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IMPACT OF MERCURY ON DAMAGE OF HUMAN ORGANISM

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Abstract: *This report focuses on the associations between effects of mercury and human organism. Mercury is characterized as a chemical element, its forms, toxicity, usage are described. Further on the author engage in the most significant ways of mercury entering organism, its transport mechanism, distribution and excretion. Mercury belongs among factors that are dangerous to human organism already in minimal concentration, they mainly come through food.*

Keywords: *Mercury, health, risk, intake, metabolism, distribution, excretion, toxicity, food, damage*

Introduction

At the conference UNESCO in 1967 was the following definition accepted: „Environment of a human being is the part of the world with which human being interacts, that means the one he uses, affects and adapts to". From the medical point of view we define in a wider perspective – as a complex of physical, chemical, biological and social phenomenon and processes, which have a direct or indirect influence on peace of people, individuals and population (Ševčíková and team, 2006).

Negative effect of the environment on plants and animals is obvious in weakening their population and reduction of their biological variety, including an extinction of some species. Because the whole development of human society has been connected with the technology of mining and processing of metals – in lakes, ponds and rivers in various parts of the world there was an increased concentration of heavy metals and other biological toxins and consequential death loss of aquatic animals (Kimáková, 1999, Kimáková 2000).

Concentrations of heavy metals in atmosphere, soils and water and in sediments present serious ecological problem. They enter food chain through which they get into human organism, where their gradual accumulation develops.

Concerning the way of interaction with the living organisms we divide heavy metals into biogenic elements, which are indispensable for life functioning (copper, zinc, iron) and abiogenic elements (such as lead, mercury, cadmium and others), whose presence in living organism is harmful (Koréneková and team, 2006).

Xenobiotics, which the most common carcinogenic, mutagenic or teratogenic effects are marked with, belong to one of the most observed groups of substances, which have a negative influence on life organisms (Poráčová and team, 2005, Fazekašová and Poráčová, J., 1999).

One of the significant negatively influential heavy metals in food chain is mercury. In Slovakia there is rather a large area contaminated by heavy metals (Kimáková 1999, Kimáková and Bernasovská, 2005 a, Kimáková and Bernasovská, 2005 b).

Mercury as a chemical element

Mercury (Hydrargyrum, Hg) comes from the Greece hydór – water and argentum – silver. It belongs to the group II. B f periodical system of elements, it has atom number 80, relative atom weight 200.6, measure weight 13.6 cm^{-3}, heating temperature -38.9 °C, boiling temperature 356.6 °C, in laboratory temperature mercury is silver liquid with metal gloss.

Mercury (Hg) is the only, in common temperature, liquid metal, which together with lead, zinc, aluminium and copper alloys (for example brass and bronze) forms alloys, called amalgams. Together with gold and silver it forms amalgams more slowly, with iron, molybdenum and vanadium it does not form any at all. For this reason technical mercury can be stored in metal bottles.

Forms of mercury occurrence

Mercury can exist in three elementary forms:

- metal mercury, which is used for example as temperature medium in glass thermometers, it does not have electrical charge (it is neutral),
- inorganic mercury, positively charged $^{+1}$ or $^{+2}$,
- organic mercury in carbonaceous compounds.

Chemical form of mercury occurrence influences its absorption and transport in a body. Electrically uncharged mercury easily converts into cells. Mercury with a charge cannot cross some barriers as, for instance, the hematoencephalic barrier in brain. It is formed by endothelium cells of brain capillaries joined by zonulae occludentes and astrocyts; due to that the metabolism between blood and tissue CNS is restricted. Similar situation is with placenta, in which the exchange of gasses and supply of nourishment into the circular blood system and the embryo is carried out in case of total separation. Mercury doe not penetrates cells immediately, but first it must become a part of another molecule. Organic compounds with mercury can accumulate in poikilothermic organisms, as fish.

Distribution and toxicity of mercury can change to positive inorganic form (Hg^{+1} a Hg^{+2}) as a result of chemical process of oxidation. Metal mercury is usually a source of chronic intoxication, there is also a possibility of subacute and acute intoxications. The main cause is inhalation of vapour. Concentration of mercury in saturated air is in low temperatures high due to its toxicity (Krätsmar – Šmogrovič, 1994; Večerek and team.; 1980; Gažo and team, 1981).

Inorganic form of mercury can be transformed to metal mercury through reduction in methyl group CH_3 and create organic compound of mercury.

Organic compounds of mercury can metabolize themselves by removing carbon (for instance demethylation) and clear mercury is produced (Kimáková, 1990).

Mercury in the environment

Increased occurrence of toxic metals in the environment has negative effect on people´s health and productivity of farm animals. It causes a decrease in quality of hygiene of animal products with higher volume of toxic elements in meat, milk, inner organs and others and a decrease of growth and reproductive indicators. Because tissues and product of farm animals play an important role in human nourishment, there is a need to observe the volume of mercury in meat, milk, eggs and in other animal products(Kimáková and Bernasovská, 2007 a; Kimáková and Bernasovská, 2007 b; Kimáková and Koréneková, 2004).

Mercury is the only, in common conditions liquid metal, which evaporates in room temperature, which significantly extends the possibilities of spreading in the environment. All the compounds of mercury are toxic. In the past there was more intoxicating by inorganic compounds of mercury, in the present time the risk of intoxication by organic compounds grows.

Toxicity of mercury is conditioned by the amount that gets into the body. The effects, further on, depend on concentration, which is reached only in certain organs, as for example brain or kidneys, which are sensitive to intoxication by mercury. The factors that have an influence on the amount and intoxication of mercury are mainly: the amount of mercury received (absorption through skin, inhalation through lungs, peroral route), entrance into blood circulation system, the speed of distribution into other organs and change in the chemical structure of mercury, which can happen in various organ during metabolism (Smith, 1996).

The use of mercury

Despite the attributes that are harmful to health mercury is irreplaceable component for many applications and productions due to its specific characteristics.

Mercury is used in modification and metallurgy of gold, silver and platinum, in electrical engineering and lightning technology (light tubes), in electrochemistry and laboratory practices (electrolyzers – electrolytic production of chlorine and sodium hydroxide, vacuum pumps, pressure pumps, thermometers, and others) Mercury is also used in the production of dental amalgams. Compounds of mercury are applied as impregnating and disinfecting substances. Mercury catalysts are very important in organic technology (Baláž and Tréger, 2003).

The most mercury is used for chemical and medical purposes, than for explosives, in production of paints, in electrical engineering, mechanical engineering and in mining of gold (Remy 1962). It is use for filling thermometers, pressure meaters, manometers, other instrument used for production of paints, amalgam and jewellery (Kolenič, 2003).

In same ethnical groups mercury is used in cosmetic products, in which vapour of mercury are released. These groups also use elementary mercury during religious ceremonies.

The followers of some Latin and Afro-Caribbean traditions, for example Sanataria, Voodoo or Espiritismo, carry amulet from mercury, they spray it on the ground, add it into candles or oil lamps. They believe in its magical abilities (according to them it brings happiness, love and fortune) and use it for their magic tricks. Sometime they use it a medicine, especially in case of digestive problems (Davidson, 2004).

In connection with the use of mercury during religious ceremonies Environmental Protection Agency published instructions, in which they warn against serious risks of intoxication by mercury (EPA, 1997).

Work environment

Professional risk for a human being from the aspect of exposition to mercury concerns various field of industry and some work activities as for instance: processing of ore containing mercury, fundamental chemical industry, production of electro-technical equipments, production of measuring tools, pharmaceutical industry, production of soap and toiletries, application of dental fillings, research and educational institutes and others.

In work environment exposition to vapour of metal mercury is the most common issue.

The exposition is often intensified by contamination of work clothes, insufficient hygiene of the whole body, eating and smoking in work place, contamination of floor and walls, bad technological discipline and similar cases (Gáliková and team, 2002, Gáliková and team, 2003). In the past chronic professional intoxications by mercury often occurred during smelting ore, containing mercury in Rudňany (Kolenič, 2003).

The ways of mercury penetration into organism

When evaluating toxic effects we consider the place where the substance penetrates into the organism. The penetration is possible through inhalation through lungs, skin or gastrointestinal tract.

It is common that the same substance enter organism in more different way (Beseda, 1999).

Absorption

Mercury can enter into the living organism in various ways. The possibilities of absorption after getting into contact with living organism through various ways are displayed in table 1.

Table 1 The amount of adsorption after the contact through various ways (Smith, 1996)

Forms of mercury	Ingestion (oral)	Dermal contact	Inhalation
metal in thermometers	very low for liquid form	medium for volatile form	high for volatile form
inorganic in cosmetics as an addition	low to medium (higher for infants and children)	low to medium	low to medium
organic methyl mercury, accumulation in fish	low	low to medium	high

Penetration through lungs – inhalation

Inhalation of harmful substances is the most important gateway of entering organism together with breathed-in air. A certain amount of breathed-in substance is caught in lungs and then absorbed, another part is breathed out. In the respiratory apparatus gasses, vapours and small soluble aerosols are absorbed.

The amount of inhaled substance though lungs depends on more factors, for example on physica-chemical character of the absorbed substance, its solubility in water and in fats, volatility and so on. It also depends on the work intensity, age and health condition of the exposed person (Beseda, 1999).

Exposition to metal mercury is primarily and most often caused by evaporation of mercury in industrial use and by exposition to vapours of Hg from dental amalgam and liquid Hg in households. Evaporations of Hg in households are usually caused by breaking a thermometer of thermostat, where silver metal Hg evaporates. Short-term exposition to high concentration in air is presented by pains in chest, bronchitis and pneumonia. In literature we can find notes about a vast epidemic among workers in goldmines, who were intoxicated by metal mercury in Amazon forest during extraction processes when processing gold (Branches and team, 1993). It is known a casuistry of a person intoxicated by mercury in a goldsmith´s workshop. Concentration of mercury in air ranges between 1 to 5 $\mu g.m^{-3}$ in the country and from 7 to 10 $\mu g.m^{-3}$ in cities. Increased amount is present in air in industrial areas, around incinerators and crematoriums (Rosival and team, 1992, Kolenič, 2003).

Penetration though digestive apparatus – gastrointestinal route

Entrance of harmful substances through this way into the organism is often cause by negligence of workers. They do not clean their hands enough or at all when they consume food. Much information about chronic and acute intoxications in this way has been learnt by comparing real cases. This fact emphasizes the inevitability to keep all safety precautions when working with toxics and harmful substances (Beseda, 1999).

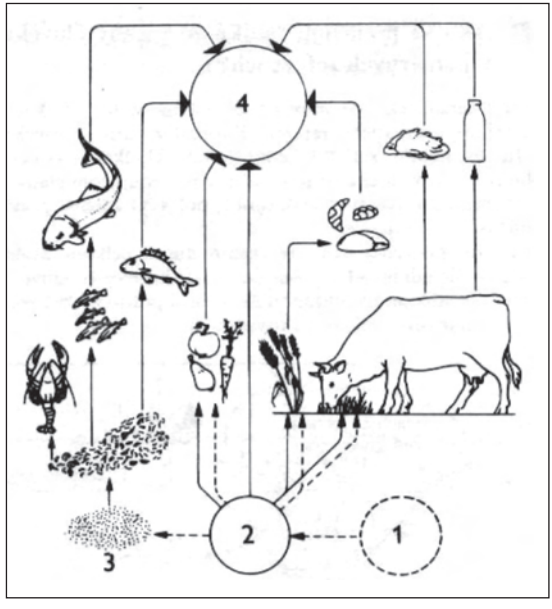
Picture 2 displays contamination of the environment by chemical substances as industrial waste, toxic metal, pesticides, industrial emissions and others. They enter the

soil, water and in this way also into the food chain and consequently they get into the digestive apparatus with food (Tőlgyessy and team, 1989).

Mercury, its inorganic and organic compounds belong among foreign substances in food. They get into food from soil, water and air as contaminants, that means as substances added into food unconsciously. The presence of mercury and its compounds in food can have a negative impact on human health and health of animals (Nuttal, 2004; Kimáková, 1999; Kimáková, 2005; Kimáková and Bernasovská, 2007a; Kimáková and Bernasovská, 2007b).

Because the entrance of mercury together with food is more significant than any other way, mercury has great significance as a contaminant of food in the whole balance of organism. Between the quality of food (its contamination by mercury) and the healthy state of population there is a direct rule of proportion. Toxicity of inorganic mercury is dues to consumption or direct contact with skin and inorganic mercury. It can appear as a result of transformation of metal Hg onto inorganic (Smith, 1006, Kimáková and Koréneková, 2004, Kimáková and Bernasovská, 2007a, b, Kimáková and Bernasovská 2005a). Mason and team (2001) point out the possibilities of non-professional exposition to mercury in terms of the number of dental amalgam fillings, especially in combination with chewing a gum and scrunching teeth. In these cases Hg is released from amalgam fillings.

Chloride mercury, when taking a large doze and concentration with water in more than 10 %, causes stomach cramps and anuresis. After the exposition through this form it also appear in tubular cells of kidneys. A loss of these cells causes afunction of kidneys, albuminuria and retence of liquids starts. As a consequence of the shock and disorder of kidneys it can lead to death in 24 hours. In the past intoxications were often the results of using calomel as an ingredient of toothpastes (Smith, 1996).



Picture 2 Scheme of food chain, through which toxic substances get from soil into human body. (Tőlgyessy and team, 1989).
1 – soil, 2 – water, 3– plankton, 4 – human being

Intoxications by organic mercury are primary common as a result of food contamination by methyl mercury. We state some cases, where unconscious contamination of food chain occurred followed by consumption of the contaminated food.

Iraq – a harvest treated by pesticides with that contented methyl mercury was accidently use for bread production, the main source of food (Bakir and team, 1973).

Japan, Canada and New Zealand – the main source was fish contaminated by methyl mercury (Takeuchi, 1975, Mc Keown-Eyssen and team, 1983, Kjellstron and team, 1986, 1989).

Faroe Islands – contaminated fish and whales (Grandjean and team, 1992, Dalgard, 1994).

Area of Mediterranean Sea – fishermen and their families are exposed to various concentrations of mercury coming from fish (Franchie and team, 1994).

USA – families of farmers were seriously affected by consumption of pork, which was feed by crops contaminated by methyl mercury (Davis and team, 1994).

Penetration through skin – physical contact

The entrance of harmful substance into the orgasm through skin is often underestimated. Serious intoxications of acute or chronic character in this way can be caused by both inorganic substances and their compounds (toxic metal and the like), or organic substances, especially by those that are well soluble in water and at the same time in lipids. This way of penetration can become significant especially in case of highly toxic substances, where even a protection mask with functioning filtrations does not need to provide sufficient protection.

Usually in common working process there is not enough attention paid to the possible penetration of chemical substances through skin, which can, in some cases, lead to serious damage of health (Beseda, 1999).

Kolenič (2003) describes a case of serious intoxication after having a cream with 10 % of $HgNH_2Cl$ applied on skin when treating rash. After three weeks of application (together 4 g of mercury) a serious damage CNS with polyneuropathy and nephritic syndrome. Damage with photoallergy was registered after having a tattoo by vermilion done.

Inorganic compounds such as calomel (mercurous chloride) were used in medicine as parts of lotions and cosmetic products (creams, face lotions, body lotions, soaps) or medicals for treating hyperpigmentation. They were used in treating syphilis. White precipitate was used in ocular medicine as antiseptics (Krätsmar – Šmogrovič and team, 1994).

Mercury compounds were a part of various cleaning and disinfection products (internal, external). Alkaline mercuric cyanide was used in disinfection in a form of diluted solutions.

Compounds of mercury are a component of dry batteries that are used in appliances for those who are hearing-impaired (Kolenič, 2003).

Parenteral penetration

Parenteral gate of entering a biologically effective substance or harmful substance is other way of entering organism than through digestive apparatus – such as through injection, intravenously, subcutaneously and intraperitoneally (Beseda, 1999).

Davidson and team (2004) stated that, for some years, vaccines against convulsive tussis, diphtheria, tetanus and Haemophilus influenza type B and hepatitis B, served

parenterally, were preserved with a small amount of thimerosal, which included 49 % of ethylated mercury.

In literature there are data concerning a curious case of a nurse who injected 2 ml (27 g) of metal mercury into her vain with suicidal tendencies. Great amount of the mercury gathered in the right ventricle, where it formed a small "pond", which was discovered by RTG examination. The person died a few years later from tuberculosis (Klein and Bencko, 1997).

Transport of mercury in organism

Individual forms of mercury are distributed and metabolized in various ways after entering the organism, as displayed in table 2.

Table 2 Mercury in organism (Smith, 1996).

Forms of mercury	Trapping of mercury in organs	Transformation into other forms	All-body decomposition (months)	Primary excreting
metal	kidneys (most often) brain fetus liver	inorganic	**1 – 2**	stool (most often) inhalation urine
inorganic	Kidneys (most often) liver brain (in case of high flow with transformation)	Metal organic	**1,5 – 2**	urine (most often) stool into hair milk
organic	Kidneys (most often) brain fetus liver muscles	inorganic	**2 – 4**	stool (most often) urine into hair milk

Through inhalation or through skin in vapour mercury is well resorbed into blood, through which it can be transported into individual organs, including brain. It penetrated into erythrocytes, where it is easily transformed into an inorganic form. Inorganic mercury is then baldly released into blood plasma and links with the protein transformers or stays in erythrocytes. Metal mercury is transformed into inorganic mercury in brain or in embryo followed by comulation.

After oral transmission of inorganic salts of mercury the concentration starts. Hg is present in mucosa of all the digestive system, the most in mucosa of intestanes. Inor-

ganic mercury that got into blood from intestines is cumulated in large amount in kidneys and livers. Only a small amount gets into the brain, the same it is with placenta.

Organic compounds of mercury have a greater ability to penetrate through biological barriers, including the hematoencephalic. Distribution of organic mercury into organs is therefore more even after peroral transition. It is also cumulated in brain tissue in a significant amount. Organic compounds of mercury easily penetrate through placenta and they are present in various concentrations in fetal organs (Bartík, 1985).

Dumont (1995) found out that within 48 hours after the exposition of organism to mercury there is a protein metalprotein cumulated in kidneys in larger amount. This protein binds mercury and therefore it cumulates is as well. There are changes in biological effect. The crated complex mercury-protein is great in size and is the reason for long-term excretion.

After some time mercury can dissociate and when released it can harm kidneys in time when the source of intoxication was eliminated. Kidneys are not only an organ where excretion of mercury happens, but they also trap it primarily and accumulate it.

Interaction with tiolon groups (SH enzymes) is considered as a biochemical base of toxicity of mercury. In case of low concentration of ions Hg2+ inhibit tens of enzymes. Various organs release accumulated mercury at different speed, however it was confirmed that kidneys and brain will be contaminated by Hg for the rest of life (Dumont, 1995).

Distribution of mercury

The extend of affecting organs is mainly connected with concentration of mercury. Its distribution depends not only on physical characters (Hg and organic compounds are lipophilic) but also on the anatomic structure of organs (Kolenič, 2003).

Histochemical studies have shown that mercury in intoxicated organism is distributed into all organs and tissues (in form of granules Hg), while the most significant concentration occurs in the centre of livers and kidneys (Kačmár and team, 1992). High concentration of Hg is in kidneys, which are the organ of their elimination (Kolenič, 2003).

Extraction of mercury

After absorption the exhalation of metal mercury is extracted through respiratory system, stool and urine. After being transformed in inorganic Hg it is extracted from the body through urine and stool.

Mercury is extracted through bile in a complex way together with glutathione and gets into the respiratory, salivary and lacteal glands. Extraction through urine is practically significant, which is irregular and last long after the exposition has finished. The values of 10 μg/l are considered as a prove of increased expositon (Kolenič, 2003).

Conclusion

Mercury belongs among heavy metals that are harmful to human organism even in the smallest amount. Presently it is possible to damage organism mainly through

getting into the body through food. That is why the issue of observing mercury and its compounds in the environment has a great significance, especially concerning monitoring mercury in food.

For the selected groups of people, where we include pregnant women, breastfeeding women, children, people permanently living in areas that are contaminated by mercury, workers of selected chemical factories, older people and patients suffering from disorders of kidneys, livers we do not recommend food with higher proportion of mercury – inner organs, sea fish (shark, swordfish, tuna, mackerels), plants and mushrooms from areas with high volume of mercury in soil. The threatened groups should prefer food with low volume of mercury – milk, dairy products, meat, fruit and vegetables that are grown away from affected areas.

VPLYV ORTUTI NA POŠKODENIE ĽUDSKÉHO ORGANIZMU

Abstrakt: Príspevok je zameraný na súvislosť vplyvu ortuti a poškodenia ľudského organizmu. Ortuť je charakterizovaná ako chemický prvok, sú popísané jej formy, toxicita, využitie. Ďalej s autorka venuje najvýznamnejším cestám vstupu ortuti do organizmu, jej transportným mechanizmom, distribúcii a exkrécii. Ortuť patrí medzi faktory, ktoré sú pre ľudský organizmus nebezpečné už pri minimálnej koncentrácii, jej hlavný príjem sa deje potravou.

Kľúčové slová: Ortuť, zdravie, riziko, príjem, metabolizmus, distribúcia, exkrécia, toxicita, potrava, poškodenie