Adverse health effects in workers exposed to trace/toxic metals at workplace

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Widespread use of metals in industrial activities has enhanced the occupational exposure to toxic metals as well as the health risks of metal hazards to humans. Elemental analysis in human tissues is the most common application of biological monitoring for screening, diagnosis and assessment of such exposures and risk. Among various biopsy materials, blood, hair, nail, teeth and body fluids may be used as bioindicators for this purpose. The present paper deals with the determination of Pb, Cr, Ni, Mn, Fe, Cu and Zn elemental concentration in workers exposed to these metals at workplace by atomic absorption spectrophotometry, with adequate quality control measures using hair as biopsy material. The study group includes the male workers such as welders, foundry man, fitter, hammer man, machine man, cupola man etc., besides office workers of locomotive workshop in Ajmer and surrounding areas exposed to different metals. Age and sex matched controls of persons working in the same area of work in offices etc. and not exposed to metal pollution were selected for valid comparison. It is proposed to validate the use of hair as a biological marker for assessing metal body burden of workers. In our study significant correlations have been found between skin disease and Cr, Mn, Fe, Cu; chest pain and Pb; hypertension and Cu, Mn; mental stress and Mn, Ni, Cu, Zn; liver problem and Ni; indigestion and Cr; Ni, diabetes and Cr, Mn, Ni; tuberculosis and Zn; breathing trouble and Cr, Mn, Fe, Ni, Zn. The advantages of choosing hair as a biopsy material are also given.

Twelve trace elements are recognized to perform functions essential to life in living organisms. The essential trace elements getting displaced from the metabolic active sites, by the accumulation of toxic trace elements from the working environment, is a matter of concern. Disruptions in metal metabolism have been reported in subjects exposed to Cu, Zn and Pb, besides other metals. They may cause conditional deficiency or act directly as cellular toxins. Certain essential trace elements have shown wide range of clinical applications namely, oral zinc supplementation increases the healing rates or surgical wounds and ulcers, cobalt plays a role in immune reactions and infections1, and manganese is essential for glucose and lipid metabolism and a number of other basic biochemical processes. Trace element composition of foods is recognized to some extent for predicting risks of deficiency or toxicity of elements2,3. However, it also depends on the influence of trace elemental composition of the local environment or soil anomalies4.

Traces of Mo, Sr, F, Se, Cr, V and Ni are required for various physiological processes, but at higher concentrations, these micronutrients tend to become toxic and derange various physiological processes, leading to a number of diseases. Few examples are: Be-lung cancer; Cr-diabetes mellitus, hypertension, lung cancer, pulmonary and gastric syndrome; Pb-neurosis, mental retardation in children, gastrointestinal and respiratory cancer; Hg-congenital abnormalities; Ni-lung cancer, myocardial infarction, dermatitis, eczema, bronchitis, mutagenic, carcinogenic and tetragenic effects; Cd-hypertension, renal dysfunction and decreased haemoglobin levels; Fe-acidosis fatal shock discoloration of the skin; Cu-fibrosis disruption of central nervous system and bronchial carcinoma5,6. It is therefore, important to determine the metal concentrations in the humans to monitor and assess their impact on human health.

World Health Organization in collaboration with United Nation Environmental Protection (UNEP) under the Global Environmental Monitoring System (GEMS) identified metals such as Pd, Cd, Hg and As detrimental to human health and initiated biological monitoring for assessment of human exposure to Pb and Cd. Different fluids such as plasma or serum, red blood cells and urine have been analysed to diagnose such abnormalities. Hair and nail have also been used to reflect their body content. Hair metal concentrations reveal both metal intoxication and metal deficiencies. Also, being exposed to circulating blood, lymph and extracellular fluids, hair can provide a continuous record of trace element concentrations of

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the body. Besides, hair is easily sampled, shipped and analysed, being a protein tissue with very low metabolic activity\(^7\). Blood levels are transient and relate to supply of elements in the previous hours and days. In contrast, hair, although offers no information of immediate levels, but fixes the trace elements and provide a lasting record of their levels\(^8\). The biggest advantage of using hair as biopsy material over blood is that in the case of blood, there is a possibility of under contamination to AIDS virus, unlike hair. In continuation to our earlier studies\(^10-12\), we report here the determination of trace metal levels (Pb, Cr, Mn, Fe, Ni, Cu and Zn) in order to assess their impact on health, by atomic absorption spectrophotometry in different groups of subjects prone to the hazards of trace metals in their occupational environment using hair as a biopsy material. Male subjects of matching ages in different groups working in the same area, but without any exposure to metals were taken as controls.

Materials and Methods

Sample collection

Hair samples of male subjects of age ranging from 30-55 years were collected from the posterior vertex of the head, as close to the scalp skin as possible, using clean stainless steel scissors. Details regarding number of samples of different diseased subjects alongwith their respective controls are shown in Table 1. After cutting, the samples were thoroughly mixed to ensure homogeneity and then stored in closed plastic bags until they were washed, digested and converted to water clear solution for analysis.

Procurement of requisite details of subjects

The personal and medical history, as well as of the details of the subjects taken for study were obtained through a questionnaire as per the recommendation of World Health Organisation. The information required to be filled in the proforma included sex, age, hair colour, personal habits (smoking, drinking, food), place of residence, occupation, possible metal exposure and use of hair and nail cosmetics.

Washing

The hair samples were cut into pieces of about 1 cm prior to washing, pre-washed with non-ionic detergent and soaked in de-ionized water for 10 min. This was followed by soaking in acetone to remove external contamination, rinsing alternately with de-ionized water and again with acetone three times as per the IAEA advisory group\(^13\). Then, the samples were dried at 110°C for 1 hr and stored in a dessicator\(^14\). The dry weight of the samples ranged from 0.5 to 1.0 g.

Wet acid digestion and preparation of water clear solution

For wet acid digestion, 10 ml digesting solution (6 ml conc. nitric acid +1 ml conc. perchloric acid) was added to the sample and allowed to react slowly at room temperature to prevent excessive foaming for overnight and then consequently heated at 160-180°C, until the mixture was water clear and less than 1 ml solution remained. Each sample was transferred to a 100 ml volumetric flask and diluted with 0.1 N nitric acid.

Analysis

The concentrations of metals were assayed by atomic absorption spectrophotometry using the Perkin-Elmer AAS Model-250 with graphite furnace and air-acetylene flame. A series of standards were prepared in de-ionized water for instrumental calibration by diluting commercial standards containing 1000 ppm of the metals. All reagents used were of analytical grade. A number of blanks were also prepared for minimization of contaminated errors. The main instrumental parameters (like band width, lamp current and wavelength) for estimation of metals by atomic absorption spectrophotometer were set up separately for each metal.

Statistical analysis

The values of metal levels in hair were expressed as arithmetic mean in μg/g with standard deviation and tabulated to illustrate concentration profile over each group. The statistical significance of mean values between different groups were determined by applying student ‘t’ test. The level of significance was set at \(P < 0.05\).

Results and Discussion

The results of the quantitative analysis for Pb, Cr, Mn, Fe, Cu, Ni and Zn in hair are given in Table 1. The samples analysed were of subjects not possessing normal health. The health disorders that included were hypertension, skin disease, ophthalmic problems, gastrointestinal ailments, diabetes, liver problems, heart ailments, tuberculosis and mental stress. Age and sex matched controls were also selected from the same work environment i.e. similar sampling sites.
Significant correlations between skin disease and Cr, Mn, Fe, Cu; chest pain and Pb; hypertension and Cr, Mn, Fe, Cu; indigestion and Cr; diabetes and Cr, Mn, Fe, Cu; chest pain and Pb; hypertension and Cr, Mn, Fe, Cu; indigestion and Cr; diabetes and Cr, Mn, Fe, Cu; chest pain and Pb; hypertension and Cr, Mn, Fe, Cu; indigestion and Cr; diabetes and Cr, Mn, Fe, Cu; chest pain and Pb; hypertension and Cr, Mn, Fe, Cu; indigestion and Cr; diabetes and Cr, Mn, Fe, Cu; chest pain and Pb; hypertension and Cr, Mn, Fe, Cu; indigestion and Cr; diabetes and Cr, Mn, Fe, Cu; chest pain and Pb; hypertension and Cr, Mn, Fe, Cu; indigestion and Cr; diabetes and Cr, Mn, Fe, Cu; chest pain and Pb; hypertension and Cr, Mn, Fe, Cu; indigestion and Cr; diabetes and Cr, Mn, Fe, Cu; chest pain and Pb; hypertension and Cr, Mn, Fe, Cu; indigestion and Cr; diabetes and Cr, Mn, Fe, Cu; chest pain and Pb; hypertension and Cr, Mn, Fe, Cu; indigestion and Cr; diabetes and Cr, Mn, Fe, Cu; chest pain and Pb; hypertension and Cr, Mn, Fe, Cu; 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reported to cause heart ailments by raising the blood pressure through its attack on the specific sites and cellular elements of the nervous system18. Biochemical abnormalities of increased caproporphyrin concentration in urine and reduced hemoglobin levels have been observed with blood lead levels, which may lead to cardiovascular disorders causing heart ailments consequently19,21. We have also obtained significant lead levels in workers with complaint of chest pain, which also shows a relationship between lead levels in exposed subjects and heart ailments.

Cu and Mn have been related to disorders in the central nervous system in significant concentrations of the order of 25 µg/g at P < 0.01 and 1.0 µg/g at P < 0.02. Such levels have been obtained from male hypertensives, who were not occupationally exposed subjects, but suffering from hypertension due to some other causative factors22. The hypertensive subjects in our study were found to contain significant concentrations of Cu (15 µg/g) and Mn in the order of (9.8 µg/g) at P < 0.05. Pb, Cr, Fe, Ni and Zn did not exhibit any contribution to cause hypertension.

Significant relation was observed between hair Mn, Ni, Cu, Zn and mentally stressed subjects. Earlier, neurobehavioural manifestations of Mn exposed workers, in Belgium have been attributed to higher Mn levels in the body23. Sukumar and Subramanian24 also observed chronic headache and dizziness in male workers having significantly higher levels of Cr, Mn and Pb in the hair, working in fire-works factory.

In our study, Cr, Mn and Ni levels in subjects suffering from diabetes were found to be significantly higher as compared to controls, whereas Pb, Fe, Zn and Cu were not significant. However, this observation cannot be solely attributed to the disease factor, as other factors also might have contributed their effect, as different observations have been reported by other researchers25. A plausible explanation for this is that in the present work, the subjects exposed to the metals were further categorized and screened for possible diseases, whereas in earlier works, as reported above exclusively the patients, otherwise not exposed to high concentration of the metals, were selected for study25.

The significant levels of Cr and Ni in gastrointestinal ailments with Pb, Mn, Fe, Cu, Zn being insignificant, as well as of high values of only Zn in tuberculosis patients found in our study, need further investigation of such cases for deriving an appropriate conclusion. Earlier, it has been reported that chronic inhalation of iron oxides, following occupational exposure to iron dust may cause benign pneumoconiosis in extreme conditions and hence mortality due to increased lung cancer. Similar studies have been reported for chromium5. Nickel has also been associated with cases of malignant tumours of nasal cavity26. This shows that there may be other metals which need to be studied for such cases.

None of the metals showed direct relationship with acidity, ophthalmic disease and hepatitis B, infact they were, in general, observed to be present in low concentrations relative to controls. In any case, the significant levels of trace/toxic metals in hair samples indicate the presence of these metals in the environment in the workplace of the subjects, as well as their proneness to the illnesses and hazards of these metals, in cases of long term exposure. In view of this, we suggest that certain preventive measures such as use of hand gloves and masks should be taken to safeguard the health of the people exposed to metals in one way or the other.

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