Advances in
Nursing and Health Sciences
Volume 1, Issue 1

Research Article

Comparing the Hair Tissue Metal Concentration of Arab, Asian and German Children

Eleonore Blaurock-Busch*

* MTM Micro Trace Minerals GmbH- Amtsgericht Nuernberg, Germany

***Corresponding author:** Eleonore Blaurock-Busch, MTM Micro Trace Minerals GmbH- Amtsgericht Nuernberg, Germany

Abstract

Elemental hair analysis is used for the detection of toxic and essential elements, and has been reliably used to determine long-term exposure. As a preliminary screening method for the presence of toxic substances, the advantages of hair analysis include the non-invasiveness, low cost, and the ability to measure a large number of, potentially interacting, toxic and biologically essential elements. Head hair analysis is increasingly used as a test to determine whether children have absorbed potentially toxic metals linked to behavioral and other health problems. [1]

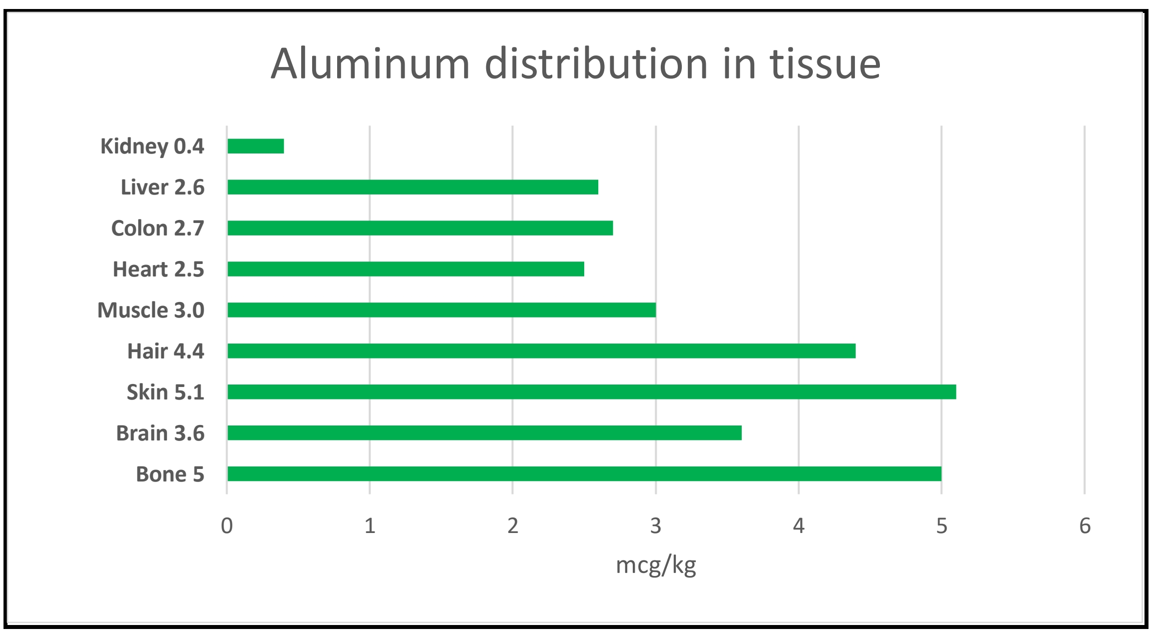
Since environmental exposure is the most common cause of toxic metal exposure in children, we evaluated a number of toxic and biological essential elements in the hair of Arab, Asian and German children, living in different countries and environments. The aim was to see how environmental toxins affect various population groups. We also aimed to evaluate differences in nutritional status between the groups.

Introduction

According to Egyptian researchers Rashed and Hossam "Biological materials are widely used as a bioindicator for environmental pollution with heavy metals. Among these are human hair and nails, which are also recommended by the World Health Organization (WHO) for worldwide environmental monitoring.[2] Indeed, hair and nails are metabolic end products that incorporate metals into its structure during the growth process.

Decades ago, the biochemist Schönheimer (1898-1941) described body tissues as being in a state of dynamic equilibrium, or homeostasis which tended to maintain stability with coordinated responses to compensate for changes in the physiological system. Hair is an exception. Unlike other body compartments, hair is a metabolic end product that is thought to incorporate trace elements into its structure during its growing process. During the growth phase of a hair cycle, the matrix cells at the papilla of the hair follicle show intense metabolic activity and produce hair at a rate of approximately 0.3 mm/day. As the growing hair approaches the skin surface, it undergoes a hardening process, or keratinization, and the trace elements accumulated during its formation are sealed into the protein structure of the hair. It is on this basis that the trace element concentrations of hair are related to the trace element concentrations in the body."[3] Therefore, the determination of heavy metal content in hair can play an important role for monitoring the impact of environmental pollution on inhabitants of a community.[4] As a method of investigation, hair analysis has been used in occupational, environmental and alternative medicine to assist screening and/or the diagnosis of chronic metal exposure. In the 4th edition of his medical textbook of laboratory diagnostics, Prof. L. Thomas graphically displayed the aluminum distribution in human tissue. Table 1 compares the storage of aluminum in hair, bone and other tissue.

Table 1: Aluminum distribution in human tissue



Source: Thomas L. Labor und Diagnose. Med. Verlagges.Marburg, 1992. S.430

Heng and colleagues evaluated the presence of harmful environmental exposures, which disproportionately affect low-and-middle income countries (LMICs), contributing to >25% of deaths and diseases worldwide and detrimentally affect children's neurodevelopment.[5] Frye et al researched how early exposure to toxic metals dysregulates nutritional metals and how this is associated with Autism Spectrum Disorder (ASD),[6] but few studies compared how different environmental settings affected children living in different countries under individual conditions. Our study aimed to find out how children of different nationalities, living in different countries are affected by their individual environmental conditions.

Purpose

The author has been involved in hair mineral analysis since 1984. Her environmental study of metal concentration in hair of different age groups and nationalities, conducted 1998 to 1999 in cooperation with the Brazilian pathologist Prof. Dr. Helion Povoa of Rio de Janeiro indicated that the hair metal concentration of children is a direct reflection on their environmental exposure. The author's study involved nearly 10000 people of various age groups and clearly showed that Brazilian children (Table 2) are more chronically exposed to aluminum than German, and are twice as burdened as US children. This study indicated that aluminum is more concentrated in the hair of children than in the hair of adults, most likely due to exposure. These results were surprising, since adults have a longer time span to store metals in tissue. Hence, the metal concentration in adult hair should be higher in adults. See Table 2.

Table 2: Mean Aluminum Concentration in Hair of Children vs Adults of different countries

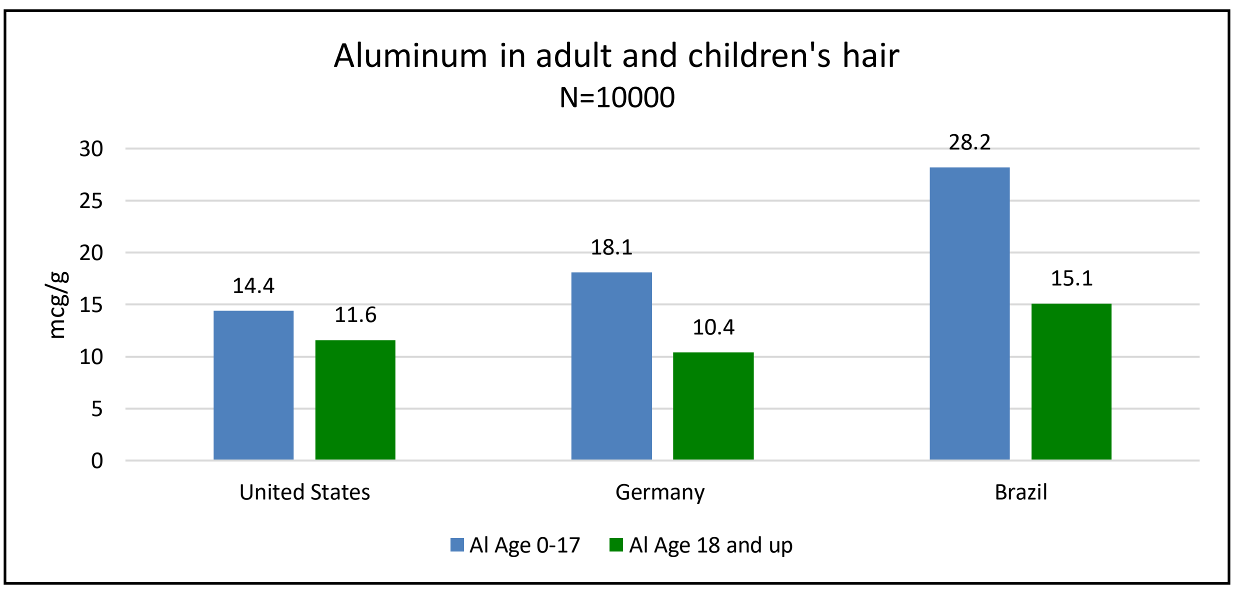
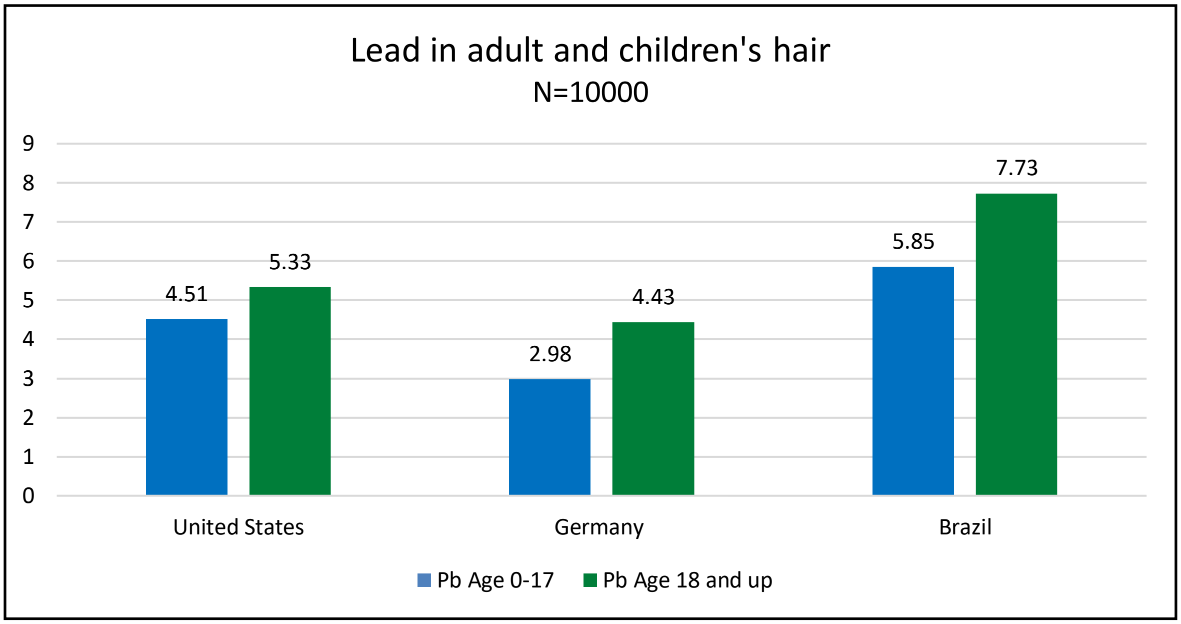


Table 3: Mean Lead Concentration in Hair of Children vs Adults of different countries



For Lead, the distribution shows opposite results. (Table 3) The lead concentration in hair of Brazilian, German and US adults, showed a higher mean value than that of children, confirming information by the World Health Organization, which stated that reductions in the use of lead in petrol (gasoline), paint, plumbing and solder have resulted in substantial reductions in blood lead concentrations globally.[7] A lower exposure results in a decreased uptake in tissue such as hair.

For aluminum, exposure has risen. According to WHO data, the estimates of mean dietary exposure to aluminum-containing food additives from consumption of cereals and cereal-based products are up. Estimates of dietary exposure of children to aluminum-containing food additives, including high-level dietary exposure, can exceed the Provisional Tolerable Weekly Intake (PTWI) by up to 2-fold.[8]

Aluminum is ubiquitous in all environments, yet aluminum sources other than those found in food products are not mentioned in this WHO report.

Metal pollution affect organisms, especially early in life and the cumulative effect of multiple metal exposures must be taken into account. Since environmental pollution is a worldwide problem, we aimed to find out how individual habits and living conditions affect the metal concentration in the hair of young people. We evaluated children from various countries, analyzed and compared the metal concentration in hair samples for over 50 elements, expecting to see similarities and/or variations due to environment, living and dietary habits.

Method

We analyzed hair samples of Arab, Asian and German children, living under various environmental conditions. The children of each group were 12years of age or younger. Table 4 shows the number of hair samples (N) tested for each group, and the mean value for each element and group. The hair submitted from Asian children came from Hong Kong, Indonesia and Punjab, India. Those for the Arab group were submitted by professors from Cairo University and Fayoum University of Egypt; the hair samples of the German group were submitted by various German healthcare practitioners.

For this study, hair samples had been cut 3-5cm from the scalp. Samples were washed with non-ionic detergents and rinsed with metal-free water before drying in a special, designated oven. The washed and dried hair was weighed close to 100mg, before it was acid digested with nonionic nitric acid and diluted to 5ml with metal-free water.

Samples were tested at Micro Trace Minerals laboratories, for the detection of heavy metals and trace elements levels. Metal testing was performed via ICP-MS spectroscopy utilizing cell technique. Strict quality control measurements and licensing requirements were followed, including the use of certified quality control standards. All reagents and standards were of ultrapure reagent grade.

It must be noted that most environmental protection agencies and international medical institutions have concluded that the profile of hair mineral imbalance might be useful as a diagnostic tool for the early diagnosis of many diseases, but all pointed out that there is a need to standardize sample preparation procedures, in particular washing and mineralization methods.

The author has established such procedures as early as 1984. At this time, the author collected samples from so-called healthy populations. These were tested and statistically evaluated, according to normal laboratory procedures. The author’s testing method, including testing and reporting of values were protocolled and provided to the Colorado Department of Public Health and Environment, which authorized these protocols during licensing procedures. In the years, procedures and protocols have been updated as needed. In 1984, hair metal testing was performed with ICP-AES. Since early 2000, the Agilent 7500 with collision cells is used. Its advantage: interferences are largely eliminated.

While state agencies provide 95percentile reference ranges for blood or urine metal testing, at present no reference ranges (RR) for metals in hair are given by state agencies. Laboratories providing hair metal analysis are thus required to statistically develop their own ranges, following standard laboratory practices. Micro Trace Minerals (MTM) followed these rules since 1984, and developed reference ranges on various populations. Originally, the majority of samples came from Germany and the US. Since that time, MTM re-evaluates statistical measurements and updates ranges regularly and as needed. Population studies, such as the ones shown in Table 2 and 3 have been publicized by the author.

As for blood or urine, hair RR are based on a 95Percentile of a so-called healthy population as outlined by laboratory rules and regulations. Test results exceeding the RR are considered pathological. It must be noted, however that not every exposed individual will experience health problems as a result of the exposure. In some cases of a chronic metal overexposure, health problems occur soon, in others years after exposure, in some people symptoms are serious, in others none are noted.

Results

In Table 4, the mean metal concentration in hair of children is shown for the various groups. The mean concentrations exceeding the MTM reference range are shown in bold numbers. The highest mean concentrations found within the three groups are bold and highlighted. For example: for the Arab group, the highest Al mean value of 37.54 is bold and highlighted.

	Detection limit mcg/g	95%ile RR MTM Children	95%ile RR **Arab** Children N=542	95%ile RR **Asian** Children N=512	95%ile RR **German** Children N=1000
Element		**µg/g**	**µg/g**	**µg/g**	**µg/g**
Ag	0.010	<1	<1	<1	<1
Al	2.500	<8	**37.54**	**33.21**	**23.71**
As	0.010	<0.2	<0.2	**0.3**	<0.2
B	0.250	<0.84	**1.82**	**2.53**	<0.84
Ba	0.010	<2.65	**4.14**	**3.96**	<2.65
Be	0.010	<0.03	<0.03	<0.03	<0.03
Bi	0.010	<0.179	<0.179	**0.23**	<0.179
Ca	10.000	RR 200-850	**1708**	**1595**	**1594**
Cd	0.001	<0.20	0.23	**0.37**	<0.20
Ce	0.001	<0.05	0.06	0.05	<0.05
Co	0.005	<0.15	<0.15	<0.15	<0.15

Cr	0.020	RR 0.02-0.15	**0.29**	**0.32**	0.26
Cs	0.005	<0.01	<0.01	<0.01	<0.01
Cu	0.100	RR 6.7--37	35	44	83.94
Dy	0.001	<0.01	<0.01	<0.01	<0.01
Er	0.001	<0.01	<0.01	<0.01	<0.01
Eu	0.001	<0.01	<0.01	<0.01	<0.01
Fe	1.000	RR 7.7-15	**40,2**	**34.13**	**16.17**
Ga	0.001	<0.07	<0.07	**0.16**	<0.07
Gd	0.001	<0.01	<0.01	<0.01	<0.01
Ge	0.003	<0.5	<0.5	<0.5	<0.5
Hg	0.020	<0.30	**1.02**	**3.30**	**0.59**
I	0.050	RR 0.15—3.5	2.77	3.14	2.08
Ir	0.005	<0.01	<0.01	<0.01	<0.01
La	0.001	<0.021	**<0.03**	**0.33**	**0,03**
Li	0.001	<0.20	<0.20	<0.20	<0.20
Lu	0.001	<0.01	<0.01	<0.01	<0.01
Mg	5.000	See note	**199**	**239**	**162**
Mn	0.050	0.07--0.5	**3.79**	**3.89**	**0.68**
Mo	0.001	RR 0.02-1.00	0.12	0.19	0.09
Nb	0.005	<0.01	<0.01	<0.01	<0.01
Nd	0.005	<0.01	**0.03**	**0.02**	<0.01
Ni	0.010	<0.85	**1.35**	**1.44**	<0.85
Pb	0.010	<3.00	**9.16**	**10.21**	**3.80**
Pd	0.050	<0.10	<0.10	<0.10	<0.10
Pr	0.005	<0.10	<0.10	<0.10	<0.10
Pt	0.005	<0.07	<0.07	<0.07	<0.07
Rb	0.001	<0.08	<0.08	<0.08	<0.08
Re	0.005	<0.01	<0.01	<0.01	<0.01
Rh	0.005	<0.01	<0.01	<0.01	<0.01
Ru	0.001	<0.315	<0.315	<0.315	<0.315
Sb	0.001	<0.20	0.20	<0.20	<0.20
Se	0.010	RR 0.40-1.40	1.11	**1.46**	0.93
Sm	0.001	<0.01	<0.01	<0.01	<0.01
Sn	0.001	<0.93	**1.48**	**1.06**	<0.93
Sr	0.001	0.11-4.28	**9.7**	**18.24**	3.58
Ta	0.001	<0.01	<0.01	<0.01	<0.01
Te	0.010	<0.01	<0.01	<0.01	<0.01
Th	0.010	<0.01	<0.01	<0.01	<0.01
Ti	0.010	<0.65	**1.38**	**1.31**	**1.76**

Tl	0,001	<0.01	<0.01	<0.01	<0.01
Tm	0,001	<0.01	<0.01	<0.01	<0.01
U	0,001	<0.10	<0.10	**0.77**	**0.16**
V	0,001	0.01--0.15	**0.70**	**0.27**	0.08
W	0.001	<0.02	<0.02	0.02	<0.02
Yb	0.001	<0.01	<0.01	<0.01	<0.01
Zn	5.000	110--227	**284**	**306**	**309**
Zr	0.050	<1.47	<1.47	<1.47	<1.47

RR= Reference Range
N=Number of tests

Highest Medium Value of all groups

Discussion of Results

This study demonstrates that metal exposure is of concern to children worldwide. All groups are burdened by metal overexposure, with the Asian group showing the greatest burden (Table 5). While it was not the intention of this research to locate the source of these groups' individual overexposure, we assume geological circumstances, pollution, diet and lifestyle are responsible.

Table 5: Number of mean values exceeding the upper hair reference range, by groups

Group	# of mean values exceeding RR	# of highest mean value among groups
Arab	*18*	7
Asian	*24*	15
German	*11*	3

Metals in the hair of Asian, Arab and German children

German group:

Of all the groups, the group of German children was the least affected, but showed the highest mean value for titanium. While titanium is a commonly used inert bio-implant material within the medical and dental fields, the exposure of children is most likely due to titanium dioxide (TiO2), which is widely used as a white pigment in toothpaste, sunscreens and medications. TiO2 is widely used as a food coloring agent. In 2006, titanium dioxide has been regarded as "completely nontoxic"; however as of May 2023 (and as a result of the European Union already having banned titanium dioxide in 2022), the U.S. states California and New York are now considering banning the use of titanium dioxide in foods because it may damage DNA and can harm the immune system.

Arab group:

Arab children are nearly as burdened as Asian children, with the exception of arsenic, bismuth, gallium and uranium; these elements did not exceed the reference range of these elements.

Arab children are burdened with aluminum. Of the 57 elements tested, the mean value for Aluminum exceeded those of the Asian and German group. Also, the mean value for iron and vanadium was higher than those of the Asian and German group. Unexpectedly, the Arab group showed an unusually high mean value for the rare earth element Neodymium. (see Rare Earth Elements)

Asian group

These children are most burdened. Of the 57 elements tested, the mean value of the upper reference range of the Asian group was exceeded by 24 elements as is shown in Table 4. In this group, the highly toxic elements arsenic, cadmium, lead, mercury and uranium showed the highest mean value of all groups.

Discussion of Elements found high in hair of children

Elements of known toxicity

Aluminum (Al)

is the most abundant metal in the earth's crust and it is widely distributed. It occurs naturally in air, water, soil and plant food and therefore is regularly taken up with the daily diet. Al is also found in medicines, cosmetics and a wide variety of products. It has been detected in breast milk, but only a small amount of this aluminum will enter the infant's body through breastfeeding. Typical aluminum concentrations in human breast milk range from 0.0092 to 0.049 mg/L. Aluminum is also found in soy-based infant formula (0.46–0.93 mg/L) and milk-based infant formula (0.058–0.15 mg/L).

According to ATDSR, brain and bone disease caused by high levels of aluminum in the body have been seen in children with kidney disease. Bone disease has also been seen in children taking medicines containing aluminum. In these children, the bone damage is caused by aluminum preventing the absorption of phosphate in the stomach. Phosphate is required for healthy bones.[9]

All three test groups showed a high aluminum burden, but the highest was located in the Arab group. According to ATSDR, urine and blood aluminum measurements can be used to determine immediate exposure. Since Al is easily stored in bone, measuring bone aluminum can also indicate exposure to high levels of aluminum, but this requires a bone biopsy. Table 1 demonstrates how Al is distributed in tissue, including hair, making hair analysis a useful tool for the diagnosis of long-term exposure.

Arsenic (As):

the samples of the Arab and German group did not indicate exposure, and the Asian group showed a marginal exposure only, which is surprising since arsenic contamination of ground water, soil and plant systems has been noted as an environmental health risk for Asian people, especially those of Punjab. In the region of Amritsar where most of the Punjab children of this group lived, the Arsenic content in hand-pumped well water varied from 9 to 85 ppb with a mean value of 29.5 ppb.[10] Most people in this region rely on well water for their daily water consumption. WHO established a safe maximum contaminant level of 10 ppb for arsenic in drinking water.

Cadmium (Cd):

the mean value of the Arab group insignificantly surpassed the reference range for cadmium in hair. For the German group, results did not indicate a burden while the Asian group showed some chronic exposure.

Cadmium is highly toxic. The element was discovered in Germany in 1817, and Germany remained the only important producer for 100 years. Currently, a large percentage of global cadmium metal production takes place in Asia. Cadmium is generally recovered as a byproduct from zinc production. Cd is primarily used for manufacturing rechargeable nickel cadmium batteries; other end uses include pigments, coatings, and plating. Solar cell manufacturing has also become another significant market for cadmium.[11] In 2021, Hong Kong was reported as the 6th largest exporter of Cadmium in the world. [12]

Cadmium is naturally occurring in the environment as a pollutant that is derived from agricultural sources. Exposure to cadmium primarily occurs through the ingestion of contaminated food and water and, to a significant extent, through inhalation and cigarette smoking. However, we did not find out if cigarette smoke exposure in the home were a cause of the problem within this group.

Cadmium accumulates in plants and animals with a long half-life of about 25-30 years. Wang et al reports that Cadmium (Cd) is one of the most serious soil contaminants in China, posing an increasing risk to human health as large amounts of Cd are emitted into the environment.[13] Epidemiological data suggest that occupational and environmental cadmium exposure may be related to various types of cancer, including breast, lung, prostate, nasopharynx, pancreas, and kidney cancers.[14]

In a previous study by the author, 25% of the Punjab children tested exceeded the hair reference range of 0.2µg/g Cd in hair, which indicates chronic exposure. Water, soil and crop pollution are a suspected cause. According to various reports, Punjab has the highest per hectare consumption of phosphate fertilizers in the country and while the European Union has set a limit of 60 mg/kg of

Cadmium in fertilizers, this limit is not applied in this Indian state, which is considered the “bread basket of India”. Typical values for the cadmium content in phosphatic fertilizers are between 3 and 110 mg Cd kg.[15]

Mercury (Hg)

is considered by WHO as one of the top ten chemicals or groups of chemicals of major public health concern. The mean value of all groups showed a mercury burden. The least affected is the German group.

According to the World Health Organisation, all humans are exposed to some level of mercury. Most people are exposed to low levels of mercury, often through chronic exposure (continuous or intermittent long-term contact). Factors that determine whether health effects occur and their severity include:

- the type of mercury concerned;
- the dose;
- the age or developmental stage of the person exposed (the foetus is most susceptible);
- the duration of exposure
- the route of exposure (inhalation, ingestion or dermal contact).

People are mainly exposed to methylmercury, an organic compound, when they eat fish and shellfish that contain the compound. Children are more sensitive to the effects of mercury and the primary health effects of a mercury burden affect cognitive thinking, memory, attention, language, and fine motor and visual spatial skills.[16] The normal diet of Chinese children contains more fish than those of German or Arab nationality.

Lead (Pb)

poses a serious health problem for children. Of all three groups, the Asian and Arab group show significant exposure; the German group did not. According to information provided by the Center for Disease Control and Prevention (CDC) “The health effects of lead exposure are more harmful to younger than older children and adults because their bodies are still developing, and they are growing so rapidly. Young children also tend to put their hands or other objects, which may be contaminated with lead dust, into their mouths.”[17] Bret Ericson from Macquarie University, Sydney, and colleagues found that lead pollution affects more than 632 million children in developing countries. [18] “The contrast between developing countries and high-income countries is stark. In the USA, for example, 2017 CDC National Childhood Blood Lead Surveillance Data showed that less than 2% of children (aged 0–5 years) had blood lead levels exceeding 5µg/dL,” the researchers observed. In German children blood lead levels decreased during the past 35 years. Using data from the early 1980s to 2019, Lerman et al revealed and discussed long-term trends in blood lead levels

(BLLs) and current internal exposure of young adults in Germany. BLLs in young adults decreased substantially in the investigated period from 1981 (78,7µg/L) to 2019 (10.4µg/L) by about 87%.[19] Shuo Wang of Qingdao University, Qingdao, China and colleagues researched blood lead levels (BLL) of Chinese children and noted a continuous declined trend in the past 30 years. Yet, so the researchers, the BLL "was still higher than that in developed countries, which indicated that more efforts are needed in children's BLLs control." [20]

Lead exposure has been shown to adversely impact mental health and increase crime and violence. A survey conducted by UNICEF and Pure Earth, an international nonprofit organization details the link between lead exposure and neurological and cognitive development and behavioral problems. "In children, the health effects on a developing nervous system, particularly in those under the age of five, can contribute to long-term diminished IQ scores, academic achievement, and ability to pay attention," said Richard Fuller, president of Pure Earth and coauthor of the report.[21]

In their study on children, JJ Quan of the Department of Nephrology, The Third Xiangya Hospital, Central South University in Hunan, China and colleagues noted that elevated mean values for some essential and toxic elements have caused signs of toxicity after excessive exposure. The researchers recruited 1165 children aged 6–12 years from China's heavy metal-polluted areas. Inductively coupled plasma mass spectrometry (ICP–MS) was used to measure urinary levels of 17 metals (titanium, vanadium, chromium, iron, strontium, cobalt, nickel, copper, arsenic, selenium, rubidium, cadmium, molybdenum, antimony, thallium, lead, and uranium) in children. A total of 253 (21.7%) children had abnormal BP. This is just one research paper that documents the negative effects of metal pollution on children.[22]

Uranium (U)

exposure in children has received comparatively little attention. The Arab children did not show a burden; the German group showed a marginal burden, and some areas of Germany are geological sources of uranium. The Asian group was significantly burden. According to the ATDSR (Agency for Toxic Substances and Disease Registry) little is known about uranium exposure in children. "No cases have been reported where exposure to uranium is known to have caused health effects in children."[23]

Interestingly, of all the Asian children included in this group, only the 150 children of Punjab consistently showed high uranium in hair (mean value 1.38µg/g Hair). For the Hong Kong and Indonesian children in this group, uranium levels in hair were inconspicuous.

It has been speculated that the teratogenic, genetic and genomic stress from depleted Uranium contamination is a cause of cancer and congenital disease. During the Iraqi War in 2004, a concentrated use of nuclear weapons was reported, and in the years since an unusually high number of children were born with congenital anomalies. Prof Busby investigated if uranium and other metals played a role and found that the uranium levels of the hair of parents of children born with congenital anomalies were significantly higher than those expected on the basis of published control group data. The pattern of contamination with regard to hair length indicated a major contamination event in the past.[24]

Prof. Hardev Singh Virk of Punjabi University, of Patiala, India reports that the testing of mentally and physically challenged children at the Baba Farid Centre for Special Children in the Malwa region of Punjab indicated an unusually high uranium exposure.[25] The author conducted these investigative studies as reported by Prof Singh Virk. The study included hair and urine sample of physically and mentally challenged children. Also tested were water and soil samples of various areas in the Malwa region. All tests showed unusually high uranium test values. [26]

Metals of low toxicity

In addition, the hair tests of the Asian group showed the highest mean levels for the elements Boron, Bismuth, Gallium, Strontium and to a minor degree Tin. These elements do not have a known biological role for human life and their toxicity is considered low. However, excessive exposure may cause toxic effects.

Bismuth (Bi): Only the Asian group showed a mean value reflective of overexposure. Bi-based compounds are used extensively as medicines for the treatment of gastrointestinal disorders including dyspepsia, gastric ulcers and H. pylori infections. Recently, its medicinal application was further extended to potential treatments of viral infection and multidrug resistant microbial infections. While bismuth-based drugs have a long history of use, we have no information if these medicines are more commonly used in Asian pediatrics. [27]

Boron (B)

The mean value of the Asian children exceeded those of the Arab group, while the German group showed a mean value below the RR. Some studies have shown some benefits of a higher boron status, but findings have been generally mixed. Some health benefits of boron have been reported for animals and humans.[28]

Gallium (Ga)

Only the Asian group showed a mean value exceeding the hair RR. Gallium does not exist in pure form in nature. Several ores, such as the aluminum ore bauxite, contain small amount of gallium, and coal may have a relatively high gallium content. Gallium is a by-product of mining and processing metals such as aluminum, zinc and copper. Gallium's main use is in electronics and the main producer is China. Although gallium is considered not harmful to humans, acute exposure to gallium(III) chloride can cause throat irritation, difficulty breathing, chest pain, and its fumes can cause even very serious conditions such as pulmonary edema and partial paralysis.[29] We tested the stable isotope Gallium-69.

Strontium (Sr)

is not regarded as an essential element, but resembles the element calcium in its properties. Like calcium, Sr is taken up and preferentially located into the bone. Here, strontium can have both beneficial and deleterious effects in humans depending on the amount taken up. The ingestion of radioactive strontium, nuclide 90Sr in particular, via contaminated water and food is a major exposure pathway for people. Exposure to radioactive strontium can cause various bone disorders including bone cancer. We tested the stable, naturally occurring strontium^{88}. [30] The mean value detected was within range for the German group. The Arab group was not as burdened as the Asian group

Tin (Sn)

Inorganic tin salts are poorly absorbed and rapidly excreted in faeces; as a result, they have a low toxicity. Only about 5 per cent is absorbed from the gastrointestinal tract, widely distributed in the body, then excreted by the kidney. Some tin is deposited in lung and bone. Some tin salts can cause renal necrosis after parenteral application. Mutagenic studies on metallic tin and its compounds have been negative. Human volunteers developed mild signs of toxicity with tin, given in fruit juices, at a concentration of 1400 mg per litre. The WHO 1973 permissible limit for tin in tinned food is 250 micrograms per kg. The adult daily intake of tin was about 17 mg per day in 1940, but has now decreased to about 3.5 mg, due to improvements in technique of tinning with enamel overcoat and crimped lids to minimize exposure to tin and lead solder. This level is well below the level of 5-7 mg per kg body weight shown to give rise to toxic symptoms.[31] The Arab group displayed the highest mean value of all groups at a level that does not signal toxicity.

Rare Earth Elements (REE)

Interestingly, we detected Lanthanum in all groups. Neodymium was detected in the Asian and the Arab children group, but not in the German group.

China used to be the leading country in the production of REEs, having provided more than approximately 90% of the global REE supply.[32] For Neodymium, China remains in control of its supply.

Lanthanum (La)

Its name is derived from the Greek lanthanein, meaning "to be concealed," indicating that it is difficult to isolate. Like all lanthanide elements, lanthanum occurs in the rare-earth mineral monazite and bastnasite. Lanthanum is as abundant as cobalt in Earth's upper continental crust and therefore not really a REE. In nature, lanthanum mostly exists in combination with cerium.[33]

Lanthanum has physicochemical similarities to aluminum. Both elements are used for their phosphate binding capacity to treat uremic patients and also for water treatment. It is also used for reducing the intensity and harmfulness of X-ray radiation and lasers as well as other lights that have high penetrating capabilities which cause damage to human tissues and organs. La is relatively nontoxic and the main route for exposure is through drinking treated water and consuming crustaceans and fish. [34]

The demand for lanthanum has risen in recent years. The Global Lanthanum Market is anticipated to expand from US$699.048 million in 2020 to a total market value of US$1,471.712 million in 2027. In industry, lanthanum is widely used, for instance

- for making batteries and fuel cells
- in the photography industry, La is useful in optics, helping the flexibility of the refractive index of cameras and video cameras as well as in the modification of the structure of the glass crystals.
- for projectors and studio lights.
- for producing powerful sparks as in the production of cigarette lighters.
- For the optical fiber production.[35]

Perhaps it is not so unexpected that we found elevated mean values for Lanthanum in all groups. The Asian group's mean value was approximately 10 times higher than those of the Arab and German group.

Neodymium (Nd)

Like lanthanum, neodymium is a chemical element present in large amounts in lanthanide mineral ores like monazite and bastnäsite. Actually, all lanthanide minerals contain neodymium, which makes this element fairly common and widely available for general use. Aside from China, neodymium is produced or oxidized from lanthanide minerals excavated in Australia, Brazil, India, Sri Lanka and the U.S.A. The worldwide production of neodymium oxide is estimated at 7.000 tonnes a year. Nd is in demand and China controls its supply.

Neodymium is used for making powerful permanent magnets, aptly called neodymium magnets, which are used in the production of earphones, microphones, computer hard disks, and other electronics. Nd is found in electric motors used for hybrid cars and electric generators including those used in aircrafts and wind turbines. [36]

Unexpectedly, the Arab group's mean value was higher than that of the Asian group. The German group's value was inconspicuous.

Essential Elements

Manganese (Mn):

Of the essential elements, manganese exceeded the upper reference range (RR) in the Asian and the Arab group by far. The mean value of the German group was moderately elevated. Manganese is one of the nutrient metals that is toxic if exposure is excessive. Manganese toxicity is similar to lead toxicity, affecting the nervous system.

Chromium (Cr)

The mean value slightly exceeded the upper RR in all groups, with the lowest in the German group. Cr-III is considered essential and nontoxic, whereas the industrially-used Cr-VI is highly toxic. We did not differentiate between the two.

Copper (Cu)

is a ubiquitously occurring element that is essential in small amounts but toxic if exposure is excessive. It naturally enters the food chain via soil or water but is also introduced into the diet by its use in plant protection products (PPPs), by its application as food or feed additive. The Arab and Asian group showed inconspicuous mean concentrations, while the mean value of the German group was significantly elevated, about twice that of the upper RR for Cu. A report by the German Federal Institute for Risk Assessment (BFR) demonstrated that the daily dietary intake of copper was above the acceptable daily intake (ADI) for German adults and children.[37]

Iron (Fe)

The mean value exceeded the upper reference range in all groups; the highest was detected in the Arab group. A high iron concentration in hair is considered a sign of a metabolic problem and should be confirmed through blood analysis, but unfortunately, this was not part of this study. Iron deficiency anaemia has been considered one of the main public health problems in the Arab Gulf countries. Researcher Abdulrahman O Musaiger of the Environmental & Biological Programme, Bahrain Center for Studies and Research, Manama stated that in his paper that the prevalence of iron deficiency anaemia among preschool children ranged from 20% to 67%, while that among school children ranged from 12.6% to 50% and concluded that action must be taken.[38] The analysis of iron in hair may be considered as a noninvasive step in diagnosing the ailment, allowing and followed by conventional diagnostics and treatment.

Magnesium (Mg)-

A recent statistical evaluation of hair measurements of all children age 12y and under showed a 95%ile upper range of 225mcg/g hair. This range was exceeded by the mean value of the Asian group. We have no explanation for this.

Selenium (Se)

The mean value did not exceed the upper RR of any of the groups, with the exception of the Asian group whose mean value was insignificantly higher (1.46µg/g compared to the upper RR of 1.40µg/g). This indicates a good selenium status of all groups.

Vanadium (V)

The German group showed mean values equal to or within the hair reference range. The Asian group showed a moderately elevated mean value, while the mean value for the Arab group was significantly elevated. At common concentrations, vanadium is non-toxic. The main source for potentially toxic effects caused by vanadium is exposure to high loads of vanadium oxides in the breathing air of vanadium processing industrial enterprises. Vanadium can enter the body via the lungs or, more commonly, the stomach. Most of the dietary vanadium is excreted. What remains becomes distributed to body tissues esp. bones. Bones act as storage pool for vanadate.[39] Vanadium-containing ores are found in the South Eastern Desert of Egypt.[40] According to Hindy and colleagues, Cairo's cement industry releases vanadium-containing air-born-dust into the surrounding environment.[41]

Zinc (Zn)

Is essential for growth, and for the function of a large number of metalloenzymes and metabolic processes; however, increased levels of zinc can become toxic. Zinc is commonly found in the earth's crust, and natural releases to the environment are expected. The most important sources of anthropogenic zinc in soil come from discharges of smelter slags and wastes, mine tailings, coal and bottom fly ash, and the use of commercial products such as fertilizers and wood preservatives that contain zinc.[42]

We found elevated mean values in all groups, with the highest in the German group. The levels found are not known to cause toxicity symptoms, but may be a reflection of metabolic problems and should be followed up by blood testing.

Conclusion

Environmental pollution affects all children. Our study reflects that Asian children are more affected by chronic metal exposure than Arab children. The German children group showed the least metal burden. Most importantly, our study determined that hair mineral analysis is an effective and noninvasive means to evaluate chronic, or long-term metal exposure, especially for heavy metals and also for REE, which are increasingly used in today's environment.

Geographical differences were apparent, especially for uranium. Metabolic problems may be the cause for the elevated mean values of the nutrient elements iron, zinc and magnesium, which necessitates the addition of elemental blood testing to confirm immediate overexposure.

Acknowledgement:

The author is indebted to Prof. Shahira Elshafie, Prof. Omnia R. Amin and Prof Ehab Ragaa of Egypt, and to the many kind doctors and professors she met while working in Punjab, India. Also, many thanks to those German practitioners who provided samples for this research.

About the author:

Eleonore Blaurock-Busch MSc, PhD is research director at Micro Trace Minerals Laboratory in Germany since 1984. She has lectured at universities, including Cairo and Fayoum University in Egypt, and LP University in Punjab. She has written numerous books and articles in German and English, some of which have been translated to French and Spanish.

Conflict of Interest: none

[1] Masters, Rogers D. Validity of Head Hair Analysis and Methods of Assessing Multiple Chemical Sensitivity". Dartmouth College. Archived 2005-09-03. Retrieved 9 August 2023
[2] Rashed MN, Hossam F. Heavy Metals in Fingernails and Scalp Hair of Children, Adults and Workers from Environmentally Exposed Areas at Aswan, Egypt. Environmental Bioindicators, 2:131–145, 2007
[3] Katz S. On the Use of Hair Analysis for Assessing Arsenic Intoxication. Int. J. Environ. Res. Public Health 2019, 16, 977
[4] Pereira R, Ribeir R, Goncalves F. 2004. Scalp hair analysis as a tool in assessing human exposure to heavy metals (S.Domingos mine, Portugal) Science of the Total Environment 327:(2004). 81–92.
[5] Heng YY, Asad I, Coleman B, Menard L, Benki-Nugent S, Hussein Were F, Karr CJ, McHenry MS. Heavy metals and neurodevelopment of children in low and middle-income countries: A systematic review. PLoS One. 2022 Mar 31;17(3).
[6] Frye, R.E., Cakir, J., Rose, S. *et al.* Early life metal exposure dysregulates cellular bioenergetics in children with regressive autism spectrum disorder. *Transl Psychiatry* **10**, 223 (2020).
[7] Exposure to Lead. A major public health concern. WHO 2021
[8] WHO 2021. Evaluations of the Joint FAO/WHO Expert Committee on Food
[9] Toxicological Profile for Aluminum (cdc.gov)
[10] Hundal HS, Singh K, Singh D. Arsenic content in ground and canal waters of Punjab, North-West India. Environ Monit Assess. 2009 Jul;154(1-4):393-400
[11] Cadmium Statistics and Information | U.S. Geological Survey (usgs.gov)
[12] Cadmium in Hong Kong | OEC - The Observatory of Economic Complexity
[13] Wang L, Cui X, Cheng H, Chen F, Wang J, Zhao X, Lin C, Pu X. A review of soil cadmium contamination in China including a health risk assessment. Environ Sci Pollut Res Int. 2015 Nov;22(21):16441-52.
[14] Genchi G, Sinicropi MS, Lauria G, Carocci A, Catalano A. The Effects of Cadmium Toxicity. Int J Environ Res Public Health. 2020 May 26;17(11):3782.
[15] Soler, J.S., Rovira, J.S. (1996). Cadmium in inorganic fertilizers. In: Rodriguez-Barrueco, C. (eds) Fertilizers and Environment. Developments in Plant and Soil Sciences, vol 66. Springer, Dordrecht. https://doi.org/10.1007/978-94-009-1586-2_95
[16] Mercury and Health. WHO Information as of 2023
[17] Children | Lead | CDC viewed Aug 12, 23
[18] https://www.forbes.com/sites/anuradhavaranasi/2021/12/28/lead-pollution-affects-more-than-632-million-children-in-developing-countries/
[19] Lermen D et al. Long-term time trend of lead exposure in young German adults – Evaluation of more than 35 Years of data of the German Environmental Specimen Bank,International Journal of Hygiene and Environmental Health, Vol 231, 2021, 113665, ISSN 1438-4639,
[20] Wang S, Jin Y, Chen J, Lu L, Li Y, Zhao Q, Bu S, Geng X, Guan G, Qu W, Zheng Y, Tang J. Blood lead levels of Chinese children from 1991 to 2020: Based on Monte Carlo simulation. Environ Pollut. 2021 Jun 1;278:116823.
[21] https://www.niehs.nih.gov/research/programs/geh/geh_newsletter/2020/10/articles/new_report_highlights_magnitude_of_global_lead_poisoning_in_children.cfm
[22] Quan, J., Chen, L., Yuan, H. et al. Coexposure to Multiple Metals and the Risk of Abnormal Blood Pressure in Chinese Children. Expo Health (2023).
[23] www.atsdr.cdc.gov/csem/uranium/physiological_effects.html
[24] Alaani, S., Tafash, M., Busby, C. et al. Uranium and other contaminants in hair from the parents of children with congenital anomalies in Fallujah, Iraq. Confl Health 5, 15 (2011)
[25] Singh Virk H. A Crisis Situation Due to Uranium and Heavy Metal Contamination of Ground Waters in Punjab State, India: A Preliminary Report. Research & Reviews: A J of Toxicology; 2017 Vol7, 2 (2017) 6-11 © STM Journals 2017. www.stmjournals.com
[26] Blaurock-Busch E et al. Metal exposure in the physically and mentally challenged children of Punjab, India. Maedica: A Journal of Clinical Medicine, Volume 5 No.2 2010
[27] Keogan DM, Griffith DM. Current and potential applications of bismuth-based drugs. Molecules. 2014 Sep 23;19(9):15258-97
[28] Khaliq H, Juming Z, Ke-Mei P. The Physiological Role of Boron on Health. Biol Trace Elem Res. 2018 Nov;186(1):31-51
[29] https://www.lenntech.com/periodic/elements/ga.htm
[30] V. Höllriegl, Strontium in the Environment and Possible Human Health Effects. Editor(s): J.O. Nriagu, Encyclopedia of Environmental Health, Elsevier, 2011, Pages 268-275,

[31] Winship KA. Toxicity of tin and its compounds. Adverse Drug React Acute Poisoning Rev.1988 Spring;7(1):19-38.
[32] USGS (2022). "Rare earths," in U.S. Mineral commodity summaries 2022 (Reston, VA: U.S. Geological Survey), 134–135.
[33] D'Haese PC et al.Human health risk associated with the management of phosphorus in freshwaters using lanthanum and aluminium. Chemosphere, Vol 220, 2019,Pages 286-299
[34-35] Lanthanum Element | Uses, Facts, Physical & Chemical Characteristics (periodic-table.com)
[36] Mining for Neodymium – Cline Mining
[37] Kolbaum AE et al. Long-term dietary exposure to copper in the population in Germany – Results from the BfR MEAL study. Food and Chemical Toxicology, Vol 176, 2023.
[38] Musaiger AO. Iron deficiency anaemia among children and pregnant women in the Arab Gulf countries: the need for action. Nutr Health. 2002;16(3):161-71.
[39] Rehder D. Vanadium. Its role for humans. Met Ions Life Sci. 2013;13:139-69.
[40] Maria Boni, Mohammed Bouabdellah, Wissale Boukirou, Francesco Putzolu, Nicola Mondillo,
Vanadium ore resources of the African continent: State of the Art, Ore Geology Reviews, Vol.157, 2023,
[41] Hindy KT, Abdel Shafy HI, Farag SA. The role of the cement industry in the contamination of air, water, soil and plant with vanadium in Cairo. Environ Pollut. 1990;66(3):195-205.
[42] Agnew UM, Slesinger TL. Zinc Toxicity. [Updated 2022 Dec 11]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-.Available from: https://www.ncbi.nlm.nih.gov/books/NBK554548/

Citation: Eleonore Blaurock-Busch, Arch Med Clin Case Stud, *"Comparing the Hair Tissue Metal Concentration of Arab, Asian and German Children"*. 2024; 1(1): 102

Received Date: January 18, 2024; Published Date: February 18, 2023