6.9	5.9	128	0.4	0.2
Vettukadu	Ground water	Post monsoon	13° 28' 21" 80° 09' 02"	7.2	2.9	149.1	1.3	0.7

analyzed (Table 3). At some locations-Edamanikuppam, Pulicat Lake, Agaram, Kallur, Bottakuppam, Kuppam, Pamulumitta, Irakam and Sulurpet chromium concentrations are higher in plant samples when compared to soil samples. Januz *et al*. (1994) reported high concentration of heavy metals in plants growing in industrial areas. The variations in heavy metal concentration in plant samples, however, may be due to differential uptake by plant species, selective absorption of heavy metals and their varying residence times in plant system.

Previous research in the sediments of Pulicat Lake shows high concentrations of cadmium and arsenic (Padma and Periakali, 1998, 1999). The average concentration of cadmium during pre monsoon was 6.25 μg g^{-1} and in post monsoon it was 7.38 μg g^{-1}. When compared with our results, the soil samples collected even from inner lake villages contain a maximum of only 7.350 μg mL^{-1} of cadmium, 7.55 μg mL^{-1} of chromium and 0.945 μg g^{-1} of lead which is several times less. Plants that grow in the metal contaminated soils have the ability to accumulate metals (Baker, 1981). Baker (1995) also

Table 3: Heavy metal concentration in plants and soil samples

Site	Sample	Name of the plant	Season	Parts used	Cd μg mL^{-1}	Cr μg mL^{-1}	Pb μg mL^{-1}
Andar Madam	Soil		Monsoon		BDL[a]	BDL	1.92
Andar Madam	Plant	*Crotalaria retusa*	Monsoon	Flowers Leaves	0. 01	0. 03	0.75
Annamalaicheri	Soil		Monsoon		BDL	BDL	BDL
Annamalaicheri	Plant	*Cassia auriculata*	Monsoon	Flowers Leaves	0.006	BDL	BDL
Edamanikuppam	Soil		Monsoon		BDL	0.28	1.43
Edamanikuppam	Plant	*Pedalium murex*	Monsoon	Leaves Stem	0.001	BDL	0.75
Kanjivayal	Soil		Monsoon		0.007	1.171	1.55
Kanjivayal	Plant	*Hygrophila auriculata*	Monsoon	Leaves Flowers	0.009	1.40	0.18
Pulicat Lake	Soil		Monsoon		BDL	1.76	2.93
Pulicat Lake	Plant	Portulaca sps	Monsoon	Leaves	0.032	0.37	0.75
Sunnambukulam	Soil		Post Monsoon		BDL	0.43	BDL
Sunnambukulam	Plant	*Aregemone mexicane*	Post Monsoon	Flowers	BDL	0.96	BDL
Talaiyaripalayam	Soil		Post Monsoon		BDL	0.02	BDL
Talaiyaripalayam	Plant	*Mimosa pudica*	Post Monsoon	Flowers Leaves	0.011	0.75	BDL
Agaram	Soil		Post Monsoon		BDL	0.29	2.53
Agaram	Plant	*Mimosa pudica*	Post Monsoon	Flowers	0.007	BDL	0.18
Kallur	Soil		Post Monsoon		0.03	1.80	BDL
Kallur	Plant	*Cathoranthus roseus*	Post Monsoon	Flowers Leaves	0.08	0.25	BDL
Bottakuppam	Soil		Monsoon		BDL	4.175	0.180
Bottakuppam	Plant	*Pedalium murex*	Monsoon	Leaves Stem	3.557	1.341	0.014
Ramapuram	Soil		Monsoon		3.403	1.587	0.151
Ramapuram	Plant	*Pedalium murex*	Monsoon	Leaves Stem	0.363	0.078	BDL
Kuppam	Soil		Monsoon		BDL	1.609	0.119
Kuppam	Plant	*Mimosa pudica*	Monsoon	Flowers Leaves	1.0	BDL	BDL
Vattuvambedu	Soil		Monsoon		5.67	2.68	0.093
Vattuvambedu	Plant	*Pedalium murex*	Monsoon	Leaves Stem	BDL	0.127	0.106
Pamulumitta	Soil		Monsoon		BDL	7.55	0.079
Pamulumitta	Plant	*Pedalium murex*	Monsoon	Leaves Stem	4.81	0.397	0.308
Sunnambukulam	Soil		Monsoon		5.23	3.86	0.945
Sunnambukulam	Plant	*Pedalium murex*	Monsoon	Leaves Stem	2.96	0.002	0.913
Gopalreddipalem	Soil		Monsoon		6.162	1.651	0.729
Gopalreddipalem	Plant	*Mimosa pudica*	Monsoon	Flowers Leaves	BDL	BDL	0.160
Medupalakuppam	Soil	`	Monsoon		4.008	1.470	BDL
Medupalakuppam	Plant	*Pedalium murex*	Monsoon	Leaves Stem	2.372	1.472	BDL
Irakam	Soil		Monsoon		0.152	1.204	0.164
Irakam	Plant	*Pedalium murex*	Monsoon	Leaves Stem	2.472	1.210	BDL
Sulurpet	Soil		Monsoon		BDL	3.884	0.729
Sulurpet	Plant	*Pedalium murex*	Monsoon	Leaves Stem	0.006	0.346	0.169
Towards Venadu	Soil		Monsoon		BDL	2.367	0.437
Towards Venadu	Plant	*Pedalium murex*	Monsoon	Leaves Stem	BDL	0.37	0.03
Tadakuppam	Soil		Monsoon		2.219	4.533	0.193
Tadakuppam	Plant	*Pedalium murex*	Monsoon	Leaves Stem	1.156	1.487	BDL
Nochikuppam	Soil		Monsoon		2.078	3.652	BDL
Nochikuppam	Plant	*Pedalium murex*	Monsoon	Leaves Stem	1.210	1.341	BDL

Table 3: Countinued

Site	Sample	Name of the plant	Season	Parts used	Cd μg mL^{-1}	Cr μg mL^{-1}	Pb μg mL^{-1}
Kasigadukuppam	Soil		Monsoon		0.649	3.9932	0.097
Kasigadukuppam	Plant	*Tribulus terrestris*	Monsoon	Stem	BDL	1.472	BDL
				Root			
Pundikuppam	Soil		Monsoon		8.867	2.196	0.776
Pundikuppam	Plant	*Pedalium murex*	Monsoon	Leaves	3.080	1.292	0.172
				Stem			
Tadakuppam	Soil		Monsoon		2.016	1.095	0.195
Tadakuppam	Plant	*Pedalium murex*	Monsoon	Leaves	1.266	1.309	BDL
				Stem			
Kuppam	Soil		Monsoon		5.322	3.994	0.257
Kuppam	Plant	*Pedalium murex*	Monsoon	Leaves	2.152	0.042	0.078
				Stem			
Irakam(North)	Soil		Monsoon		7.350	4.797	0.237
Irakam	Plant	*Pedalium murex*	Monsoon	Leaves	2.122	0.983	0.080
				Stem			

a - Below Detection Limit

reported that 400 species of plants have the ability to accumulate high levels of metals. The presence of a higher number of plants in lake villages may, therefore, play an important role in the reduction of heavy metal pollution in inner lake soil samples.

Water samples indicate that pH and chloride concentration do not seem to play major role in the bioavailability of heavy metals in plants. Cadmium, chromium and lead concentrations in soil and plant samples at twenty seven locations in both the inner and outer lake villages reveal that at least one of the three heavy metals has higher concentration in all the plant samples than in soil samples. At eighteen locations, chromium concentrations are relatively higher in soil samples. This preliminary study reiterates the need for regular monitoring of water, soil and plant samples of Pulicat Lake and its environment for heavy metal concentrations, more so in view of the availability of medicinal herbal resources in this region.

ACKNOWLEDGMENTS

Authors are grateful to the authorities of University of Madras for financial support under UGC-University with Potential for Excellence (UWPFE) programme for the funding support to carry out this work and also for the teaching and fellowships to the research scholars (S.K, B.P and P.D). Authors also acknowledge the DST-FIST-AAS Instrumentation facility available at the Department of Applied Geology, University of Madras.

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