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Assessment Of Occupational Exposure To Zinc Measured By Using Hair And Nails As Biopsy Materials

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Abstract:
Zinc is an important element in human metabolism. It is absorbed in intestine and binds to plasma proteins. It is abundantly used in various types of industries. The workers exposed to this metal in their work environment take up this metal via respiration, ingestion and absorption through exposed parts of the skin. In this investigation the assessment of Zinc in human body is done by using biological tissues like hair and nail. The proteins in the tissues bind with the metal. The tissues are wet acid digested and converted into water clear solution. The analysis is affected by AAS ECIL-4129 under standard operating conditions. This research paper reports the Zn levels obtained in the study.

Key Words: *Zinc, Atomic Absorption Spectrophotometer, Hair, Nails*

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I. Introduction:

Zinc (Zn) is an essential element in the human body. Its most common ore is sphalerite (ZnS), which is usually associated with sulfides of lead, copper, cadmium and iron. The natural zinc content of soils is upto 300 mg/kg. Galvanizing is primary industrial application of zinc , as also in alloy production as in brass, white metal, die-casting alloys, German silver and rolled zinc sheets. Other applications include the manufacture of dry batteries, process plates and electrodes for Leclanché cells, as well as white pigments. Zinc dust is used in various chemical and metallurgical industries and zinc compounds in textiles, glass, paper, and rubber industries. In therapeutics, zinc compounds serve as astringents, dermal preparations, antiseptics, and emetics.

The atmospheric concentration of zinc varies considerably and is usually elevated near point sources. In rural areas, zinc levels typically range from 0.01 to 0.1 µg/m³, while in urban locations they fall between 0.1 and 0.5 µg/m³ [1]. Essential and toxic trace elements (heavy metals and metalloids) in urine of children, teenagers and young adults from Central European Cohort in the Czech Republic were reported by Sharma et al[2] . whereas Kneip et al observed a mean value of 0.21 µg/m³ in Tuxedo, New York[3]. Taber and Warren reported values ranging from 0.3 to 0.49 µg/m³ across 22 American cities[4].

The solubility of zinc in water depends on its chemical form. Carbonates, oxides, and sulfides of zinc are only sparingly soluble, while the more soluble chlorides and sulfates tend to hydrolyze, forming zinc hydroxide and zinc carbonate. Consequently, water has low Zn levels. But because of leaching through galvanized pipes, brass, and zinc-containing fittings surface waters have relatively more Zinc levels. Zoeteman and Brinkmann reported wide variations in zinc levels from 0.002 µg/mL to 0.69 µg/mL in potable waters[5-6].

Studies on potable, surface and groundwaters across different regions of India, revealed Zinc levels were below 5 µg/Ml[7].

Among all sources, food contributes the largest share of zinc in the human diet. The zinc content of food items vary considerably: high in meat products , while cereals and nuts also make a significant contribution. Animal protein plays an especially important role in dietary zinc intake. Conversely, processed foods, citrus fruits and non-leafy vegetables provide only small amounts. Pandya reported in processed foods an average zinc level of 28.28 µg/g in Ahmedabad[8]. Estimates of daily zinc intake also differ across studies—Soman et al reported a range of 13.5–24.0 mg/day for adults[9], whereas Bhat et al found lower values of 7.7–10.5 mg/day in Tarapur[10]. In the human body, zinc makes up about 2–3 g in a 70 kg adult, with an average daily requirement of 10–20 mg, which increases during pregnancy and lactation.

Absorption and metabolism of zinc in the body

Zinc absorption primarily occurs in the small intestine, especially in the distal duodenum and proximal jejunum. Its uptake and regulation are largely controlled by metallothionein. After absorption or parenteral administration, zinc binds to plasma proteins—including albumin, α-2-macroglobulin, and transferrin—and is

then distributed to body tissues. Because of its strong affinity for nitrogen- and sulfur-containing ligands, zinc is found in biological molecules such as proteins, amino acids, and nucleic acids. Enzymes that require zinc can broadly be divided into two classes: (i) zinc metalloenzymes and (ii) zinc–enzyme complexes.

Zinc deficiency in humans leads to acrodermatitis enteropathica and may also cause growth retardation, rough skin, anaemia, erythema, alopecia, and other symptoms of immaturity. In animals, similar deficiencies are associated with rough skin and stunted growth.

Generally, zinc is considered non-toxic; however, acute zinc toxicity might cause from vomiting to impaired muscular coordination. Cases of acute renal failure due to $ZnCl_2$ is observed by Prasad and Oberleas[11].Chronic zinc toxicity presents with dizziness, vomiting, diarrhoea, anaemia, fever and disorders of the central nervous system[12-13].

II. Experimental:

Sample Collection

Scalp hair and fingernails of workers employed in Automobile Workshops, Locomotive Workshops, Jewlery Manufacturing Units, Metal Finishing Workshops were obtained to evaluate potential zinc exposure. Samples from individuals with no Zn in work environment were collected and analyzed as controls.

Personal, medical and environmental histories of the subjects were recorded through a questionnaire at the time of sampling and biopsy materials sealed in airtight plastic bags to avoid contamination.

Sample preparation and zinc determination

Hair and fingernail samples washed with solvents including deionized water, Triton X-100, acetone and finally deionized water again were oven-dried at 110 °C, weighed 1g and digested using a concentrated nitric–perchloric acid mixture. After complete wet digestion, the resulting solution or residue was diluted with 1N nitric acid for subsequent analysis.

AAS analysis of Zn levels was done by ECIL-4129 by usual method setting integration time of 3 seconds, lamp current of 5 mA and spectral bandwidth of 1.0 nm of light source. The prepared hair and nail solutions were aspirated into a flame, and zinc concentrations were measured.

Calibration

Pre-calibration with different dilutions of 1000 ppm zinc stock solution. The analytical sensitivity was approximately 0.012 µg/mL Zn for 1% absorption.

III. Results And Discussion

Zinc levels in both biopsy materials of exposed and unexposed subjects were analyzed and classified according to selected parameters. Age was the first factor considered. Table 1 shows the agewise variation in range, average with SD. In hair samples, although zinc concentrations were more in 11-20 years age group than in 51-60 years age group, but they exhibited no clear linear pattern from the 11–20 year group up to the 51–60 year group, with the highest values observed in hair of 11-20 year age group and 41-50 years in nails .

Data evinces that zinc levels are generally higher in nails than in hair across most age groups. Significantly reduced Zn concentrations have been reported in urban areas by researchers[14]. Significant difference between llamas and alpacas in hair Zn and Se concentrations was found by researchers[15]. Researches reveal zinc concentrations vary with age. Kauf et al measured hair zinc in newborns up to two years old and found that levels peaked around 80 days after birth[16]. Gibson and Dewolfe assessed zinc content in the hair of preterm, full-term low birth weight, and control infants[17]. Their findings showed a steady decline in zinc levels during the first three months of life. Heavy metal analysis in human teeth has been accomplished by researchers[18].

Zn concentrations were found in a study reported on tanneries as source of pollution during hair burning liming operations.[19]. Interaction of Lead with Calcium, Iron and Zinc in the biological samples of Malnourished Children has been reported[20].

Bertazzo et al demonstrated that zinc concentrations in males increased significantly from 164.95 ± 10.88 µg/g in children aged 2–5 years to a peak of 221.13 ± 8.19 µg/g in individuals aged 20–40 years, then declined gradually to 178.40 ± 12.78 µg/g in those over 80 years[21]. Folin et al also recorded a decrease in zinc levels, from 183.76 µg/g in the 20–29 year group to 154.95 µg/g in the 50–59 year group[22].

Wilhelm et al reported no relation between age and Zn levels[23]. Costa et al also investigated the age dependence of Zn and reported higher mean levels in the 12–20 (228.0 ± 64.0 µg/g), 21–40 (231.0 ± 54.6 µg/g), and >80 year (233.7 ± 36.4 µg/g) groups, with the lowest concentration observed in the 2–5 year age group[24].

Table 2 presents the mean Zn levels in hair across different hair colours and age groups. After an initial decrease from 11-20 to 31-40 years of age, no distinct age-related variation was observed in subjects with black hair. In brown hair as well as in mixed hair, no particular trend of increase or decrease of Zn concentrations was

observed from 11-20 to 51-60 years age group. Grey hair, not observed in 11-20 years age group exhibited rise in zinc concentrations from 21-20 to 51-60 years and the levels were also statistically significant.

Sturaro et al reported lower Zn levels in brown hair compared with black, which is not the result in the present study[25]. Bertazzo et al found nearly similar Zn concentrations in brown and black hair, but lower levels in white hair[21]. Allegri et al observed higher Zn levels in brown hair and lower levels in white hair relative to black hair in male subjects[26]. By contrast, Costa et al reported low Zn levels in brown hair but high levels in white hair when compared with black hair[24].

Table 3 presents Zn concentrations in tissues of subjects with different occupations. Statistical analysis (*t*-test) revealed significantly higher hair Zn levels in jewellery manufacturing units, metal finishing workshop workers compared to controls. Ramakrishna et al[27] reported lower Zn concentrations in welders relative to controls. Raghupathy and Sharma found elevated Zn levels in smelter workers compared to the general population of Udaipur, while Zn levels in mine workers were similar to those of city residents[28]. Georgescu et al also reported elevated Zn levels in metallurgical workers, supporting the present findings as in fingernails, the Zinc concentrations were significant in automobile workshop and locomotive shed workers[29].

The duration of exposure investigated was 0-5, 6–15, 16-25, 26-35 and 36-45 years with average Zn levels showed in [Fig. 1(a) & 1 (b)] Overall, no trend of Zinc was noticed with duration of exposure in the specimens. Statistical analysis, however, indicated significant Zn concentrations in 36-45 exposure group for both the biopsy materials, while only in hair tissue in 0-5 and 6-15 years exposure group whereas in fingernails significant levels were found in 16-25 years exposure group.

Table 1 Variation of average zinc levels (μg/g) with age in biopsy materials

Age Group	Number of subjects	Hair		Fingernails	
		Range(μg/g)	Mean± SD(μg/g)	Range(μg/g)	Mean± SD (μg/g)
11-20 yrs	47	68.23-279.63	170.27 (41.21)	103.18-320.19	190.11 (59.42)
21-30yrs	77	81.22-360.41	159.42 (34.59)	101.19-390.63	179.30 (67.11)
31-40yrs	71	92.79-221.89	155.27 (26.23)	101.18-409.27	179.60 (67.34)
41-50yrs	79	129.53-270.29	166.15 (32.78)	102.18-391.89	194.34 (60.10)
51-60yrs	66	112.16-262.92	163.58 (31.03)	103.40-545.07	180.14 (55.23)

*Values significant at P<0.05 level

Table 2 Variation of Hair Zinc concentrations (μg/g) with age and colour

Subjects	Group of Age	Number of subjects	Hair	
			Range(μg/g)	Mean± SD(μg/g)
Black	11-20yrs	26	101.13-279.63	171.69 (42.66)
Brown	11-20	9	120.13-220.59	164.23(35.74)
Mixed	11-20	11	68.23-180.47	155.21(34.75)
Grey	11-20	1	79.54	-
Black	21-30yrs	36	81.22-206.23	166.78(30.12)
Brown	21-30	5	133.76-153.70	144.06(7.97)
Mixed	21-30	32	120.23-290.41	159.13(37.87)
Grey	21-30	4	92.79-360.41	106.83(74.09)*
Black	31-40yrs	26	109.04-220.95	156.27(34.94)
Brown	31-40	8	121.18-194.20	155.84(22.48)
Mixed	31-40	28	109.47-221.89	154.95(26.43)
Grey	31-40	9	98.75-209.74	113.74(37.47)*
Black	41-50yrs	24	130.80-205.21	199.37(23.81)
Brown	41-50	9	129.53-264.54	168.33(38.34)
Mixed	41-50	36	131.59-23.77	168.46(32.69)
Grey	41-50	10	134.04-270.29	136.85(34.90)*
Black	51-60yrs	13	130.26-220.39	169.08(34.35)
Brown	51-60	9	112.16-190.67	145.20 (33.64)
Mixed	51-60	31	129.05-262.92	130.23(29.44)*
Grey	51-60	13	127.11-210.73	140.03(24.59)*

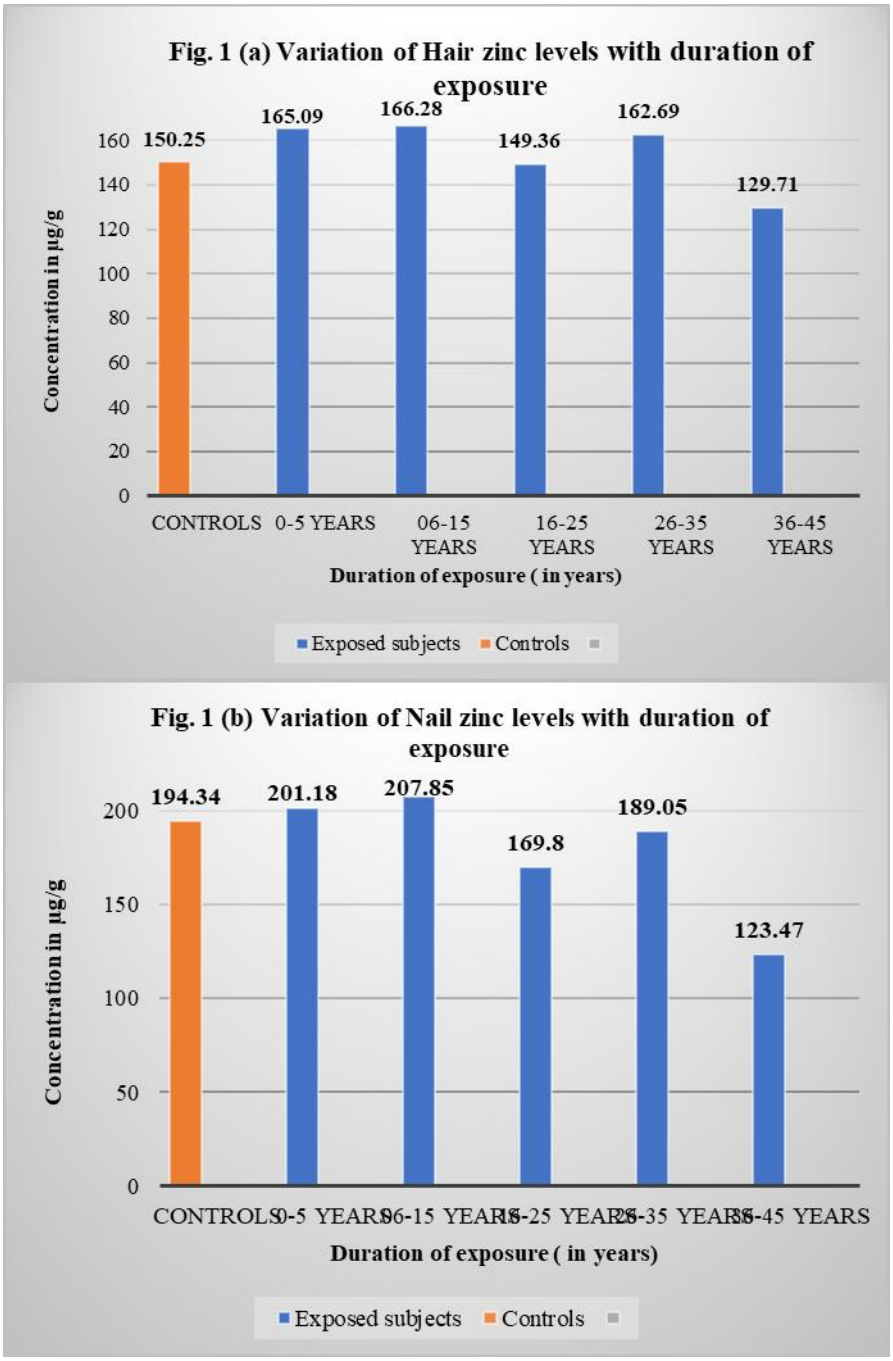
*Values significant at P<0.05 level

Table 3 Variation of average Zn (μg/g) in biopsy materials in different occupational exposure.

Subjects	Group of Age	No. of subjects	Hair		Fingernails	
			Range(μg/g)	Mean± SD(μg/g)	Range(μg/g)	Mean± SD (μg/g)
Controls	11-30yrs	22	67.43-275.65	189.55 (40.35)	101.29-314.24	197.62 (60.44)
Automobile Workshops	11-30	24	144.96-243.46	179.86 (31.82)	124.45-189.92	156.46 (22.79)*
Locomotive Workshops	11-30	23	68.23-354.21	160.85 (46.21)	101.19-366.86	147.75 (57.65) *
Jewelry Manufacturing Units	11-30	26	114.24-288.31	220.43 (30.20)*	102.45-389.73	232.13 (71.17)
Metal Finishing Workshops	11-30	29	105.01-360.41	217.07 (30.57)*	103.12-390.63	212.14 (73.28)

Controls	31-60yrs	41	94.85-200.03	165.62 (25.72)	102.17-314.24	183.03 (60.25)
Automobile Workshops	31-60	43	92.79-260.48	146.08 (32.14)	101.18-304.04	164.68 (54.02)
Locomotive Workshops	31-60	42	119.55-258.78	106.05 (29.92)*	107.75-389.90	162.75 (63.18)
Jewelry Manufacturing Units	31-60	46	106.58-211.37	181.60 (25.62)	102.37-444.09	193.86 (53.98)
Metal Finishing Workshops	31-60	44	100.18-270.29	184.16 (36.71)	103.34-545.07	197.82 (62.44)

*Values significant at P<0.05 level



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