The 11th National Symposium on Hydrology
National Institute of Hydrology, Roorkee (India), November 22-23, 2004

Environmental Impact of Human activities to Urban Lake Sediments: Potentially Toxic Elements (PTEs) Contamination in Hussainsagar Lake, Hyderabad

V.V.S. Gurunadha Rao, Mitsuo Yoshida,*
B.A. Prakash, S.V.N. Chandrasekhar, and K. Mahesh Kumar

Environmental Hydrology Group
National Geophysical Research Institute (NGRI), Hyderabad 500 007
Tel 040-234343635 Fax: 040-23434651 Email: gurunadharao@ngri.res.in
** Institute for International Cooperation, Japan International Cooperation Agency (JICA), Tokyo 162-8433, Japan. Email: Yoshida.Mitsuo.2@jica.go.jp*

Abstract

Hussainsagar Lake in the heart of twin cities of Hyderabad and Secunderabad used receive toxic substances from the industrial wastewater discharges draining into it. The toxic substances of particular interest are potentially toxic elements (PTEs), heavy metals and other trace elements, derived from urban runoff as well as industrial and municipal sewage effluents. PTEs entering the lake can adsorb onto the fine particles in the water, which may in turn settle down on lake bottom sediments. The accumulated PTEs in the sediments may risk the aquatic organisms and exceeds the lake water quality objectives. In order to assess the accumulation of PTEs, NGRI has carried out sediment sampling during June and August 2003 at inlet/out channels of the Hussainsagar lake and JICA has determined the PTEs concentrations utilizing the ICP-MS.

The pattern of PTEs distribution inside the lake sediments indicate elevated concentrations sites are limited to industrial channel coming from Kukatpally. Other sides show elevated concentrations of mercury, which may be result of cultural activities of Ganesh festival. The variation pattern of toxic elements implies that the source is mainly the industrial wastewater discharges. Eight PTEs are found in this type: As, Cr, Cu, Pb, Zn, Ag, Ni and Hg. Almost all the above elements are exceeding the threshold limits levels. The concentrations of heavy metals at the entry of Kukatpally channel into the lake have shown relatively elevated concentration 2 to 3 times with regard to background levels of above toxic substances in the lake. Slightly reduced concentrations of the substances could be noticed during the August sampling, which may be due to leaching through fresh urban runoff entering the lake during monsoon season. In addition to the PTEs analysis, preliminary water quality analyses also indicated the above toxic elements persistence in the lake water. These results indicate influence of anthropogenic activities on the lake pollution.

Introduction

Hussainsagar, the picturesque lake situated between the twin cities of Hyderabad and Secunderabad is an ecological and cultural landmark on the Hyderabad. Lake was excavated in 1562 mainly to harvest drinking water from Musi River by Balakpur Canal. However with passage of time the lake lost its importance as a source of drinking water supply. However, it is till recently extensively used for washing clothes, cattle and recreation. The deterioration of lake water quality is due to unplanned industrialization and urbanization around the lake after 1960's. During last decade the lake has assumed importance in national news due to recurrent fish kills and its conservation is attracting national and international experts. The protection of lake in terms of improved water quality, control of pollution and beautification of its environment for recreation purposes has assumed greater significance with the installation of monolithic Buddha statue in the lake. It was installed on the rock of Gibralter on the Hyderabad side of the tank bund.

Recently in the urban lakes conference, the HUDA has brought the problems of encroachment, pollution from domestic sewage and industrial discharges, weeds and how HUDA is trying to restore the lake environment. It is noted that pollution in the lake has a further impact of nitrates in groundwater. The phosphates and toxic substances adsorb to the sediments and remain in the lakes. The present status indicates the nutrients loads have exceed their concentration as regards Eutrophic condition and it presents a hypereutrophic status. Diseases like jaundice, typhoid and gastro enteritis may rise and vector transmitted diseases like malaria also increase among the population living adjacent to the shoreline of lakes and consuming the impacted groundwater. HUDA is trying to treat the lakes not in isolation but as a part of drainage basin/watershed it forms in the city. Further that there is depletion of groundwater levels in the city and there is good scope of enhancing the groundwater recharge potential through lake waters.

A recent study by water authorities showed a supply-demand gap in the Hyderabad city, where the demand stand at 1070 Million Liters per Day (MLD) whereas the supply is pegged at 480 MLD through surface water diversions and rest is withdrawn from groundwater sources. The restoration of lakes will enhance the groundwater recharge potential, partly salvaging the demand. Many activities like dredging, desilting, construction of ring bunds and sewage treatment plants have been undertaken.

The Hussainsagar catchment area of the lake is drained by 5 nalas covering separate watersheds and total catchment area is about 275 sq km covering Kukatpally, Dulappally, Bowenpally, Yusufguda and Khairatabad watersheds (Fig. 1). The maximum length of watersheds is about 15 km. The lake is fed by four streams Kukatpally (70 MLD) Picket & Bowenpally (4 MLD), Banjara (6 MLD), Balkapur (13 MLD). Among the four, the Kukatpally nala brings major bulk of inflows to the lake. Except for the storm runoff during rainy season most the inflows enter the lake through Kukatpally nala of about 55 MLD domestic sewage and 15 MLD industrial effluents. The Kukatpally watershed covers about 168 sq km. The catchment area has major industrial areas like Kukatpally, Blanagar, Sanathnagar and Jeedimetla. The length of the lake is 3.2 km, width is 2.8 km and maximum depth 12.5 m with a surface area of 440 ha.

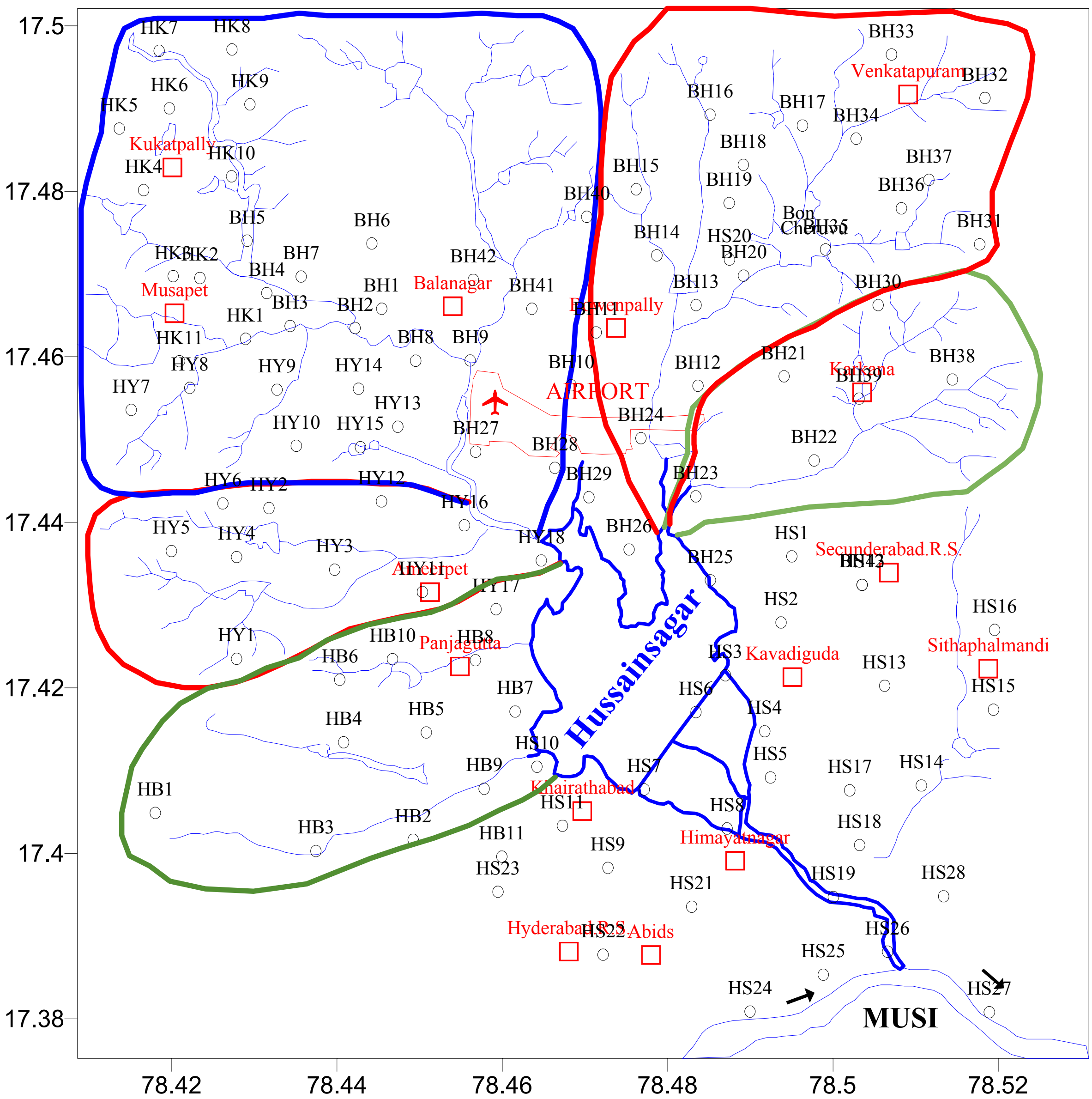

Fig. 1 Watersheds in Hussainsagar Catchment, Hyderabad

Environmental problem

During the last 4 decades Kukatpally and Dullapally watersheds have undergone intensive industrialization and consequent urbanization. Out of the four IDAs in the two watersheds, three IDAs have extreme adverse environmental impact on the Hussainsagar are Kukatpally, Balanagar and Jeedimetla with more than 300 industrial units in public and private sector. The range of products manufactured in the industries includes chemical reagents, organics, pharmaceuticals, drugs, bio-chemicals, synthetic chemicals, detergents, aircraft batteries and alloys, rubber products etc. Still further expansion of industrial activities is noticed even today. Initial phase of industrialization of the lake catchment area a pipeline called Kukatpally main (K Main) was laid during 1996 by Municipal Corporation of Hyderabad to carry effluents from the industrial area down stream to a common STP. With increasing number of industries, the carrying capacity of K Main has exceeded leading to leakage of pipeline. Further some industries are still letting their wastes directly into Kukatpally stream. Increasing urbanization with the settlement of industrial labour further complicated the issue as a large volume of domestic sewage started entering the lake through the Kukatpally stream. Ultimately the Kukatpally stream formed the carrier channel for carrying domestic sewage as well as industrial effluents.

In the beginning the lake could adsorb the pollution and once the carrying capacity of lake exceeded, the adverse manifestations of the lake pollution emerged during 1970 in the form of deteriorating water quality resulting in eutrophication. During 1984 the water hyacinth has been physically removed and blooms of blue green algae introduced. During 1992 the lake water pollution has reached a peak point resulting in growth of water hyacinth (Kodarkar, 1995). Further the environmental problem has escalated by two expanding slums along the western side of the lake. Traditional washing of clothes with lake water is a practice till recently on the eastern part, which is also causing pollution to the lake.

Table 1 Progressive degradation of water quality in Hussainsagar

Parameter	1973 Zafer et al 1976	1986 Muley 1987	1991 Siddiqui & Rao 1993	2003 NGRI
pH	8.2	8.0	8.0	8.5
Conductivity(µs/cm)		3780	1899	1350
Dissolved Oxygen (mg/l)	6.5-9.5	0.6	Nil	2.0 –3.0
BOD (mg/l)				15-20
COD (mg/l)				64 -122
TDS (mg/l)			1234	850
Chlorides (mg/l)	23 –77	390	200	200
Sulphates (mg/l)	---	159	137	120
Total nitrates as N (mg/l)	--	3.22	5.45	6.1
Total Phosphorous (mg/l)	---	5.85	10.8	3.05

The above data in Table 1 indicate till 1970 the lake seems to be pollution free. Later deterioration of lake water quality could be linked to nutrient loading from domestic sewage. The nutrient loading to the lake through the Kukatpally channel which is main drainage entering the lake as regards phosphate loading has been estimated by Kodarkar (1995) range 15.7 mg/l during summer, 12.3 mg/l during monsoon and 16.6 mg/l in Winter. The minimum and maximum values were 9.1 and 22 mg/l respectively. The nitrate as nitrate is 11.9 mg/l in summer, 18.5 mg/l during monsoon and 21.1 mg/l during winter. During 1988-89 the lake used receive about 1041 kg of phosphate and 1024 kg of nitrate as nitrate per day. The enormous nutrient loads after entering the lake water are being adsorbed by sediments in the lake. Particularly phosphate adsorption is very high. Aquatic microorganisms and algae are consuming a very little fraction. In addition there three more streams carrying urban sewage to the lake further enhance the nutrient loading to the Hussainsagar, making the lake attaining hyper Eutrophic status. The progressive annual enhanced nutrient loading to the lake water lead to extensive proliferation of the water hyacinth leading to hyper eutrophication water hyacinth spread on the entire lake surface during 1984. Fish kills in the lake Hussainsagar have been reported since 1976 during summer months after heavy premonsoon showers due to high turbidity and algal blooms. One cause of the fish kills is anthropogenic pollution. Hussainsagar has become a victim of anthropogenic pollution and its renovation/restroration has become a challenge to the scientific community involved in conservation of the environment. Further another KS Main has been constructed during 2000 to carry the industrial effluents to Amberpet Sewage treatment plant by passing the Hussainsagar lake. During last decade lot of countries have come to assist the local government in lake restoration programme through design of efficient primary treatment plants on the inlet channels. In this context the Japanese Development Bank has also shown keen interest to fund the project. The present database helps formulation of guidelines for carrying out dredging operations of Hussainsagar sediments.

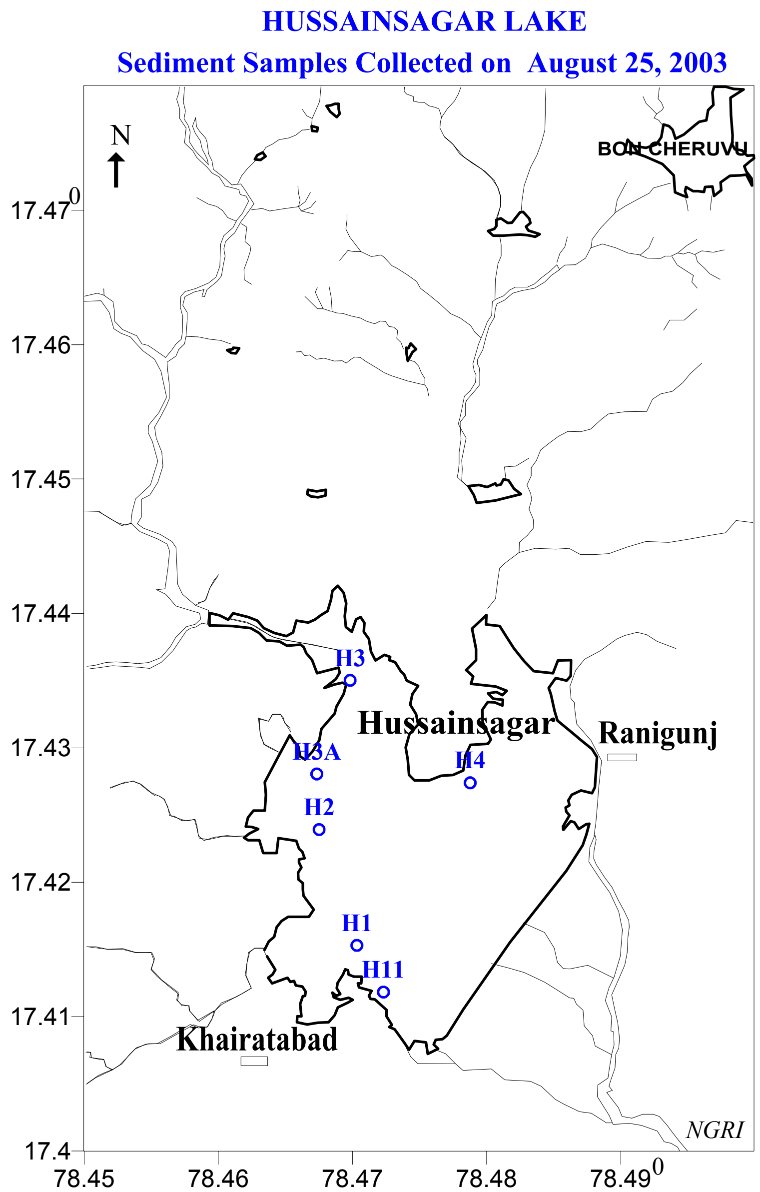

Fig. 2 Location of Sediment samples in Hussainsagar Lake

Sediment Sampling

Under a CSIR network program on groundwater monitoring in urban watersheds NGRI has taken up 5-year study of the Hussainsagar catchment area for assessment of surface water and groundwater conditions. The project aims to develop scientific database on lake water quality as well as sediment quality to suggest measures for restoration strategies. In this direction bimonthly monitoring of lake water and lake sediment samples have been analyzed for nutrient loading as well as for DO, BOD and COD parameters. The industrial effluents discharges have spoiled the Hussainsagar and there is every possibility of heavy metal adsorption to the lakebed sediments. To assess the status of Potentially toxic Elements adsorption on to sediments, sediments samples have been collected at 5 locations in the lake during June and August 2003 and were analyzed in Japan for the heavy metal concentrations (Fig. 2). The sediments have been collected at a depth ranging from 1.5 - 2.0 m in the lake.

Analytical Method

The collected samples were disintegrated and dried under 60°C, and powdered by a ceramic mill. Then the powder samples were sieved by a 68 micron, and the finer fraction was used for the analysis. A 15.0 gm sample split was digested in 90 mL aqua regia ($HCl-HNO_3-H_2O$) at 95 degree in Celsius for one hour. The solution is diluted to 300 mL with distilled water. Analysis was made by an Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). Total 37 elements were measured: B, Na, Mg, Al, P, S, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Sr, Mo, Ag, Cd, Sb, Te, Ba, La, W, Au, Hg, Tl, Pb, Bi, Th, and U. The upper detection limit for Ag, Au, Hg, W, Se, Te, Tl, and Ga is 100 ppm, that for Mo, Co, Cd, Sb, Bi, Th, U, and B is 2 %, and that for Cu, Pb, Zn, Ni, Mn, As, V, La, and Cr is 10 %. The aqua regia digestion of sediment or sludge extracts only a fraction of the major elements (pseudo-total analysis) because silicates are not completely dissolved with this method. Owing to this limitation, results are total to near total for trace and base metals and possibly partial for rock-forming elements such as Na, Mg, Al, K, Ca, Mn, and Fe. However, environmentally concerned components like heavy metals or PTEs not bound to silicates are efficiently dissolved (Ure, 1995), which is indicative for the assessment of toxicity.

Results and Discussion

The results of analyses of sediment samples during June and August 2003 is presented in Table 2. Most of the PTEs are exceeding the threshold element levels of heavy metal concentrations in sediments (Table 3). Particularly Mercury concentration has registered higher value, which may due to cultural activities around the lake during festivals with immersion of idols with lot of paint. In general the PTE concentrations reported at H3 are found to be 3-6 times higher than lake average values, which may be attributable to entry untreated industrial effluent flows through the Kukatpally nala even today. Cadmium, one of the toxic metals, finds its way to water bodies through waste water from the metal plating industries and industries of cadmium nickel batteries, phosphate fertilizer, pigments, stabilizers and alloys (Low and Lee, 1971). The effects of acute cadmium poisoning in humans are very serious among them are high blood pressure, kidney damage and destruction of testicular tissue and red blood cells. Even low concentration of cadmium is known to have detrimental effects on humans with hypertension problems and its associated carcinogenic problems. The suspended load consisting of silt, clay, iron and manganese oxides and organic matter transports cadmium. Koelman and Lijklema (1992) studied the adsorption of cadmium onto sediment and suspended matter of lake Volkerak in the Netherlands and have reported that cadmium is bound almost completely to the geochemical iron, manganese and organic matter. Wiley and Nelson (1984) studies the adsorption of cadmium onto the sediments of sturgeon lake, Oregon and found pH is the critical parameter controlling the cadmium adsorption. Bajracharya et al (1996) reported that zinc and ammonium ions suppress significantly adsorption of cadmium onto the sand soil.

Table 2 Comparison of some PTE concentration (ppm) analyses of sediment samples of Hussainsagar Lake (June and August 2003)

PTE	Location in the Hussainsagar Lake (ref. Fig 2) H1	H2	H3	H4	H5	H11	
Arsenic	4.3	14.3	36.6	3.5	9.6	27.4	- June
	5.0	4.4	12.5	6.7		9.3	- August
Chromium	37.0	52.0	205.0	35.5	69.4	67.0	
	35.9	35.6	147.7	60.0		54.5	
Nickel	32.1	42.9	60.6	25.3	43.9	70.6	
	65.1	31.0	48.0	38.2		38.9	
Zinc	102.6	173.0	1214.2	85.0	359.8	435.6	
	129.0	74.6	709.5	235.1		253.2	
Copper	68.5	57.07	342.5	39.8	85.5	116.6	
	152.4	35.2	179.2	68.2		106.6	
Mercury (ppb)	2622	1064	3988	759	2189	1806	
	2463	641	3850	1235		1392	
Cadmium	1.49	2.0	37.1	1.06	4.12	3.2	
	0.81	1.26	27.0	1.71	4.68	3.0	
Lead	48.6	46.8	169.2	32.8	69.3	91.1	
	89.94	36.33	108.2	65.6		64.0	

Sample Preparation: dry up at 60 degree C and sieved to 230 mesh
Extraction: 1.00 g sample leached with 6 ml 2-2-2-HCl-HNO3-H2O at 95^{0}C for one hour and diluted to 20 ml
Instrument: ICP-AES Perkin Elmer model Plasma Vision 2000 and ICP-MS Perkin Elmer Model Elan 6000.

Table 3 Several criteria for environmental screening of freshwater sediment contamination (unit: mg/kg except specified). Concentration values in the shaded cells are used for sediment contamination screening criteria in present study.

	NOAA SquiRTs for Freshwater Sediment*						Netherlands**			Japan
PTEs	Background		LTEL	TEL	PEL	UET	Ref	Interv.	Test	EQS soil
As	1.1		10.798	5.9	17	17	29	50	30	50
Cd	0.1-0.3		0.583	0.596	3.53	3	0.8	12	5	9
Cr	7-13		36.286	37.3	90	95	100	380	250	
Cu	10-25		28.012	35.7	197	86	36	190	100	
Pb	4-17		37	35	91.3	127	85	530	150	600
Mn	400		630			1100				
Hg	0.004-0.051			0.174	0.486	0.56	0.3	10	2	3
Ni	9.9		19.594	18	35.9	43	35	210	100	
Zn	7-38		98	123.1	315	520	140	720	500	

* NOAA Screening Quick Reference Tables (SQuiRTs) (NOAA, 1999). LTEL; Lowest ARCs H. azteca Threshold Effects Level, TEL: Threshold Effects Level, PEL: Probable Effects Level, UET: Upper Effects Threshold. The 'Background' values is obtained from fresh water sediments.

** Guide values and quality standards used in the Netherlands for assessing soil contamination. Ref.: Reference value, Interv.: Intervention value, Test: Test value (Alloway, 1995)

*** Critical soil total concentration: the range of values above which toxicity is considered to be possible (Kabata-Pendias and Pendias in Alloway,1995); EQS soil: Environmental Quality Standards for Soil (Japan)

Conclusions

The preliminary database generated on Potentially toxic heavy metals concentrations of lakebed sediment samples in Hussainsagar Lake has indicated that the PTEs adsorbed are exceeding the threshold effects level in respect of As, Cd, Cr, Cu, Pb, Hg, Ni and Zn. The database will be serving the needs of lake restoration program by identifying and evaluation of individual contaminant adsorption on to the sediments. Depending on their concentrations, the dredged out sediments can be sent to a landfill away from the lake to avoid toxic heavy metals leaching back into the lake. Further the data base strongly recommends that the dredged out sediments containing hazardous heavy metals viz., Arsenic, chromium, Nickel, Zinc, Mercury, Cadmium and Lead to name a few must be sent to Treatment Storage Disposal Facility (TSDF) of Hyderabad maintained by APPCB near Dindigal for safe disposal. HUDA has initiated preliminary experimental dredging and further evaluations are in progress.

Acknowledgements

Dr. Dimri, Director, NGRI has encouraged the joint collaboration work and we wish to thank him. Mr. M. A. Aziz and Mr. T. Bhaskar Reddy helped in sample collection in the lake and we wish to thank them. Discussions held with HUDA officials have helped in designing the sampling program and we wish to thank all the HUDA team.

References

Alloway, B.J., 1995(ed.), *Heavy Metals in Soils*, *2nd Edition*. Blackie Academic & Professional, Chapman & Hall, London, 368p.

Bajracharya K, Bary DA, Vigneswaran S and Gupta AD., 1996. Heavy metal adsorption in soil : Comparison of bisolute adsorption models and laboratory experiments. In V.P. Singh and B. Kumar (eds.) Water Quality Hydrology, Kluwer Academic publishers. The Netherlands Vol.3 pp.19-26.

Kodarkar, M.S., 1995. Conservation of Lakes (with special reference to water bodies in and around Hyderabad). Indian Association of Aquatic Biologists (IAAB) Publication No.3, pp. 82.

Jain, C.K. and Ram D., 1997. Adsorption of lead and Zinc on bed sediments of river Kali . Water Res. 31(1)154-162.

Wiley JO and Nelson PO, 1984. Cadmium adsorption by aerobic lake sediments J. Environ. Engg. ASCE 110 (1) 226-243.

Kowelmans AA and Lijklema L, 1992. Sorption of Terachlorobenzene and cadmium to sediments and suspended solids in lake Volkerack /Zoon, Water Res. 26(3) 327-337

Jain CK and Sharma MK, 2002. Adsorption of cadmium on bed sediments of river Hindon: Adsorption models and kinetics. Water, Air and Soil Pollution 137: 1-19.

Jain CK, 2001. Adsorption of zinc onto bed sediments of the river Ganga: Adsorption models and kinematics. Hydro Sc. Journal 46 (3) 419-433.

Low KS and Lee CK 1991. Cadmium uptake by the mass Calysupers deleserti, besch. Bioresour.Technolo. 38, 1-6.

Muley, EV 1987. Preliminary report on the fish kills in lake Hussainsagar. Project sponsored by Municipal Corporation of Hyderabd and Andhra Pradesh Pollution Control Board. Pp. 42.

Zafar, AR, Khan, KR and Seenayya, G, 1976. Report on short term study of Hussainsagar lake, Hyderabad, HUDA.

Siddiqui, SZ and Rama Rao, KV, 1993. Physicochemical and biological characteristics of Hussainsagar, an industrially polluted lake, Hyderabad. Proc Acad Environ Biol. 2(2):161-167.

NOAA, 1999, Screening Quick Reference Tables (SQuiRTs). Coastal Protection & Restoration Division, NOAA, USA.

Ure, A.M., 1995, Methods of analysis for heavy metals in soils. In Alloway (ed.), *Heavy Metals in Soils, 2nd Edition*. Blackie Academic & Professional, Chapman & Hall, London, 58-102.