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BIOLOGICAL INFLUENCES OF MERCURY ON LIVING ORGANISMS

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ABSTRACT:

Human Beings have been exposed to heavy metals for an immeasurable amount of time. The industrialization of work has dramatically increased the overall environmental load of heavy metal toxins to the point that our societies are dependent upon them for proper functioning.[1] Industry and commercial process have actively mined refined manufactured, burned and manipulated heavy metals compounds and for a number of reasons. Today heavy metals are abundant in our drinking water, air and soil, due to our increased use of these compounds.[2] They are present virtually every area of modern consumerism from construction materials to cosmetics, medicines, processed foods, fuel sources and personal care products.[3,4]

It is very difficult for anyone to avoid exposure to any of the many harmful heavy metals that are prevalent in our environment.[5]While it does not appear that we are going to neither neutralise the threat of heavy metal toxicity in our communities nor decrease our utilisation of the many commercial goods, we can take steps to understand this threat and put into action policies of prevention and treatment that may help to lessen the negative impact created by these metals on our health.[6]

INTRODUCTION:

Mercury is generally found at very low concentrations and is very reactive in the environment. Total mercury levels are generally less than 10 ng/g in materials such as granites[7], feldspars and clays and in the range of 40 to 200 ng/g in soils, sediments that are not directly impacted by anthropogenic discharges.[8] Generally majority of mercury in aquatic systems is inorganic forms (about 95-99%) and is found in sediments rather in dissolved phase.

There are about natural anthropogenic sources of mercury to the environment.For example mercury is a trace component of many materials and economic ore deposits of mercury occur as native mercury and as Cinnabar (HgS).[9] Various industrial discharges coal combustion, medical waste, incineration are important anthropogenic

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sources. Abundant mines where mercury was used for extraction purposes are also important sources.[10]

In organic mercury exists in three know ox nidation states as elemental mercury (Hg). As Mercurous iron (Hg^{+}) as mercuric iron (Hg^{++}).[11] The oxidation state of mercury in an aqueous environment is dependent upon the redox potential the pH and the nature of the anions and other chemical forms present with which mercury form stable complexes.[12] Mercurous compounds (Hg^{+}) are not common as they are rapidly oxidised to mercuric forms (Hg^{++}) by hydrolysis.

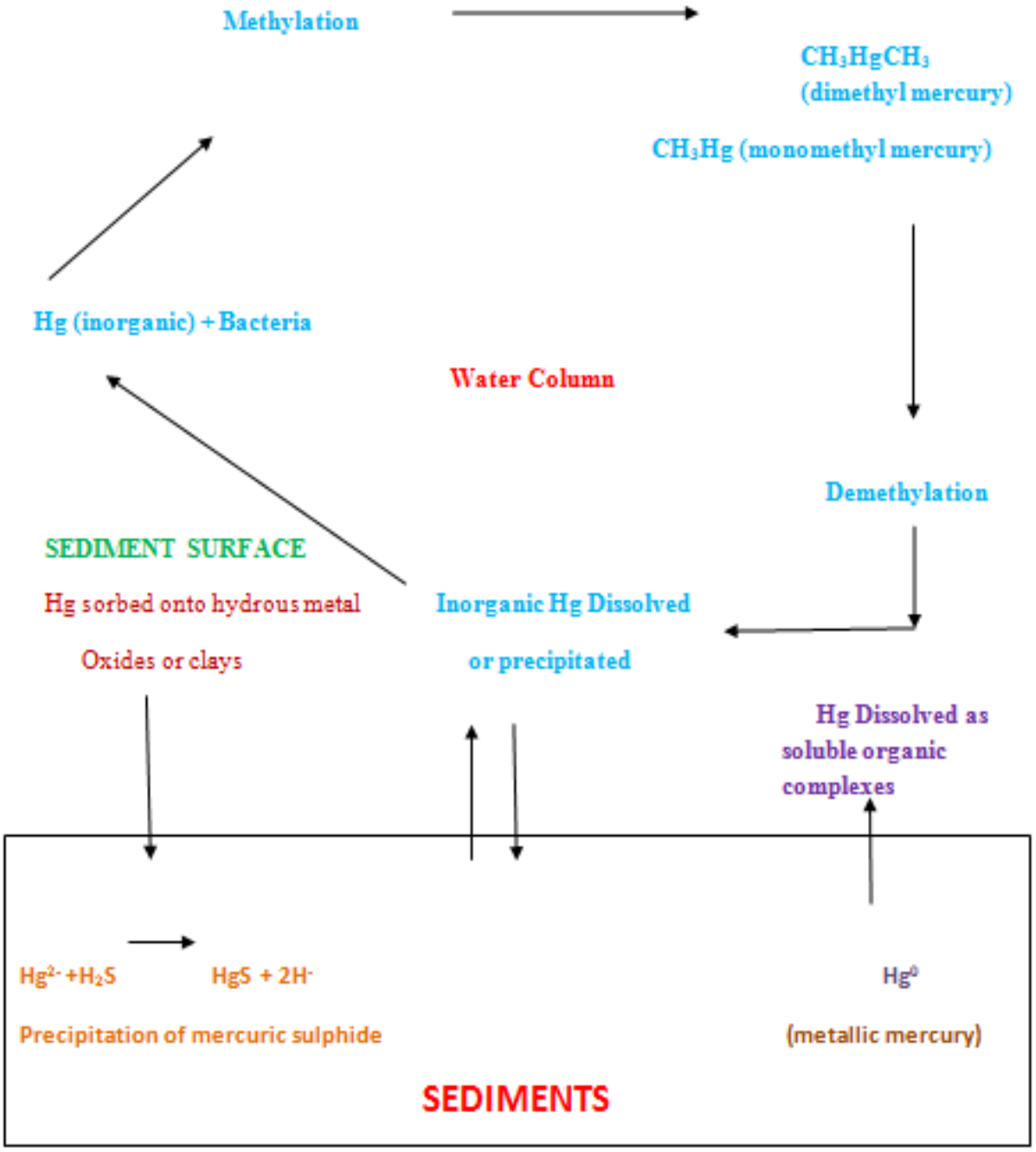

Figure 1: Key process that affects the speciation and mobility in aquatic systems

Figure (1) summarizes the key process that may affect mobility of mercury and methylation of mercury in receiving environments. The presence of organic matter in the sediments can either enhance mercury mobility by forming soluble organic complexes, or retard mobility, by creating an environment conducive to precipitation of mercuric sulphides.[13] The presence of iron oxy hydro oxides (precipitated form sewage waters) at sediment surface may also scavenge mercury by sorption onto hydrated oxyhydrooxide surface.[14] In general the sediment water interface tends to accumulate inorganic mercury and both pore water and water column are possible sites of mercury methylation.[15]

Mercury is not destroyed by metabolism but rather converted to different forms and oxidation states. The metabolism of mercury and mercury compounds appears to be similar for animals and humans, and involves and oxidation reduction cycle.[16] Inhaled mercury vapour rapidly oxidized to the divalent form in red blood cells.Oxidation of elemental mercury also occurs in lungs of humans and animals, and some evidence suggests hepatic- mediated oxidation. Animal studies suggest that the divalent inorganic mercury cation may be further reduce to elemental mercury.[17] Organic mercury compounds are also converted to divalent mercury by cleavage of the carbon – mercury bond with subsequent metabolism occurring via the oxidation reduction cycle. Aryl mercury compounds (for Eg: Phenyl mercury) undergo this conversion more readily than do the short chain (methyl) mercury compounds.[18]

Speciation and mobility of mercury in aquatic systems

An important characteristic of mercury is its low solubility as a result of its high probability to coagulate, i.e. to be removed from the soluble aqueous phase.[19] This can occur by a number of physico-chemical processes, e.g. precipitation as mercuric sulphide, co-precipitation with hydrated iron and manganese oxides, complexation with organic matter etc.[20]

The solubilization / coagulation of mercury depends on the forms of mercury present, on the amounts and nature of organic inorganic matter present as well as of the environmental conditions for eg: pH, chloride levels. [21] Balogh etal showed that mercury levels in water are strongly correlated with total suspended solids concentrations, suggesting that mercury can remain suspended in water column attached to the colloidal and particulate matter.[22] In aquatic systems, dissolved mercury can be partitioned between inorganic and organic forms and this is largely controlled by rates of methylation and demethylation by micro-organisms. Organic mercury can occur as as organomercuric salt (RHgx), for eg: methyl mercuric chloride or as an organo mercuric compound (R2Hg) for eg: dimethyl mercury. While the majority of mercury in aquatic ecosystems in the inorganic form (about 95% to 99%), organic mercury complexes remain important influences on the mobility and bioavailability of mercury.[23]

Evidence suggests that, when dissolved mercury in natural water systems exists mostly in organic forms, a high level of mercury in fish tissues is observed. Mercury methylation is a biologically mediated process between dissolved inorganic mercury and primarily sulphate reducing. The factors that influence the amount of methyl mercury present in aquatic system include the amount in organic mercury and physiochemical characteristics of aquatic systems such as pH, organic matter dissolved sulphate and sediment sulphide.[24] For Eg: mercury methylation activity in sediments was found to be positively correlated with the level of organic matter.Thus an aerobic zones such as basins of small lakes, flooded forests soils and water lands provide ideal condition for mercury methylation.[25] However the science of mercury methylation and demethylation is not fully understood and rates of methyl mercury formations are not readily predictable.

The relative abundance methylated mercury species is of particular concern since these compounds are highly toxic, they are the major form of mercury that accumulates in fish tissues, and they can enter the food chain by direct uptake from solution.[26] Two aspects of chemical structure confer the unique toxic properties of methyl mercury. The bond between mercury and the methyl group is stable with the methyl group providing a lipophilic character to the compound, while Hg(II) has a tendency to bind with sulfhydryl (or selenol) groups. Consequently, methyl mercury is both membrane permeable and thiol reactive, properties which contribute to toxicity, the long biological half-life, and the tendency towards bioaccumulation of mercury in aquatic organisms.[27]

The organo mercuric salts exhibit properties and reactions similar to those of inorganic mercuric salts and thus do not bio accumulate as well as methyl mercury.The organo mercuric compounds other than methyl mercuric species are generally subject to abiotic environmental degradation, being volatile thermally and unstable and light sensitive. eg: decomposition by ultra violet radiation to elemental mercury and free radicals.

Effect of mercury on Human life

Reproductive effects

Excess quantity of mercury can cause infertility, miscarriage and premature births. Mercury lowers progesterone levels which is needed to allow the uterus to support pregnancy. Progesterone insufficiently can be associated with low libido (sexdrive and pre-menstrual syndrome PMS). [28] Low progesterone levels can lead to infertility. Infact PMS and infertility are common among young female dental workers due at least in part to their mercury exposure.

Male dental workers also have a relatively high incidence of infertility. Mercury also leads to lower testorone(maleharmone) levels. Both progesterone and testosterone production are zinc dependent. Mercury interferes with zinc metabolism and thereby indirectly affects hormone production.[29]

Mineral displacement

Mercury (usually with a +2 charge) can grab the biological spaces that should be filled by another essential mineral. As a result, there may be plenty of the mineral found in the blood, urine, hair, etc. but due to the displacement at the active sites; mercury interfaces with the activity of the essential mineral. Symptons that can be caused by a deficiency of minerals displaced by mercury include:[29][30]

- Magnesium: irregular heartbeat, chocolate cravings, cramps, PMS, receding gums, elevated blood pressure, etc.
- Iron: Anemia, fatigue etc.
- Copper: Anemia, thyroid dysfunction, impaired digestion, easy bruising, etc.
- Zinc: Anorexia nervosa, loss of taste and smell, loss of appetite, low libido, PMS, impaired growth, acne and other skin disorders, etc.
- Iodine: Thyroid dysfunction, thickened bile, etc.

Digestive effects

Mercury acts as an antibacterial and has been used in some medicines (vacines, eye drops, etc. as a preservative). Mercury could be an important cause of bowel yeast or parasite overgrowth due to killing of beneficial bacteria which normally repels parasites and aid indigestion.[31] Yeast overgrowth with its attendant symptoms of fatigue, sweets cravings and vaginal infections is often traced to the antibiotic effect of dental mercury. Suspect this as a root cause when yeast is a continuing problem inspite of repeated treatment. The symptom (yeast overgrowth) will not likely go away until the root cause (mercury) is dealt with.

Thyroid Problems

Problems of low body temperature often improve when mercury- containing amalgams are removed. Normal body temperature is about 98.6^0 F orally. Those with a body temperature range 96.2 to 97.6 degrees are often considered

to have hypothyroid (low thyroid function).[32] It has been observed that their temperature can rise to 98.2 in as little as one day after amalgam removal and to 98.6 soon afterward. It is plausible that a low body temperature, which can be a sign of low thyroid function, is another symptom caused by mercury. Of course it would be far better to correct the cause of the apparent thyroid malfunction by removing the fillings or other cause responsible for the low body temperature, rather than prescribing thyroid hormone.[33]

Brain and Learning

Birth defects involving the brain and learning ability can be caused by mercury, as the metal can pass through both the placental barrier into the fetus and the blood- brain barrier. Accumulation in the brain leads to mental and nervous system effects such as brain fog, depression, vision difficulties, and others as listed above.

Mental effects are among the most common due to mercury's strong affinity for the brain. Mercury inhibits the effects of certain neurotransmitters:[30] [33]

- Dopamine: Controls pain, well being.
- Serotonin: Relaxation, sleep, well being.
- Adrenaline: Energy and stamina.
- Noradrenaline: Melatonin (Sleep cycles)

Inhibition of these neurotransmitters by mercury can account in part for the feelings of depression and loss of motivation.

Other mental / neurological symptons include:

- General neurological symptons
- Mental illness
- Demyelinization, which can lead to such diseases as multiple sclerosis (MS)
- Developmental problems
- Cerebral Palsy
- ALS (Amyotrophic lateral sclerosis, or Lou Gehrig's disease)
- Alzheimer's disease
- Psychological problems, including loss of function and memory, anger and emotionality, and timidity

Mercury effect on energy

Mercury binds to nitrogen and sulfur in protiens, oxygen from lungs, sulfur from liver's detoxification systems, and selenium from the colon. Lower levels of body tissue oxygen due to mercury's binding it may lead to:[34]

- Fatigue caused by low blood sugar secondary to low blood oxygen.
- Parasite infestation by setting up an anaerobic (less oxygen) environment, and by lowering the level of good bacteria which fight off parasites.
- An anaerobic environment also favors the development of yeast infections and cancer, since yeast is a fermenting spore and cancer is a fermenting cell rather than a normal respiratory (oxygen using) cell.

Mercury binds with hemoglobin, which is located inside the red blood cell and carries oxygen for transport to tissues. Mercury bound to hemoglobin results in less oxygen carrying capacity of red blood cells and therefore less oxygen will reach the tissues. The body senses need more oxygen and may attempt to compensate for this by increasing the production of hemoglobin. A normal or increased hemoglobin level combined with symptoms of lack of oxygen(fatigue, weakness, appearing pale, rapid heart rate, shortness of breath etc) could indicate mercury toxicity. This can confuse the doctor since patient seems like they are anemic, but infact the blood count seems fine.[35]

The activity of other minerals on metabolism and energy production can be reduced by mercury's tendency to fight for sight.[32] A deficiency of the function of minerals can lead to fatigue and other symptoms;

- Mercury blocks magnesium and manganese transport required for memory, resulting in lowered ability to concentrate.

- Cobalt, calcium, magnesium, potassium and sodium are all required for energy.
- Zinc is needed for manufacture of adrenaline.
- Cobalt, a component of B12 prevents pernicious anameia, which can cause fatigue.

These mineral deficiencies may be primarily due to dietary deficiencies. However, deficiencies may also be secondary.[36] The mineral may be in the body, but cannot get to where it is needed because mercury has blocked the way. This is like putting a two large battery in a toy- it won't fit in the slot made for a smaller battery, both denying power to the toy and blocking the slot from receiving the correct size battery. For this reason, knowing the mercury load is critical to understanding the mineral balance in the body. Lab test can only tell the levels available - they do not tell if the minerals are performing their function in the body.[37] Symptoms and physical signs can often be helpful in clarifying the illusion that the "labs are all normal…"

Increased toxicity

The mercuric ion (Hg^{+2}) binds to sulfhydryl groups (-HS) in proteins and disulfide groups (-SS) in amino acids. Mercury from amalgam binds to –SH (sulfhydryl) groups which are used in almost every enzymatic process in the body. Mercury therefore has the potential to disturb all metabolic processes. The sulfur containing groups have an important detoxification function in the body by binding to a variety of chemicals, toxins, minerals, etc. Mercury binding to these sulfur groups may prevent them from detoxifying the chemicals.[32][35] Mercury binding the bile lowers the ability of the body to absorb fat, leading to increased absorption of toxic oil-soluble chemicals such as solvents and pesticides like a dry sponge.

Selenium is an antioxidant which binds in place of oxygen which protects against the radical damage from chemicals which can lead to cancer. Mercury can bind to selenium, making it useless for this protective purpose.

What else mercury can do

Mercurous ion (Hg+) pushes out Na^+ (sodium), K^+ (Potassium) and Li^+ (lithium). Sodium and potassium are part of the cellular sodium / potassium pump which causes muscle movement. Interference with sodium and potassium can lead to muscle weakness for this reason. Leg and muscles, cramps maybe due to potassium deficiency.[38]

Lithium is sometimes given as lithium carbonate to patients suffering from bipolar depression (manic depressive illness). Since lack of lithium is one of the causes of disease. Lack of lithium may itself be caused by mercury, preventing lithium from working as it should be in the brain. Mercury is like the two hundred pond bully attacking a seven pound baby; the small baby doesn't have much of a chance.[39] Two hundred and seven are the molecular weights of mercury (the bully) and lithium (the baby) respectively .If you have been diagnosed with bipolar depression, maybe what you need is less mercury, not more lithium pills.

Mercury fights for binding sights in the kidney, another organ for which it has a special affinity. A mineral and electrolyte balance is needed in order for the kidney to perform functions, and a poorly functioning can lead to edema (fluid build up in the body).These minerals are prevented from entering into their reactions when mercury is there to interfere. [40] Suppression of potassium by mercury also affects the kidneys which take you form making adrenaline to maintaining a electrolyte balance and the lowered adrenaline level can lead to lower energy.

Detoxification systems such as metallothionein, cytochrome P-450 and bile are adversely affected by mercury. Metallothionein binds toxic metals in the body to prepare them for excretion. Mercury ties up this material so it cannot clear out other metals such as lead, cadmium, and aluminium.[41]

Some people appear to be allergic to whatever food they eat. No matter what they eat, at least one thing is in common is ingested – mercury (or nickel). Mercury released from amalgam during

chewing maybe the cause of most symptoms which seem to be caused by the food. It may show a low to moderate level of mercury initially, but sharply increased level after chewing gum.[42]This is also what happens when food is chewed. Such a test result combined with apparent allergy to most food points to mercury as a probable culprit. Nickel, which may also be contributing to the problem, is in stainless steel dental posts and braces.

Political agreement

The continued release of mercury into the environment from human activity, the presence of mercury in the food chain, and the demonstrated adverse effects on humans are of such concern that in 2013 governments agreed to the Minamata Convention on Mercury.[43] The Convention obliges government Parties to take a range of actions, including to address mercury emissions to air and to phase-out certain mercury-containing products.

WHO response

The World Health Organization publishes evidence about the health impacts of the different forms of mercury, guidance on identifying populations at risk from mercury exposure, tools to reduce mercury exposure, and guidance on the replacement of mercury-containing thermometers and blood pressure measuring devices in health care. WHO leads projects to promote the sound management and disposal of health-care waste and has facilitated the development of an affordable, validated, non-mercury-containing blood pressure measuring device.[44]

CONCLUSION

We are beginning to understand the threat that heavy metals and toxins are to our health. However, heavy metals toxicity is a condition that often goes overlooked in traditional medical diagnosis. While it is rare for individual to experience a disease or health condition solely form heavy metal toxin, it is reasonable to conclude that these toxins exert a dramatic effect on the health of an individual and contribute to the progression of many different debilitating conditions.

These effects range from simple gastrointestinal disturbances, to severe emotional and cognitive disturbances. Metal toxins have the ability to impair just not a single cell tissue, but many body's systems that are responsible for our behaviour, mental health and proper physiological functioning that we depend on sustained life.

If undetected these agents can cause a measurable pain and suffering for any afflicted individual. Fortunately there are avenues that an affected individual can pursue to detoxify heavy metals already in their system.

Popular therapies (known as chelation) today rely on intravenous solutions to help eliminate heavy metal toxins. EDTA and DMSA are two compounds that are being used for the removal of heavy metals today.

These therapies have been shown to be effective but also potentially harmful to many indiviuals. Alternatively chelation therapies have been developed that are safer than traditional therapies and may prove to be just as effective.

These therapies popularly known as oral chelation therapies rely on nutritional substances that have been shown to help detoxify heavy metals within thebody and help support body's overall health.

Heavy metal toxicity is frequently the result of long term low level exposure to pollutants common in our environment; air, water, food and numerous consumer products. Exposure to toxic metals is associated with many chronic diseases. Recent research has found that even low levels of lead mercury, cadmium, aluminum and arsenic can cause a wide variety of health problems.

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