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Evaluation of Human Exposure to Environmental Element Pollution in Lucknow City and Nearby Areas

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INTRODUCTION

Heavy metals and their salts are potent environmental pollutants, as they are active metabolic inhibitors and exert toxic effect at specific concentrations on both terrestrial and aquatic plants and animals (Kumar et al., 2003). The pollution caused by heavy metals from various industrial discharge, traffic, urbanization, waste disposal, agricultural activities, burning of fossil fuels, heavy traffic, etc., are common problem faced by many countries. Heavy metals such as Rn, Pb (II), Hg (II), Cd (II), and As have been classified as priority pollutants by all. Daily, people are exposed to both natural and manmade sources of elements, but their exposure status and difference due to various factors, are to be explored.

EFFECTS OF EXCESS OF TOXIC ELEMENTS

In the case of toxic elements, excess levels of Cd adversely affect the foetus growth, Pb causes anaemia, peripheral neuropathy, and Hg develops encephalopathy, ataxia, visual disturbance and even paralysis (Martin, 1997). Further, higher amount of U-Cd were reported by Iwata et al. (1991), Suwazono et al. (2000) and Ezaki et al. (2003) in Renal Tubular Dysfunction (RTD) patients from non-polluted area in Japan. Certain elements are established toxicants as well as environmental pollutants, which are tied withill health of common residents of the region. Therefore, periodically monitoring for the levels and sources of the agents of ill health is required for preventive measures.

ELEMENT INTERACTION

When there are multiples of exposures from many sources of multi-elements, elements involve in interaction in the body of subjects. Because of the elemental interaction, their effects are many folds (additive) or reduced (antagonistic) effects. The interaction between arsenic (As) and selenium (Se) has been one of the most extensively studied. The antagonism between As and Se suggests that low Se status plays an important role in aggravating arsenic toxicity in diseases development. Therefore, it is evident that this interactionand effects are subject as well as element specific in nature. Therefore, it is inquisitive to understand element interaction through multi-element analysis with use of biological samples such as blood, teeth, urine, etc.

EFFECTS ON P53 GENE EXPRESSION

If the p53 gene is damaged, tumour suppression is severely reduced. Elements causing cancer may affect p53 and their interference may be in the functions of p53. Abernathy et al. (1999) reported that after 24 hr arsenite treatment/exposure, altered expression of p53 and change in cell cycle distribution were caused in cell lines and cells transfected with a mutant p53 gene showed increased arsenite sensitivity. Sanjay Mishra et al. (2010) related water sources of elements (As, Cr, Ni, Pb, and Hg) and their effects on p53 gene expression and cause of cancer. In healthy condition, the gene p53 continually produce the protein known as Tumour Protein tp53 or p53 protein because of its roles in cancer suppression action, but the protein p5 is regularly degraded in the cell. The degradation of p53 is, as mentioned, associated with MDM-2 binding**.** In a negative feedback loop, MDM-2 is itself induced by p53. The elements acting as mutants may interfere with MDM-2. Thus, environmental element pollutants may affect directly p53 gene or its regulatory gene MDM2.

Variability Of Human Requirements For Nutritional Elements

In addition to toxic elements, nutritional elements such as Cr, Zn, Cu, Se, etc. are important because of their nature of levels either harmful, or deficient and physiologically optimum levels. The definition of nutritional requirement of essential elements has been fixed for a population but there is considerable variability of requirement among individuals.

Effects Of Deficiency And Excess Of Essential Trace Elements

Chromium, zinc and cobalt, have many significant biological roles in metallo- enzymes and are required at trace levels by all living organisms (Wood et al., 1975). However, they prove to be hazardous even when their concentrations are slightly increased above the trace quantity needed for nutritional requirement and physiological interactions. Exposure to deficient or excessive amounts of essential trace elements include a range of clinical and biochemical end- points.

REVIEWS OF RELATED LITERATURES

Carpenter et al. (2019) reported that there are sources of lead(Pb) from environmental factors namely soil, water, leaded paint and gasoline, improperly discarded batteries, and earthquakes. The prevalence of elevated blood lead (B- Pb) levels (EBLL) was significantly higher in the mountain area (82 of 100, 82.0%; P < .001) than in the urban area (42 of 78, 53.8%) and the coastal area (56 of 95, 58.9%; P < .001) among healthy Haitian children. More than half of the Haitian children showed environmental sources of lead from discarded batteries. Menezes- Filho et al. (2018) demonstrated that for urban children, dust represents the main exposure to sources of metals like lead (Pb). Median and range of B- Pb were 1.2 (0.3‾15.6) µg/dL determined in four elementary schools in the town of Simões Filho, Brazil.

Evident exposure

Alvarez et al. (2018) found out that children living in the urban setting had significantly higher BLLs as compared with matched rural township children (F = 125, df220,2, p <0.001). Neighborhoods with a history of lead contamination can present current risk of lead exposure for older children between the ages of 5 and 12 years, as well as for infants and toddlers.

Pb from air, water and food

Han et al. (2018) reported that China faces severe health challenges, in particular the threat of children’s Pb poisoning. Chinese children's blood lead levels (BLLs) (percentage of BLL>100µg/L) and the correlation and regression analysis indicated that soil and air were two major pathways of Pb exposure for children in China. Although a noticeable decrease has been shown, the Chinese children's BLLs were still significantly higher than the levels of developed countries.

Mercury from coastal fish

Assessed mercury (Hg) pollution in China's coastal waters. They reported that with a 50% increase in Hg concentrations in water in the Bohai Sea, the bioaccumulated MeHg concentration (4.5 µg/L) in the fish consumers is higher than the threshold level indicating association between water pollutants and the pollutant intake by humans. Besides, Jo et al.(2010) reported that the blood mercury concentration of the residents of Busan, Korea and those who ate fish more than 4 times per week was higher than others with statistical significance (male p = 0.0019, female p = 0.0002).

Mercury in blood

Kim et al. (2013) reported that the geometric mean Hg concentration in Korean whole blood was 3.92 µg/L. Blood B-Hg level and Hg intake from diet.

Exposure to toxic elements

Cadmium is a toxic element in cigarette smoke associated with ischemic vascular disease (Yoon et al. 2019).

UIA and cadmium

Yoon et al. (2019) reported that those with an unruptured intracranial aneurysm (UIA) had more pack-years of smoking (19.5±3.8 vs. 12.5±6.8, P=0.044) and higher mean serum cadmium levels (1.77±0. 19 vs. 0.87±0.21 µg/L, P=0.027), whereas arsenic levels showed no difference between groups. They concluded that UIA incidence was associated with pack- years of smoking and serum cadmium level, but aneurysm size was not associated with serum cadmium level. higher in coastal areas than in urban or rural areas. B- Hg level correlated with the intake of Hg consumed from diet. Johansson et al. (2002) found that males and females (adult elderly population with a mean age of 87 years) did not differ in blood- mercury (B-Hg) concentrations or in any of the other studied variables (between smokers and non- smokers, and cognitive function, arterial BP, age, gender or BMI) Gowdy et al. (1977) reported that B- Hg levels are higher in urban residents than in rural probably because of increased exposure to combined industrial and environmental sources.

Urine levels positive

Roca et al. (2016) reported that significant differences were also obtained between the rural (agricultural region) and urban area studied for urinary levels of As, Co, Cs, Se, U and Hg, with higher levels in children living in the urban area from Valencia Region, Spain.

Decline in pollution of Hg

McKelvey et al. (2018) found that NYC adult blood and urine geometric mean mercury concentrations decreased 46% and 45%, respectively. Adult New Yorkers with blood mercury concentration ≥ 5 μg/L (the New York State reportable level) declined from 24.8% (95% CL = 22.2%, 27.7%) to 12.0% (95% CL = 10. 1%, 14.3%). The decline in blood mercury in NYC was greater than the national decline, while the decline in urine mercury was similar.

URINE AS A BIOMATERIAL

Heavy metals testing remains an ongoing challenge for diagnosing acute or chronic exposure to heavy metals (Hackenmueller et al. 2019). All populations worldwide are exposed to some amount of elements like lead, cadmium, nickel, arsenic, mercury and that there is great variability in exposures within and across countries and regions .Human biomonitoring (HBM) programs, are the most straight- forward approaches to get information on the actual exposure levels in the population and assess over time and biosample, like urine is extensively used for such elements exposure prediction.

Baseline value of Hg

In a Human Biomonitoring programme of nationwide cross- section of Spanish adults (18-65y), Castaño et al. (2019) reported that geometric mean Hg (baseline/reference) values of urine are 1.11 μg Hg/l of 1704 urine samples collected from Spanish regions. They viewed that fish and seafood are the major sources of mercury exposure and that the Spanish as well as the Portuguese populations have higher levels than other European countries and inhabitants in coastal regions have higher values than from inland regions.

WATER AS AN ENVIRONMENTAL SAMPLE

Radon in water

Radon (222Rn) is a radioactive alpha- particle- emitting gas originating from the decay series of uranium and thorium and is found anywhere in soil, air and water. Milvy and Cothern (1989) reported that its range of average natural radioactivity is 500 to 600 pCi L(- 1) and the cost to reduce its total levels from 600 pCi L(- 1) to 5.0 pCi L(- 1) is about 9 million. Celaya González et al. (2018) pointed out that our population is receiving around 50% of average effective dose of 222Rn and the naturally occurring radioactive gas together with its progenies, if inhaled, is responsible for causing the risk of lung cancer. Hence, there is a need of studying its status in the water sources of different types and places, effective dose of people, factors influencing its levels in the water.

Justification for radon measurement in water

Radon is of importance because it is released from public drinking water suppliers in the process of taking showers and baths and in washing dishes and clothes (Milvy and Cothern 1989). In many of the houses, the water supply was shown to contribute significantly to levels of indoor 222Rn (Lawrence et al. 1992). Therefore, the transport of radon at the water- air interface is a very important process for the accurate measurement of radon in water. By using a mathematical model and an experiment the radon transfer velocity coefficient (k) from the water- air interface was found to be (1.4±0.2)×10(-6)ms(- 1). This radon transfer velocity indicates that the escape is a relatively slow process, which justifies the assessment and monitoring of radon status in water (Ongori et al. 2015).

Health risk

Ahmed et al. (2019) showed groundwater contaminations and associated health risks in the Surma basin, Bangladesh, since the mean concentrations of As, Fe, Mn concentrations exceed WHO's values. Weathering of source rocks, reductive dissolution of Fe and Mn- oxyhydroxide minerals and various anthropogenic inputs are the key sources of contamination. Children are more susceptible to the non- carcinogenic and carcinogenic risks than adults in the area.

Dental caries

In the coastal region of Indonesia, average groundwater calcium content was 126.75 mg/litre (high category), and average dental caries was 2.2 (low category). Spearman correlation analysis showed p = 0.029 (p < 0.000) that there was a positive relationship between the calcium content of groundwater with dental caries (Yani et al. 2019).

Bladder cancer

Amin et al. (2019) showed a significant association between bladder cancer mortality and arsenic intake from well water of some parts of USA. Thus, it is evident that quality water, being influenced by several natural and anthropogenic factors, determines safe and healthy living condition of any place.

FOOD AS A SAMPLE OF ENVIRONMENTAL SOURCE

Food either in raw or cooked forms, is one of the most important sources of essential elements' requirement as well as body burden of non-essential elements through consumption. It is the major source of human intake of both essential and toxic minerals which are observed by the food plants from soils of different qualities. Measurement of mineral status in food will predict whether subjects are under the influence of mineral malnourishment or toxic effects of excess levels of elements.

Normal levels

Hu et al. (2019) reported the typical concentrations of food elements namely Zn, Cr, Ni, Fe, Pb and Cu that ranged from 16.02 to 61.48 mg kg- 1, 0.23- 13.64 mg kg- 1, 0.10-5.90 mg kg- 1, 19.16- 170.05 mg kg- 1, 0.15-3.62 mg kg- 1, and 0.53-2.74 mg kg- 1, respectively. The total selenium content of selected food items purchased from the North West part of Greece was within the range from other countries (Pappa et al. 2006). Flesh and meat products, dairy products, bread, vegetables, legumes, roots, fruits, and mushrooms from the south and southwest territories of the Kaluga Region, Russia were analyzed for 17 elements and their concentrations of essential and toxic elements in the different foods were found in the normal ranges (Zaichick 2002).

Higher levels of Pb, Cd, Ni, Cr

Alberti- Fidanza et al. (2002) found that higher levels of Pb, Cd, Ni, Cr were present in bread (21.5+/- 14.0, 5.6+/-0.02, 55.6+/- 1.7 and 66.9+/-0.1 microg/100 g of edible portion, respectively), followed by meat, filled pasta and cheese, whereas lower values were observed in vegetables and fruit. A large variability in trace element content between raw and cooked foods was observed. Hu et al. (2019) reported the concentrations of Zn, Cr, Ni and Pb in all vegetables that were above the national tolerance limits.

Zinc deficiency

The deficiency of zinc (Zn) and iron (Fe) is a global issue causing not only considerable yield losses of food crops but also serious health problems. Although only 13% of the soil samples were Zn deficient and none was Fe deficient, the levels of these micronutrients in grain were rather low (median values of 21 mg kg(- 1) for Zn and 36 mg kg(- 1) for Fe), and even less adequate in white flour (Nikolic et al. 2016). Zn deficiency in wheat grain poses a high risk for grain quality relevant to human health in Serbia, where wheat bread is a staple food.

Biosampling of human subjects Subjects

The volunteers of three urban places in Lucknow city and one rural place (Barabanki) have donated three biological samples namely blood, teeth and urine. The Table 3.1 shows the no. of the human samples collected in these four places. Based upon their places of residences from city and rural areas the subjects were mainly sorted out into rural (control) and urban (experimental) categories. Further, each category (rural or urban) was grouped into two subgroups depending upon their personal/ lifestyle factors. Among the subgroups, the diabetics had Random Blood Sugar (RBS) level above 120 mg/100 ml of blood while non-diabetics had RBS 100- 120 mg/100 ml. In the case of blood pressure (BP) levels the hypertensives had BP above or equal to 140/90 mmHg (Malhotra et al., 1999), whereas normotensives had 110 to 120/80 mmHg. The subjects were identified as medium and high-income groups depending upon their monthly income respectively ranging Rs. 5000- 10000, and above Rs. 10000.

Table: The details of three types of human samples collected from four places in and around Lucknow city

SN	Names of samples	Place of sampling	no. of samples		
			Male	Female	Total
1	Blood	Barabanki (R)	12	15	27
		Alambagh (U)	12	17	29
		Gomti Nagar (U)	16	15	31
		Lucknow City	13	17	30
2	Teeth	Barabanki (R)	7	6	16
		Alambagh (U)	6	7	13
		Gomti Nagar (U)	11	7	18

		Lucknow City	4	5	9
3	Urine	Barabanki (R)	12	12	24
		Alambagh (U)	12	10	22
		Gomti Nagar (U)	7	7	14
		Lucknow City	7	9	16

Biosamples

Among three biological samples, entire, permanent teeth were collected from eight private dental clinics from the four places of Lucknow. The tooth samples that were to be removed for orthodontic or dental treatment purposes, were extracted by the dentists from the donors. After washing and drying the tooth samples, they were transported neatly with clean plastic bag to the laboratory for further process of analysis. Blood and urine samples were collected from Chandan Hospital, Near Chinhat , Lucknow, Sahara Hospital, Gomti Nagar, Lucknow and other four private clinical laboratories, Lucknow. The details of blood samples collected from control and cancer patients were given in the Table 3.2. All these three samples were collected with the consent of donors during the period from Jul. 2020 to October-2021.

Table : The characters of controls and different cancer patients from Lucknow

SN	ubject of control/ cancers	Sex	Age	Place	Alcoholic	Tobacco chewer
1	Normal	Male	42	Hazaratganj	No	no
2	Normal	Female	38	Hazaratganj	No	no
3	Colon cancer	Female	55	Cinhat	No	Yes
4	Colon cancer	Female	48	Transport Nagar	No	Yes
5	Gastro oesophageal cancer	Male	52	Dewa Road	No	Yes
6	Palate cancer	Male	36	Lucknow Cantt	No	Yes
7	Tongue cancer	Female	38	Gonda	No	Yes
8	Eye lid cancer	Male	42	Hussainganj	No	No
9	Stomach cancer	Male	46	Vikas Nagar	No	Yes
10	Bone cancer	Female	31	Basti	No	No

Sampling ethics

To collect biological samples, especially the teeth, blood and urine an ethical committee has been formed. Dr. Satya Prakash, Assistant Professor in Zoology, RGU and Dr. Amit kumar Gupta, Professor in Zoology, Lucknow University, Dr. S. Rajasekara, Department of Zoology, Regency Hospital, Lucknow, Dr. Akash Verma, Pushpamjali Hospital Lucknow were the members of the ethical committee and the samples were collected with the approval of the committee. The donors of the samples were all the volunteers who gave consent for sampling. The volunteers were also informed the purpose of sampling for environmental monitoring studies and will not be used for other purposes.

ENVIRONMENTAL SAMPLES

Water

Deep bore well water used for drinking; agriculture and industrial purposes were collected from randomly selected drilled tube wells of three urban areas of Lucknow city and one adjoining village. Fifty-nine samples were collected from three urban areas and one rural area from May to December 2021 (Table 3.3). The correct locations of the tube wells from where sampled, were identified and recorded; further other parameters, such as depth of groundwater tube wells, time, date, etc. were also noted. The water samples (N 59) were collected personally by gently filling in 250 ml leak-proof and properly levelled plastic bottles specifically designed for study of radon activity in water, ensuring least radon loss during sampling, transport and storage period, following the guidelines reported by Dimova et al. (2009) and Erdogan et al. (2017).

Table: The details of water samples collected from four places in around Lucknow city

Place of water sampling	No. of samples		
	Bore well	Corporation	Total
Barabanki (R)	3	7	10
Alambagh (U)	3	10	13
Gomti Nagar (U)	2	8	10
Lucknow City (U)	3	10	13

Food Samples and preparation

The food samples were collected in fresh from the markets (Table 3.4) in clean plastic bags and transported to the laboratory for drying and digestion in acids and diluted with double distilled water and stored in clean plastic containers as per the procedures followed for other biological samples. The element concentrations of dry weight of food samples were determined with use of ICP.

Table 3.4: The details of food samples collected in around Lucknow city

SN	Names of food samples collected	
	Non- diabetic food	Diabetic food
1	Orange	White rice
2	Guava	Potato
3	Apple	Cake
4	Turmeric	French fries
5	Garlic	White bread
6	Cinnamon	Coffee
7	Palak	Fruit juice
8	Ragi	Sugar
9	Bitter guard	Jaggery
10	Butter fruit	Soft drinks

SUMMARY AND CONCLUSIONS

The concentrations of elements (Rn, As, Cd, Pb, Hg, Ni, Co, Cr and Zn) determined in three samples have delineated that there are apparent differences in exposure status and sources between subjects from urban and rural places from Lucknow. Particularly, higher levels of essential elements (Co, Fe, Cr and Zn) observed in the urban subjects are due to higher intake from food, alcohol consumption and drinking water which are considered as sources from individual' s life style, whereas, the higher levels of Cd, Pb and Ni are ascribed to elevated sources from environmental pollution.

It is evident that industrial workers showed higher levels of B-Pb, B-Hg and T-Hg hence their working environment is to be monitored and maintained in a viable condition with preventive, precautionary and protective measures. In addition to occupation and environmental sources, other factors (habits of food, alcohol consumption, smoking, drinking water from different sources) are viewed as additional sources of elements for the Lucknow subjects.

In the case of diabetics from both the rural and urban area, there are differences in element levels in comparison to non-diabetics and it is viewed that higher Pb and Hg from environment and lower Cr from food intake are the casual factors related to diabetes.

Element levels were different between male and female cancer patients. Though higher B-Cd level was found in the cancer patients than the rural and urban subjects, it was not statistically significant due to less number of cancer patients.

Multi-element exposures causing interaction in human body have been found in the form of positive interactions resulting in synergistic effects in the subjects.

While correlating element levels among three biosamples, it is known that blood and urine are the indicators of acute status of elements and also influenced by daily metabolic activities. But teeth comparable to bone, are unique in accumulating elements in their various parts namely enamel, dentine and pulp. The different natureof element exposure observed based on levels in three human samples are ascribed to their biological characteristics, such as composition, development and growth period

Based on element levels of various subgroups compared among three samples, it is evaluated that the biosample use for assessment of human exposure to elements could be adopted in the following order of preference, urine, teeth and whole blood.

The element levels measured in the food indicated that six food items were also the main source through intake. In comparison with reported reference values, the element levels were within the normal ranges thereby revealing the natural source of elements from soil and water rather than from contaminated sewage source. The water level of radon is below the level of daily admissible intake. The p53 gene expression found in the blood samples of normal and different cancer patients is in three patterns, namely typical in normal subjects and both lower and higher in the cancer patient and thus, the p53 expression is either dependent or independent of carcinogenicity.

LIMITATIONS OF THE STUDIES

1. 1. The sampling of biological materials carried out, though in random, a few categories of subjects could not be included at different places and collection of such samples was made possible from the hospitals and clinical laboratories, because of the sampling implication with clinical approach and ethical and safety values.

2. All the three biological samples could not be collected from the sample subjects, since these clinical samples were collected by different dentists and laboratory technicians, the donor's interest in volunteering and because of practical difficulties, time requirement and place of sampling.

3. Only raw food items with limited sample numbers were included in the study and cooked food items were not collected due to limitation in element analysis.

4. Though samples were collected in random, the subjects of young age were not included in the study because of much fluctuation in the age limits and non co-operation of the subjects in disclosing their correct age. The less number of blood samples was collected from the cancer patients.
5. Number of elements analysed was restricted to nine elements due to constrain in covering more elements. The number of elements analysed in the blood of cancer patients is lesser than in other subjects of the study.

6. Though only a single Certified Reference Material (CRM) of human hair powder was used for quality assurance, because of non-availability of CRM for certain specific sample and time constraint. To compensate the use of external quality control sample, internal quality control samples were prepared and used as per the standard procedures.

SCOPE FOR FURTHER STUDIES

1. The other biopsy (hair, nails, milk, cord blood etc.) and autopsy samples can be employed for assessment of human exposure to elements.

2. The similar investigation may be carried out with good number of samples including various subjects for evaluation of impact of personal characters on element levels.

3. In the cases of diabetes, hypertension and cancer, element levels may be studied with more number of samples and with consideration of finding association with other biochemical parameters.

4. Though only one radon element has been selected in the study, other elements, like uranium, plutonium could also be selected for exposure monitoring of such radioactive elements.

5. The workers of special jobs in mining, thermal power plant, welders, traffic police etc. can be selected for the studies about occupational exposure.

6. The status of other essential elements (Se, Mg, I, Mo, P etc.) and toxic elements (Al, Sb etc.) and their relation with the health status can be studied.

7. Other instrumental techniques like Neutron Activation Analysis, Striping Voltammeter may be employed and the accuracy of the results can be compared. Similar to food, element levels of air, soil and water pollution may be assessed and compared with body levels of elements.

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