Methyl Mercury: Sources, Impacts and Effects on Lake Water Quality

Krishna Ladwani[1], Kiran Ladwani[1], Ramteke D.S[2] and Wate S. R[2]

Environmental Impact & Risk Assessment Division, NEERI, Nehru Marge
Nagpur -440020, Maharashtra, India.
e-mail – krish_22_3@yahoo.com

ABSTRACT

Mercury is both a global pollutant and a contaminant that is to a potentially toxic species (Methyl mercury) under the natural condition found in the environment. Its compounds are present as the trace contaminants in various biological and environmental samples such as air, water, soil, animal tissue and coal fly ash as a result of both natural and anthropogenic activities.

Mercury is the metallic element that occurs naturally in earth crust, from degassing of rocks, soil, water and the volcanoes. Anthropogenic sources such as coal burning power plants, coal and other fossil fuel combustion, metal smelting, preparation of paints and lubricants, sewage and hospital waste incineration, have increased the amount of mercury on the surface of earth.

In lake water mercury can precipitate or undergoes the bioconversion to volatile and soluble form like methyl mercury. Mercury enters in the aquatic life from the atmosphere in its inorganic form which then converts to methyl mercury by some bacterial activities. Wetland lakes, sediments and anoxic bottoms are of the three locations where the methyl mercury is rapidly formed.

Methyl mercury is of greater concern because it accumulates in food webs to the levels that are toxic to fish and wild life. Methyl mercury is one of the neurotoxin that bioaccumulates in the fish it is also responsible for the severe neurological regeneration in animals. Peoples are exposed to methyl mercury almost entirely by eating the contaminated fish. Because of these processes, even a minuscule amount of mercury in water last can have adverse effects on aquatic organism and their predators. This paper highlight the potential sources effects and impacts of methyl mercury on human life and aquatic life in lake water quality.

INTRODUCTION

Mercury is naturally occurring in the environment. It is also known as quick silver. Mercury is a heavy metal, having atomic number 80, atomic weight 200, melting point - 38^{0}c and specific gravity of 13.55gcm-^{3}[6]. Mercury is liquid at room temperature.

Mercury is having three stable oxidation states 0, 1, 2 as elemental Hg, mercurous and mercuric resp [5]. It is existing in the three forms i.e. elemental mercury, inorganic mercury, and organic mercury [9].

Elemental mercury or metallic mercury: It is the element in its pure, uncombined form. It is a shiny, silver-white metal that is liquid at room temperature, but is rarely found in this form in nature.[14] Mercury slowly evaporates in to air, forming vapour. The quantity of Vapour formed increases as temperature rises. Elemental mercury is used in thermometers and some electrical switches.[11]

Inorganic mercury: These are most commonly found in nature, including the mercuric sulphide (HgS), mercuric oxide (HgO) and mercuric chloride ($HgCl_2$). Some mercuric salts such as mercury chloride also form vapour, but they stay in the air for a shorter time than elemental mercury because they are more soluble in water and more reactive.

Organic mercury: It is formed when mercury combines with carbon and other elements. Such as a methyl mercury, dimethyl mercury, methyl mercuric chlorides etc. The one of the form which is most commonly found in the environment and which is more toxic then other forms of the mercury is methyl mercury.[1]

In the sediments of river, lakes and oceans metallic mercury is transformed in to methyl mercury with the help of some micro organisms. Methyl mercury is a toxic organic compound this is important because methyl mercury bio accumulates through aquatic food webs. Almost all mercury in the fish muscle is methyl mercury; people are exposed to methyl mercury by eating the fish. This is the primary exposure for human and wild life. [10] ,[11]

Mercury concentrations in many regions of the globe have increased as a result of industrial activities. Mercury can occur as a localized issue near the part of release and as a longer range transbutaory issue atmospheric emission transport and deposition.[4]

SOURCES

Mercury is found every where in the air, soil, water. Mercury enters in the environment by both natural and anthropogenic sources:

Natural Sources

Natural sources of mercury include volcanoes, evaporation from soil and water surfaces, degradation of minerals, forest fires and the most common ore is cinnabar(α -HgS) which contains about 86.2% and meta cinnabar (β-HgS) or both (polymorphs of HgS) and fossil fuels such as coal and petroleum.[8],[17].

Anthropogenic Sources

Levels of mercury in the environment are increasing due to discharges from hydroelectric mining pulp and industries, emission from coal using power plants also contribute to high levels of mercury. Mercury release from ongoing human activities are grouped as follows:[17]

The important sources of anthropogenic release of mercury includes

1) Release from mobilization of mercury impurities
   - Coal fired power and heat production.
   - Energy production from other fossils-cement production
   - Mining and other metallurgic activities

2) Releases from intentional extraction and use of mercury
   - Mercury mining
   - Chlor-alkali production
   - Use of fluorescent lamps
   - Manufactures of products containing mercury e.g. thermometers, manometers.

3) Releases from waste treatment
   - Waste incineration (municipal, medical and hazardous waste), Landfills.

As mercury can be released in to air naturally by volcanoes and forest fires or as result of human activities such as coal burning and waste Incinerations ;then transport through the atmosphere over long distance and fall in to lake and forest with dust particles and rain so this mercury present in the inorganic form is relatively harmless because it is not readily assimilated by living organisms.[6]

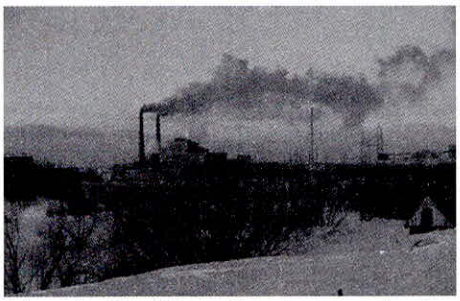

Fig. 1 : Coal burning power plants (anthropogenic source) (17)

Fig. 2 : Volcanoes (Natural sources) (17)

MERCURY IN ENVIRONMENT

As in the atmosphere Hg vapours are slowly converted by oxidative process to divalent mercury which is then returned to earth surface by rainfall ,where it gets accumulates in the soil and water, some of Hg is then converted back to Hg0 (mercury

vapour) and returned to the atmosphere.[9] However the other fractions of the mercury (HgII) are washed in to the river ,streams, lakes, ocean where it is accumulated in to aquatic sediments. Hence inorganic mercury is converted in to methyl mercury by the process known as methylation.[16]

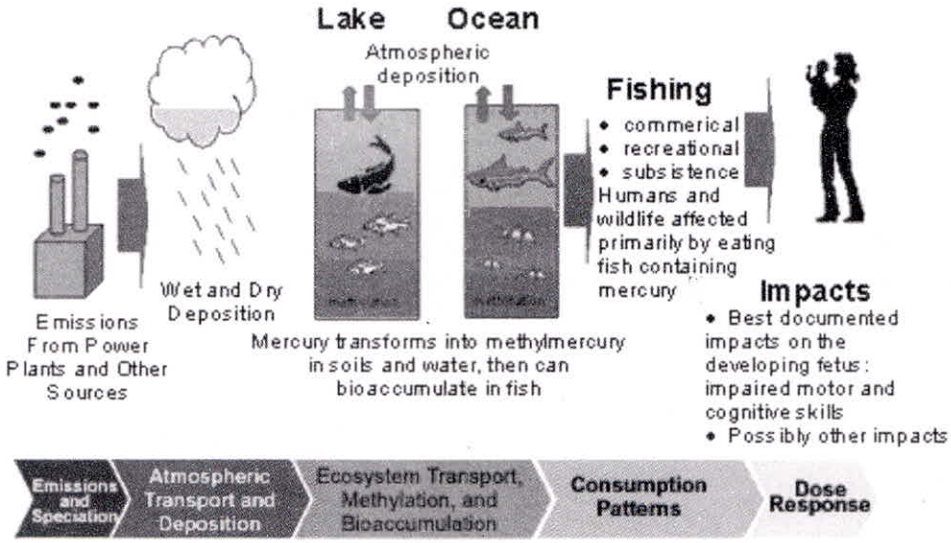

Fig. 3 : Mercury in Environment

(Source: http//www.Human%20Exposure%20%20Mercury%20%20US%20EPA.htm)

METHYLATION OF MERCURY

The methylation of mercury is the process which is generally carried out by the group of micro-organisms particularly methanogenic (methane producing)and sulphate dependent bacteria. Aerobic and facultative anaerobic bacteria .Species of methylating mercury include klebsiella pneumonia, E.coli,clostridium cochleeararun are thought to be involve in the conversion of Hg2+ to Methyl mercury under the anaerobic conditions.[8]

$$\underset{\text{Reduction}}{Hg^{0}} \xleftarrow[\text{Oxidation}]{} Hg^{+1} \quad \text{or} \quad \underset{\text{Demethylation}}{Hg^{+2}} \xleftarrow[\text{Methylation}]{} HgCH_3$$

Methylation occurs primarily in aquatic, low pH(acidic)and at high temperature. Total methylation is dependent upon the pH; at low pH more methyl mercury is formed while at the higher pH conditions dimethyl mercury formation takes place.[4] Dimethyl mercury will not be stable at all but long before this condition seems to be favour the organisms that produces the monomethyl mercury rather than the dimethyl mercury.

accumulates in fish and shell fish by the process known as biomagnification[18]. It is the process through which the methyl mercury concentration increases as it moves from one tropic level to another. As the large predatory fish consume many smaller fish, concentration of methyl mercury in their tissues increases.[2] The older and larger the fish, the greater the potential for high mercury levels in their bodies. These fishes are caught and eaten by the human and animals causing methyl mercury to accumulate in their tissues. As the methyl mercury is very toxic so it causes the adverse impacts on human and wild life.[18][16]

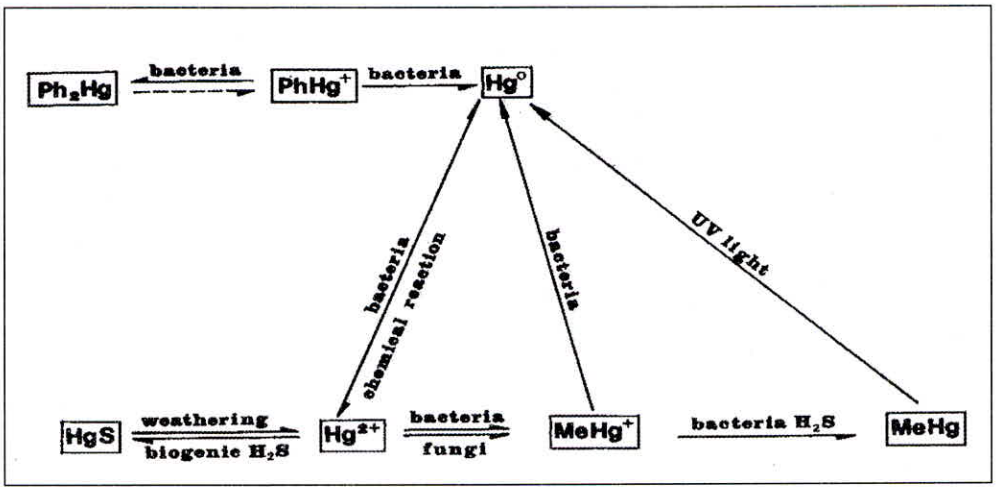

Fig. 4 : Mercury Transformation by Microbes and Chemical or Physical (10agents

(Source : mercury in eco system 1986 [10])

IMPACTS OF METHYL MERCURY

Methyl mercury is very toxic to living organisms. Although 10% of mercury in water is methyl mercury, it is very soluble, mobile and bio accumulative. Mercury becomes the more toxic to higher organisms in food chain because it biomagnifies. Methyl mercury is absorbed through the intestine of humans and distributed through body. It readily enters in brain, where it may remain for a longer period of time. In a pregnant woman, it can cross the placenta in to the fetus, building up the fatal brain and the other tissues.[13][12] Scientific evidences shows that exposure to methyl mercury is more dangerous for young children than for adults. Aside from differential behaviours and a higher proportion of air, food and water intake relative to the body size, the immature or developing organs and systems of children are less able to eliminate mercury[3].

1) Chronic exposure of methyl mercury to adults affects the central nervous system and symptoms includes the memory loss, behaviour changes, paresthesia, blurred vision, malaise, speech difficulties etc.

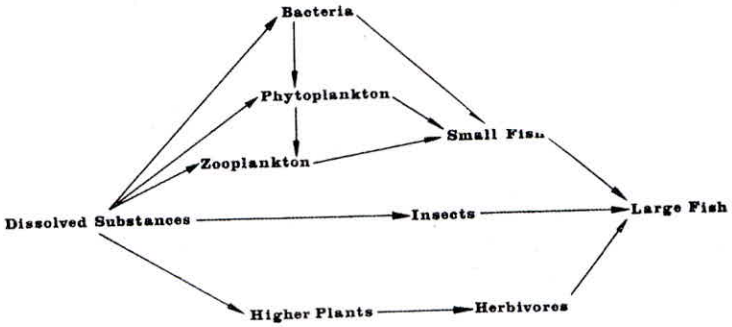

Fig. 5 : Diagrammatic representation of the flow of Mercury through an aquatic food chain Aquatic food chain

(Source: mercury in eco system, 1986 [10])

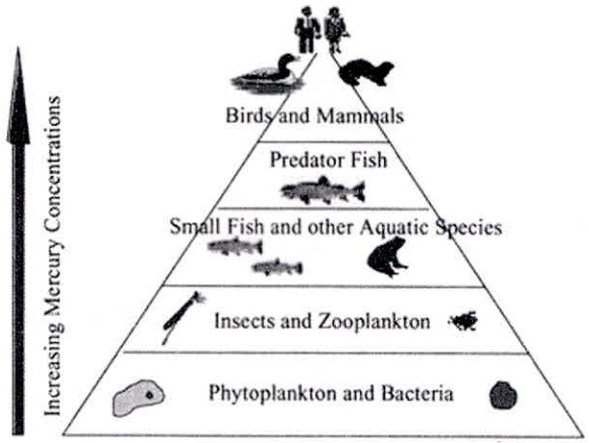

Fig. 6 : Accumulation of Mercury in the Food Chain [20]

2) Acute exposure to high levels of elemental mercury affects the CNS and kidney and causes the symptoms such as insomnia, memory loss, neuromuscular changes, headaches, slowed sensory and motor nerve functions.
3) Infants may effected by the methyl mercury they shown to be exhibit CNS effects may such as mental retardation ataxia deafness.

Methyl mercury also affects the wild life. Some known effects of mercury to the wild life are as follows:

1) Reproductive failure
2) Impaired muscular coordination
3) Behavioural abnormalities (e.g. running in circles)
4) Abnormal vocalization[3]

Thus general condition is that at a low pH more of the methyl mercury will be mono methyl mercury and stay within the system[8]. Acid rain may increase the biomethylation as more MeHg is formed under the acidic conditions. The form of the mercury in the environment varies with the season, changes in organic matter, nutrients and oxygen levels and hydrological interactions within an ecosystem.[15]

ACCUMULATION OF MERCURY IN FOOD CHAIN

In lake water mercury is converted in to methyl mercury by bacteria and the other process. It enters in the food chain through phytoplankton's species. Phytoplankton are then eaten by plankton consumers which are eaten by larger fishes MeHg mercury) killed hundred peoples and genetically damaged a large population. The minamata incident was followed by a more tragic report of Hg poisioning from Iraq in 1972 were 450 villagers died after eating wheat which had been dusted with a mercury containing pcaswesticides. These two tragic events boosted the awareness of hg as a pollutant so that is was studied more extensively then any other toxic element. [21]

Table 1 : Factors influencing the methylation of mercury in aquatic ecosystem [7]

Sr. No	Physical or chemical conditions	Influence on methylation
1	Low dissolved oxygen	Enhanced methylation
2	Decreased pH	Enhanced methylation within the water column
3	Decreased pH	Decreased methylation in sediments
4	Increased dissolved organic carbon	Enhanced methylation within sediments
5	Increased salinity	Decreased methylation
6	Increased nutrient concentration	Enhanced methylation
7	Increasd temperatures	Enhanced methylation
8	Increased sulphate concentration	Enhanced methylation

CONCLUSION

The methylation, biomagnifications, bioaccumulations and toxicity of mercury are often linked to problem of increasing eutrophication. Increasing most of the factors that cause the eutrophication within water body including increased sulphate content also increased the rate of methylation and subsequent toxicity to human life and wild life.[7]

REFERENCES

1. aiche.confex.com/aiche/2007
2. http:/www.csa.com/discovery guides/discovery guides-main.php
3. www.epa.gov/mercuryexposure.htm

4. Ecosystem response to mercury contamination Edited by reed harris,david p.krabbenhoft,Robert mason,micheal w. mercury robbin reash temae staoman (Pg.no. 1-7)
5. Environment inorganic chemistry properties Processes and estimation methods Edited by itamar bodek,ph.D, William f.Rechl David h. Rosenblatt ,1988
6. Elements and their compounds vol.2 Edited by E. Merian M.Anke,M.ihnat and M.Stoppler,2004(Pg.no. 932-933,946-949)
7. Environment pollution science 2nd edition Peppler IL,Gerbs,C.P,Brussau MIL,2006 (Pg.no. 284-286)
8. Environmental mercury contaminantion H.artney R.H,1972
9. Heavy metals in the environment H.B.Bradl., 2004
10. Mercury in eco system S.Mitra,1986 (Pg.no. 199,89)
11. Mercury in the environment www.epa.gov/mercury/_19k
12. www.mercuryagrowing scourage.htm
13. Organic mercury compounds www.mercuryandhealth.htm
14. Mercury facts www.MERCvermontmercuryfacts.htm
15. Methylation of mercury Mercury and the environment and health biogeochemistry
16. Mercury in the environment http://www.csa.com/discoveryguides/discoveryguides_main.php
17. Sources of mercury Sourcesofmercury.htm
18. Mercury cycle People.uwecedu/.../Hg/mercury_water/cycling.htm
19. www.usgs.gov/themes/factsheet146-00/index.htm
20. www.whyfiles.org/2omercury/images/accumulation.gif
21. Water sci. Tech,23,(1991)