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Trace element contents in the hair and nail samples collected from Chandrapur Super Thermal Power Station (CSTPS)

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Abstract

Hair and nails provide a picture of the concentrations of different elements in an organism. Furthermore, they are partially independent of the influence of metabolic processes and homeostatic mechanisms. The present study demonstrates, a long-term bioaccumulation of toxic trace elements like, Fe, Ni, Cr, Cd and Pb that results in deficiency of Zn hair samples collected from male and female subjects living in rural area in proximity to Chandrapur Super Thermal Power Station (CSTPS). Chandrapur Super Thermal Power Station (CSTPS) is the largest thermal power station of India, with the capacity to produce 2340 MW power generation, which is approximately 25% of the state's share. Evidence from present study also confirm the role of emission from Thermal Power Station as significant contributor to pollution of surround air, water and soil and, thus, related to health risk for human community. Besides, previously documented health risk in adult age may generate significant consequences in the short and long term warranted adequate prevention policies to avoid further complications.

Keywords – Hair, nail, bioaccumulation, trace elements.

1.   Introduction

The intake of trace elements in the human body can be monitored by measuring their concentrations in different biological matrices including blood, hair and nails. Although urine and blood are commonly indicators of short-term trace element exposure, the keratin-rich matrices of hair and nails tends to reflect long-term exposure [1-6]. Trace elements act as catalyst in many biochemical reactions in our body, so as the importance of trace elements in various metabolisms have long been recognized. Determination of trace elements in humans can indicate susceptibility to certain diseases, support therapeutic interventions and explain disturbances associated with many pathological conditions. [7-9].

Human hair is a reliable and convenient biological indicator of environmental pollution. [10-11]. The analysis of human hair for is used to study environmental and occupational exposure as well as to assess bodily status of several metals [1,3,4,6]. Hair, unlike blood or other tissue can be collected easily, is easy to transport and store [10,12].

Coal plays as essential role in our global energy scheme for the power generation as most of the world's coal production is consumed by thermal power projects to generate electricity. Most of the European power generation producers have ruled out the construction of new coal-fired power plants and on the path of declining trend as renewable energy sources expands enormously [13-14]. Coal-fired power plants are a major source of emissions for a number of air pollutants including potentially toxic trace elements (PTE). [15]. Coal-fired thermal power plants currently make up for 40% electricity global demand. Chandrapur Super Thermal Power Station (CSTPS) is the largest thermal power station of India, with the capacity to produce 2340 MW power generation, which is approximately 25% of the state's share. Based on a comprehensive health impact assessment conducted by Centre for Research on Energy and Clean Air, CREA [16] and report by Maharashtra Pollution Control Board (MPCB, 2020) [17], hence the study area selected for the collection of hair and nail samples.

2. Methodology

Study Site
The district Chandrapur located in eastern part of the Vidarbha region within the state of Maharashtra was earlier known as 'Chanda' subsequently to Chandrapur. During the British colonial period it was called Chanda district, which was again changed to its original name 'Chandrapur' at around 1964. Chandrapur Super Thermal Power Station (CSTPS) is the largest thermal power station of India, with the capacity to produce 2340 MW power generation, which is approximately 25% of the state's share. The district is home to Ballarpur Industries Limited (BILT) paper mill. Based on a comprehensive health impact assessment

conducted by Centre for Research on Energy and Clean Air, CREA [16] and report by Maharashtra Pollution Control Board (MPCB, 2020)[17], study area selected for the collection of hair and nail samples as shown in Fig.1.
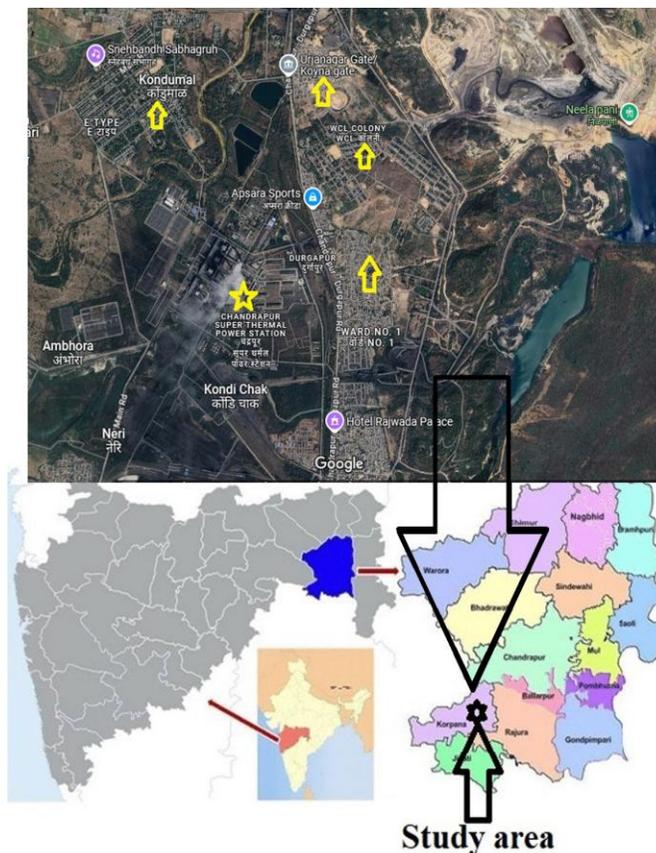

Fig. 1. Map Showing study area in the Vicinity of Chandrapur Super Thermal Power Station (CSTPS) in Maharashtra, India

Collection of hair and nail samples and preparation of sample for AAS spectroscopy
To obtain more nail in expected quantity, participants asked in advance not to trim their nails for a couple of weeks or for longer duration. Nails are collected by clipping with a steel clipper from the two great toes (or thumb) and small toes (or other fingers). Instructions were provided to participants in advance to obtain as much nails as possible and clipping should be from both feet and hands. The nail clippings from the great toes and thumbs and rest of the toes or fingers are better to be stored separately as the time frame represented by the great toe or thumb is different from the rest of the toe or fingernails. The nail samples were packed in cellophane bags having labelled indicating name, sex,

and age and stored in room temperature. Accordingly, male and female subjects from different developmental stages, pre-puberty (age 11 to 13 yrs.), adolescent (age 18 to 20 yrs.), young adulthood (age 23-25 yrs.), middle adulthood (age 33 to 35 yrs.), middle aged adults (age 42 to 45 yrs.) and Late adulthood (age 58 to 60 yrs.) were selected. [18].

Preparation of nail samples for AAS

The nail samples were cleaned manually and all dirt on the surface removed, and then was washed with water-acetone solution. In the cleaning process of samples the solution of water 50% and acetone 50% were used to remove all types of exogenous contamination, from fats and lipids to various other organic and inorganic substances as recommended by International Atomic Energy Agency [19] Therefore, the heavy metals do not affect with washing procedures to remove the external contaminants due to strong complex with different group which might affect their concentration in the nail sample. [20].

Nail samples were collected between October, 2022 to November, 2023 from 30 male and 30 female inhabitants each from residents and workers residing in the villages nearby to CSTPS.These samples were brought to the laboratory for further procedures. The steps in the laboratory includes the washing of the samples, digestion of the samples, prior to estimation of elemental content by Atomic Absorption Spectroscopy (AAS). The nail samples were cleaned manually and all dirt on the surface removed, and then was washing with water-acetone solution. In the cleaning process of samples the solution of water 50% and acetone 50% were used to remove all types of exogenous contamination, from fats and lipids to various other organic and inorganic substances as recommended by International Atomic Energy Agency, 1985 [21-22]. Therefore, the heavy metals do not affect with washing procedures to remove the external contaminants due to strong complex with different group which might affect their concentration in the nail sample. [23]. Decomposition of nail samples is very important in determination of these elements by using a mixture of nitric acid (HNO3) with hydrogen peroxide [24]. (Fig.2)

Fig. 2: Samples preparation for Atomic Absorption Spectroscopy (AAS) A. Nail Samples **B.** Ash prepared after washing and digestion, **C.** Samples **ready** to assess by AAS in solution form

Atomic Absorption Spectrophotometer (AAS) analysis of nail trace elements

For the determination of trace elements in the present study, flame Atomic Absorption Spectrophotometer (AAS) has been used. The Atomic Absorption Spectrophotometer used for measurement of trace elements (Cu, Zn, Co, Mn, Fe, Cr, Cd, Ni, As, Pb and Hg) is Shimadzu makeAA-7000F, 1.04 ROM version and with serial number - A30925501246 at Central Research Facility of Manipal University, Jaipur. For the purpose of atomisation, air-acetylene flame has been used. The lamps used for the elemental determination were hollow cathode lamps filled with Neon (Ne). The AAS determination of cations was performed under the recommended condition for each heavy metal.

3. Results and Discussion

Hair and nails provide a picture of the concentrations of different elements in an organism. Furthermore, they are partially independent of the influence of metabolic processes and homeostatic mechanisms [9]. Values obtained by Atomic Absorption Spectroscopy (AAS) for the concentration of trace elements in hair and nail samples collected from male and female subjects working in Chandrapur Super Thermal Power Station (CSTPS)with respect to different age groupswere expressed in unit PPMexcept Mercury (Hg) which are in PPB, but for the sake of understanding and to maintain the uniformity in order to make conclusive statement regarding relative fluctuations amongst different sampling site values are represented in µg/gm unit (mean ± SE) are summarized as in Table. 1 and 2.

During present investigation on the concentration of trace elements of scalp hair in different male and female subjects especially is middle adulthood age group residing Durgapur and in nearby villages state the following order : Zn > Fe > Cu > Cr >Mn> Co >Pb> Ni>As > Cd> Hg. While in nail samples from same volunteers, concentration of trace elements shows following order : Fe > Zn > Cu >Mn> Co > Ni >Cr > Cd >Pb> As > Hg in all investigated subject age groups. These findings of ours highlighted greater exposure of participants with harmful toxic elements, nickel and lead in older ages, which are in line with reports from so many similar studies in India and in different parts of the world [25-28]. Results on concentrations of trace elements shows fluctuations in hair and nail samples; trace elements Cu, Zn, Co, Cr, As, Pb and Hg have higher level in hair than nail, while trace elements Mn, Fe and Cd have higher values in nail than hair.

Table.1. Table showing concentrations of trace elements (µg/gm) in hair samples of both the male and female subjects residing nearby Chandrapur Super Thermal Power Station (CSTPS). (Mean± SE)

| Trace Elements	11-13 Yrs		17-20 Yrs		23-25 Yrs		33-35 Yrs		42-45 Yrs		58-60 Yrs	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Cu	6.71600± 4.64	6.35840± 4.51	8.31600± 5.16	6.35840± 4.51	13.93220± 6.7	10.76700± 5.9	16.64820± 7.3	11.61860± 6.1	18.53740± 7.7	14.92520± 6.9	20.62334±8.1	17.40540±7.5
Zn	38.4740± 11.1	40.0680± 11.3	45.5580± 12.8	48.3080± 12.5	52.8400± 13.0	54.9840± 13.3	63.9040± 14.3	66.5500± 14.6	57.7440± 13.6	60.9460± 13.9	53.9520± 13.1	62.3752±14.1
Co	2.79600± 2.99	2.55200± 2.86	3.28200± 3.24	3.19800±3.20	4.22800± 3.68	3.95600± 3.56	4.89740± 3.96	4.70200± 3.88	6.14600± 4.43	5.38800± 4.15	6.40400± 4.5	5.90800± 4.35
Mn	2.75600±2.97	2.40940± 2.78	3.73200± 3.46	3.34800±3.27	4.91600± 3.97	4.10600± 3.62	5.44800± 4.18	5.00600± 4.00	6.33600± 4.50	5.88600± 4.34	7.10800 0 ± 4.8	6.15680± 4.44
Fe	32.4920± 10.2	33.1140± 10.2	40.9380± 11.4	39.1140± 11.2	47.9860± 12.4	46.0160± 12.2	54.3000± 13.7	51.2540± 12.8	52.9840± 13.0	46.7740± 12.2	34.7060±10.5	32.7320±10.2
Cr	3.32920± 3.26	2.89560± 3.04	4.29400± 3.71	4.14960± 3.64	5.26420± 4.10	4.82460± 3.93	6.05520± 4.40	5.40040± 4.16	6.44360± 4.54	5.52540± 4.20	7.20940 0 ± 4.8	5.95540±4.37
Cd	0.00911± 0.17	0.00830± 0.16	0.02460± 0.28	0.01181± 0.19	0.08916± 0.53	0.05174± 0.41	0.17300± 0.74	0.08758± 0.53	0.34680± 1.05	0.09622± 0.55	0.52360± 1.29	0.24520± 0.89
Ni	0.19340± 0.79	0.16500± 0.73	0.40620± 1.14	0.38720± 1.11	0.54240± 1.32	0.41920± 1.16	0.62440± 1.41	0.54280± 1.32	1.07080± 1.85	0.87940± 1.68	1.65860 ± 2.3	1.30060±2.04
As	0.07374± 0.49	0.04574± 0.38	0.09326± 0.55	0.04574± 0.38	0.12586± 0.63	0.07054± 0.48	0.18420± 0.77	0.08162± 0.51	0.23780± 0.87	0.10834± 0.59	0.41436 ± 1.1	0.16012± 0.72
Pb	0.06690± 0.46	0.03228± 0.32	0.26120± 0.91	0.03228± 0.32	0.37080± 1.09	0.28900± 0.96	0.80900± 1.61	0.41520± 1.15	1.16040± 1.93	0.63820± 1.43	2.16480± 2.63	0.73180± 1.53
Hg	0.00576± 0.14	0.00126± 0.06	0.00609± 0.14	0.00252± 0.09	0.00733± 0.18	0.00395± 0.11	0.01042± 0.18	0.00487± 0.12	0.01560± 0.22	0.00813± 0.16	0.02902 ±0.30	0.01554± 0.22

Table.2. Table showing concentrations of trace elements (µg/gm) in nail samples of both the male and female subjects, residing nearby Chandrapur Super Thermal Power Station (CSTPS). (Mean± SE)

Trace Elements	11-13 Yrs		17-20 Yrs		23-25 Yrs		33-35 Yrs		42-45 Yrs		58-60 Yrs	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Cu	5.06780± 4.03	4.9554 0 ± 3.9	10.25000±5.7	8.2714 ± 5.14	12.24020± 6.3	9.9788 0 ± 5.6	15.9060± 7.1	11.5662± 6.1	18.1106 ± 7.6	13.8776± 6.7	10.25000±5.7	16.14720± 7.2
Zn	28.36120± 9.5	28.7232 ± 9.6	40.5907±11.4	43.3606 ±11.8	48.0084±12.4	51.3818 ±12.8	54.8870± 13.2	59.4656± 13.8	46.9806 ±12.3	55.6710± 13.3	28.4190 ± 9.5	33.2816±10.3
Co	1.59640± 2.26	1.0394 0 ± 1.8	2.19300± 2.65	1.5348 0 ± 2.2	3.53180± 3.36	1.7876 0 ± 2.4	4.60400± 3.84	2.35280± 2.74	5.7748 0 ± 4.3	3.15260± 3.18	6.2008 0 ± 4.4	3.5948 0 ± 3.4
Mn	2.70480± 2.94	2.5474 0 ± 2.9	3.51860± 3.36	2.8310 0 ± 3.0	4.53540± 3.81	3.9846 0 ± 3.6	5.89180± 4.34	4.78720± 3.91	6.2960 0 ± 4.5	5.66340± 4.26	6.8700 0 ± 4.7	5.7930 0 ± 4.3
Fe	38.4118± 11.1	36.9274 ±10.9	48.7400± 12.5	47.3600 ±12.3	62.9462± 14.2	55.718 4 ±13.3	66.3046± 14.6	61.5022± 14.0	55.8644 ±13.4	51.3120± 12.8	44.8146±11.9	38.928 8 ±11.2
Cr	1.9682 ± 2.51	1.8042 0 ± 2.4	2.21140± 2.66	1.7364 0 ± 2.4	2.54000± 2.85	2.1126 0 ± 2.6	3.25300± 3.23	2.46580± 2.81	4.0914 0 ± 3.6	2.99300± 3.09	4.7564 0 ± 3.9	3.5952 0 ± 3.4
Cd	0.01174± 0.19	0.0105 1 ± 0.2	0.10006± 0.57	0.0923 4 ± 0.5	0.19860± 0.80	0.1203 2 ± 0.6	0.3712 0 ± 1.1	0.21380± 0.83	0.6964 0 ± 1.5	0.39152± 1.12	0.8274 0 ± 1.6	0.6034 0 ± 1.4
Ni	1.15940± 1.93	1.0690 0 ± 1.8	2.52060± 2.84	2.3940 0 ± 2.7	3.66600± 3.43	2.8448 0 ± 3.0	4.3590 0 ± 3.7	4.06800± 3.61	6.7084 0 ± 4.6	6.07400± 4.41	7.2026 0 ± 4.8	6.6604 0 ± 4.6
As	0.05636± 0.42	0.0396 2 ± 0.4	0.07684± 0.50	0.0604 4 ± 0.4	0.08516± 0.52	0.0706 4 ± 0.5	0.1039 4 ± 0.6	0.07818± 0.50	0.1518 0 ± 0.7	0.08572± 0.52	0.1884 0 ± 0.8	0.8294 0 ± 1.6
Pb	0.01290± 0.20	0.0111 6 ± 0.2	0.02740± 0.30	0.0198 4 ± 0.2	0.09202± 0.54	0.0431 8 ± 0.4	0.3264 0 ± 1.0	0.18580± 0.77	0.4746 0 ± 1.2	0.24940± 0.89	0.6176 0 ± 1.4	0.3764 0 ± 1.1
Hg	0.00397± 0.11	0.0024 4 ± 0.1	0.00666± 0.15	0.0039 5 ± 0.1	0.01047± 0.18	0.0056 6 ± 0.1	0.0171 2 ± 0.2	0.00766± 0.16	0.02327± 0.3	0.01562± 0.22	0.05284± 0.4	0.0194 0 ± 0.2

This results of ours finds its parallel in similar studies conducted in India and abroad [25-28]. As opposed to results obtained in the control area, observed concentration of trace elements in hair and nail samples with an exception of Zn were found higher values in male than female subjects, which found its parallel in similar studies on affected persons by occupational exposure of these metals [27-29]. Results in the present study shows hypertoxicity of trace element iron (Fe) in middle to late adulthood above the reference range as suggested by IAEA that is 23.7±9.7 µg/gm [2, 30]. The results of this study indicates that people living in the vicinity of CSTPS especially male subjects exposed to such alterations in the environment results in higher concentration of Fe innail samples which may cause adverse health effects [31]. Although iron (Fe) is essential trace element needed for oxygen transport and electron transport but high iron (Fe) accumulation in affected people may have serious health implications as it leads to failure of vital organs like brain and heart. [8, 32-33]. High iron levels in hair and nail samples can be a sign of iron overload, that is haemochromatosis, may result in fatigue, headache, irritability, bronzing of skin, diabetes and liver cirrhosis. [8, 32-34]. Iron overload in the body may result in fatigue, headache, irritability and lowered work performance in day-to-day activities.

Fluctuations in values of Zn amongst different age group indicates that, values of zinc in increases with age up to middle adulthood then it starts declining, more prominently in male, these values are much below reference value suggested by IAEA that is 138±44 µg/gm. [30]. By comparison with other studies our results showed similar lower Zn concentrations in scalp hair. [25-26] Zinc deficiency can lead to numerous complications such as stunted growth, diarrhea, impotence, hair loss, psoriasis, impaired appetite, and depressed immunity. [27]. Iron overload leads to overproduction of free radicals aggravating oxidative stress and in turn affects absorption of zinc. [26].
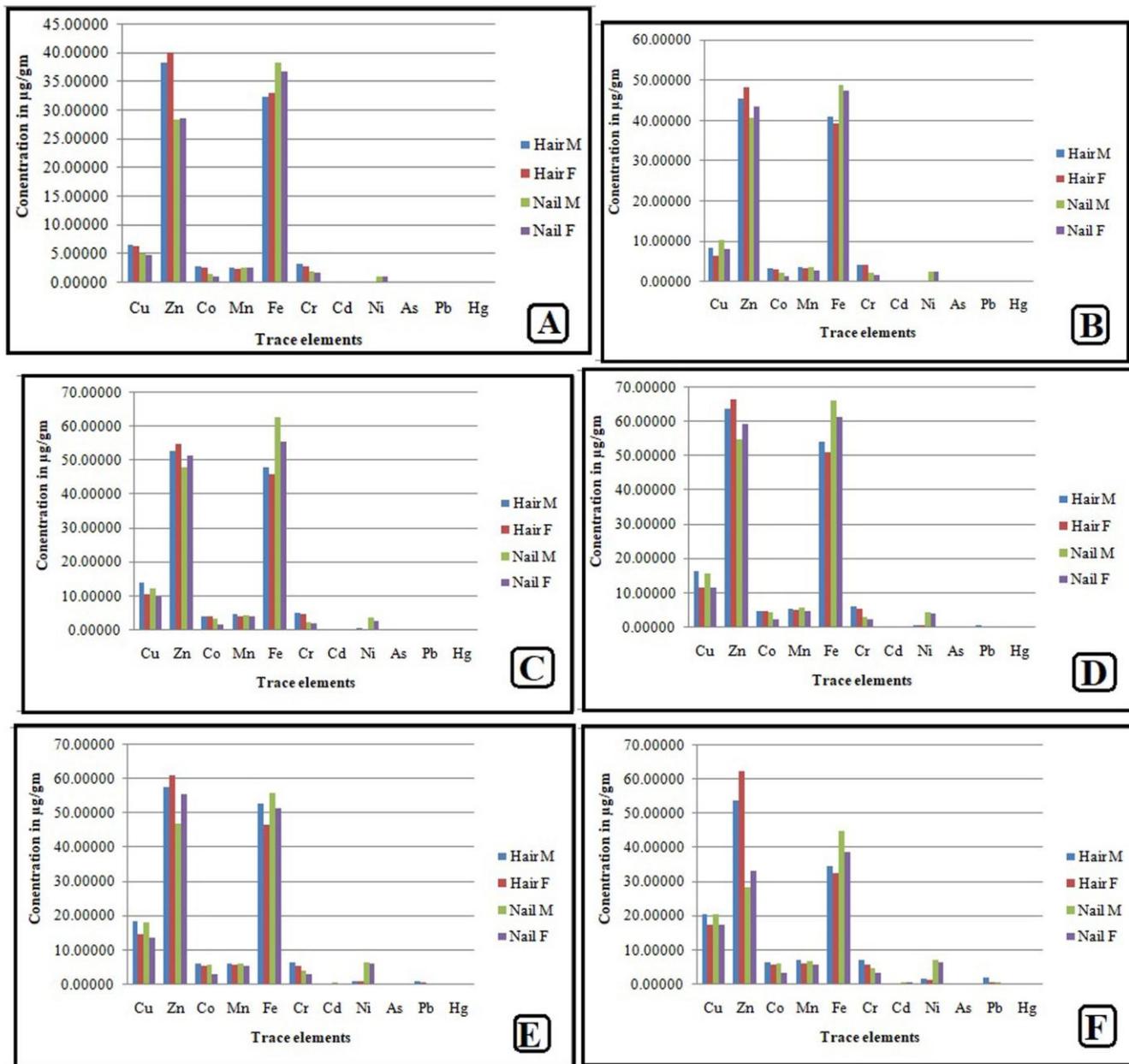
Fig. 3 Graphical represnentaion of fluctuations in concentration of trace elements in hair and nail samples of affected persons residing in the vicinity of Chandrapur Super Thermal Power Station (CSTP) along the different age groups A-11-13 Yrs, B-17-20 Yrs, C-23-25 Yrs, D-33-35 Yrs, E-42-45 Yrs, F 58-60 Yrs.

Interactions between essential nutrient metals and non-essential toxic metals may act as important factor for assessing trace element toxicities and deficiencies. [35]. Apart from Zn deficiency and iron toxicity, hair and nail samples from affected populace reveals toxicity of Pb and Cr trace elements in present investigation. Lead and zinc can compete for absorption in the gastrointestinal tract, can displace zinc which may leads to zinc deficiency [26]. Chromium (Cr) levels in our findings are exceptionally higher than those reported in other studies and were above the threshold level prescribed by IAEA. [30]. Several studies reported elevated level of trace element Cr in the hair and highlighted the potential for health risks associated with chromium

exposure, including carcinogenic properties. [28,36]. We found that exposures of our participants to toxic trace element Pb is within the range for the regional population. This finding of ours is in line with the many studies in similar situations where residents living near the thermal power project likely to have elevated health risks from metal exposures. [28]. These findings regarding elevated level of Hg concentration in human hairs from the participants residing in proximity to CSTPS are in line with above studies. Although the level of mercury in hair in present study are lower than the recommended level of Hg in hair by WHO that is >1.0µg/Kg for MeHg, still it may be sufficient to implicate multiple adverse health complications on the affected persons as reported by many workers. [37-38].

Trace element nickel (Ni) is important for our body as it is involved in hormone action, enzyme activity, and other activities as well. However, according to some studies on harmful impact of Ni, certain compounds like Nickel carbonyl are carcinogenic and dangerous for humans [39]. Studies have also revealed that high exposure to nickel in occupational groups is associated with respiratory diseases like asthma, Chronic Obstructive Pulmonary disease (COPD) and occupational bronchitis [28, 40]. The industrial workers and residents residing in and around CSTPS were studied and the result showed that Ni and Cd in hair were in greater concentrations in the workers. In the present investigation on trace elements in hair sample of male and female subjects residing in proximity to CSTPS, results shown that, values are higher than the reference values suggested by IAEA, that is 0.05 ± 0.02 µg/gm. [30]. These finding of ours are in line with similar studies by authors in different parts of the world [24, 39, 41].

Conclusion

The present study demonstrates, a long-term bioaccumulation of toxic trace elements like, Fe, Ni, Cr, Cd and Pb that results in deficiency of Zn hair samples collected from male and female subjects living in rural area in proximity to Chandrapur Super Thermal Power Station (CSTPS). According to previous bio-monitoring studies in similar situations on affected persons by non-occupational and occupational exposed human populace, values for the concentration of toxic elements in hair and nail samples are higher in male than female as male subjects having more exposure than females. Evidence from present study also confirm the role of emission from Thermal Power Station as significant contributor to pollution of surround air, water and soil and, thus, related to health risk for human community. Besides, previously documented health risk in adult age may generate significant consequences in the short and long term warranted adequate prevention policies to avoid further complications.

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