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Research on toxic metal levels in scalp hair of Japanese

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Abstract

For the purpose of obtaining standard levels of toxic metals in the Japanese, hair samples are collected from 5,846 healthy Japanese (2,201 men and 3,645 women; average age 39.9±16.3, means±SD) and the contents of mercury, lead, arsenic, cadmium, beryllium and aluminum in hair were measured with an inductively coupled plasma mass spectrometer (ICP-MS). Among the adults aged 16 or older, men's average content of mercury was high at 5.38±4.37 ppm and women's was 3.37±2.45 ppm. Thus men showed higher contents. The content of lead was 1.09±4.87 ppm with men and 1.56±10.58 ppm with women, who showed higher contents. Arsenic content was measured to be 69±86 with men and 38±92 ppb with women. Men had higher arsenic contents. Cadmium content was 28±106 ppb with men and 28±55 ppb with women. Beryllium content was 1.6±2.0 ppb with men and 2.0±4.1 ppb with women. And aluminum content was 5.01±5.82 ppm with men and 6.02±6.61 ppm with women. Thus, a significant difference was not noted. Children aged 15 and younger had higher contents of cadmium and aluminum than adults. Hair mineral analysis is deemed useful in diagnosing acute or chronic poisoning by these toxic metals or determining exposure to them.

Key words: mercury, cadmium, lead, aluminum, beryllium, arsenic

Introduction

The purpose of anti-aging medicine is to realize a healthy and high quality of life (QOL). However, the bad environment is a big hindrance.[1] Recently it has become an issue that a human body absorbs toxic metal from polluted air, contaminated soil, tap water, a food additive, refined food, cigarette smoke and part of seafood.[2] For instance, it is the inception of lead contained in polluted atmosphere or exhaust gas or tap water supplied from lead pipes, or cadmium absorbed by smoking, arsenic in an agricultural chemical contained in food, mercury which is said to cause atopic dermatitis or Minamata disease, aluminum which is said to be one of the causes of dementia and beryllium which causes bronchitis or various inflammations.

As a method to evaluate toxic metal accumulation in a

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human body, hair mineral analysis, blood test and bone test are available. Recently, however, the usefulness of hair metal analysis has been drawing attention, which is comparatively simple, and has high reproducibility.[3] Also, this method is noninvasive and expense is within an allowable range, so it becomes prevalent among the medical facilities practicing anti-aging medicine.
In this study, the authors measured toxic metals, using human hair, for the purpose of presenting the standard values of the Japanese, and to report the results.

Materials and Methods

The examinees were 5,846 healthy people (2,201 men and 3,645 women; average age 39.9±16.3), who were tested during the period from May 2002 to July 2003. Age and sex distributions are shown in Figure 1.

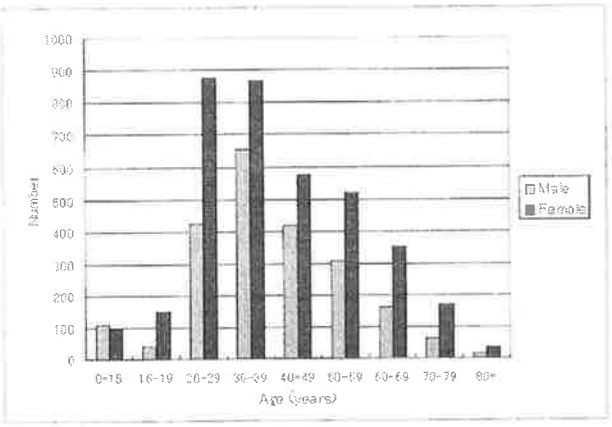

Figure 1. Age & Sex Distribution

The material used was 0.2g of scalp hair obtained from each examinee. The hair test material was weighed exactly 0.075g. The hair was then washed in accordance with the method recommended by Hair Analysis Standardization Board.[4] In other words, the test material was washed in 20ml of aceton, followed by sonification in 50 ml of 0.01% Triton solution. Next, the test material was completely solved by alkali treatment with tetramethylammonium hydroxide (CH3)4NOH, and then distilled water was added and adjusted the solution weight to 15.00g. Measurement was made with inductively coupled plasma-mass spectrometer (ICP-MS, Agilent 7500 ICP-MS, made by Agilent Technologies) installed at La Bell Vie Preventive Medicine Research Laboratory (Tokyo, http://www.LBV.jp) [5] and the contents of mercury (Hg), lead (Pb), arsenic (As), beryllium (Be) and aluminum (Al) were measured. The unit of ppb (part per billion=ng/g) or ppm (part per million=μg/g) was used and expressed as average± standard deviation.

Results

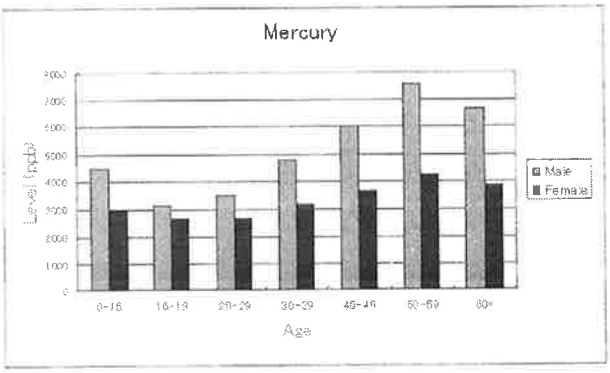

Figure 2. Mercury in Hair

Figure 2 shows mercury content in hair by sex and age. Among the adults aged 16 years or older, men had an average lead content of 5.38±4.37ppm and women's averaged 3.37±2.45ppm. Men aged 16 to 59 years had the amount of mercury in hair ranging from 3.1 to 7.6ppm. Women in the same age group had mercury ranging from 2.7 to 4.2ppm. Mercury content tends to increase with age. But the content decreases slightly with persons aged 60 years or older. For all age groups, men showed significantly higher amounts than women ($p<0.01$).

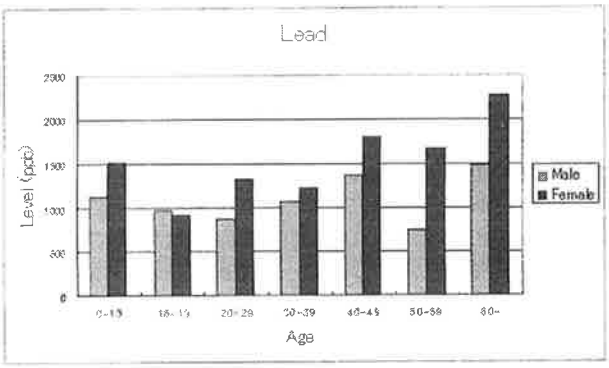

Figure 3. Lead in Hair

Men have the amount of lead in hair (Fig.3) ranging from 0.75 to 1.5ppm, and women have the same ranging from 0.9 to 2.3ppm. For all age groups except for 16 to 19 years, women tended to show higher contents. No clear relation

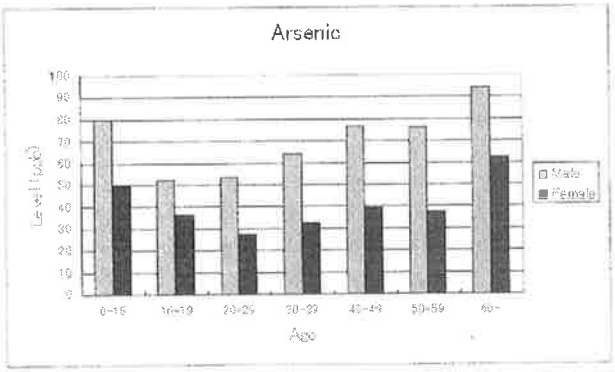

Figure 4. Arsenic in Hair

between age and amount was found among men. Women showed a trend of gradual increase with age from 15 years to 60 years and older, even though some dispersion existed. Arsenic content in hair (Figure 4) was 69±86 ppb for men aged 16 years or older and 38±92 ppb for women. For all age groups, men had a content of 50 to 95 ppb and women's contents ranged 25 to 60 ppb. Thus, men showed higher contents than women for all age groups ($p<0.01$). Among men a high content of 80 ppb was seen with the age group from 0 to 15 years of age, but it was lowest at 55 ppb with the age group from 16 to 19 years of age. The content of arsenic increases with age and the highest value of 95 ppb was seen with the age group of 60 years and older. With women, high contents were seen with the age group from 0 to 15 years of age, whose content was 80 ppb and the age group aged 60 years and older who had the content of 95 ppb. But for women aged 16 to 59 years, the content ranged 40 ppb or under.

Cadmium content was 28±106 ppb with men aged 16 years and older, and 28±55 ppb with women. Notably high values were seen with men aged 0 to 15 years at 70 ppb and women aged 0 to 16 years at 40 ppb. But both men and women aged 16 years or older had contents of about 30 ppb (Figure 5). This tendency was not different between

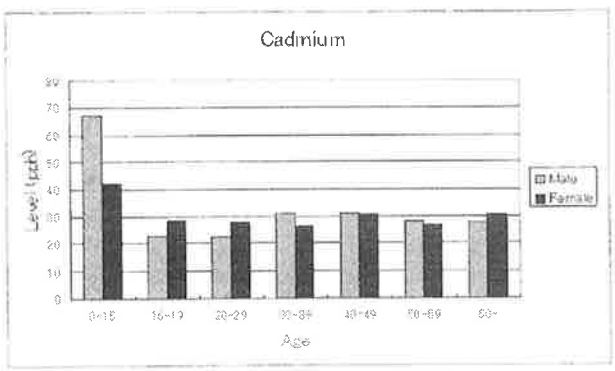

Figure 5. Cadmium in Hair

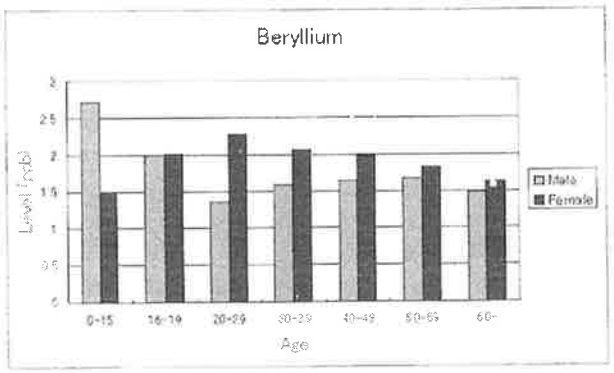

Figure 6. Beryllium in Hair

men and women. No difference was seen in cadmium content in hair between men and women aged 16 or older.

Beryllium content in hair was 3 ppb or less with both men and women. This is very low, compared with other metals (Figure 6). Men aged 0 to 15 years had a remarkably high value of 2.7 ppb, but men aged 16 years or older had contents of 2.0 ppb or less. Any clear trend in age-specific content was not seen. Women's content shows a gradual rise from 0 to 29 years of age, reached 2.3 ppb at the age group from 20 to 29 years of age and gradually decreased with age from 30 years onwards. Men aged from 0 to 15 years had high contents, but women aged 20 years and older had higher contents than men in the same age category.

Aluminum content in hair was 5.01±5.82 ppm with men aged 16 years or older and 6.02±6.61 ppm with women. Both men and women in the age group of 0 to 15 years of age had the content of 11 ppm or more. This content is notably high, and very high, too, compared with other metals (Figure 7). In the age group of 16 years of age and older both men and women had high contents ranging from 4.2 to 6.2 ppm and they were almost constant, regardless of age. Any notable difference was not seen between the sexes.

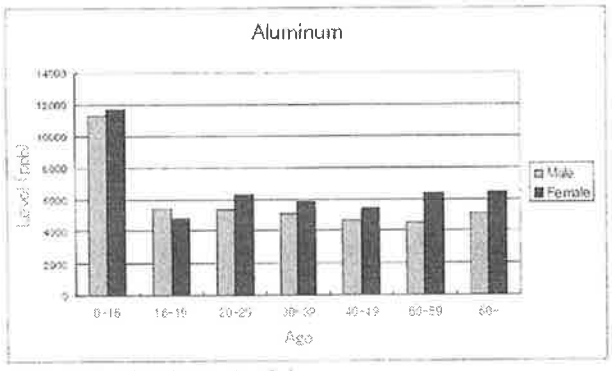

Figure 7. Aluminum in Hair

Discussion

In recent years, lack of essential minerals caused by environment pollution, accumulation of toxic metals, wide use of processed food and soil lacking minerals has become a concern. It has also been shown that toxic metals such as lead, zinc, arsenic, cadmium and beryllium interfere with normal cellular metabolism.[2,3]

According to National Survey of Urban Contamination of 2002, there were totaled 134 cases of contamination exceeding the environmental standards, including 45 cases of contamination with lead and 40 with arsenic. Ecological damages caused by dioxin or heavy metal are reported nationwide. Sources of lead pollution can be found in our daily life environment such as water pipes made of lead or air pollution. Meanwhile, cancer has been the largest cause of death since 1981 according to the dynamic statistics of population by the Ministry of Health, Labour & Welfare, and 295,399 people died of cancer, at a rate of 235.2 deaths per 100,000 population which accounts for 30.7% of total number of annual death. IARC (International Agency for Research on Cancer), part of World Health Organization (WHO), based in Lyon, France, and the U.S. EPA (Environmental Protection Agency) conducted the evaluation of carcinogenic risks of six toxic metals (arsenic, beryllium, cadmium, nickel and mercury). IARC determined that arsenic, beryllium and cadmium are carcinogenic to human, and EPA determined that there are adequate data showing that arsenic and nickel are carcinogenic to human.

Toxic mineral is a toxic heavy metal such as lead or mercury, which interferes with various physiological functions and metabolism, once accumulated excessively in a human body. Even if metal accumulation is not large enough to cause toxicosis, it may cause a health problem such as anorexia or chronic fatigue.

Inductively Coupled Plasma Mass Spectrometer

An inductively coupled plasma mass spectrometer was used for this hair mineral analysis.[5,6] This apparatus is an element analyzer developed in 1980 and capable of detecting any element, from lithium (Li) to uranium (U) down to a minute level of ppb, a unit of one billionth. The principle is to ionize the atomized sample solution put in the emission source of plasma together with argon gas, separate the target ions with a quadruple mass analyzer and measure them with a channeltron. The cations of the sample generated in the plasma are taken into a vacuum system from a small hole (orifice) sized 1 mm in diameter, which is opened at the top of a circular cone made of copper plate, positioned with its base to face the plasma, and then further move into a quadruple mass analyzer after passing through an orifice of a skimmer cone made of copper plate with the structure similar to the above said copper cone. A mass spectrum in the range from 3 to 260 AMU is obtained by changing voltage applied to the quadruple electrodes automatically. Behind the two cones, two ion lenses are arranged to form a shape by focusing the ion stream. Along the way the ion stream enters the magnetic field, which passes the ions with a particular mass-to-charge ratio to the 3rd lens, deviating other ions to collide with the wall. The screened ions are narrowed down to have almost the same mass and focused by the 3rd lens and again undergo another magnetic field. The ions are further narrowed down to a small range of mass, and the mass spectrum is measured at the ion detection part. The mass spectrum of the sample solution is compared with the standard solution of additives, and the element densities of the sample solution are sought. Many elements can be simultaneously measured. Argon gas with minimum purity of 99.995% is required.

This method which is able to identify a minute quantity of an element or ion and to measure its density is widely used, not only limited to hair mineral analysis [7,8] but also for the purpose of evaluating the purity of a chemical used for the production of an organic electronic material, polymer molecule electronic material or semi-conductor, and is also useful in the environmental evaluation analysis such as a survey of soil pollution.

Significance of Hair Mineral Analysis

Hair mineral analysis has been conducted mainly in the U.S. since the 1970s.[9] It is a biopsy of minerals contained in the soft tissue of hair (biopsy=analysis of a body tissue), and specifically refers to the measurement of minerals in this research paper. In his book "Nutritional Balancing & Hair Mineral Analysis" Dr. Lawrence D. Wilson wrote as follows.[3] Hair is one of the soft tissues and hair analysis makes it possible to measure minerals deposited in the cells of hair or filled in the void space between the cells. For a period of 2 to 3 months, hair analysis cannot detect mineral contents in tissues other than hair. However, by testing the hair, it is possible to predict what might be happening in tissues other than hair.

Hair analysis is a screening test, and is not intended to diagnose an illness or health conditions. However, the test is a relatively simple, easy to operate, and fast, providing abundant information at a low cost. A screening test is

often underestimated among the medical circle, but likely serves to prevent a physical or psychological disorder and plays an important role in early detection of illness.

There are several good reasons why hair is a good material for biopsy. First it is easy to obtain and noninvasive. And hair is a stable biopsy material, which does not need a special treatment and is preservable for several years. Also, hair contains minerals almost 10-100 times as much as blood. In addition, the recent technological progress makes it possible to reduce the cost of mineral analysis and improves accuracy and reliability. These are also important factors.[5,6]

Knowledge and improvement of nutritional (mineral) balancing in the human body is indispensable to keep a younger body insusceptible to illness. Also, hair analysis is useful in evaluating the efficacy of a chelation therapy which helps to remove a toxic metal out of a body [1,12]. Data accumulation by hair analysis is beginning to enter the field of anti-aging medicine.

Mercury

Mercury and its compounds are metals which become liquid at room temperature, have high electric and heat conductivities and coefficient of thermal expansion. Since mercury form alloys with many metals, it has been widely used for industrial, agricultural, medical or other purposes.

Regarded as a highly harmful material among water pollutants, mercury is strongly regulated and its threshold of total mercury content is strictly regulated to be 0.005mg/l or less. The reason why the standard for environment is equally stringent as the one for water supply is because mercury is difficult to remove in the normal process of water purification and causes bioaccumulation.

According to the "Method of Examining Drinking Water (2001 edition)", mercury content in soil is about 0.08mg/Kg, and total mercury is 0.03 to 0.1μg/l in the water of unpolluted rivers and lakes and 0.005 to 5.0μg/l in sea water. Mercury compounds are classified as organic and inorganic. Inorganic mercury is a compound which comprises one or two atoms of mercury, and inorganic mercury compounds are methyl mercury, alkyl mercury and phenylmercuric compounds. These mercury compounds are collectively regulated as "total mercury".

Natural mercury is derived from volcanic gases or gases erupted from the earth crust or ground water gushing from mercury ore. Waste water discharged from the plants that produce vinyl chloride, acetaldehyde and sodium hydroxide or from the wood pulp industry, are a large source of pollution among the artificial pollution sources. They use mercury in quantity as a catalyst. Today it is prohibited to use agricultural chemicals that comprise mercury. Mercury amalgam is used as teeth filling and inorganic mercury compounds are used in some medicines or laboratory reagents. Their waste disposal is also a problem.

Mercury is a substance which is extremely harmful to life, and causes either acute or chronic poisoning.[14] The intestinal absorption of inorganic mercury is low, compared with organic mercury. And inorganic mercury has less toxicity than organic mercury. But inorganic mercury is accumulated in kidney, and causes renal disturbance. Also, it is known that inorganic mercury is changed to alkyl mercury by bacteria in water bottom sediments, and its accumulation in fish and shellfish is a problem.

Alkyl mercury combined with methyl group (CH_3-), ethyl group (C_2H_5-) or propyl group (C_3H_7-) is easily absorbed from intestinal tract, lung and skin, and is hard to discompose and slow to excrete once having entered into a body. Therefore, such an alkyl mercury compound is easily accumulated in body and remains highly toxic. Particularly, it affects cranial nerve system, and causes various nerve disorders such as perception disorder, ataxia, deafness, language disorder, narrowed visual field and paralysis. The typical example is Minamata disease. Mercury may also be the cause of metal allergy or atopic dermatitis.

Furthermore, alkyl mercury is environmentally problematic, because it causes high bioaccumulation. Even if its concentration in water is minute, it is accumulated in fish or shellfish at a high level through the food chain. A goldfish raised in a solution comprising methyl mercury of 0.0003mg/l showed no serious suffering. But methyl mercury in body will be concentrated to 1,000 to 3,000 times as dense as the methyl mercury solution. Land-dwelling life such as sea birds preying at an estuary are tainted with mercury.

Other organic mercury compounds tend to get decomposed to inorganic mercury compounds in body. Their toxicity is not so strong as alkyl mercury, but they are more easily absorbed and more harmful than inorganic mercury.

It is indicated that mercury content in hair correlates with those in various body organs.[15] National Institute for Minamata Disease conducted hair analysis on 3,458 individuals from the prefectures of Chiba, Wakayama, Tottori and Kumamoto. As a result women had the average content of mercury in hair of 1.83 ± 1.55 ppm (μg/g) and men had the same of 3.32 ± 2.60 ppm. The maximum instance was 26.76 ppm. By region, Sotobou area of Chiba prefecture indicated high values (Yasutake A2003). Quantity of mercury in hair has a significant correlation

with sex, age, fish intake, permed hair or not and intake of fish and shellfish such as tuna.[16-20] Also, there is a tendency that an alcohol drinker has higher contents of both organic and inorganic mercury compounds in hair than a non-drinker. Particularly, when a woman has her hair permed, thioglycollate contained in the perm liquid removes mercury from hair by about 40 to 50%.[17] This is judged to make a difference in mercury content in hair between men and women that was also observed in the present study.

The WHO assessment criteria of 1967 set the tentative safety criterion of mercury in hair at 50 ppm, based on Minamata disease occurred in Niigata. However, a disorder was noticed when hair mercury content was less than the criterion. Since 1990, therefore, WHO's International Programme on Chemical Safety (IPCS) and EPA have been changing their view and say that it is desired that mercury in hair should be 10 ppm (10,000 ppb) or less. The present survey on mercury content in hair showed that most was 10,000 ppb or less, but a few instances exceeding it were noticed in some areas. Also, mercury showed the highest level among all of the tested metals. It could be said that hair is also playing a role in the bodily mechanism for excreting mercury.

Regarding the intake of methyl mercury, WHO and FAO have determined that the weekly intake of methyl mercury should be 1.6μg or less per kilogram of body weight, and EPA set the daily intake of 0.1μg per kilogram of body weight as the limit. These criterions are set stringent, with the adverse effect on a developing fetus to be taken into consideration. This limit can be translated to the consumption of a small fish a day or 50 g of a big fish containing more mercury per week.

Lead

Lead is one of the metals which man has been using since the earliest time, including its compounds. According to the "Method of Examining Drinking Water (2001 edition)", lead content is about 13mg/kg of soil, from 0.001 to 0.01•Ïg per litter of the water in clean rivers or lakes and 0.01•Ïg/l in sea water.[3] The standard of lead content is determined to be 0.01mg/l or less.

Water pollution by natural lead is derived from waste water exhausted by a mine or gushing water from an ore deposit. Artificial sources of pollution are lead smelters, lead batteries, paints, exhausted water and smoke from agrichemical plants, exhaust gases from cars, etc. Also, in some areas lead eluted from a water supply pipe (lead pipe) matters. Today most local governments prohibit the new installation of lead pipes. And installed lead pipes are also being removed and changed to the pipes of a different make. A special instance that matters is the soil pollution by lead bullets shot at the rifle ranges of the Self-Defense Forces.

The bioaccumulation of lead at the level observed in a general environment does not affect an aquatic plant. In an ecosystem lead may accumulate highly in the animal which has taken in the metal from baits, but it is said that lead does not bioaccumulate like mercury or cadmium.

Acute poisoning by intake of lead in a large quantity causes gastroenteritis such as abdominal pain, vomiting or diarrhea and kidney disorder such as anuresis.[21,22] Tetraethyl lead, which is added to gasoline, is easy to evaporate and absorbed from lung or skin, causing cranial nerve disorder. Lead is more controversial with its chronic poisoning. Lead in body is accumulated mainly in bones. Symptoms of chronic poisoning are anorexia, headache, anemia, constipation, infertility and miscarriage. According to IARC classification on carcinogenicity, inorganic lead compounds are "probably carcinogenic to humans", and organic lead compounds are "possibly carcinogenic to humans". And children are particularly susceptible to lead toxicity, which is said to have relation with the cause of degenerated intelligence or violent behavior. Excessive accumulation of lead can seriously affect human health.

In this study lead content in hair was 1.5 ppm or less with both men and women aged 39 years or younger, 1.5 ppm or more with women aged 40 to 58 years, and 2.0ppm or more with women aged 60 years or older. Thus, it was shown that aged women had higher lead content. This may be due to the use of lead in cosmetics in the past.

Arsenic

An arsenic compound is either organic or inorganic. In nature there are arsenic trioxide (As_2O_3) and its oxidized compound, arsenic acid (As_2O_5). They are derived from volcanic activities. Arsenic trioxide is most poisonous among arsenic compounds. The artificial sources of contamination are waste water discharged from paint, leather, pharmaceutical and chemical plants or mineral mines, and agricultural chemicals such as pesticide and insecticide. A special case with arsenic is its history of criminal use as a poison since the 16th century. In many cases, arsenic contamination of groundwater seen in Asian countries since 1980s is vast-scaled, and the cause is not known yet.[23-25]

According to the "Method of Examining Drinking Water (2001 edition)", arsenic content is about 1.8mg/kg of soil, 0.9 to 1.3μg per litter of the water in clean rivers or lakes

and 0.15 to 5.0μg per litter of sea water 13). The ground water in a volcanic area sometimes contains 20 to 50mg/l of arsenic. The environmental standard and standard of drinking water quality are determined to be 0.01mg/l or less.

Mercury and most of the other heavy metals, once methylated, become difficult to be excreted by combining with SH group, so that their toxicity increases. However, methylated arsenic hardly reacts with SH group in body. Therefore, even if ingested by humans, highly methylated arsenic compounds do not act toxic on humans, and most of them will be excreted into urine from the body.[24-26] Hizikia fusiforme, shrimp and other seafood contain methylated arsenic, but it is said that such foods do not become harmful to human health. Arsenic does not cause bioaccumulation through human food chain. It is more likely that toxicity of arsenic trioxide and arsenic acid is weakened, methylated by seaweeds or phytoplanktons in freshwater or sea water.

Acute poisoning with arsenic is often used in suicide or crime. Once orally ingested, arsenic trioxide causes gastrospasm, garlic smelling, nausea, diarrhea and burning sensation from throat to upper abdomen.[24-26] Then, neurotic symptoms such as dizziness, numbness and convulsion occur, and a sufferer further experiences tachycardia, circulatory disturbance and shock state. However, what matters with water pollution and soil contamination is chronic poisoning caused by the use of groundwater near a mineral mine or the inhalation of dust comprising arsenic in a mine smelter. Arsenic is promptly excreted into urine, but residue in nail and hair for several years. The symptoms of chronic poisoning are mainly weakness, anorexia and nausea. In addition, keratinization of skin, black foot disease, peripheral nerve disorder, skin cancer, etc. are reported.

This research shows that arsenic in hair is 50 to 80 ppb with men and 30 to 60 ppb with women. Regardless of age category, women showed less arsenic content.

Cadmium

Cadmium is a silver white and soft metal produced in the production of lead, and used for cadmium plating, as a material of soluble alloys or as a stabilizer for polymers in the form of cadmium stearate, and its sulphides are used as a yellow pigment or paint. Japan is the world's largest consumer of cadmium with the annual consumption (of 7,200 tons) accounting for 40% of the world total, and its 80% is used for nickel- cadmium batteries. As Japan is a volcanic country, soil in Japan contains slightly more cadmium than other countries. Artificial sources of pollution are the waste water from the mining and smelting of lead or copper, battery plant, plating plant or metal processing plant. Although minute, cadmium is found in raw rice. Therefore, the average inception of cadmium by the Japanese is 50μg a day, significantly larger than the average of 20μg a day in Europe and the U.S. It is desirable to take measures to decrease cadmium content in raw rice.[23]

According to the "Method of Examining Drinking Water (2001 edition)", cadmium content is very minute in soil, 0.02 to 0.1μg per litter of the water in clean rivers or lakes and 0.05 to 0.11μg per litter of sea water.[13] The standard is set at 0.01mg/l or less. In the environment bioaccumulation matters, as cadmium is easily absorbed by many living organisms. Particularly it is significant with microorganisms and mollusks, having concentration factor on the order of several thousands. Most of the other organisms have concentration factors from a mild degree of 100 to a middle degree. A rice plant concentrates a dilute solution containing 0.008 ppm of cadmium to more than 4000 times in leave and culm, and to 500 times in raw rice grain.

Cadmium incepted by body is mostly excreted from kidney, but a part of it is accumulated in kidney or liver, causing various disturbances.[27-29] Cadmium is highly poisonous to humans. Oral inception of the metal causes acute poisoning such as serious gastroenteritis and inhalation of dust or fume causes coughing, chest pain or dyspnea. Chronic cadmium poisoning often becomes an issue. It mainly causes renal dysfunction and osteomalacia. Itaiitai disease is famous as a disease caused by environmental contamination. Its name is derived from a patient's appealing of severe pain, crying "itai itai (pain)"day and night. According to IARC evaluation cadmium is "carcinogenic to humans".

A report on smoking tells that Austrian smokers have cadmium in hair of 75 ppb(μg/kg) and non-smokers have the same of 38 ppb. Thus, cadmium content rises by smoking, too.[30] This research reports cadmium in hair of 30 ppb for both sexes, which is lower than Austrian non-smokers.

Beryllium

Beryllium metal, beryllium copper alloys and beryllium oxides are frequently used at the forefront of space electronics, atomic energy and ceramic industries. Beryllium and its compound taste sweet and are strongly poisonous. The world total production of beryllium ore is estimated to be about 10,000 metric tons p.a., which is equivalent to 400 metric tons of beryllium. The demand for

the metal is growing at an annual rate of 4%. Rather than the exhaust from the production or use of beryllium, the exhaust from fossil fuel is the major cause of air pollution. Coal contains 1.8 to 2.2mg/kg of beryllium and oil contains 100μg/l.

Few data are available about the effect of beryllium on environment including both aquatic and terrestrial living things. Generally speaking, rivers and lakes have low density of beryllium and its content in soil is low, so that the metal does not have much effect on environment.

Beryllium is not specifically regulated under the laws on recycling, waste disposal, air pollution and water pollution. According to the labor safety law and the Ministry of Labor's regulations on prevention of hazards due to specified chemical substances (Specified Chemical Regulations), "pharmaceutical preparations containing more than 1% of beryllium and its compounds" and "alloys containing more than 3% beryllium" are designated as the first type of substance and it is required to take sufficient measures in production and handling. Exposure in the occupational circumstances occurs in the processing of beryllium ores, beryllium metal, beryllium alloys and beryllium oxides.

Acute beryllium poisoning mostly occurs in a working place,[31,33,34] such as the absorption of beryllium fluoride and beryllium sulfate. Such absorption causes endorhinitis, pharyngitis, bronchitis and chemical pneumonia. The direct contact of skin or mucous membrane with the metal or compound causes contact dermatitis and conjunctivitis.

In the 1930s, such chronic poisoning was reported as caused by beryllium adhered to work clothes or exposure to polluted air in a working place handling beryllium, but such instances are not heard today.[31] Also, there is contact stomatitis caused by prosthetic material comprising beryllium. It should be noted that chronic poisoning by beryllium progresses latently over a long time of 20 years or longer.

Berylliosis is different from a typical disease of pneumoconiosis in pathology. Main symptoms are exertional dyspnea, coughing, stethalgia, fatigue and general malaise. Lung lesion is macroscopically a wide scattering of nodules and interstitial fibrosis, and pathologically it is mainly granulomatous lesion.[35]

The present research indicated the beryllium content in hair of 1.4 to 2.3 ppb, below the other metals. This amount of beryllium is considered non-toxic.

Aluminum

Aluminum is a light metal which exists in soil abundantly. Today this metal is indispensable in our daily life, omnipresent in various forms in our environment. It is said that aluminum, which is stabilized in soil, has recently eroded into raw water sources for drinking water because of acid rain and becoming denser.[2,3]

Aluminum is not specifically regulated under the laws on recycling, waste disposal, air pollution and water pollution. According to WHO's water quality standard aluminum in water should be 0.2mg/l or less and the most stringent French standard limits the aluminum content to 0.05mg/l or less. It is reported that some sources of drinking water contain a high concentration of aluminum ranging 10-1000mg/l. As an agglomeration precipitant comprising aluminum is used in drinking water, the metal is detected at a level of 0.01-0.1mg/l.

Aluminum ion is harmful to both animals and plants. Aluminum ion has a character to easily combine with oxygen atom of carboxyl group, and is easily bonded with such substantial cell constituents comprising many carboxyl groups as cell wall, periplast, and nucleic acid. The ion prevents a plant from growing its root and causes disturbance to nerve cells of an animal.[36]

The research, which compared the concentration of aluminum in drinking water of each country and occurrence of Alzheimer disease, indicated that disease occurrence in the areas highly dense with aluminum is 1.3 to 4.5 times more than the areas with a low concentration of aluminum. It is deemed to be one of risk factors of Alzheimer disease or senile dementia.[37-39]

The acceptable daily intake of aluminum recommended by WHO and FAO (United Nations' Food & Agriculture Organization) is 7mg/week/kg (=60mg/day a person weighing 60kg). The daily intake of aluminum from foods, food additives, drinking water and kitchen utensils ranges from 2.5mg to 13mg. 99% of orally incepted aluminum is not absorbed but excreted. The 1% remainder is absorbed from digestive tract and excreted into urine through kidney. A human body contains 35 to 40mg of aluminum, which is found in lungs, bones and blood and brain 40). A dialysis patient cannot excrete aluminum into urine and its toxicity may occur easily.

This research indicated that aluminum in hair was 5-6 ppm with aged 16 years or older. The level was the second highest after mercury.

Significance of Age Difference and Hair

Among the metals tested in this study, some were noticed to show particularly high levels in children aged 15 years or

younger. Cadmium and aluminum were noticed to be highly dense with both men and women. Highly dense only with men were arsenic, beryllium and mercury. The metal whose level was high only with women was lead. The reason for such variation is not known. A difference in inception, affection by a mother, age difference in metal accumulation could be considered possible reasons.

Particularly mercury and cadmium demonstrate stronger toxicity to children whose nerve system is still growing. Therefore, the metals' high levels in such children are grave concerns. On the other hand, as they are in the very process of development, it is deemed possible that hair root cells exert all their powers to exclude as much harmful metals as possible out of a body. It has been indicated that a significant amount of heavy metal is discharged from the body in the process from hair growth to loss of hair. The hair has its toxic metal chelation function.

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