

Spectrophotometer-based student education program on health hazard assessment due to Cr(VI) and Pb contamination in surface and groundwaters of Hyderabad City, India

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ABSTRACT: A student-centric research education program with the active participation of undergraduate students is initiated. The aim is to imbibe “responsible citizenship behavior” in them so that each member becomes conscious and well trained to take up environmental-related issues and challenges for long-term sustainability of the ecosystem. In this work, we report spectrophotometer-based estimation of hexavalent chromium ($57\text{--}268\ \mu\text{gL}^{-1}$) and lead ($34\text{--}158\ \mu\text{gL}^{-1}$) concentrations in different surface waters and groundwater samples in and around the city of Hyderabad, India. Our results indicate that the studied surface water bodies and aquifers are contaminated to variable degrees and pose a serious threat to the ecosystem. In view of low geochemical baseline values for chromium and lead, the origin of heavy metal pollution is inferred to be anthropogenic, mainly originating from industrial effluents. The toxicological data are integrated with health data for risk assessment and impending health hazard. Finally, the novelty of this student-centric research program is highlighted.

Keywords: lake water, groundwater, heavy metals, India, pollution.

INTRODUCTION

India, with more than 1.3 billion people, needs generation of public awareness, education programs and consciousness towards environmental issues. The Honorable Supreme Court of India, therefore, directed educational institutions to make “study of the environment” a compulsory subject in schools and colleges. Following this landmark judgment, the course curriculum of all educational institutions does contain Environmental Science as a compulsory subject. Acknowledging this path-breaking effort, we

felt that it is also essential to promote environment-related program(s) beyond classroom teaching. Our plan is to build teams that are environment-conscious not merely by textbook reading, but also through active awareness and practical education programs. This way it is possible to develop human resources (responsible citizens) in large numbers, who can ultimately contribute to the overall development of a safe and sustainable environment in the country. Towards achieving this, our objective is to execute a series of simple laboratory experiments and exercises along with our undergraduate students on natural samples using easily affordable instruments. The

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overall supervision for this fresh initiative is assured by scientists from the CSIR-National Geophysical Research Institute, Hyderabad, upon our request. A team of young student individuals with keen interest on environmental chemistry/geochemistry, having either urban or rural background were, therefore, handpicked by the faculty members of our department. This team with a current strength of 15 is known as the “St. Pius UG Environment Research Group” (SPUGER Group). The ultimate goal of such an attempt is to build a trained team that can develop its own environmentally friendly project and execute it in a well-planned manner. This way it is possible to develop a huge pool of environmentally conscious and self-motivated personnel in the country.

A simple, yet interesting scientific question is attempted to be addressed as a first step. The toxicity of dissolved hexavalent chromium has become a matter of great concern in recent years (OEHHA, 2011). However, our extensive literature survey revealed that no attempt was made so far to estimate the contents of dissolved hexavalent chromium in water samples of Hyderabad City in India. In this work, therefore, we report concentration of dissolved chromium (Cr(VI)) in surface and groundwater samples collected from various locations of Hyderabad, using a spectrophotometer. Additionally, we also determine the concentration of lead in these water samples, as it is a heavy metal of major public health concern (WHO, 2011). Lead is chosen because it does not degrade and its legacy due to contamination gets imprinted as higher concentrations of lead in the environment (Davies, 1983). We then attempt to evaluate the plausible origin of these dissolved heavy metals in water samples, and discuss their significance in the light of impending health hazard, taking examples of studied clinical cases that were reported in the study area. The novelty of this

student research program is also highlighted herein.

MATERIALS & METHODS

The city of Hyderabad, with an average elevation of 540 m a.s.l., represents a plateau region. In general, the terrain is nearly flat. However, at some places, the topography is gently undulating. The rocks of Hyderabad are characterized by both pink and grey hornblende-biotite granite, alkali feldspar granite, and hornblende-biotite granite gneiss, which are of late Archean Age. Presence of pegmatite and quartz veins and dolerite dykes are also seen that cut across the host rocks at many places (Anantha Reddy, 1983).

Water samples were collected from different surface water bodies (Fig. 1) and adjacent groundwater sources (not shown) lying within 0.5–1.0 km of the surface water bodies in the city of Hyderabad. The polypropylene bottles (1 liter) for sample collection were soaked in 5% HNO₃ for 24 hours followed by rinsing them a number of times with deionized water. These bottles were dried and water samples were collected in duplicate in these bottles after filtration. One of the bottles containing a filtered water sample was acidified with 5 ml HNO₃ to prevent the adsorption of heavy metals on to the walls of the bottles. The collected water samples were tightly sealed to avoid loss due to evaporation and then transported to the laboratory. The pH of each sample was measured (7.1–7.9) in the laboratory with the help of a precalibrated systronic pH meter (Model 335) using those samples that were not acidified. The calibration of the pH meter was done using specific buffers. Analytical grade chemicals and double distilled water were used throughout our investigations. We used a simple and low-cost analytical method for estimation of heavy metals so that the instruments can be operated by undergraduate students. The concentrations of heavy metals in terms of absorbance were recorded by Elico-164 double beam

spectrophotometer. In order to obtain the maximum sensitivity of the spectrophotometer, the wavelength for maximum absorbance was chosen for each calibration plot and subsequent sample analysis. The calibration curves were generated between concentration versus absorbance for Cr(VI) and lead, respectively,

which were subsequently used in the evaluation of the dissolved heavy metal concentrations in water samples collected from the various locations. These methods are essentially similar to those outlined by Nagaraj et al. (2009) for hexavalent chromium, and Shiri et al. (2011) for lead.

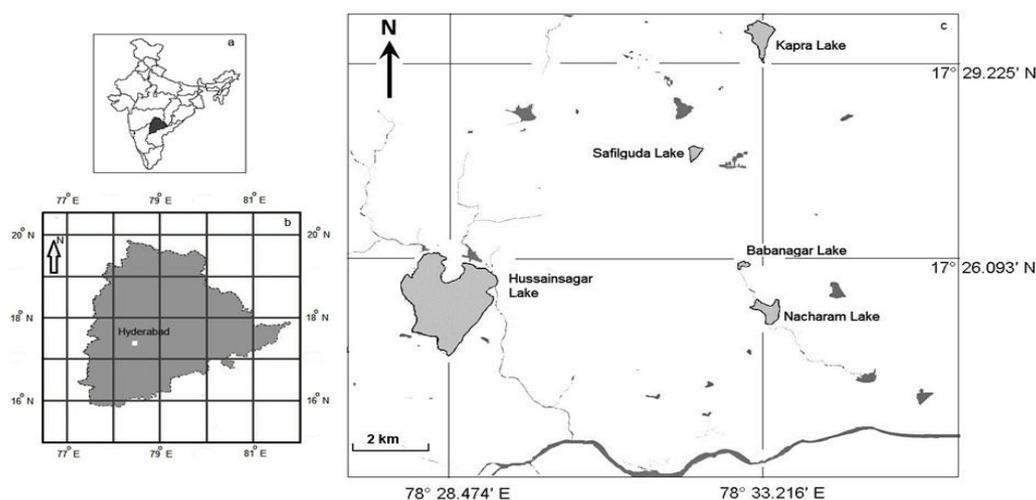


Fig. 1. Location map. a) Newly formed 29th state of India, Telangana. b) Latitude and longitude of Telangana State showing the location of Hyderabad City. c) Enlarged view showing existing water bodies in specified portions of Hyderabad City. Names of lakes studied are mentioned. Groundwater samples were collected within 0.5–1.0 km of the studied lakes.

A standard Cr(VI) solution of $500 \mu\text{gml}^{-1}$ was prepared from pure $\text{K}_2\text{Cr}_2\text{O}_7$. Reagent solutions such as hydroxylamine hydrochloride (0.2% w/v), 4,4'-sulfoxylbisbenzeneamine (Dapsone, 0.2% w/v) and N-(1- Naphthyl) ethylenediamine dihydrochloride (NEDA, 0.5% w/v) were prepared by dissolving the required amount of reagents in double distilled water. To a series of $\text{K}_2\text{Cr}_2\text{O}_7$ solution containing 0.2, 0.4, 0.6, 0.8 and 1 ml $\text{K}_2\text{Cr}_2\text{O}_7$ solution of strength $500 \mu\text{gml}^{-1}$ taken in 10 ml volumetric flasks, 2 ml hydroxylamine hydrochloride, and 2 ml Dapsone solutions were added and kept for 5 minutes for completion of reaction. The volumes were made up to the mark with double distilled water after adding 1 ml NEDA solution. The absorbance of each solution was measured at 540 nm against the corresponding reagent blank. The calibration curve was constructed

by plotting Cr(VI) in μgml^{-1} against absorbance. The molar absorptivity obtained ($3.77 \times 10^4 \text{ molL}^{-1}\text{cm}^{-1}$) is in excellent agreement with that reported ($3.49 \times 10^4 \text{ molL}^{-1}\text{cm}^{-1}$) by Nagaraj et al. (2009).

Likewise for lead determination, a standard Pb^{2+} solution of $3 \times 10^{-6} \text{ M}$ was prepared by dissolving 0.001 g lead nitrate in 1000 ml water. A sodium tetraborate buffer solution of concentration 0.05 M in 1 M sodium hydroxide was prepared and the pH was adjusted to 6 by adding a few drops of HCl solution. Alizarin yellow GG ($3.23 \times 10^{-3} \text{ M}$) solution was prepared by dissolving an appropriate amount in double distilled water. Pure stable cetyltrimethylammonium bromide (CTAB) solution of strength $5 \times 10^{-7} \text{ gL}^{-1}$ and 0.1 M NaCl solution were prepared by dissolving the required amounts in distilled water. AR grade methanol and n-hexane were used as solvents for extraction

of organic phases. In a 100 ml volumetric flask, the required volumes of Pb^{2+} solution and 12 ml Alizarin yellow GG solution were taken, and the pH was adjusted to 6 by adding 3 ml buffer solution. The volume was made up to 100 ml with double distilled water after adding 1 ml NaCl and 7 ml CTAB solutions. The solution was kept for 12 min for complex formation, and then transferred to a 100 ml separating funnel. The funnel was shaken vigorously and kept for 5 minutes to give a perfect floated layer in the aqueous organic interface; 3 ml methanol was added to the flask to extract the lead. The absorbance of the lead–Alizarin complex in the separated organic phase was measured at 364 nm against a reagent blank prepared in the same manner. A calibration curve of Pb^{2+} versus absorbance was plotted. The molar absorptivity ($0.7 \times 10^6 \text{ molL}^{-1}\text{cm}^{-1}$) is similar to that reported earlier ($1.3 \times 10^6 \text{ molL}^{-1}\text{cm}^{-1}$) by Shiri et al. (2011).

The Cr(VI) content of natural water samples were measured in a similar manner as was done during calibration; 2 ml of each water sample and the other reagent solutions were taken in 10 ml standard flasks, and the absorbance of the solutions was measured directly by the spectrophotometer. Another set of measurement was also carried out by adding known amounts (0.1 and $0.25 \mu\text{gml}^{-1}$) of Cr(VI), and these measurements are referred to as spiked Cr(VI). In both the cases, the concentration of Cr(VI) was estimated using the standard calibration curve. For spiked samples, the amount of spike added was subtracted. The effect of foreign ions was examined by adding a masking agent (1 ml of 5% EDTA) in the reaction mixture. The error in the absorbance was found to be less than $\pm 1\%$, hence, the interference was negligible.

For the analysis of lead in water samples, 12 ml Alizarin yellow GG, 3 ml buffer solution, 1 ml NaCl and 7 ml CTAB solution were taken in a 100 ml volumetric flask, and

the volume was made to 100 ml by adding water samples under investigation. The organic layer containing lead–Alizarin complex was separated, and the absorbance at 364 nm was recorded. To investigate the influence of foreign ions, 0.1 molL^{-1} cyanide ion was added as masking agent. The error in the absorbance was less than $\pm 3\%$ and, hence, neglected. The lead contents were then estimated using the calibration curve.

RESULTS & DISCUSSION

Table 1 presents the Cr(VI) and lead contents of water samples collected from various locations in Hyderabad City and its surroundings. The corresponding guideline values, recommended by WHO (2004) and BIS (1991) that are permissible/desirable for drinking water are also given. It is pertinent to mention here that the permissible value for chromium represents Cr (total) and not Cr(VI). In order to have better insight to the data that are obtained in this study, we prefer to discuss them in the backdrop of previously published dissolved Cr (total) and lead concentrations available on some of the surface water bodies as well as groundwater samples in and around the city. It is reiterated once again that we measured Cr(VI) while the previous researchers reported Cr (total).

The Cr(VI) contents of all the surface and groundwater sources studied by us range from 57 to $268 \mu\text{gL}^{-1}$ (Table 1). Satyanarayanan et al. (2007) conducted a geochemical study of groundwater samples from structurally deformed granitic terrain near Hyderabad City and obtained a low range (4.6 – $6.5 \mu\text{gL}^{-1}$) for total chromium, indicating that the natural background of chromium in groundwater of the city is low. On the other hand, the Cr(VI) contents of all our samples (both surface and groundwaters) far exceeded the range obtained by these workers. This indicates that all the analyzed water bodies and groundwater samples in their vicinity are contaminated by secondary sources. Of the various surface water bodies reported in this study, the Hussainsagar and

the Nacharam Lakes are the two well-studied lakes. The Cr(VI) contents obtained in this study for these two water bodies are $103 \mu\text{gL}^{-1}$ and $57 \mu\text{gL}^{-1}$, respectively (Table 1). The previously reported two estimates of Cr (total) for Hussainsagar Lake water show large differences (73 and $500 \mu\text{gL}^{-1}$; see Table 1 and references therein). One plausible explanation for such large differences could be that there is a time gap of 25 years between the two estimates. While the low Cr (total) of $73 \mu\text{gL}^{-1}$ was reported in 1987, the high value of $500 \mu\text{gL}^{-1}$ was documented in 2012. This may indicate progressive deterioration of the lake water over this time period. The value of $103 \mu\text{gL}^{-1}$ for Cr(VI) obtained in the present study seems reasonable and offers credence to the measurements. The concentrations of heavy metals like Ba, Cd, Mn, Pb, Sr, V and Zn for the Nacharam Lake were reported by Govil et al. (1999). However, the chromium content was not reported by them. In a recent study, Purushotham et al. (2013) reported high and variable total chromium ranging from $11.6 \mu\text{gL}^{-1}$ to $418.9 \mu\text{gL}^{-1}$ in groundwater samples from a rapidly growing industrial hub near Maheshwaram area, ~ 30 km south of Hyderabad City. The Cr(VI) contents of all the samples analyzed in this study fall between these two extremes. Further, it is also interesting to note that the groundwater samples collected near Nacharam and Babanagar areas show significantly more Cr(VI) compared to the corresponding lake water (Table 1). The reason for such results is not clear and requires further research.

The lead contents of the studied surface water and groundwater samples range from 34 to $158 \mu\text{gL}^{-1}$ (Table 1). The Hussainsagar Lake yielded a value of $90 \mu\text{gL}^{-1}$, which is close to the recently reported minimum limit of $78 \mu\text{gL}^{-1}$ (Table 1; Reddy et al., 2012). In fact, the lead content of water from this lake is highly variable. For example, Srikanth et al. (1993) reported lead values ranging from 38 to $62 \mu\text{gL}^{-1}$, whereas values ranging from

78 to $261 \mu\text{gL}^{-1}$ were reported by Reddy et al. (2012). In another interesting study conducted before and after idol immersion, Reddy and Vijay Kumar (2001) reported higher lead values of $350 \mu\text{gL}^{-1}$ and $450 \mu\text{gL}^{-1}$, respectively, for this lake water. The groundwater from Nacharam area yielded lower values of $34 \mu\text{gL}^{-1}$ compared to the water of Nacharam Lake ($65 \mu\text{gL}^{-1}$), indicating that the lake water is more contaminated in lead than the groundwater. In general, the high concentrations of lead in water samples obtained in this study (34 – $158 \mu\text{gL}^{-1}$) are either comparable to or higher than those obtained by Satyanarayanan et al. (2007) for groundwater samples from a structurally deformed granitic terrain near Hyderabad (20.4 – $82.3 \mu\text{gL}^{-1}$) away from any industry. Similar range of lead content was also reported by Purushotham et al. (2013) for groundwater samples pertaining to the industrially growing Maheshwaram watershed area (6.7 – $81.7 \mu\text{gL}^{-1}$). Therefore, it is difficult to understand the migration of lead in the aquifer and its subsequent enrichment.

In order to understand the relationship between the surface water bodies and groundwater in their vicinity, a cross-plot between Cr(VI) versus lead is presented as Figure 2. This diagram shows that the Cr(VI) contents of all studied water bodies are significantly high ($>50 \mu\text{gL}^{-1}$). Further, surface waters from a majority of lakes, such as the Kapra, Safilguda, Babanagar and Hussainsagar, as well as groundwater samples from Babanagar and Safilguda areas (Fig. 2) have excessively high contents ($>100 \mu\text{gL}^{-1}$) of Cr(VI). Figure 2 also illustrates that out of the five studied lakes, the lead content in four of them is higher, having values ($>65 \mu\text{gL}^{-1}$). The groundwater from Safilguda area is also high ($90 \mu\text{gL}^{-1}$) in lead content (Fig. 2). The other water sources have moderate concentrations of lead ($\sim 34 \mu\text{gL}^{-1}$ or more) and are within the desirable limit recommended by BIS, 1991 (Table 1).

Table 1. Cr(VI) and lead concentrations of water samples from different lakes and groundwaters in the vicinities around the city of Hyderabad. Published data of dissolved Cr (total) and lead contents are presented for comparison

Source of water	Heavy metal content in $\mu\text{g.L}^{-1}$ (this study)						Heavy metal content in $\mu\text{g.L}^{-1}$ (published work)		Reference/Guide line value/Desirable limit in $\mu\text{g.L}^{-1}$	
	Cr(VI)			Pb			Cr (total)	Pb	Cr (total)	Pb
	Unspiked sample	Spiked with Cr(VI)		Unspiked sample	Avg	Avg				
		0.1 $\mu\text{g/ml}$	0.25 $\mu\text{g/ml}$							
Hussainsagar Lake	105	100	105	91.8 87.1	103	89.5	93 - 105	78 - 261	Reddy et al., 2012	Reddy et al., 2012
Groundwater within 0.2-1.0 km of Hussainsagar	--	--	--	--	--	--	--	--	--	Srikanth et al., 1993
Groundwater within 1.0-2.0 km of Hussainsagar	--	--	--	--	--	--	--	--	--	Srikanth et al., 1993
Nachanam Lake	50	65	55	62.6 67.5	56.7	65.1	500	350 (before) 450 (after) immersion	Chandra et al., 2012	Reddy and Vijay Kumar, 2001
Groundwater near Nachanam Lake	85	90	85	39.2 29.6	86.7	34.4	--	7 - 28	--	Srikanth et al., 1993
Babanagar Lake	120	115	120	54.5 52.6	118.3	53.6	--	1 - 9	--	Srikanth et al., 1993
Groundwater near Babanagar Lake	255	280	270	38.0 37.3	268.3	37.7	--	0.9 - 5.0	--	Govil et al., 1999
Safilguda Lake	155	155	150	159 157	153.3	158	--	37.3 - 90.5	--	Govil et al., 1999
Groundwater near Safilguda Lake	155	170	170	80.0 99.5	165.0	89.8	--	--	--	--
Kapra Lake	195	210	190	87.1 85.7	198.3	86.4	--	--	--	--
Groundwater near Kapra Lake	75	85	70	40.6 44.2	76.7	42.4	--	--	--	--
Hyderabad Groundwater (different locations)	--	--	--	--	--	--	4.6 - 6.5	20.4 - 82.3	Saty anaray anan et al., 2007	Saty anaray anan et al., 2007
Maheshwaram Groundwater (south of Hyderabad)	--	--	--	--	--	--	11.6 - 419	6.7 - 82.7	Purushotham et al., 2013	Purushotham et al., 2013
Guideline value in $\mu\text{g/l}$ (WHO, 2004)	--	--	--	--	--	--	--	--	50	10
Desirable limit in $\mu\text{g/l}$ (BIS, 1991)	--	--	--	--	--	--	--	--	50	50

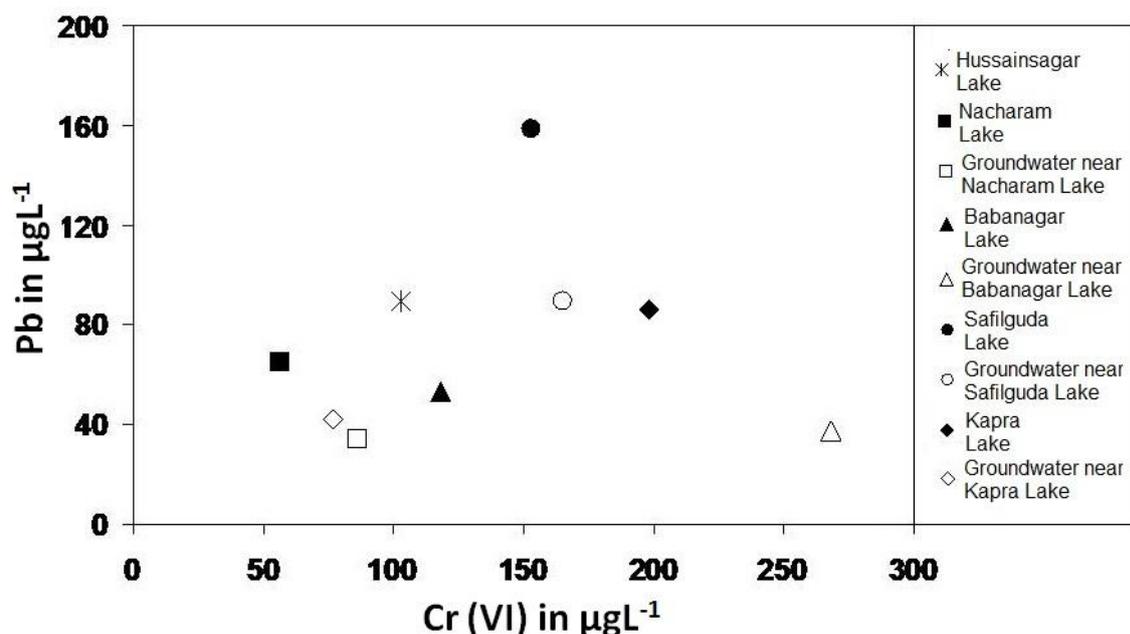


Fig. 2. Cross-plot between Cr(VI) and lead concentrations (μgL^{-1}) in water samples (See text for details)

The above results of excess chromium and lead in water samples obviously raise the important question about their sources. We discuss the plausible sources in the following arguments.

Chromium-bearing minerals, if present in excess in the soil, can react with soil organic acids to produce complexes. Under such a situation, the migration of metal in the soil becomes faster and could potentially contaminate the aquifers in a region. However, except for industrial pockets, such a possibility of excess chromium in the natural soil of Hyderabad is ruled out, because the geochemical baseline mapping using top and bottom soils of Hyderabad reveals that the average background values range from 50 to 80 ppm (Govil, 2013), which is not significantly different from the average earth's crust (Taylor and McLennan, 1995). Chromium and its compounds can be discharged in surface water through various industries. While metal industries mainly discharge Cr(III), hexavalent chromium largely originates from tanning and paint industries. Cr(VI) compounds are

also used as pigments in dyes, paints, inks and plastics, besides being used as a protective coating on metal parts during electroplating with chromium. Lead is a common heavy metal that is dispersed in the environment, and the main source of this heavy metal pollution is attributed to anthropogenic activities. There are a large number of anthropogenic sources of lead. The solubility of lead compounds in water is the function of several parameters, like the pH, hardness, salinity and the presence of humic material. Lead is an element which cannot be destroyed and, therefore, in the environment, one lead compound gets transformed into another lead compound.

With the above information as the backdrop, it may be pointed out that there are several industries in and around our study area which include textile, engineering products, chemicals and pharmaceuticals, plastic and rubber, steel and other metal products, electrical machineries and lead acid batteries, communication equipments, motor vehicles, other transport equipments, paper

and paper products, printing and paint industries, poultry, tanneries and leather products, food processing, dyeing of saris and dress materials, bangle and ceramic industries and so on (Ministry of MSME, 2014). Therefore, the high heavy metal pollution of Cr(VI) and lead in many surface water bodies and groundwater in their vicinity may be attributed to direct entry of domestic sewage and industrial effluents through various channels that flow to the lakes directly (see also Lubick, 2009). Heavy metal pollution of surface waters due to intensified industrialization and other human activities are very common, as documented in the Shur River of Iran (Karbassi et al., 2008). There could be other sources of pollution as well that include:

1. cloth, cattle and vehicle washing,
2. dumping of domestic solid wastes along the shorelines of the water bodies,
3. immersion of large numbers of colorful idols during festival seasons, and so on (e.g., see Reddy and Vijay Kumar, 2001).

The adverse effects on health due to presence of hexavalent chromium in drinking water has become an issue of growing concern in the USA only during the recent past. The final Public Health Goal for hexavalent chromium is set at $0.02 \mu\text{gL}^{-1}$ by the Office of Environmental Health Hazard Assessment in California (OEHHA, 2011). The values of Cr(VI) documented by us in this study for all the natural water bodies and groundwater samples of Hyderabad City are alarmingly high. So far as the lead content in water is concerned, the guideline value recommended by WHO (2004) is only $10 \mu\text{gL}^{-1}$, whereas the BIS (1991) sets a much higher value of $50 \mu\text{gL}^{-1}$ as the desirable limit. Therefore, going by the BIS standard, the groundwater samples are within the desirable limit except for the Safilguda area. The majority of lakes studied in and around the city, however,

are contaminated with high contents of lead ($>50 \mu\text{gL}^{-1}$). Now the important question which has not been addressed by the previous researchers so far is whether or not there is any connection between high Cr(VI) and lead contents in waters vis-a-vis health of the city's population. For this, the studied clinical cases that were reported in the study area assume significance. In a noteworthy study (IIHFW, 2009), the effect of industrial pollution on the citizens living in and around Hyderabad City was addressed. The outcome of this interesting study is as follows:

1. acute diseases were noted in 24.6% of the study population,
2. chronic diseases were documented in 7.6% of the population.

Acute diseases were found to occur at higher incidence to those who live close to industrial points (27.8%). Acute renal impairment (ARI), skin diseases, diarrhea and malaria constituted major acute illnesses. There are several studies which show the toxic effects of hexavalent chromium in humans. Das and Mishra (2008) documented severe skin diseases and skin ulcers among the users of chromium-contaminated water in and around the chromite-bearing Sukinda mines of Orissa. Indigestion and diarrhea are common in the human population chronically exposed to hexavalent chromium (MiningWatch, 2012). Poisoning following dermal exposure to hexavalent chromium leading to prolonged acute renal failure is reported recently by Lin et al. (2009). Taking a cue from all these studies, and integrating the results of our study with that conducted by IIHFW (2009), we speculate that the reported skin diseases, diarrhea and ARI might be a result of Cr^{6+} ingestion.

Likewise, the adverse effects of lead on health are outlined by several researchers (e. g., Skerfving and Bergdahi, 2007). In two significant studies, it was found that

1. the lead contents in blood samples of children and industrial workers who reside

close to the industries located in the twin cities of Hyderabad and Secunderabad are high (Ramoo, 2000) and

2. 51.3% of children in the city tested for lead levels $>10 \mu\text{g}(\text{dl})^{-1}$, which, in some cases, were as high as $>40 \mu\text{g}(\text{dl})^{-1}$ (Koshie, 2002).

In another study conducted by Tripathi et al. (2000), whole blood samples of children from two highly industrialized cities, such as Mumbai (Bombay) and Hyderabad were compared for lead levels. It was found that the mean lead level of blood in children from Hyderabad was higher ($13.3 \mu\text{g}(\text{dl})^{-1}$) than those from Bombay ($8 \mu\text{g}(\text{dl})^{-1}$). All these results are, therefore, in good agreement with documented excess lead (up to $\sim 100 \mu\text{gL}^{-1}$) in water samples of Hyderabad City that are presented in this study. We therefore recommend that depending on the type of contaminants present at a specific site, water should be treated for chemical contaminations for safe use.

Finally, we wish to highlight the novelty of the student education research program that gave us a sense of satisfaction of at least partially fulfilling the societal need by way of grooming a few individual "responsible citizens" of the country. The undergraduate students of SPUGER Group availed a unique opportunity to gain hands-on experience in the fields of environmental research and education. It is an interdisciplinary field that uses the tools of applied and basic sciences to solve human health problems related to the environment. This program is expected to enable them to work on specific projects in future, where they will have ample opportunity to expand their knowledge and learn a variety of research techniques. The novelty of this program is that it provides a holistic education to the students and helps them become responsible citizens. Through this approach to education, we, the faculty members, could visualize that there is definite improvement in their critical

thinking, self esteem, ability to work as a team, and personal and civic responsibility. The major goal now rests with the students, where they take the acquired knowledge back to their areas/regions/villages to teach others about the impact of environmental issues on human lives, and how to make our environment free from pollution.

CONCLUSIONS

To our knowledge, the present student-centric undergraduate research study is perhaps the first of its kind in India. In this study, we have presented results pertaining to water samples of five lakes and groundwaters in their vicinities. A large number of researchers have previously conducted heavy metal analyses in waters of two major lakes, namely, the Hussainsagar and the Nacharam Lakes. Groundwater samples in the vicinity of these lakes were also analyzed by these researchers. Our study shows that while the lead concentration of the Hussainsagar Lake is well within the extreme values reported by different workers, its concentration in Nacharam Lake has increased drastically over the past one-and-half decades. The groundwater in the neighborhood of Nacharam Lake, however, is low in lead concentration and comparable with earlier study. Considering data from all sources presented in this study, it can be noted, on the whole, that the contamination of water bodies due to dissolved lead is above the permissible limit for drinking purposes, according to the guidelines set by WHO (2004). It may be noted that the above comparison is made for lead data between our study and those of previous researchers. However, a similar comparison is not possible in the case of Cr(VI), as all the previous studies reported Cr (total). It is in this respect that our research is the first of its kind, where the concentrations of hexavalent chromium is presented. The study further reveals that the concentrations of dissolved hexavalent chromium in the

analyzed samples are alarmingly high. The results on dissolved hexavalent chromium in conjunction with higher incidences of ailments, such as chronic skin diseases, diarrhea and acute renal failure amongst the city population, is perhaps indicative of Cr⁶⁺ ingestion. High levels of lead in all the surface and groundwater bodies of Hyderabad City when taken together with increased blood lead amongst the city population, clearly points to the fact that the lead poisoning is due to anthropogenic activities. We therefore recommend that general public awareness is mandatory to tackle such a grim situation. Obviously, the authors along with the team members of SPUGER Group will have to go a long way to do the needful.

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