be completely overruled (dashed line in Figure 5). This intervening region, between the identified palaeo-channel and the lake, is almost completely covered with sand dunes, and therefore, the possibility of a smaller and as yet unidentified channel passing through the Lake from the main river cannot be discarded entirely. It is worthwhile to mention that near the coast, rivers change course frequently; this possibility, therefore, cannot be completely negated on the basis of the present evidence.

Most myths have their roots in some real events. Almost all myths regarding Konark are associated with a water body near to the Konark Sun Temple and indicate the presence of the Chandrabhaga river. Old illustrations and photographs also indicate the presence of water in the proximity of the temple. An aerial examination of the area through satellite imagery depicts the trail of a lost river which is otherwise difficult to identify in the field. All the evidence, including (a) sinusoidal pattern of the river as seen in *Google Earth* and Landsat imagery; (b) high NDVI indicating enhanced vegetation along the channel; (c) patches of water bodies at various locations along the channel; (d) the thermal infrared band showing darker tone within the palaeo-channel area indicating higher moisture content than the surrounding region; (e) association of the river with tectonic depressions and lineaments; (f) *V*-shaped depression seen along the elevation profile indicating a past river valley; (g) a subsurface river valley identified through shallow surface investigation, indicate the presence of a palaeo-channel near Konark, towards the north of the Sun Temple. Combining the myths with scientific and historical evidence, the identified palaeo-channel may be correlated to the lost river Chandrabhaga. What caused the extinction of this river remains a subject of further investigation.

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A student-centric research and education programme on heavy metal pollution of water bodies from selected Indian cities

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A research and education programme on environmental chemistry has been initiated to train a few selected undergraduate students so that they can take up environment-related issues and challenges for long-term sustainability of the ecosystem. The main goal of this programme is to instill 'responsible citizenship behaviour' in them in order to carry forward the huge task of environmental protection through research activities and community awareness programmes. Here we report spectrophotometer-based estimation of hexavalent chromium (9.5–337 $\mu g\ l^{-1}$), lead (20–158 $\mu g\ l^{-1}$), cadmium (from below detection limit to 34 $\mu g\ l^{-1}$) and nickel (from below detection limit to 19 $\mu g\ l^{-1}$) concentrations in different rivers, surface and groundwater bodies collected from selected cities

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of India. Our results indicate that with the exception of nickel, majority of the studied water bodies and aquifers are contaminated to variable degrees with the analysed dissolved heavy metals. In view of low geochemical baseline values for chromium, cadmium and lead, the origin of heavy metal pollution is inferred to be anthropogenic, mainly originating from industrial activities and indiscriminate dumping of waste material. The toxicological data are integrated with published health data and it is found that the heavy metal-polluted water bodies pose serious threat to the human population and the ecosystem. At certain sites, we suggest that remediation measures need to be taken up immediately. We also briefly highlight the novelty of this student-centric research programme.

Keywords: Environmental chemistry, groundwater, heavy metal pollution, student-centric programme.

A student-centric research and education programme on environmental chemistry has been initiated at the St. Pious X Degree and PG College for Women in Hyderabad, India with active participation of undergraduate (UG) students. The aim of this programme is threefold. First and foremost is to impart training and motivate young minds towards scientific research of contemporary interest. This is similar to the 'catch them young' Summer Research Fellowship programme for students launched by the Science Academies of India to promote scientific research in the country. The second important aspect of the programme is to instill 'responsible citizenship behaviour' in students, so that each of them becomes conscious and well-trained to take up environment-related issues and challenges for long-term sustainability of the ecosystem. The third significant feature is to work for the promotion of 'women in science' in India. With these broad objectives in mind, a team of young student-individuals with keen interest in environmental chemistry/geochemistry having either urban or rural background were handpicked by faculty members of the chemistry department. This team with a current strength of 15 is known as the 'St. Pious UG Environment Research Group' (SPUGER Group). The research and education programme is being carried out in collaboration with the CSIR-National Geophysical Research Institute at Hyderabad, to obtain the necessary guidance and scientific input at every stage.

As a first step, a simple yet interesting problem related to heavy metal pollution of water bodies has been taken up. Extensive literature survey revealed that although chromium (Cr; total) was reported in most of the rivers, surface and groundwater bodies of the country[1–6], very few attempted to estimate the contents of dissolved hexavalent chromium in water samples[7,8]. In this context it may be noted that chromium is a heavy metal which in dissolved form can be present as either trivalent or hexavalent state. While trivalent chromium is a dietary requirement for a number of organisms, hexavalent chromium is highly mobile and toxic and is capable of causing several health problems[9]. Therefore Cr(VI) is analysed in natural water bodies. In addition to hexavalent chromium, we also determined the concentrations of three other heavy metals such as cadmium (Cd), lead (Pb) and nickel (Ni), as they are also of major public health concern. Moreover, lead and cadmium do not have any beneficial role and they are definitely toxic[10]. Table 1 presents information on different health problems that can occur in the presence of Cr(VI), Cd, Pb, Ni, etc.[9,11–14]. The results on dissolved toxic metals in water samples are evaluated to decipher their plausible sources. We then discuss the significance of our results in the light of impending health hazards, taking examples of clinical cases that were reported in the study area. Mitigation measures that can be effective to tackle the present situation are outlined briefly. Finally, the novelty of this student research programme is highlighted.

River water samples were collected from three different locations that are widely separated geographically (Figure 1 *a*) during March–May 2014. Two sample locations are on the banks of River Ganga; one location is close to Jajmau area in Kanpur, Uttar Pradesh and the other is close to Dakshineswar in Kolkata, West Bengal. The third sample was collected on the banks of River Godavari at Bhadrachalam, Telangana. In addition to all these river samples, one groundwater sample from Bithoor area of Kanpur was also collected. Water samples were also collected from different lakes (Figure 1 *b*) and adjacent groundwater sources (not shown) lying within 0.5–1.0 km of the lakes in the city of Hyderabad, Telangana.

Polypropylene bottles (1 litre) for sample collection were soaked in 5% HNO_3 for 24 h followed by rinsing them a number of times with deionized water. The bottles were dried and water samples were collected in them in duplicate after filtration using Whatmann No. 40 filter paper. For outside samples (Kanpur, Kolkata and Bhadrachalam), collection was made in two bottles after filtration, and both the bottles were acidified with 5 ml HNO_3 to prevent the adsorption of heavy metals onto their walls. pH of each sample was measured (7.7–8.3) at the sampling site with the help of a calibrated systronic pH-meter (model 335). A double-point calibration of the pH-meter was done using specific buffer tablets of 4.01 and 9.18. The collected water samples were sealed properly to avoid loss due to evaporation and then transported to the laboratory. For samples collected at Hyderabad, one of the bottles containing filtered water sample was acidified with 5 ml HNO_3 while the other was not acidified. These bottles were sealed properly before transporting them to the laboratory. The pH of each sample collected in the city was measured (7.1–7.9) immediately (within 1 h) at the laboratory using the samples that were not acidified.

Table 1. Studied toxic heavy metals with their proven health effects

Heavy metal	Some common sources of environmental exposure	Toxic effects	Reference
Chromium (VI)	Metal alloys and pigments for paints, tanneries, cement, paper, rubber, and other materials.	Allergic reactions, skin rash, nose irritation and nose bleeding, ulcer, weakened immune system, genetic material alteration, kidney and liver damage, and cancer.	9, 11
Lead	Industrial, vehicular emissions, paints and burning of plastic, paper, etc.	May result in toxic biochemical effects in humans; causes problems in the synthesis of haemoglobin; effects on the kidney, teeth, bone, gastrointestinal tract, joints and reproductive system. May cause acute damage to the nervous system.	12
Cadmium	Electronics, plastic, batteries and contaminated water. Cadmium is also present as an impurity in several products, including phosphate fertilizers, detergents and refined petroleum products.	Irritation of the lungs and gastrointestinal tract, kidney damage, abnormalities of the skeletal system and cancer of the lungs and prostate.	13
Nickel	Airborne fumes and dust containing nickel. Nickel exposure for the general population arises mainly from drinking water and food. Electroplating, electroforming, nickel–cadmium batteries, dye and electronic equipment are the other sources.	Nickel allergy in the form of contact dermatitis, lung fibrosis, cardiovascular and kidney diseases and cancer of the respiratory tract.	14

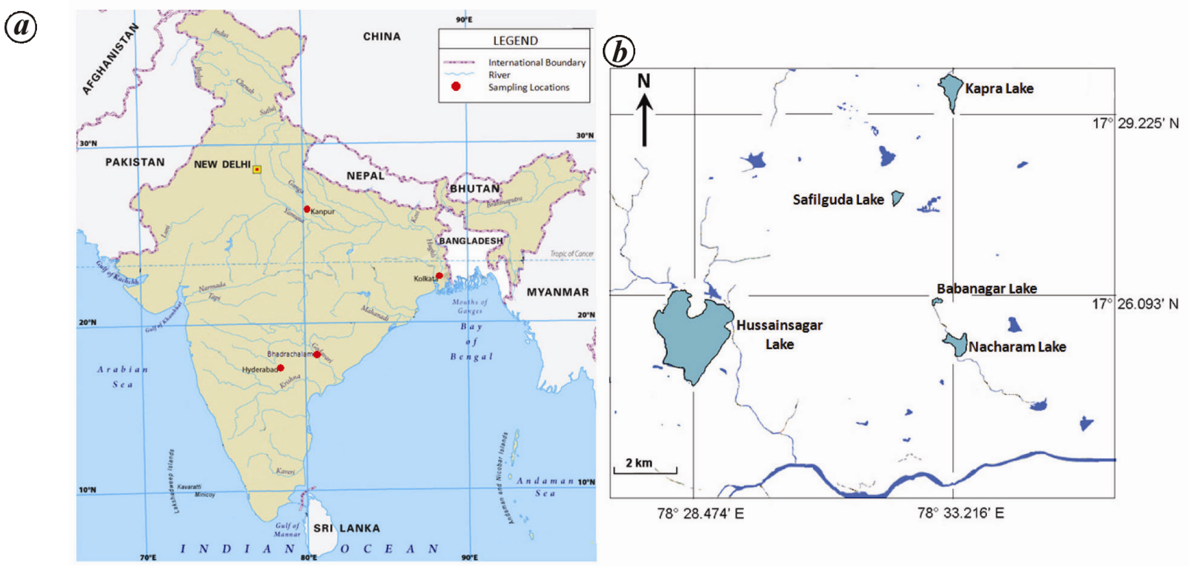

Figure 1. Sample location map. ***a***, Water samples were collected from the rivers Ganges and Godavari. While the Ganges waters were from Kanpur and Kolkata, water samples from the Godavari were collected at Bhadrachalam. One groundwater sample was also collected from Bithoor area in Kanpur. ***b***, Sample collection at Hyderabad was from different lakes and groundwater bodies in their vicinity. Existing water bodies in specified portion of Hyderabad city are shown. Names of studied lakes are mentioned. Groundwater samples were collected within 0.5–1.0 km of the studied lakes (not shown).

We used a simple and low-cost analytical method for estimation of heavy metals so that the instrument is easily operated by UG students. The concentration of each metal in terms of absorbance was recorded using an Elico–164 double beam spectrophotometer. In order to get maximum sensitivity of the spectrophotometer, the wavelength for maximum absorbance was chosen for the calibration plot of each element and subsequent sample analysis. Blends of suitable compounds have been identified through a number of trial runs so that each element of interest (i.e. Cr(VI), Cd, Pb and Ni) makes strongly coloured complexes, without interfering much with other elements. In certain cases, depending upon the necessity, specific suppressor was also used to minimize the effect of unwanted ions. Since the intensity of the coloured complexes is dependent on the concentration of the element of interest in a standard or sample solution, we have first prepared the standard calibration curves for each element. For this, the absorbance of light as a function of known concentration at a particular wavelength was plotted. The calibration curve for each element was generated between concentration and absorbance, which was subsequently used to evaluate the dissolved heavy metal concentrations in natural water samples collected from various sites. For more details on calibration, experimental procedure, accuracy and precession of the analysis, see Supplementary material (online).

Figures 2 and 3 show concentrations of all 13 samples that were analysed in the present study for Cr(VI), Cd, Pb and Ni. The guideline values recommended by the World Health Organization (WHO)[15] and desirable limits suggested by the Bureau of Indian Standards (BIS)[16] for these heavy metals are also marked in the figures. Two river water samples from Ganges and Godavari (Figures 2 and 3) were mostly within the desirable limits according to BIS, and hence will be discussed sparingly. In the case of chromium, the guideline/desirable value is given for Cr (total), whereas we estimated Cr^{6+} in samples collected by us. In this context it may be noted that the two dissolved forms of chromium (Cr^{3+} and Cr^{6+}) can convert back and forth in water and in the human body depending upon the ambient environment. Therefore, the US Environmental Protection Agency[17] suggested that Cr (total) measured in a sample should be treated as Cr^{6+}, the more toxic form of chromium.

Figure 2 *a* shows that with the exception of two river water samples collected from the Ganges at Kolkata and Godavari at Bhadrachalam, all other samples are higher in Cr(VI) content relative to the guideline value recommended by WHO[15], and the content of Cr(VI) is highly variable. Maximum concentration is documented in the groundwater sample at Bithoor area of Kanpur. The Ganges water at Jajmau and groundwater collected near Babanagar Lake in Hyderabad are also very high in Cr^{6+} (compare with horizontal line in Figure 2 *a*) and their values are comparable to each other. Presence of a large number of processing units (>450) for leather tanneries in and around the Jajmau area[18], which dump hazardous wastes and effluents indiscriminately, are primarily responsible for contributing high concentration of Cr(VI) even in the flowing river water of the Ganges. Extremely high content of Cr(VI) documented in the groundwater of Bithoor area, although surprising, can be attributed to indiscriminate dumping of solid wastes from tanneries[8]. This interpretation is in conformity with a recently completed chromium survey conducted on groundwater samples collected from different locations of Kanpur district,

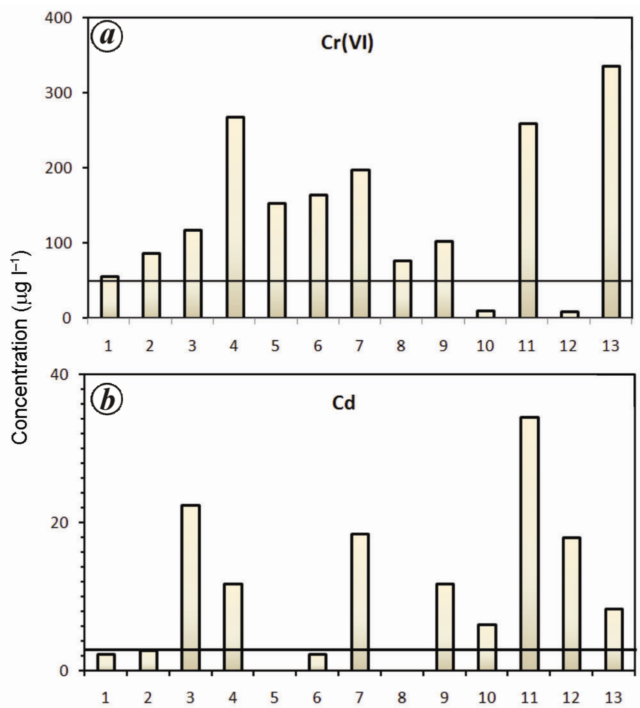

Figure 2. Concentration of toxic heavy metals. (***a***) Hexavalent chromium and (***b***) cadmium content in different water bodies. These sample numbers are as follows: 1, Nacharam Lake; 2, Groundwater near Nacharam Lake; 3, Babanagar Lake; 4, Groundwater near Babanagar Lake; 5, Safilguda Lake; 6, Groundwater near Safilguda Lake; 7, Kapra Lake; 8, Groundwater near Kapra Lake; 9, Hussainsagar lake; 10, Ganges (Kolkata); 11, Ganges (Kanpur); 12, Godavari (Bhadrachalam) and 13, Gounndwater from Bithoor (Kanpur). The guideline value recommended for drinking water by the World Health Organization (WHO)[15] and the acceptable limit given by the Bureau of Indian Standard (BIS)[16] for each metal is shown by solid horizontal line. BDL, Below detection limit. See text for details.

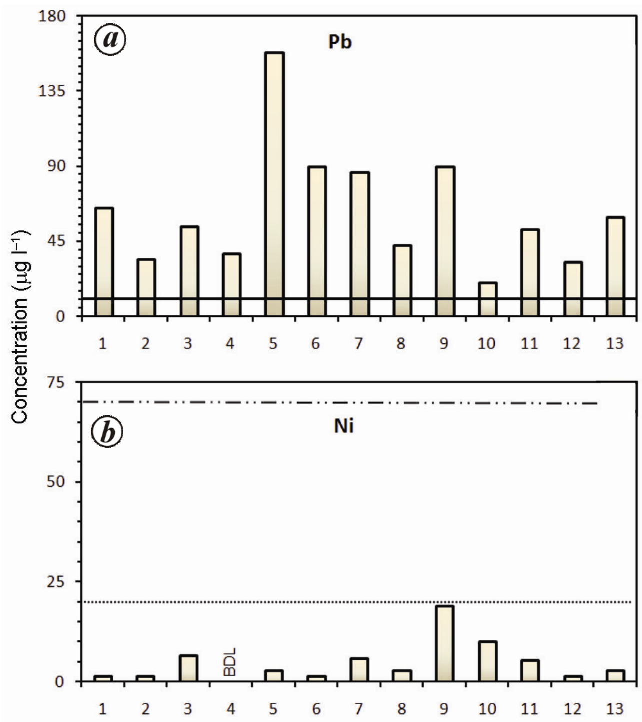

Figure 3. Concentration of toxic heavy metals. (***a***) Lead and (***b***) nickel content in different water bodies. Numbers along the abscissa correspond to different water bodies mentioned in Figure 2. The guideline value of Pb recommended for drinking water by the WHO[15] and the acceptable limit given by BIS[16] is shown by horizontal solid line. Similar values for Ni (dashed-dotted line[15] and dotted-line[16]) are also shown. See text for details.

where concentrations of both Cr(VI) and Cr (total) were found to be extremely high at several locations due to disposal of Cr-rich hazardous waste[8]. There are also reports from the Central Pollution Control Board (CPCB)[19] which state that the waste from these industries is being dumped illegally over decades in deep borings, open lands and different sites along the banks of the Ganga.

The high levels of Cr(VI) documented in the surface and groundwater bodies of Hyderabad city may owe their origin to different industries in and around our study area, which include textile, engineering products, plastic and rubber, steel and other metal products, electrical machineries, communication equipment, printing and paint industries, tanneries and leather products, food processing, dyeing of saris and dress materials, bangle and ceramic industries, etc.[20]. Therefore, a high degree of Cr(VI) contamination may be attributed to direct entry of untreated or partially treated industrial effluents through various channels that flow directly into the lakes[21]. Likewise, indiscriminate dumping of hazardous chromate wastes might be responsible for contaminating the groundwater bodies[22]. In addition to the sources mentioned above, another plausible source of Cr(VI) contamination in a city like Hyderabad is the use of chromate and dichromate salts by a large number of research laboratories and educational institutions. Although a comprehensive survey to quantify the magnitude of this anthropogenic source is beyond the scope of this study, oral discussion and telephonic conversations with some scientists and academicians revealed that the unused chromate and dichromate solutions are generally dumped into the sink or spilled onto the ground. Therefore this could be a potential anthropogenic source in Hyderabad. In this context, it may be noted that only 2.829 g of potassium dichromate salt dissolved in 10,000 litres of water has 100 $\mu g\ l^{-1}$ of Cr^{6+}. Utmost care should therefore be exercised by all the research institutes and other organizations so that the ecosystem is maintained clean and safe[23].

The concentration of Cd in the samples is characterized by highly variable values. While the highest content of this element is recorded in the Ganges water at Kanpur, as seen in Figure 2 *b*, there are two samples that yield Cd concentration below detection limit. Figure 2 *b* also shows the permissible limit set by WHO[15] and acceptable limit by BIS[16]. There are eight samples (~62% of the total number of samples analysed) that exceed the guideline value recommended by WHO[15] and BIS[16]. Various anthropogenic sources could be responsible to contaminate the natural water bodies considered in this study. For example, Cd is widely used in steel industry, batteries and plastics, waste water, fertilizers, e-waste, etc.[13]. These sources are common in our study area[20,24] and hence constitute the major contributors of cadmium into the environmental samples.

Figure 3 *a* presents the concentration of Pb in each water body, which shows its highly variable range. All the values are higher than the guideline value recommended by WHO[15] and acceptable limit set by BIS[16]. Maximum content of Pb is recorded in the Safilguda Lake of Hyderabad. One of the major problems associated with Pb is that it does not degrade and hence any anthropogenic input gets imprinted as higher concentrations in the sample[25]. Therefore the observed variable range is a reflection of contamination originating from different point sources. A large number of anthropogenic sources of lead exist starting from tetra alkyl lead in gasoline, lead arsenate as fungicides, plasters, paints, motor vehicles and other transport equipment, house dust, waste water, etc.[12]. The solubility of lead compounds in water is a function of several parameters like pH, hardness, salinity and the presence of humic material[12]. As stated above, lead is an element which cannot be destroyed. Therefore high content of lead in water samples can be attributed to different kinds of anthropogenic activities that are polluting the surface and groundwater bodies collected from various locations.

The concentration of Ni in the study area shows some variation with maximum value going up to ~19.0 $\mu g\ l^{-1}$. This maximum value is significantly lower than the guideline value for drinking water recommended by WHO[15] and is marginally below the acceptable limit set by BIS[16]. Thus all the water bodies considered in this study are safe in terms of Ni concentration. In view of its low concentration in the studied samples, we attribute the observed variations in Ni (Figure 3 *b*) as an artefact of natural variation of its concentration originating primarily from geogenic source.

Thus out of the four heavy metals studied here, at least three pose serious threat to the ecosystem and the population residing in these locales. We therefore discuss the health hazard aspect of these heavy metals citing reported medical cases in the study area.

Our results on Cr^{6+} and Cd contents in river and groundwater samples from Kanpur show, in general, alarmingly high values and pose serious threat to human health. Both these heavy metals can originate from tanneries[26]. Moreover, some of the health hazards originating from ingestion of these elements (Cr^{6+} and Cd) are of common nature. For example, there are several studies which show the toxic effects of hexavalent chromium in humans. Indigestion and diarrhoea are common in humans who are chronically exposed to hexavalent chromium[27]. Poisoning following dermal exposure to hexavalent chromium leading to prolonged acute renal failure is also reported recently[28]. There are cases where toxicity of Cr^{6+} has resulted in kidney and liver damage as well as lung cancer[29]. Likewise, cadmium exposures are associated with kidney and bone damage. Cadmium has also been identified as a potential human carcinogen, causing lung cancer[30].

In a study conducted at Kanpur[7], comparison was made between the health status of one group of residents living in areas where the groundwater is contaminated with high levels of Cr(VI) originating from tanneries with another group of residents with similar social and demographic features, but living in areas without elevated levels of Cr(VI) in groundwater. Health status of both the groups was evaluated using questionnaires pertaining to their health, besides conducting some health-related tests. It was found that the first group of residents with known Cr(VI) contamination had more self-reports of digestive and dermatological disorders and hematological abnormalities. The above findings together with high contents of Cr^{6+} and Cd in water bodies of Kanpur documented in this study clearly point to the fact that the health hazard is associated with ingestion of Cr(VI) and Cd originating from anthropogenic tannery industries. We therefore suggest that in order to protect public health and environment, there is an urgent need for groundwater remedial measures. The industrial waste management regulation also needs a critical review for its effective implementation.

The assessment of the health effects of hexavalent chromium due to groundwater contamination that was carried out at Kanpur city, perhaps was not attempted on a major scale in any other cities of India. The case of Kanpur is a special one, as the city was in the limelight due to dumps and effluents from tannery industries over a long period of time[19]. It is therefore obvious that similar integration of high Cr(VI) content in water bodies of Hyderabad city with associated health hazard among its population has never been attempted directly. In fact, Cr(VI) data on surface and groundwater bodies of Hyderabad city were not available prior to the present study. However, in a study conducted by the Indian Institute of Health and Family Welfare (IIHFW), Hyderabad[31], the effect of industrial pollution on citizens living in and around Hyderabad city was addressed. The outcome of this study was as follows: (i) Acute diseases were noted in 24.6% of the study population. (ii) Chronic diseases were documented in 7.6% of the population. Acute diseases were found to occur at higher incidence for those living close to industrial points (27.8%). Acute renal impairment (ARI), skin diseases, diarrhoea and malaria constituted major acute illnesses. Taking a cue from the studies conducted on exposure of Cr(VI) and Cd on human health[27,28,30] and integrating the results of our study with those by IIHFW[31], we speculate that the reported skin diseases, diarrhoea and ARI among the population of Hyderabad city might be a result of Cr^{6+} as well as Cd ingestion.

Our results on concentration of lead show that all the samples contain higher dissolved Pb if the desirable limit set by WHO[15] or BIS[16] is considered. Since majority of the samples having high contents of Pb were collected from the surface and groundwater bodies of Hyderabad, we therefore analyse and integrate our Pb data from Hyderabad city with the reported health data. The adverse effects of Pb on health have been outlined elaborately[12,32]. Three significant studies were made in the city of Hyderabad to assess the adverse effects of Pb[33–35]. In the first study it was found that 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[33]. In the second study[34], which was similar to the first one[33], it was found that 51.3% of children in the city tested for lead levels >10 $\mu g(dl)^{-1}$, which in some cases were as high as >40 $\mu g(dl)^{-1}$ (ref. 34). In another study, whole blood samples of children from two highly industrialized cities such as Mumbai and Hyderabad were compared for Pb levels[35]. It was found that the mean lead level of blood in children from Hyderabad was higher (13.3 $\mu g(dl)^{-1}$) than that from Mumbai (8 $\mu g(dl)^{-1}$). Therefore, the high lead content in Hyderabad city as observed in the analyses of our samples, is validated by the above studies originating from entirely different lines of evidence[33–35].

The exorbitant cost involved in cleaning up the mess arising from heavy metal contamination is enormous[36]. Therefore, the best way to eliminate/minimize the effect of heavy metal pollution is to make people aware about the impending danger; so that the problem is tackled before any damage is initiated. Since heavy metal pollution can originate from both natural as well as anthropogenic sources, the threat is common to many nations, including the developed ones. Therefore, over the past few decades several new methodologies and treatment approaches have been developed to mitigate the adverse effects of contaminated soils and water bodies. However, before taking up the *in situ* remediation of highly contaminated soil and water bodies (e.g. tannery-affected city of Kanpur), it may be a good idea to adopt some interim remedial measures such as covering or fencing the contaminated sites, thereby restricting access. This ensures no direct contact and temporarily reduces migration of any contamination. Simultaneously as a follow-up step, public should be educated about the menace of heavy metal pollution, so that no industry/agency is allowed to dump effluents or waste materials in an indiscriminate manner. This should be followed by proper mitigation measures. There are many innovative technologies that can potentially be used for *in situ* remediation of contaminated soil and water bodies. Some of the widely used technologies include: (i) geochemical fixation[37–39], (ii) permeable reactive barriers (PRBs)[40,41], (iii) reactive zones[42,43] and (iv) natural attenuation[44,45]. However, it is necessary to have an in-depth understanding of the heavy metal cycle together with site characterization so that the most suitable and cost-effective technology can be adopted as the remedial measure.

We also wish to highlight the novelty of this student centric-research programme that gave us a sense of satisfaction by way of partially fulfiling the societal need of grooming a few students as 'responsible citizens' of the country. The UG 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. The modest beginning made through this programme is expected to enable them to work on specific projects in the future, where they will have ample opportunities to expand their knowledge and learn a variety of research techniques. The novelty of this programme is that it provides holistic education to the students and helps them become responsible citizens. Through this approach to education we could visualize that there is a definite improvement of their critical thinking, self-esteem, ability to work in a team, personal as well as civic responsibility, etc. The major goal now rests with the students, where they take the 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.

To our knowledge, the present student-centric UG research study is perhaps the first of its kind in India. The study reveals that the concentration of dissolved hexavalent chromium in the analysed samples in a majority of cases is alarmingly high. Contamination of water bodies due to presence of dissolved lead and some water bodies due to the presence of cadmium is also above the permissible limit for drinking purposes according to the guidelines set by WHO[15] and BIS[16]. In view of low geochemical baseline values of Cr, Cd and Pb in the study area, the origin of heavy metal contamination is inferred to be anthropogenic, derived from different sources. Our results on dissolved cadmium and hexavalent chromium in conjunction with higher incidences of ailment such as chronic skin diseases, diarrhoea and acute renal failure amongst the population of Hyderabad and Kanpur cities are perhaps indicative of heavy metal 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 point to the fact that lead poisoning is due to anthropogenic activities. We therefore recommend that general public awareness is mandatory to tackle such a grim situation, where team members of SPUGER Group would do the needful.

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Repertoires and geographical variation in song of oriental magpie robin (*Copsychus saularis*) in northern Thailand

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The relation of geographical variation of magpie song to study area, can show obvious degree of similarities and differences in the structure of the song. Spectrogram studies revealed that all song types shared some common features. The frequency range of song was fixed between 1.99 and 5.57 kHz. A basic strophe (syllable) and a climax strophe are synthesized to form a complete song. It was found that songs were always introduced by repeating a basic strophe followed by a climax strophe and terminating with the basic strophe. A strophe contains one or more core elements. The last core element is referred to as the marking element, which is followed by a fine structure of specific elements. Discriminant function analysis revealed that the mean length of strophe (MLSt), the mean length at terminal part of strophe (MLTPSt), the number of element at the terminal part of strophe (NETPSt) and the number of element in strophe (NESt) were found to be the best determinants for differentiating song structure and classifying it into eight study sites. The geographical isolation and long distance of the study site, allowed birds to learn and produce song variations. This variation of song structure can show the unique characteristic of songs in each study area as well.

Keywords: *Copsychus saularis*, song dialect, song syntax, song variation, species recognition, spectrogram.

SONGS are produced by syrinx, which is a structure at the bottom of the trachea. Its development is controlled by the song repertoire in the brain[1,2]. The size and complexity of song repertoire as well as the unique features of the song, enable birds to recognize their own species or other species and to implement mate selection and territorial defense[3,4]. Species recognition provides mechanisms for production and reception of species-specific signals, acting as inter-specific barriers between members of different populations[5–7]. Acoustic parameters appear to be involved in species recognition and these differ from species to species in their relative importance. Studies show that the song structure of normal indigo bunting (*Passerina cynaea*) has a very evident syntax in which, elements are usually repeated and occur in pairs[8]. The rhythm or temporal patterning of the song appears to be

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