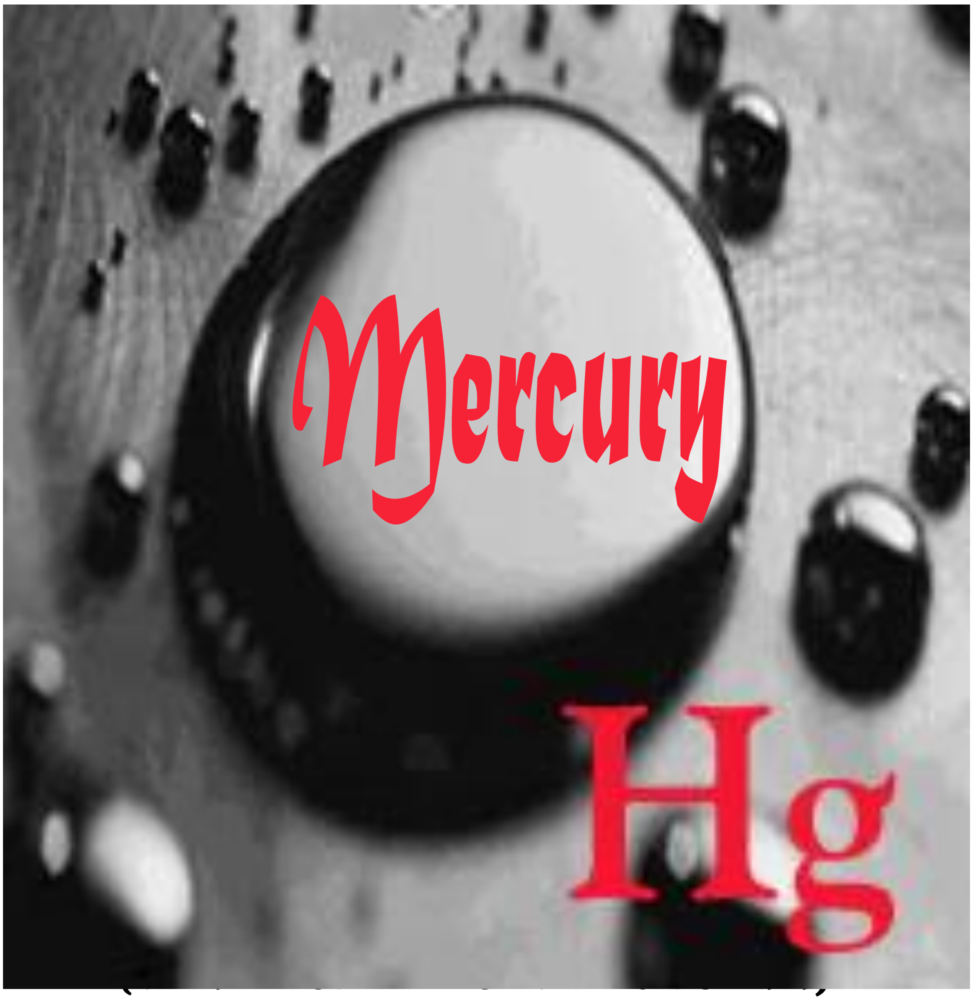
PARIVESH

MERCURY

- ENVIRONMENTAL IMPLICATIONS & TOXICITY



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FOREWORD

Mercury is the only liquid state metal, which finds very wide commercial application in industries, electrical appliances, mercurial catalysts, healthcare sector for extensive use in thermometers, sphygmomanometer, dental amalgams, agriculture for seed treatment, as laboratory reagents etc. Because of extensive commercial use, the mercury consumption in the country is quite high. The Mercury Cell process based Chlor-alkali industries are one of the major users and thus prime source of mercury release to the environment alongwith the coal-fired thermal power plants, plastic industries, pulp and paper industries, discarded medical instruments, used electrical appliances, electronic waste, certain pharmaceuticals and agricultural products.

The mercury is highly toxic in both forms (a) elemental; (b) compounds; irrespective of whether inhaled, ingested or absorbed through the skin. The microbes convert inorganic mercury of aquatic environment into methyl mercury and various organic mercury compounds. These compounds may be bio-accumulated and bio-magnified in food chain, particularly in the body tissue of fresh water and marine organisms and consequently get transferred to human beings. The Environmental issues of elemental mercury and its various forms, their toxico-kinetics and human health impacts have been widely documented. The mercury compounds are recognized as cumulative poison and are potent neuro and nephro toxic substances. Alkyl mercury has been known to cause permanent mental retardation.

The potential hazard of mercury and its compounds to human health demands strict regulations and standards. Recognizing the need of mass awareness for proper management of mercury in the environment, various aspects of environmental implications and toxicity of Mercury are highlighted herewith. Thankful acknowledgement is extended to my colleagues Dr. R. B. Lal and Dr. C. S. Sharma for compiling and collating the information under the supervision of Dr. S. D. Makhijani. The manuscript has been typesetted by Shri K. P. Srivastava.

Shri J.S. Kamyotra, Member Secretary supervised the issue.

Hopefully, the information contained in this issue will be useful to environmentally conscious community.

(S. P. Gautam)

17th November, 2009

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

NATURE, OCCURRENCE, DISTRIBUTION & CHEMISTRY OF MERCURY

Mercury is the only metal element, which is liquid at ambient temperature and sometimes called *Quicksilver* because of its silvery white appearance. It rarely occurs free in nature and is mainly found as bright red crystalline solid *Cinnabar ore (HgS)***.** Mercury is a heavy, odourless, lustrous liquid metal that sinks in water. It is mobile, ductile and converts into malleable mass on being solidified at –39 ^{0}C, which may be cut with a knife. There are about 1,501,430,636,558,496,585,414 atoms in 0.5 grams of mercury. Each and every atom of mercury is capable bio-chemically to disable an enzyme or other critical protein in our body. Thus, mercury has the potential to produce significant health effects through series of bio chemical reactions in our body.

Physical Chemistry of Mercury	
Chemical Symbol	Hg (Hydrargyrum)
Atomic Weight	200.61
Atomic Number	80
Valency	1 - 2
Density	13.456
Boiling Point	356.9 ^{0}C
Solidity	-39 ^{0}C

Mercury has very wide commercial and industrial applications. It is an excellent conductor of electricity, therefore it is widely used in electrical apparatuses i.e. meters, switches, batteries etc. Being highly mobile, it cannot be disintegrated into harmless components. In the industrial processes, mercury is actually not consumed, therefore whatever mercury is used comes back with wastes, effluents, air emissions or in the products. The mercury hazards have been recognized since last few decades due to environmental awareness. It is estimated that more than 90 percent of the mercury used in the industrial processes literally vanishes into various environmental components.

Chlor-alkali industries had been the major source of mercury release to the environment till sometimes back, because of obsolete technology. However, now all of the Chlor alkali industries except few are based on upgraded advanced and cleaner Technology viz. Membrane Technology which does not use mercury in the process. Because of which chances of mercury release from processes have been substantially reduced. Other industries, which contribute substantially to mercury pollution are coal fired industrial plants viz. thermal power plants, steel industries and cement plants. Plastic industries (mercury used as a catalyst), pulp and paper industry, medical instruments, electrical appliances, certain pharmaceutical and agricultural product accounts for significant consumption of mercury.

Elemental mercury is less hazardous than its other forms such as methyl mercury and other organic mercury compounds. Methyl mercury can translocate into air, soil and the food chain, mostly through aquatic organisms and become a health risk.

The average concentration of mercury in the earth's crust is about 0.07 mg/kg. More than 90% of the world's supply of mercury is provided by seven countries: USA, Spain, Yugoslavia, Italy, former Soviet Union, China and Mexico.

Salient Facts Related To Mercury

- Mercury is the most toxic substance known to mankind.
- Routes of exposure are inhalation or absorption.
- Elemental and inorganic mercury are methylated through bacterial action.
- Amalgam fillings are the largest source of methyl mercury in non-industrial exposed population.
- Approximately one gram of mercury in a typical clinical thermometer is enough to contaminate water body with a surface area of about 20 acres, to the degree that the fishes inhabiting there would be unsafe to eat.
- Each sphygmomanometer (blood pressure equipment) has approximately 60 grams of mercury.
- Mercury vapours from dental amalgam are the most dangerous form of mercury.
- Mercury can pass the skin, blood, brain and the placenta barrier and cause devastating health effects.
- The present total global mercury emissions into the atmosphere are 5000 tonnes per year, of which 80% are of anthropogenic origin.
- There are indicators showing 0.5 – 3.0 times increase in the anthropogenic emissions of mercury since pre-industrial times.

1.2 EXISTENCE OF VARIOUS FORMS OF MERCURY IN ENVIRONMENT

Mercury and its compounds exist in the environment in two forms:

- *Inorganic Mercury and its compounds*
- *Organic Mercury and its compounds*

The inorganic mercury is available either in mercurous (Hg^0) or mercuric (Hg^{2+}) form, while organic mercury is covalently bonded with alkyl or aryl groups.

The metallic mercury when enters in the aquatic environment, the bacterial action converts it slowly to methyl mercury, both the methyl mercury ions (CH_3Hg^+) and Dimethyl mercury $(CH_3)_2Hg$ are formed. Mercury is particularly dangerous in Organomercury compounds.

The inorganic mercury directly accumulates in body tissues, while organic mercury in form of aryl salts of mercury, breaks down into organic mercury in the body tissue. The alkyl salts of mercury, particularly methyl mercury is able to diffuse easily through the membranes and spread throughout the body.

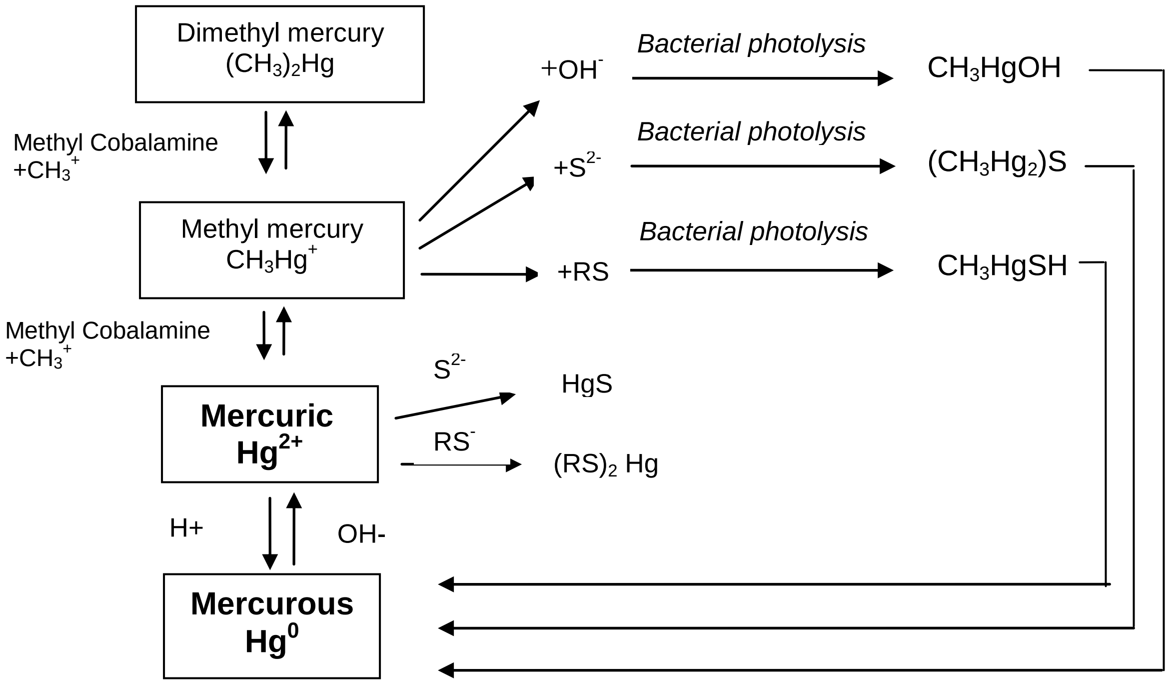


Fig. 1: Environmental Chemistry of Mercury in Environment

1.3 GLOBAL PRODUCTION OF MERCURY

Mercury is natural component of the earth, with an average abundance of approximately 0.05 mg/kg in the earth's crust, with significant local variations. The ores of mercury, which are mined generally, contain about one percent mercury. The estimates for global primary production of mercury, as reported by the US Geological Survey, are presented in Table 1.

Table 1: Estimated world production of primary (mined) mercury (metric tons)

Country	1981-85 *1	1986-89 *1	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Algeria	386-877	587-764	637	431	476	459	414	292	368	447	224	200	240
China	800	850-1200	1000	760	580	520	470	780	510	830	230	200	200
Finland *2	65-130	135-160	141	74	85	98	89	90	88	63	80	80	45
Kyrgyzstan	-	-	-	-	300	1000	379	380	584	610	620	620	600
Mexico	221-394	124-651	735	340	21	12	12	15	15	15	15	15	25

Russia	-	-	-	-	70	60	50	50	50	50	50	50	-
Slovakia /Cz	144-158	131-168	126	75	60	50	50	0	0	0	20	0	0
Slovenia	-	-	-	-	7	?	6	0	5	5	5	0	0
Spain	1416-1560	967-1471	-	-	-	643	393	1497	862	863	675	600	237 *3
Tajikistan	-	-	-	-	100	80	55	50	45	40	35	35	40
Ukraine	-	-	-	-	100	50	50	40	30	25	20	-	-
USA	570-962	140-520	562	58	64	W	W	W	65	W	-	-	15
USSR	1600-1700	1500-1650	800	750	**Country not in existence**								
Yugoslavia	0-88	51-75	37	9	-	-	-	-	-	-	-	-	-
Other countries	200-400	100-200	-	-	-	-	223	200	-	-	830	380	448
Totals for reported activity (rounded)	5500-7100	4900-6700	4000	2500	1900	3000	2200	3400	2600	2900	2800	2200	-
Derived by Hylander & Meili (2002)	5600-6100	6100-6600	6100	3700	3100	3000	2000	3300	2800	2500	2000	2100	1800

Ref: The US Geological Survey (Jasinski, 1994; Reese, 1997; 1999; unless noted; aggregation as presented in the Submission from the Nordic Council of Ministers) and by Hylander & Meili (2002) for the year 2000.

Notes and Legend:

W Withheld in the references
\- Not relevant or not available
/Cz Up to 1992 as part of Czechoslovakia
1 Reference: Metallgesellschaft (1992), as cited by OECD (1994). This reference's totals for 1990 and 1991 were 400-900 metric tons higher than the presented totals from USGS.
2 Numbers for Finland from 1990-1997 are from Finnish Environment Institute (1999).
3 Spain has reported a production in 2000 of 237 metric tons from the Spanish mercury mines.

1.4 Mercury Trade in India

Mercury is not geologically extracted in the country, but imported for commercial uses. Mercury and mercury containing wastes are included in the waste streams of the Basel Convention on trans-boundary movements of hazardous waste and their disposal. In order to control the movement of Basel wastes, the export and import of mercury bearing wastes has been banned under Schedule 8 of the Hazardous Waste (Management and Handling) Amendment Rules, 2003. But elemental mercury and mercury containing equipments are continued to be freely imported

2.0 MERCURY IN THE ENVIRONMENT

2.1 NATURAL SOURCES OF MERCURY

Mercury can be found virtually in all geological media in small, but varying concentrations. The major sources of mercury are the natural degassing of the earth's crust i.e. evaporation from soil and water surfaces, degradation of minerals and forest fires. Elemental and oxidized forms of mercury are being continuously added to the environment due to their volatile nature.

Several cycles are involved in the transport and distribution of mercury in the environment. The global cycle involves the atmospheric circulation of elemental mercury vapours from sources on land to the oceans; erosion and leaching of mercury containing geological formation by rainfall that also transport the mercury to streams and lakes through surface.

2.2 ANTHROPOGENIC SOURCES OF MERCURY

Industrial use and commercial products containing mercury are recognized as significant sources of mercury release in the environment. Air emissions from coal burning power plants, incinerators, and hazardous waste combustions are the major contributors of mercury. Mercury is also contributed directly from municipal and industrial sites, hospitals, dental clinics, wastewater and from breakage or disposal of mercury containing products such as fluorescent lights, thermostats and thermometers. The major sources of anthropogenic release of mercury are as follows:

A. From mobilization of mercury impurities

- Coal-fired power generation and heat production,
- Energy production from other fossil carbon fuels,
- Cement production (mercury in lime),
- Mining and other metallurgical activities, and
- Petroleum production.

B. From intentional extraction and use of mercury

- Chlor-alkali production,
- Products such as thermometers, manometers and other instruments viz. electrical and electronic switches containing mercury,
- Use of fluorescent lamps, instruments and dental amalgam fillings, etc., and
- Use of batteries, fireworks and laboratory chemicals.

C. From waste treatment & cremation, etc.

- Municipal, medical and hazardous wastes incineration,
- Landfills,
- Recycling and storage.

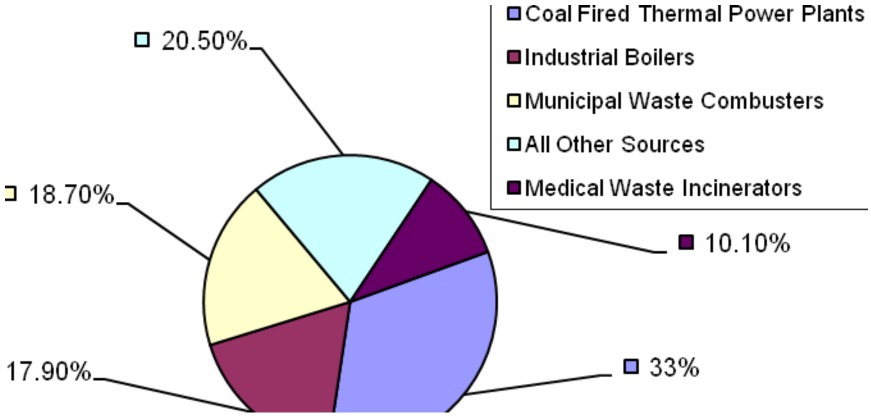


Fig. 2: Typical Sources of Man Made Mercury Pollution in the Environment in Developed countries

2.3 CHEMO-DYNAMICS OF MERCURY

2.3.1 Mercury in Atmosphere

The atmospheric chemistry of mercury involves the several interactions:

- Gas phase reactions;
- Aqueous phase reactions (in cloud and fog droplets);
- Partitioning of elements and oxidized mercury species between the gas and solid phases;
- Partitioning between gas and aqueous phase.

The typical model of interactions between mercury species in the atmosphere is presented below:

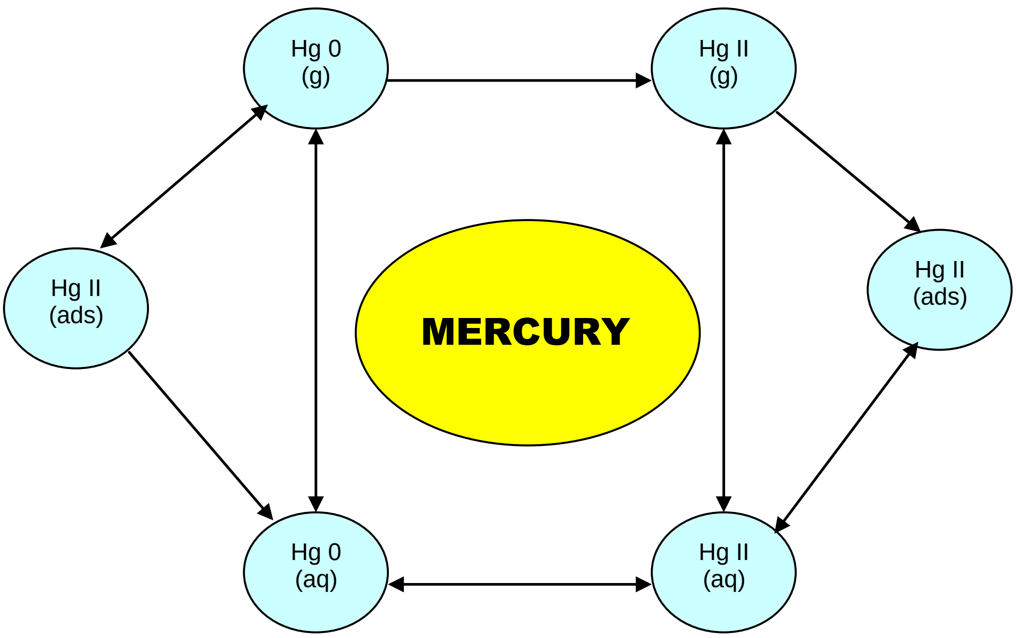


Fig. 3: Mercury oxidation, reduction and mass transfer process in the atmosphere

2.3.2 *Mercury in Aquatic Environment*

Methyl mercury can be formed in the environment by microbial metabolism. The efficiency of microbial mercury methylation generally depends on factors such as microbial activity and the concentration of bioavailable mercury, which in turn are influenced by temperature, pH, redox potential and the presence of inorganic and organic complexing agent.

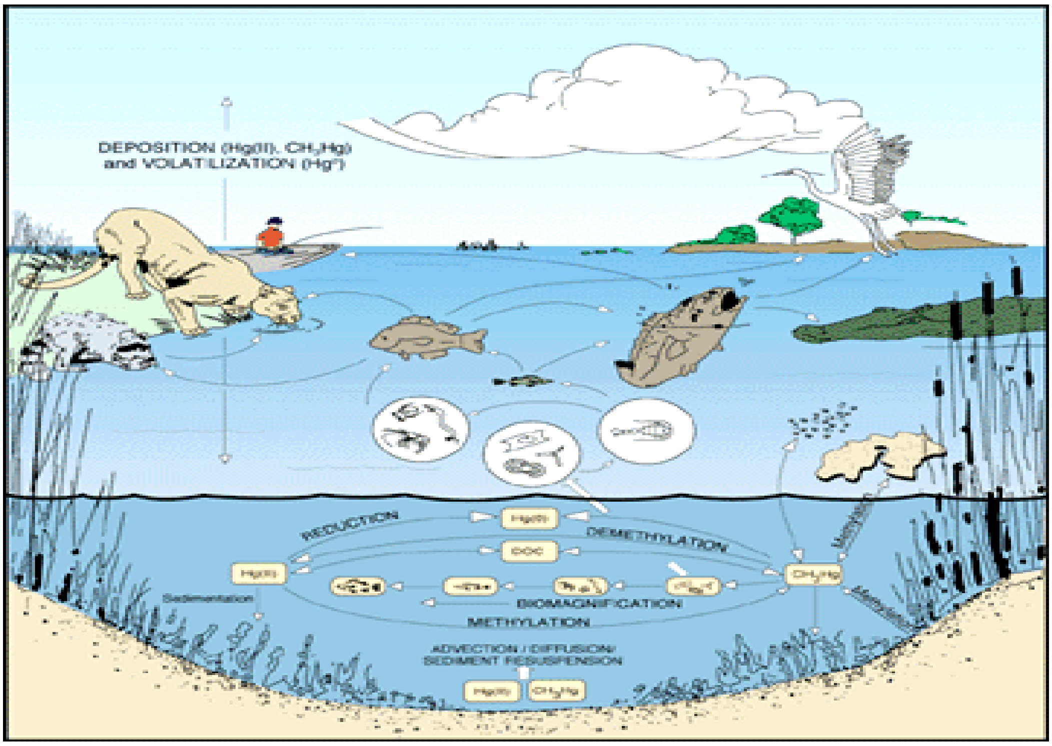


Fig. 4: Aquatic Mercury Cycle *(From website <The US Geological Survey>)*

The dynamic interaction between various mercury species in ocean waters is represented below:

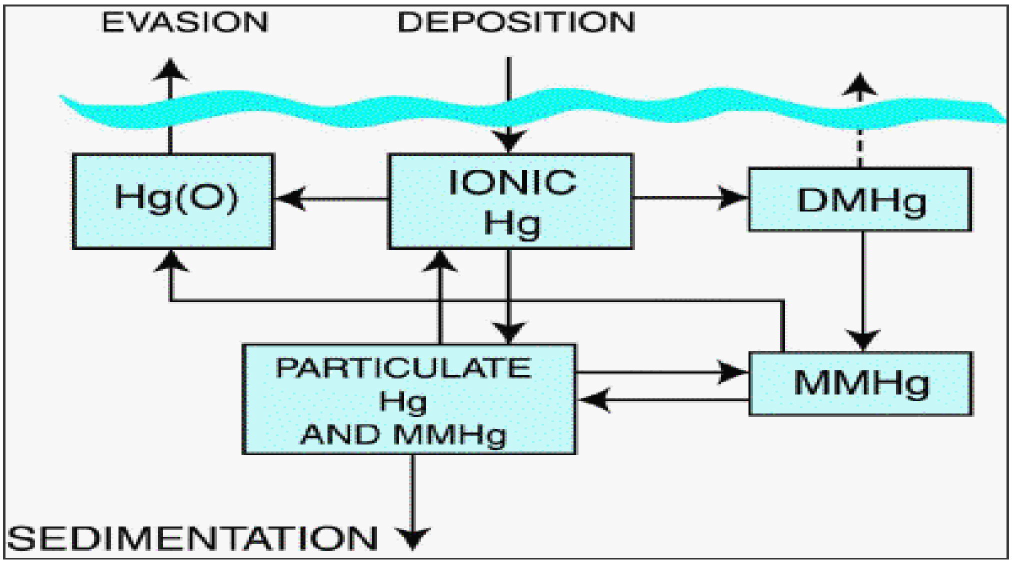


Fig. 5: Dynamic interactions between the various mercury species in ocean waters

Hg(0) = elemental mercury; DMHg = dimethylmercury; MMHg = (mono)methyl mercury

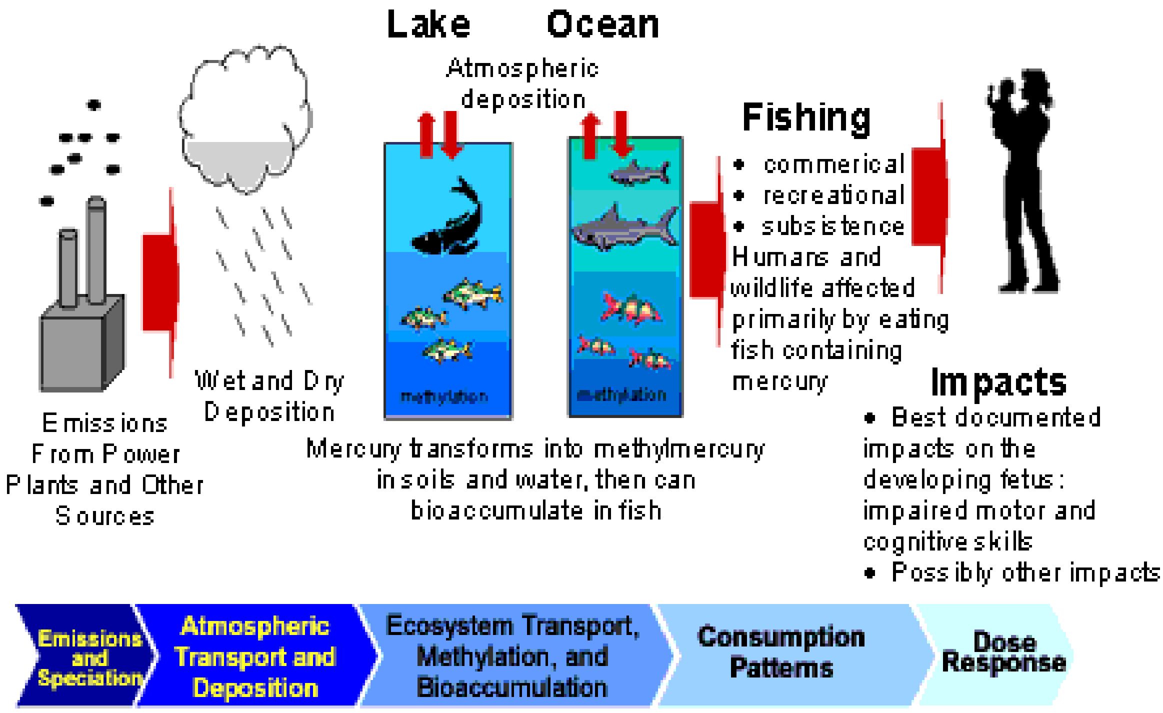


Fig. 6: Pathways of Mercury to the Environment
(From USEPA Website)

2.3.3 Mercury in Soil/Sludge

Soil conditions are typically favorable for the formation of inorganic and organic compounds with mercury. The level of mercury in soil is an indicator of its potential to contaminate groundwater and surface runoff. Soil contamination could be caused either by direct dumping or land filling of mercury contaminated wastes. Mercury in water body sediments may indicate the history of contamination. The Minamata Bay had to be dredged of toxic mercury contaminated sediments in order to restore the water quality.

The concentration of Mercury in municipal solid waste (MSW) composts is usually very low and thus there is little likelihood of significant transfer of mercury to other environmental components. The MSW composts having mercury levels much higher than the background levels found in uncontaminated soils may not be suitable for agricultural uses.

2.3.4 Mercury in Food and Food Chain

Mercury enters into the terrestrial food chain by way of seed eating animal species, resulting in increased level of mercury in tissues and eggs of predatory birds, singing birds and rodents. Some part of mercury also enters via plants in ionic, complexes and gaseous form through leaves and roots. Human beings can be affected on consumption of contaminated plants and animals on setting the mercury poisoning.

2.4 DETECTION TECHNIQUES AND MERCURY ANALYTICAL METHODS IN ENVIRONMENTAL MATRICS

The mercury can be analyzed irrespective of its matrix (water, soil, air and biological materials) to determine the total inorganic and organic mercury content or the relative concentrations of individual mercury compounds. Most of the existing methods determine the total mercury content and very few techniques are available which can segregate between the organic and inorganic mercury content. Some of the most commonly used techniques are summarized in Table 2.

Table 2: Detection Technique and Analytical Methods for estimation of Total Mercury

S. No.	Method of Analysis	Detection Limit	Sample Matrix	Advantages	Disadvantages
1.	Flame Atomic Absorption Spectroscopy (FAAS)	20 ng	Air, soil, water	More sensitive than colorimetric method & less time consuming	Less efficient than cold vapor AAS technique
2.	Cold Vapor Atomic Absorption Spectroscopy	1 ng	Air, soil, sediment, water, biological samples	More efficient than flame AAS	-
3.	Flameless or Graphite Furnace Atomic Absorption Spectroscopy	0.9 pg	Soil, water, biological samples	Most efficient AAS technique & free from interference by other element	-
4.	Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES)	0.2 µg	Water, soil, biological samples	More efficient than AAS	-
5.	Anodic Stripping Voltammetry (ASV)	1 ng	Air, soil, water	Most sensitive & reliable method to determine trace amounts of mercury in different oxidation state	-
6.	Colorimetric method (Dithiozone)	0.5 µg	Air & biological samples	Sensitive to determine mercury	Subjected to multiple interference because of non-specific reagents
7.	Neutron Activation Analysis (NAA)	0.5 ng	Water, sediment, air & biological samples	Most sensitive & reliable method to determine trace amounts of mercury in biological samples	Time consuming & expensive
8.	Atomic Fluorescence Spectrophotometric (AFS) Method	0.01 µg	Water	-	Less sensitive than AAS

3.0 MERCURY USES & APPLICATIONS

3.1 OVERVIEW

The elemental mercury has been known for thousand of years and used in large number of products and processes utilizing its unique characteristics. Mercury is an excellent material for many purposes being liquid at normal temperature, good electrical conductor, having very high density, high surface tension, expanding or contracting uniformly over its entire liquid range in response to changes in pressure and temperature.

Table 3: Mercury Species and Industrial Uses

Mercury State	Principal Uses
Inorganic	
▪ Elemental Hg	Industrial, Scientific and electrical instruments, gold refining, dentistry, chlor-alkali industry.
▪ Mercurous Hg (I) (e.g. calomel, HgCl)	Laxative, vermifuge, teething powder
▪ Mercuric Hg (II) (e.g. corrosive sublimate $HgCl_2$)	Antiseptic
Organic	
▪ Aryl, Alkoxy, alkyl (e.g. CH_3Hg^+)	Paper pulp, fungicide (now banned) diuretics, preservatives.

COMMERCIAL USES OF MERCURY

As the Metal

- For extraction of gold and silver
- As a catalyst for chlor-alkali production
- In manometers for measuring and controlling pressure
- In thermometers
- In electrical and electronic switches
- In fluorescent lamps
- In dental amalgam fillings

As Chemical Compounds

- In batteries (as a dioxide)
- Biocides in paper industry, paints and for disinfection of seed grain
- As antiseptic in pharmaceuticals
- Laboratory analysis reactants
- As Catalyst
- Pigments and dyes

3.2 APPLICATIONS OF MERCURY IN INDUSTRIES

Human have mined and used mercury for more than 2000 years throughout the world. Mercury find its applications for various industrial uses. Mercury is used in various forms and also released to the environment in various forms from color-alkali industries, coal-fired plants, plastic industries, pulp and paper industries, medical instruments and electrical appliances, certain pharmaceuticals and agricultural products. The widespread mercury emissions from fossil fuel energy production, mining and industrial practices like chlorine production have increased mercury pollution almost three times since the beginning of the industrial age. It is estimated that human activities are liable to emit approx. 2500 tonnes of mercury each year globally.

Mercury consumption in Industries has been substantially reduced over the years, leading to significant reduction in the import of Mercury. However, there are about 3,000 industries, which directly or indirectly uses mercury. Total mercury imports in India as per DGCI & S are presented in Table 4.

Table 4: Total Mercury Imports in India as per DGCI&S

S. No.	Financial Year	Total Mercury Imports in India as per DGCI & S (MTPA)
1.	2001-02	260.0
2.	2002-03	531.2
3.	2003-04	197.5
4.	2004-05	173.9
5.	2005-06	155.4
6.	2006-07	220.4
7.	2007-08	120.1
8.	2008-09 (up to Dec 2008)	35.0

Source: DGCI & S Publications

Table 5: Estimated Industrial Uses of Mercury

S. No.	Sector / Product	Mercury use per unit	Production	Calculated Mercury Use (Tonnes)
1.	Chlor-alkali Industry	About 40 gm mercury used per tonne of caustic soda produced in mercury cell processed based caustic soda plants.	2,30,000 Tonnes Caustic soda	10
2.	Thermometers	Varies between 0.6 to 1 gm	89,57,000 Nos. Thermometer	7.2
3.	Alkaline Batteries	Approx. 25 mg	NA	NA
4.	Mercury Zinc	Total 33 to 50% by weight of battery	1,650 million Battery	25
5.	Zinc Carbon	Total 1% Hg by (Leclanche) weight of the battery	NA	NA
6.	Fluorescent lamps	0.0252 to 0.080 gm/lamp	150 million Lamp	7.89
7.	Thermostat switches	Between 3 to 6gm	4051,000 Nos. Switch	18.23
8.	Alarm clocks	Average 0.6 to 0.7 gm per unit	1481,000 Nos. Clock	0.96
9.	Hearing aids	0.4 gm per unit	95,500 Nos. Hearing aid	0.04

NA: Data Not available.

Some Mercuric Facts on Coal

The mercury contents of fossil fuel such as coal are quite small but the burning of large quantities of fossil fuel constitute pollution hazard. The mercury content in coal depend on its origin and varies from 0.02 to 0.31 ppm, averaging 0.11 ppm in Indian coals derived from various coal mines. Coal may contain mercury in various forms, which gets transformed into vapours when the combustion of coal takes place. It is estimated that the substantial amount of mercury emissions are generated from coal-fired power plants. The Coal combustion is responsible for more than 42% of mercury emissions in Eastern Africa, while about 40% mercury emissions from former Soviet Union.

The Indian coal does not contain much mercury; however there may be generation of mercury emissions due to traces of mercury present in the coal during combustion. The total coal consumption for energy production is expected to increase further because of capacity enhancement of thermal power in the country and hence the mercury emissions due to coal uses are liable to increase in future.

Source:

- Environmental Protection Agency (US), Mercury study report to Congress, Washington; EPA,Pub.No.EPA/600/P.97/002 Ab
.
- Pacyana, E.G. & Puchna, J.M. Global Emission of Mercury from Anthropogenic sources *in 995. Norwegian*

Institute for Air Research P.O. Box 100, 2027 Kjeller, Norway.

Fig. 7: Coal fired Thermal Power Station

Chlor-Alkali Industry

In India the caustic soda is produced by mercury cell process and membrane cell process technologies. Older Chlor-alkali plants were based on mercury cell technology because of which these were the largest mercury consumers (approx 55 tonnes of mercury/year), since mercury was being used as catalyst during production of chlor-alkali.

The mercury cell technology has been under phase-out and the chlor alkali industries are under pressure to convert to clean membrane technology. With the changes in production technology in chlor- alkali industries the mercury release to the environment will be substantially reduced. However, the mercury already released to the environment by these caustic soda industries before phase out, will continue to transform in environment form one matrix to another over a long period of time.

PRIMARY CELL CHEMICAL REACTION

$$2\,NaCl \xrightarrow{\text{Electrolyte}} 2\,Na + Cl_2\uparrow$$

On Cathode — Chlorine Gas By-Product

SECONDARY CELL (DENUDER) CHEMICAL REACTION

$$2\,Na + Hg + 2\,H_2O \longrightarrow NaOH + H_2\uparrow + Hg$$

Na - Hg Amalgam

NET REACTION

$$2\,NaCl + 2\,H_2O \xrightarrow[\text{Energy}]{\text{Electrical}} 2\,NaOH + Cl_2 + H_2$$

Chemical Reaction during Production of Caustic Soda by Mercury Cell Electrolytic Process

Electrical Apparatus & Control Instruments

Mercury finds widespread use in fluorescent and discharge lamps, in industrial power rectifiers, and to a great extent in mercury cell batteries. Mercury metal is used in control instruments such as barometers, gauges, thermometers, lamp seals, electrical switches etc. Most of the mercury used in such appliances may be assumed to be lost, e.g., by breakage of waste fluorescent lamps and batteries. The recycling options available for discarded/waste electrical equipments are still rudimentary, however being developed.

Mercury in Fluorescent Lamp

Mercury-bearing lamps (fluorescent, compact fluorescent, mercury vapor, sodium vapor and metal multi-vapors and mixed) use mercury as a vital component for their functioning. Mercury concentration in these lamps varies considerably depending on the manufacturer, the type of lamp and the manufacturing year.

Once the active life of these lamps have ended, they become part of hazardous waste due to their potential for release of mercury in the environment, therefore these lamps must be properly disposed off. As the use of fluorescent lamps (FLs), including Fluorescent Tube Light (FTL) and Compact Fluorescent Lamp (CFL), is increasing due to their energy efficiency over the conventional incandescent lamps; the numbers of FLs that have to be treated are growing. Though these FLs release relatively less quantity of mercury, when disposed as compared to other mercury lamps; they remain of major concern due to the large & further growing number of FLs in service, particularly, in domestic sector.

Ministry of Environment & Forests, Government of India has constituted a Task Force for evolving a policy for management of mercury in fluorescent lamp sector and a Technical Committee to suggest a set of Guidelines, recommending measures & standards, for environmentally sound management of mercury in fluorescent lamp sector. These guidelines are applicable, in principle, to other mercury-bearing lamps, as well.

LIGHTING INDUSTRY IN INDIA

Lighting industry has an annual growth of about 12% per annum in the past few years. Amongst the various products, the consumption of CFLs has contributed a very large growth rate, as high as 50% in the year 2006. This product segment has registered total quantity of > 100 million pieces during year 2006; 140 million pieces in 2007; and 200 million in 2008. Several new plants have come up in CFL sector recently and CFL manufacturing capacity is being augmented fast.

Fluorescent lamps production has increased by 3.3% in 2006, and 186 million pieces has been produced, 190 million pieces in 2007; 186 million pieces in 2008.

Mercury is an essential ingredient for most energy efficient lamps. Fluorescent lamps and high intensity discharge (HID) lamps are the two most common types of lamps that utilize mercury. Fluorescent lamps provide lighting for most schools, office buildings, and stores. HID lamps, which include mercury-vapor, metal halide, and high-pressure sodium lamps, are used for streetlights, floodlights, and entertainment, sports and industrial lighting purposes. Followings types of lamps contain mercury:

- Fluorescent Tube Lamps (FTL)
- Compact Fluorescent Lamps (CFLs)
- High Intensity Discharge (HID) Lamps, including Mercury Vapor
- Metal halide and high Pressure Sodium
- Neon Lamps (some use mercury and phosphor powder)

High Pressure Mercury Lamps

Mercury Blended Reflector Lamp

Fig. 8: Fluorescent Lamps containing Mercury

Range of Mercury Consumption in different types of Fluorescent Lamps

The mercury content in different types of lamps may vary and it depends on the technology used in the dosing of mercury i.e. liquid mercury & pill technology. The typical mercury concentration in mercury bearing lamp sectors is presented in Table 6.

Table 6: Typical Mercury Concentration in Mercury bearing Lamps

S No.	Type of Lamps	Mercury Content (mg/lamp)	Country/ Region for data
1	Fluorescent Tube Lamps (FTL) (double end)	15 (1997) 10 (2002) 15-45 10-22 23-46 15-60	European Union Russia USA Canada India
2	Compact Fluorescent Lamp (CFL)	5 10 12-30 3-12	European Union Canada Russia India *
3	Mercury Vapor & Metal Halide Lamp	~ 20 (75 W) ~ 250 (1000 W)	Global
4	High Pressure Sodium Lamp	~ 8.3 (50 W) ~ 25 (1000W)	Global

Source: UNEP - Toolkit for identification and quantification of Mercury release - November 2005

* On the basis of inspections and information collected from the manufacturers

It is estimated that total Mercury consumption in FTL sector is around 7.5 MT Hg / annum, considering about 250 million units / annum of production and average 30 mg of Mercury in each FTL.

It is estimated that total Mercury consumption in CFL sector is around 0.5 MT Hg / annum, considering about 100 million units / annum of production and average 5 mg of Mercury in each CFL.

Fluorescent Tube Lights (FTLs)

A 40-watt fluorescent tube emits 2,150 lumens as compared to 455 lumens by a standard incandescent 40-watt bulb. In addition, fluorescent tubes typically last longer and produce much less heat than incandescent lamps. The newer generation, fluorescent tubes (T-8 and T-5 tube lights), especially contain tri-band phosphor and are highly energy efficient.

Compact Fluorescent Lamps (CFLs)

Compact fluorescent lamps are energy efficient as most of the electric energy used is converted into light rather than heat. CFL are simply small fluorescent tubes with attached electronic ballast. When compared to standard incandescent bulbs, the CFLs consume 80% less electricity and past ten times longer life.

Light Emitting Diodes (LEDs)

LEDs are new entrant in the field of lighting and are causing lighting revolution in areas where lighting intensity required is not very high. These LEDs have about 11 years of life, a real advancement in lighting technology. This small lights have no element to break, no glass to shatter and are not affected by heat or cold and can be lit up using ordinary batteries or very low voltages. These are used in a big way in automobile industry and for traffic lights now a days. Research is going on to improve upon the quality of LED for its use in lighting applications.

Due to ongoing heavy electrification in villages, the Incandescent Lamp has seen unprecedented growth of over 20%. CFL however continues to grow @ about 40% p.a. Similarly, another Energy Efficient Products like Metal Halide Lamps also recording growth between 20 to 24% per annum. Fluorescent Tube Light continues to enjoy market growth of over 10% on regular basis. It is estimated that all Energy Efficient Products shall continue to grow within next few years.

THERMOMETER

Mercury Thermometer – Some Facts
• Typical mercury based glass thermometer contains 0.5 to 3.0 gm of mercury, which is seldom recovered on breakage of thermometer, but mostly lost. • Average monthly breakage rate of mercury based glass thermometer in a 300 bedded hospital is around 70. • Hospitals having nursing schools attached to them, register a very high breakage rate (5-6 per ward/month). • A major reason of breakage of clinical thermometers in wards is the instrument slipping out of the hand, while shaking it to bring the temperature down. • Mercury thermometer breakage is seldom handled carefully. Some of the major ways in which spills are handled are: sweeping it down to the drain, collecting it in a container and discarding it along with garbage.

Mercury based Glass Thermometers used in healthcare

Mercurial Sphygmomanometer used in healthcare

Dental Amalgam

Mercury is frequently used for dental amalgam. Amalgam is the mercury alloy used primarily for dental fillings. The mercury is set free under certain circumstances by external effects such as mechanical or biological influences. Mercury tends to vaporize from the amalgam and gets impregnated in the gums. After few years, some patients might develop a white silvery line on their gums, called **"***Amalgam Tattoo***"**. It is estimated that approx 51 kg of mercury is discarded within NCT – Delhi from dental amalgam each year, which finds its way to the sewage network or to the community garbage, then to landfills.

Mercury in Dental Amalgam

Mercury Cells (Batteries)

Mercury cells are primary cells consisting of zinc oxide, a cathode of Mercuric oxide (HgO) mixed with graphite (about 5 %) and an electrolyte of Potassium hydroxide saturated with zinc oxide. The EMF of mercury cell is about1.3 volts and by suitable design the mercury cell can be made to deliver about 0.3 ampere hour per cubic centimeter.

Various sizes of Button Cell batteries containing Mercury

Thimerosal

Thimerosal, a mercury containing preservative is added to vaccines to protect against bacterial contamination. It is composed of nearly 50 % mercury which can metabolizes to ethyl mercury and thiosalicylate.

Mercury in Thimerosal

Thimerosal Based Vaccination

Paints

The fungicidal properties of some mercury compounds are utilized and these compounds are added during the production of protective paints. Mostly organic mercury compounds such as phenyl mercury acetate, oleate are used. The stability of the mercury compounds in the paints is quite low. Photochemical breakdown and vaporization of both mercury compounds and mercury metal to surrounding environment reduces the mercury content from the painted surfaces in the paints quickly.

Agriculture

Inorganic & organic (alkyl, alkoxy, aryl) mercury compounds have been used for seed dressing (potatoes, grains, flower bulbs, cotton, etc.) and as foliage sprays against plant diseases. Such uses are hazardous since mercury compounds are openly utilized in the ambient environment. However, in present time the seed dressing with mercury compounds has been considerably reduced.

Amalgamation

In electrolytic processes, mercury is used for the recovery of metals like Zinc, gold etc. as a reducing agent. In gold amalgamation process, the gold bearing rock or sand after crushing is treated with mercury, which forms an amalgam on the surface of the gold. The amalgamated particles are allowed to stick with the amalgamated copper plates, the rest of the ore being washed away; they are then removed, the mercury is distilled off in iron retorts.

Pharmaceuticals

Mercury compounds are used extensively for their antiseptic and preservative properties in soaps, cosmetics, antiseptic preparations. Most of the mercury used is liable to lost to the environment through sewage and drain waters.

Pulp & Paper

Organic mercury compounds (especially phenyl mercury acetate) are utilized to prevent microorganisms (bacteria, fungi, algae, etc.) from growing in the pulp, during its digestion and processing.

Other Industrial Uses

Smaller amount of mercury is used in the production of plastics, in the tanning industry, and as heat transfer agent.

Processing of Ores

The smelting process of sulfide ores (Cu, Pb, and Zn) also generates mercury vapour since mercury may also be present in ores along with other metals. Mercury may be released, while processing phosphorites, bauxite, minerals of Iron and Manganese (oxides).

3.3 MAIN CONTRIBUTORS TO MERCURY EMISSIONS IN INDIA

The main contributors to Mercury emissions in India are Steel Industries, Thermal Power Plants, Cement Industries and Paper Industries, Incineration of Hospital Waste, municipal solid waste; Coal fired thermal power plants, Emissions from various industrial uses of mercury.

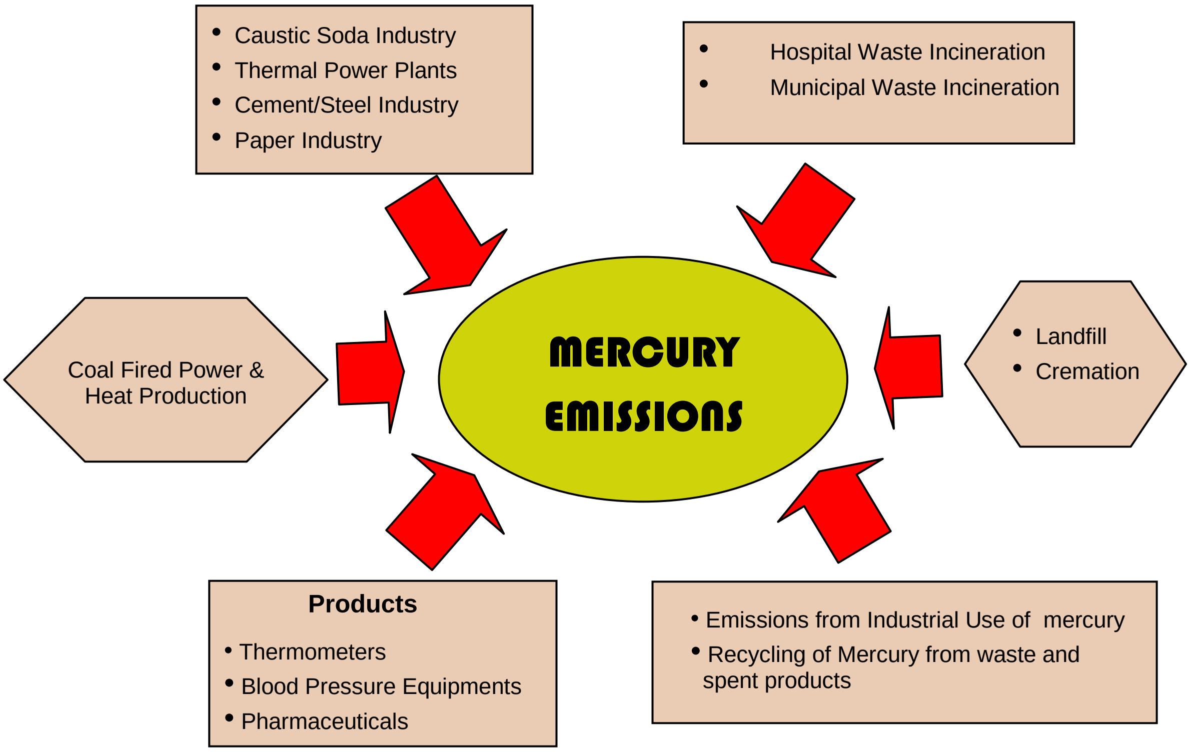


Fig. 9: Main contributors to Mercury Emissions in India

3.3.1 Mercury Release to Environment from Caustic Soda Industries

Though the Caustic soda Industries have provided adequate measures to meet the environment norms, there is still a problem with regard to mercury consumption and release to environment through different products and waste streams from which industries are required to take measures to minimize the release of mercury to environment. The reasons for high mercury release in Indian Chlor-Alkali Industry are:

- High mercury consumption per tonne of product. Limitation of mercury consumption per tonne of product being ensured,

- Loss of mercury through cell room ventilation, products and solid waste (Brine mud, End-box butter sludge),

- Availability of poor quality of salt (Solar evaporated salt) leading to high brine sludge generation and subsequent mercury loss through brine sludge,

- Average quality of salt used by the caustic soda industry is as below,

Constituents			**BIS Specification**
Sodium (%)	:	98.46	99.5
Calcium (ppm)	:	1400	440
Magnesium (ppm)	:	1000	150
Insolubles (%)	:	0.44	0.2

- The sludge generation rate in Indian industries is 0.03 to 0.05 tonne per tonne of caustic soda produced in comparison to average sludge generation of 0.015 tonne/tonne of caustic soda produced in other countries,

- Frequent power interruption and poor housekeeping,

- High maintenance problem due to poor quality salt leading to cell cut-outs and cell opening frequently. Higher ambient temperature- High rate of evaporation and high number of air changes in cell room,

- Improper treatment system before disposal of mercury bearing solid waste into Sanitary Landfill,

- Inadequate distillation unit for mercury recovery. Mercury release to the environment should be limited, and

- Insufficient pollution control system for removal of mercury from cell room ventilation gas and other sources.

Table 7: State-wise and Production Technology-wise Distribution of Chlor-alkali Industries in India (As on February, 2009)

State	Production Technology wise No. of Chlor-Alkali Units		
	Mercury Cell Process	Membrane cell process	Both the Processes
Andhra Pradesh	-	01	-
Assam	01	-	-
Gujarat	01	08+01*	01
Haryana	-	01	-
Jharkhand	01	-	-
Karnataka	01	-	01
Kerala	-	-	-
Maharashtra	-	03	-
Madhya Pradesh		-	01
Orissa	01	-	-
Pondicherry	-	02	-
Punjab	-	02	-
Rajasthan	-	02	-
Tamilnadu	-	03	-
West Bengal	01	01	-
Uttar Pradesh	01	-	01
Total	**07**	**24**	**04**

**Production closed*

Source: 10th CREP Tasks Force meeting held on February 2009.

Table 8: State wise Status of Mercury Cell Technology based Caustic Soda Industries

S. No.	State	Location of Industry	Unit
1.	Assam	Nagoan	One
2.	Gujarat	Valsad	One
3.	Karnataka	Karwar	One
4.	Madhya Pradesh	Shahdol	One
5.	Orissa	Ganjam	One
6.	Uttar Pradesh	Sonbhadra	One
7.	West Bengal	24 Parganas	One
TOTAL 07 INDUSTRIES			

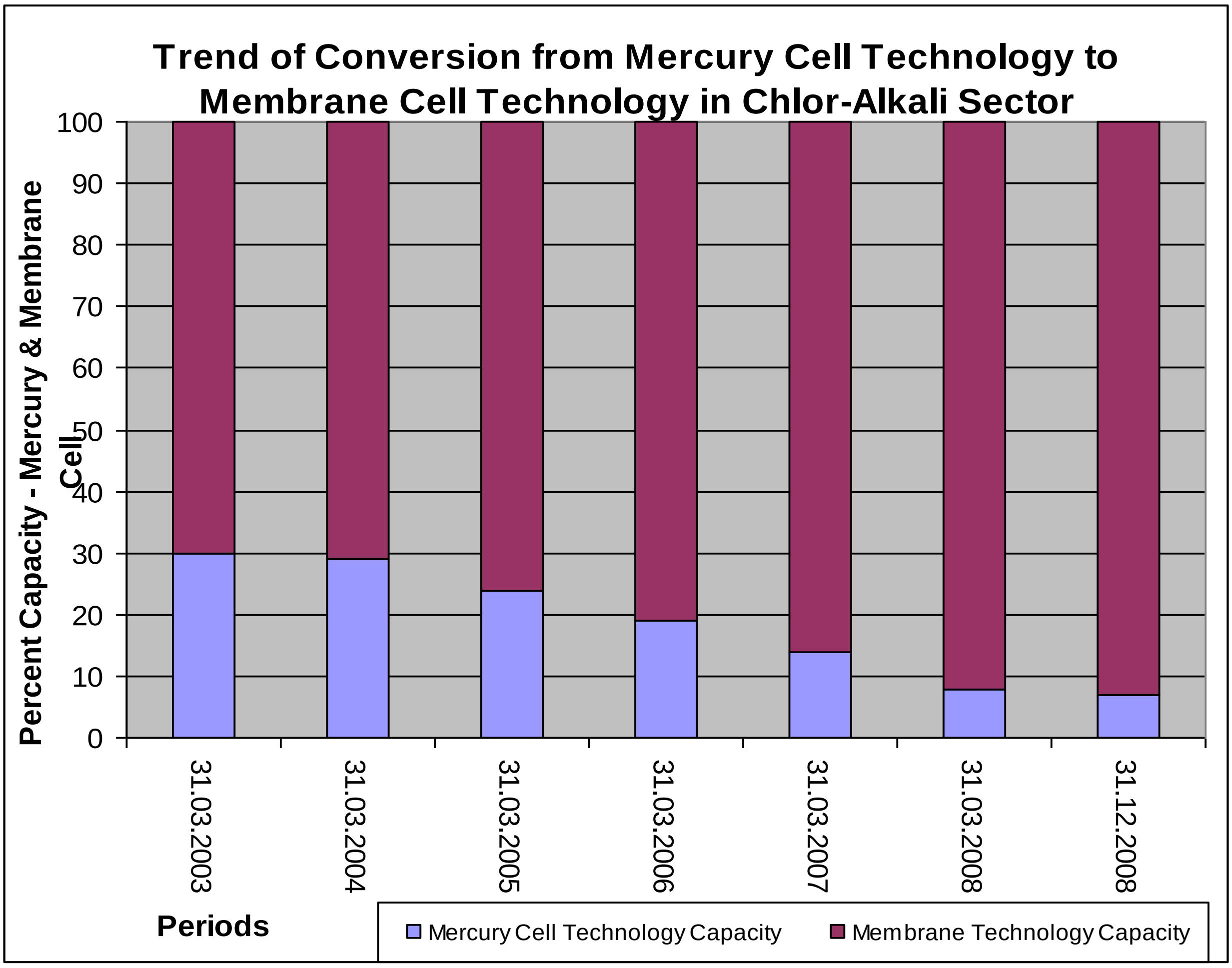
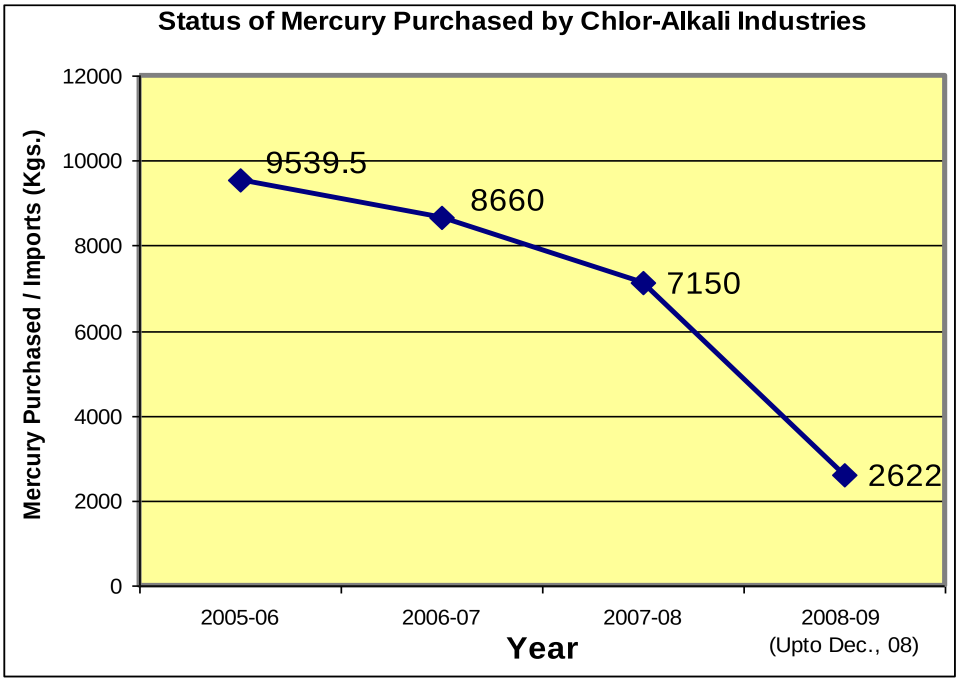


Fig. 10: Technology conversion trend in Chlor alkali Industries



Source: 10th CREP Tasks Force meeting held on February 2009

Fig. 11: Mercury Purchased by Chlor alkali Industries

In order to reduce mercury consumption and to minimize the release of mercury from caustic soda industrial units, the following measures are being contemplated by Central Pollution Control Board:

- Conversion of Mercury cell based caustic soda industries to Membrane Cell Technology,
- Process improvement in existing mercury cell based plants through use of better quality salts by installing full fledged salt washing unit for removal of impurities to reduce brine sludge generation,
- Filtration of products for removal of mercury,
- Scrubbing of cell house ventilation gases,
- Improvement of house keeping practices

Fig. 12: Typical Caustic Soda Manufacturing Unit

The existing caustic soda units in the country are regularly being directed to minimize release/loss of mercury from various sources through adoption of following measures:

- Zero Discharge of mercury bearing liquid effluent by complete recycling of mercury bearing effluents,
- Continuous monitoring of mercury in effluents by installing on-line mercury analyzer and strip recorders in control room. Warning system should be installed for taking necessary measures, whenever the mercury concentration exceeds the threshold limit.
- Treatment of Cell room ventilation gases
- Removal of mercury in products. Automatic short circuiting prevention devices should be placed to avoid build up of mercury in brine,
- Use of good quality salts,

- Disposal of brine sludge in secured landfill. Measures to convert mercury into stable complexes ion, which does not precipitate and is also not lost by evaporation,

- Brine sludge containing mercury should be filtered and mixed with cement in the proportion 3 (mud) : 1 (Cement) : 0.8 (Sand). The mixture after curing can be disposed off in sanitary landfill. Leaching test on the concrete block should be perform to ensure mercury release below 0.001 mg/l,

- Reduction of mercury consumption,

- To bring down mercury release to environment at 2.0 gm/tones of product Chlorine handling & safety measures,

- Maintenance of good housekeeping practices. The floor of cell room should be coated with the epoxy resin and special rubber. The spillage mercury should be collected by vacuum pump,

- Direct removal of mercury from contaminated gaseous stream by ensuring that the electrolysis cells should be tightly closed and kept under negative pressure. The resulting gases should be washed in hypochlorite tower and absorbed through MR unit,

- The equipments such as end boxes, the caustic exit of decomposer, caustic receiver, tanks and end box washing water receiver etc. should be kept under negative pressure,

- The caustic solution generated in the decomposer should be first cooled and then to be filtered continuously through a vertical leaves pre-coat filter,

- The chlorine gas to pass through a demister and then cooled. The demister drainage water to be circulated to the brine system, and

- The hydrogen gas from the decomposer should be cooled indirectly to 20- 30 ^{0}C. The gas is to be further cooled down to 7-9 ^{0}C and passed through a Mercury Removal system.

3.3.2 Mercury Emissions from Coal

The emission of mercury through fossil fuel burning was estimated through monitoring of power plants in Singrauli area. The source monitoring and ambient air quality with respect to mercury was undertaken to estimate the mercury balance due to coal combustion.

Mercury content in coal produced by different coal mines are varied widely with locations, types of Siam and in between the layers of deposition. The average mercury levels among various coal samples during the study period were found 0.272 ppm. (Ranged between 0.09 to 0.487 ppm). Further assessment of mercury is required to assess mercury levels in various qualities of coal. It was estimated based on coal consumption and average mercury level in coal that about 77.91 metric tonnes of mercury estimated to be generated from which about 59.29 MT per annum mercury is being estimated as mobilized from fossil fuel burning in power plants alone.

The Singrauli area having an installed production capacity of 9.5% of total thermal power generated in the country may be responsible for 16.85 % of total mercury combustion to environment through power generation. Central Pollution Control Board (CPCB) is regularly monitoring various thermal power plants for its mercury emission.

3.3.3 Mercury in Electronic Waste (e-Waste)

The global market for electrical and electronic products continues to expand and accelerate, while the life span of the product is limited, resulting in corresponding increase of electronic scrap. UNEP report 2005 indicated that “Every year 20 to 50 million tonnes of electrical and electronic waste are generated worldwide, which could bring serious risk to human health and the environment.

e-Waste constitutes over thousands of different substances and chemicals, many of which are toxic and are likely to create serious problems for the environment and human health if not handled properly. E-Waste contains many toxics such as heavy metals, including lead, cadmium, mercury, hexavalent chromium, polychlorinated biphenyls (PCBs), Polyvinyl chloride (PVC) etc.

It is estimated that almost 22% of the annual world consumption of mercury is used in electrical and electronic equipments. Mercury and its compounds are used in thermostats, sensors, relays, switches, medical equipments, fluorescent lamps, mobile phones and in batteries.

The computer revolution in country is enhancing computer obsolescence. It is estimated that out of approx 8 million Personal Computers in the country, more than two million computers are fourth generation computer having Intel 486 chip or lower. These old generation computers are regularly discarded with advancement of computer technology. According to an estimate, the average waste generation of various toxic metals per computer is Mercury – 0.57 gm; Lead – 1.75 gm and Cadmium – 2.8 gm and the quantum of mercury waste received in future may be estimated to big quantities.

Fig. 13: Piles of e-Waste containing various toxic metals including mercury

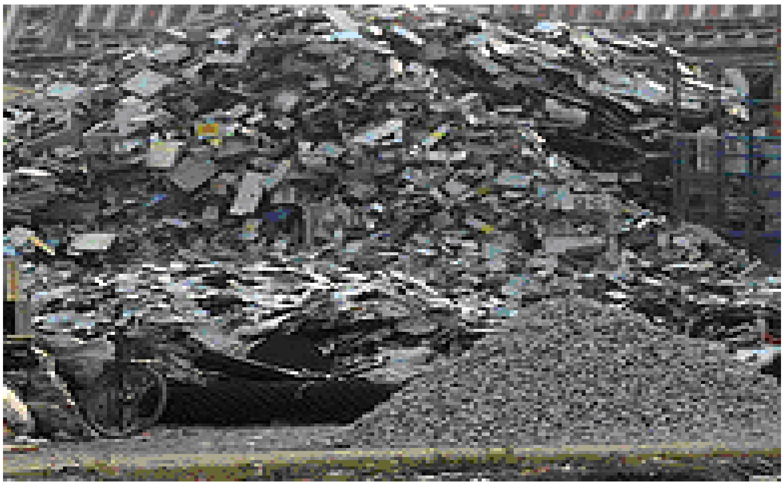


Fig. 14: e-Waste containing various toxic metals including mercury

Fig. 15: Discarded Computers - another source of mercury

Fig. 16: Electronic Waste processing for recovery of various electronic parts for recycling

Fig. 17: Electronic Waste processing for recycling in a household (Cooking of food may be seen in foreground)

4.0 EXPOSURE PATHWAYS, UPTAKE, BIO ACCUMULATION & BIOTRANSFORMATION OF MERCURY

4.1 IN TERRESTRIAL PLANTS / ANIMALS

The commonest way via which mercury and its compounds enters and accumulates in terrestrial plants/animals is the food chain. Mercury enters the terrestrial food chain by way of seed eating species, particularly rodents and birds, because of wide application of mercury compounds in agriculture for seed dressing. This wider application of organic mercury compounds may result in uptake and accumulation of mercury in tissue and eggs of predatory birds, game birds, singing birds and rodents.

Another route by which mercury may enter the terrestrial food chain is possibly via plants. Plants take up small amounts of mercury in ionic, complexes and gaseous form through leaves, also from dry fallout and via roots. Some microbial activities in the topsoil can also increase the bio-availability of mercury to plants.

Man being omnivorous in nature consume both plants and animals and may have exposure with mercury bearing food which may lead to mercury poisoning.

4.2 IN AQUATIC ORGANISMS (BIO-ACCUMULATION AND BIOLOGICAL MAGNIFICATION)

Mercury enters the aquatic environment either as inorganic mercury or as phenyl mercury. These forms of mercury are quickly adsorbed by organic and inorganic particulates present in the aquatic environment and are readily converted into the methyl-mercury form. Now, the problem with this highly toxic and mobile methyl-mercury is that aquatic organisms are able to bio-accumulate it directly from the water or through the food chain.

Phytoplankton (the main primary producers in the aquatic environment) as well as zooplankton concentrates both inorganic and alkylated mercury and thus it may enter the food chain.The accumulation of mercury in aquatic organisms results from absorption by ingestion or directly from water through the organism outer surfaces (skin or epithelium) and or across the gill membranes during respiration. Since mercurials are almost one thousand times more soluble in lipids than in water, they are easily extracted from water or food by contact with the lipid portions of the tissues. Thus, 85 – 95% of total mercury in contaminated fish tissue is in the form of methyl-mercury because of its affinity for sulphahydryl groups and lipids. The predatory species accumulate high quantity of mercury as compared to herbivorous species because of biological magnification of methyl-mercury at each trophic level.

The magnitude of biological accumulation of mercury by aquatic organisms depends upon species, its exposure interval, feeding habits (trophic level), metabolic rate, age or size of the organism, and the various water quality parameters such as temperature, pH, organic pollution loadings, hardness, alkalinity, heavy metal loadings and dissolved oxygen. The bio-accumulation and bio magnification mechanism is a complex combination of biological and chemical parameters. Also, because of these factors the concentration of mercury in the organisms at the top of food chain can be 3,000 times greater than the mercury level of the water in which they live. The amount of inorganic and organic dissolved and particulate matter in an aquatic environment may be significant in the accumulation of mercury by fish. Organisms living in oligotrophic lake have high mercury levels as compared to those from eutrophic lake.

4.3 IN HUMAN BEINGS

Mercuric salts, and to a much greater extent, organic mercury, are readily taken up by organisms in water which may enters into the human tissues via food chain. The other sources of mercury uptake in human body include, dental fillings, skin-lightening soaps and creams, paint, occupational exposure during manufacture, formulation and use (chlor-alkali plants), etc. the uptake of mercury from these sources may occur due to absorption via inhalation, skin, ingestion and axonal transport.

4.3.1 Absorption During Inhalation

Absorption of mercury vapour via mouth or nose directly may be another route of uptake for elemental mercury and studies indicate that approximately 80% of mercury vapours inhaled is retained by body tissue. The maximum retention occurs in the alveoli of lungs.

The uptake of metallic mercury vapours from inspired air into the blood depends on the dissolution of mercury vapour in the blood as it passes through the pulmonary circulation. The dissolved vapours are oxidized to Hg^{2+} immediately after absorption partly in the red blood cells and partly after diffusion into other tissues. The oxidation and absorption of mercury vapours in humans can be reduced considerably by alcohol or the herbicide amino triazole.

4.3.2 Absorption during ingestion

Liquid metallic mercury is poorly absorbed and most of it is excreted in the faeces. However, humans who accidentally ingest metallic mercury shows increased blood levels of mercury. If metallic mercury accidentally enters the tissues, then sometimes it can result in local tissue reactions with or without signs of systemic poisoning. Children are more prone and susceptible to mercury poisoning than adults. Accidental intake of mercury may take place particularly when mercury chemical thermometer is broken accidentally in mouth during body temperature measurement.

4.3.3 Absorption through skin

Elemental mercury liquid and vapour can be absorbed through the skin in small amounts by the topical application of skin-lightening creams containing inorganic mercury salts.

5.0 TOXIC EFFECTS OF MERCURY & ITS COMPOUNDS

Metals have been recognized as powerful toxins for many years. The wider clinical application of mercury compared as antibacterial agent may reflect toxic nature of mercury compounds.

Mercury is very toxic and it may be fatal if inhaled and harmful if absorbed through the skin. It may cause harmful effects on the nervous system, digestive and respiratory systems and kidneys. Short term exposure to high concentrations of mercury vapour leads to acute mercury poisoning. The severity of health effects from mercury exposures are influenced by following factors:

i) Chemical form of mercury i.e. inorganic or organic mercury,
ii) Mercury Dose,
iii) Age of the person exposed (the foetus is the most susceptible),
iv) Duration of exposure,
v) Route of exposure i.e. inhalation, ingestion, dermal contacts
vi) Health status of the person exposed.

5.1 LONG TERM HEALTH EFFECTS FROM EXPOSURE TO MERCURY

The harmful health effects of long-term exposure to elemental mercury are generally thought to be caused by inhalation. However, mercury liquid and vapours are also absorbed through the skin in small amounts and this route of exposure can contribute to the overall exposure. Isolated poisoning is more likely to be caused by elemental or inorganic mercury. The metal is physically attractive and there are many recorded examples of children playing with it to the detriment of the whole family. Children occasionally swallow small photographic or hearing aid batteries which may contain as much as a gram of mercuric oxide. Such accidentally swallowed batteries often pass through the body unbroken, but sometimes the battery lodges in the stomach and acid disintegration of the battery casing can lead to serious poisoning.

5.1.1 Toxico - Kinetics of Inorganic Mercury

At least 80% of the elemental mercury (Hg) inhaled as vapour is absorbed. Curiously, prior ingestion of alcohol can reduce this to 50%, because it inhibits oxidation of Hg (0) to Hg (II) by catalase and hydrogen peroxide in erythrocytes. Absorption of the metal from the gastrointestinal tract is poor. About 10% of the mercury absorbed is distributed to the brain and about 10% to the blood, most mercury accumulates in the kidneys.

In the body both Hg (0) and Hg (I) are oxidized to Hg (II). In this oxidation state mercury is highly relative and can disrupt membranes, combine with sulphydryl groups to inhibit enzymes and damage DNA.

5.1.2 Toxico-Kinetics of Organic Mercury

About 90% of most organic mercury compounds are absorbed from the intestine and phenyl mercury is also absorbed through the skin. The inter relationship of mercury species is presented below. According to Clarkson (1992) methyl mercury takes about 30 hrs to equilibrate in the blood compartment and rather longer in the brain. In primates, including humans, the ratio between brain (target organ) and blood mercury concentration is 5:1, higher than in other species. The hair : blood ratio is about 250:1. Due to such high hair blood ratio, the internal dose to the critical organ may be substantially high.

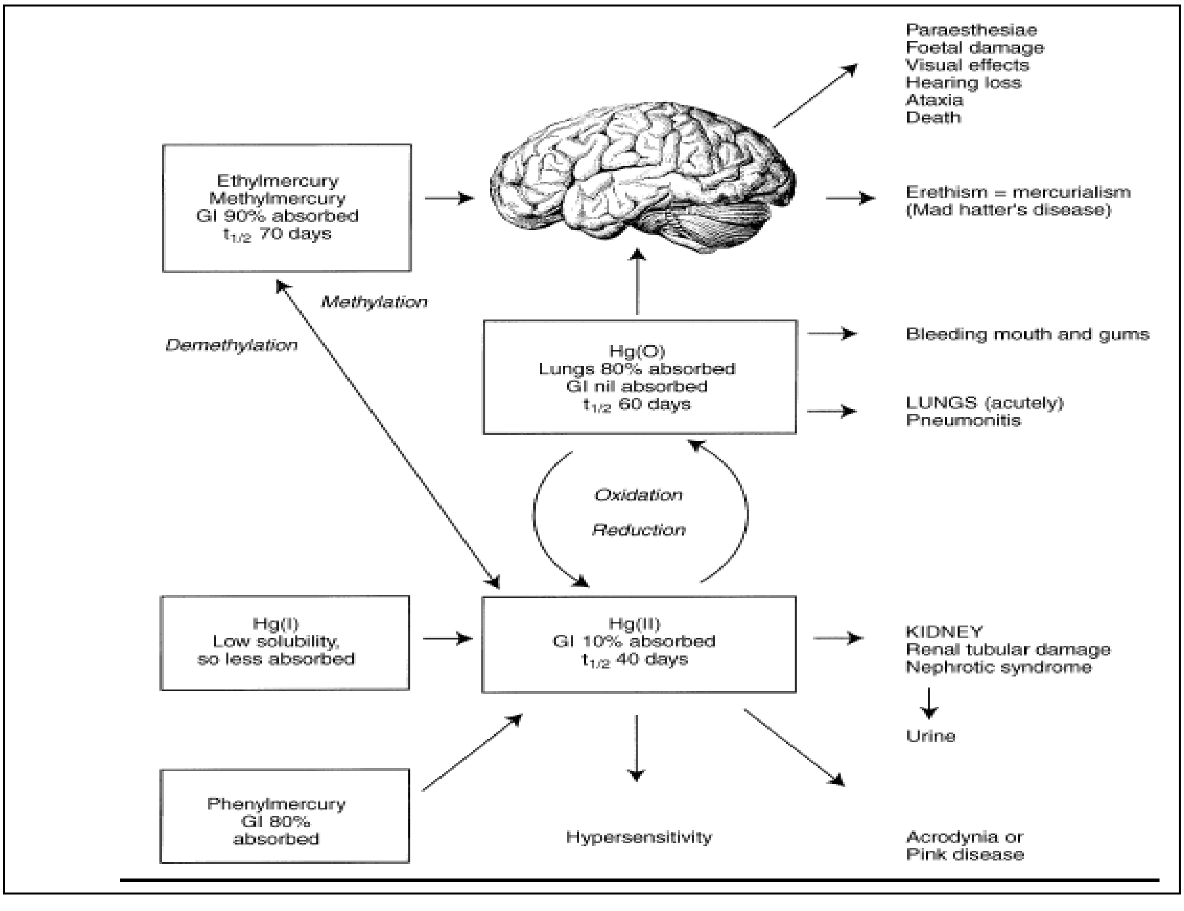


Fig. 18: Mercury, some interactions and effects of the different chemical species within the body

Methyl mercury enters the brain and other body tissues because it is lipid soluble (only the CH_3Hg Cl is lipophillic). Recent studies suggest that methyl mercury, when combined with cystein has a structure, which resembles methionine and enters brain and other cells via the neutral amino acid carriers.

The Central Nervous System (CNS) is the target organ for methyl mercury toxicity. Methyl Mercury crosses the placenta freely and has devastating effects on the foetal brain. It also inhibits the polymerization of micro tubes, a process essential for cell division and neuronal migration crucial to normal development of the foetal brain. The toxicity effect of mercury in both adults and foetuses are dose related, but the foetus is 5-10 times more sensitive.

Methyl mercury exhibits an extremely long latent period. The earliest symptoms are paraesthesia, malaise and blurring of the vision. More severe exposure leads to constriction of the visual fields, deafness, dysarthria, ataxia and finally mental derangement, coma and death.

5.1.3 Effects on the Nervous System

Mercury is a potent neurotoxin. Even at extremely low levels of exposures, it can permanently damage the human central nervous system. Typical symptoms of mercury poisoning include loss of sensation in the fingers and toes, tremors, blurred vision, poor muscular co-ordination and disintegration of brain cells.

Methyl-mercury is highly toxic to the nervous system. The developing central nervous system is more sensitive to methyl-mercury than the adults. Studies from one population exposed to methyl-mercury from fish also suggest an association with increased incidence of cardiovascular system disease (Salonen et al., 1995 and Rissanen et al., 2000).

5.1.4 Effects on Kidney

Elemental mercury can be oxidized in body tissues to the inorganic divalent form. The kidney accumulates this inorganic mercury to a larger extent than most other tissues with concentration in occupationally unexposed groups typically of 0.1-0.3 µg/g (Drasch et al., 1996 & Hac et al., 2000). High exposure may cause glomerulonephritis with proteinuria and nephritic syndrome (Tubbs et al., 1982).

The Hg (II) may be concentrated in the kidney in proximal renal tubules as various solutes are reabsorbed from the glomerular filtrate. It causes severe damage to the brush border membranes with mitochondrial and lysosomal damage.

5.1.5 Effects on Skin

Allergic skin sensitization has been reported in people with occupational exposure to mercury liquid or vapour. Once a person is sensitized to a chemical contact, even a small amount causes outbreak of dermatitis with symptoms such as skin redness, itching, rash and swelling.

Exposure to elemental mercury may also result in '*Acrodynia or Pink disease'* (Fagala and Wigg, 1992). Acrodynia or pink disease is the syndrome of mercury toxicity, found in certain individuals, which may be caused by stimulation of the sympathetic nervous system.

A type of inorganic mercury known as calomel ("sweet mercury") was once commonly used to treat many ailments, including yellow fever, typhus and syphilis. Until the recognition of their toxicity in the 1940s, calomel-based teething powders caused a scourge of mercury poisoning called "pink disease" or acrodynia among infants and children.

Mercury Poisoning as Pink Disease

Fig. 19: Mercury Poisoning as Pink Disease

Table 10: Health Effects of Mercury

S. No.	Mercury Form	Sources of environmental contamination	Environmental effects	Source of human contamination	Toxicity related health effect
1.	Methyl mercury	Mercury disposed off in water bodies	Tendency to bio-magnify in the food chain, contaminating fish and marine mammals	Consumption of contaminated fish and marine mammals	Methyl mercury is classified as a possible human carcinogens
2.	Mercury	Combustion of coal, incineration of mercury bearing waste	Deposit in the environment and sometimes travel long distances	Deposit in water bodies and also falls with rain water	Enters body via food
3.	Mercury vapours	-	-	Ambient air, dental amalgam	Dangerous if inhaled or ingested

Toxicity of Mercury Compounds

- Dimethyl mercury is the most dangerous compound and is so toxic that even a few micro liters spilled on the skin glove can cause death.
- Through bioaccumulation methyl mercury in the environment works its way up the food chain.
- Ethyl mercury is a breakdown product of the anti-bacteriological agent, which has effects similar but not identical to methyl mercury.

Visible Symptoms

The symptoms of methyl mercury poisoning are varied and can mimic other illnesses. Many of the symptoms take a number of weeks or even months to appear. The symptoms include:

- depression, emotional instability, memory reduction and irritability
- defects in hearing, vision and speech
- difficulty in writing, delays in motor and language development, inability to walk properly and
- Death in extreme case.

5.2 DISEASES CAUSED BY MERCURY EXPOSURE

The important forms of mercury from a toxicological view point are metallic, the divalent inorganic forms and methyl mercury compounds. Elemental mercury has a high vapour pressure and the mercury vapours may cause poisoning via inhalation. Mercurial erethism is characterized by behavioral and personality changes such as extreme shyness, excitability and loss of memory etc. (*Hiroshi Satoh, 2000).* In recent years it has been recognized that a number of illnesses with poorly defined symptoms, such as multiple sclerosis and Alzheimer's diseases are related to mercury.

Organic mercury compounds have been used primarily for seed dressing and thus most victims have been workers in chemical manufacturing plants, farmers and members of their families, who have accidentally ingested dressed seeds.

Exposure to high concentrations of mercury vapour affect primarily the lungs, causing pleuritic pain and shortness of breath and also fever lethargy, nausea, vomiting and blurring of the vision, within hours of exposures. The lungs show bronchiolitis with interstitial in filtrates and pulmonary function test indicate restrictive changes with reduced diffusion capacity. Mercuric chloride is exceedingly toxic in all metabolic systems; it causes severe necrosis throughout the gastrointestinal tract, with cardiovascular shock and acute renal failure.

Minamata Disaster

Minamata Disease was discovered for the first time in the world at Minamata City, Kumamoto Prefecture, Japan, in 1956, and for the next time at Niigata City, Niigata Prefecture, Japan, in 1965. The both cases were attributed to the methyl mercury that was generated in the process for producing acetaldehyde using mercury as catalyst. Methyl mercury had accumulated in fishes and shellfishes and those who consumed them had been poisoned with it. These cases of the poisoning with organic mercury poisoning were the first to take place in the world through the food chain transfer of environmental pollution. The cases of organic mercury poisoning that had been known prior to Minamata disease, occurred as the result of the direct poisoning of those who were engaged in organic-mercury handling occupations or those who took it accidentally.

The Shiranui Sea that caused the first Minamata disease i.e. that in Minamata has an area of 1,200 square kilometers and once enjoyed abundance of fishes, shellfishes and other food species and a population of approximately 200,000 were engaged in fishery and other relative jobs. The residents living there were accustomed to eat fishes and shellfishes as main dishes throughout years. Some of them ate 500 grams of them a day accumulating mercury through food. On the other hand, the residents living along the Agano River, Niigata, that caused the second Minamata disease also ate the fresh water fishes caught in great quantities there.

Minamata Disease

The name Minamata disease used to describe the methyl mercury poisoning that occurred among the people living along Minamata Bay in Kyushu, Japan in the 1950's & 60's (*Watanabe C, Satoh H (1996).* The source of methyl mercury was effluent from a chemical company, where mercury was used as a catalyst in the production of acetaldehyde.

The methyl mercury concentrated in food chain, resulting in sufficiently high concentration in fish and shell fish, which are the diet source for villagers to cause mercury poisoning. Such type of exposure to methyl-mercury was highly uncommon and unusual, although the number of victims eventually certified with Minamata disease was over 2,200. In the Minamata Bay area, infants began to manifest a severe disease resembling cerebral Palsy *Harada M (1978).* The mothers of these children had consumed contaminated fish and shell fish during pregnancy, which affected the developing fetal central nervous system.

Another outbreak of methyl mercury poisoning occurred in Niigata prefecture in 1965. Dubbed Niligata Minamata disease was also caused by acetaldehyde plant effluent. Approximately 700 persons affected by the poisoning.

Methyl Mercury Poisoning in Iraq

In Iraq, three epidemic poisonings have been reported. In 1955-56, in 1959-60 and the largest outbreak in 1971-72. These outbreaks were caused by the distribution of seed grains treated with methyl mercury. Rural people consumed the grains by using it to make homemade bread, instead of planting the seeds. The total number of victims was 6530, including 459 deaths. There were also some fetal cases, in which the mothers consumed the contaminated bread during pregnancy thereby exposing the foetuses to methyl-mercury in Utero (*Amin_Zoki L. et.al. 1974)*.

Methyl Mercury Poisoning Episode in Iraq

In late 1960's and early 1970's, when Iraq experienced a series of abysmal harvests its leader decided to import newly branded "*Wonder wheat*" from Mexico. The risk was that the seed might grow mouldy during the long, humid ocean transport to Iraq if it was not dressed with some fungicide. Methyl mercury was used as the fungicide due to its cost-effectiveness. The use of methyl mercury had been banned in Scandinavia and several American states due to environmental and toxicological risks.

The wheat seeds dressed with methyl mercury were sent to Basra in Iraq's south. Because the shipment arrived late, trucks and trains that had been at hand were reassigned. So it took another couple of months before the grain reached the farmers. By then the sowing season was over. Farmers were left with a pink grain that they were *told not to eat*, only to plant. But the harvests had been lousy and farmers had little or nothing to feed their animals and themselves. The Iraqi farmers feeded the grain to chickens or sheep and watched to see if there were any bad side effects. Nothing happened for weeks. Then the farmers initiated giving the grain to their livestock and eating it themselves. Children got to like the pink bread.

The impact of methyl mercury on their health was soon visible and the doctors could not ascertain the cause of sickness. In rural areas, when the people saw that the doctors could not help, the people brought their sick family members home due to the tradition that a person should preferably die at home with his or her family members around.

Methyl mercury treated Grain Sacks

Fig. 20: Home made Bread prepared from methyl mercury treated wheat

5.3 CHRONIC MERCURY EXPOSURES - GUIDELINES & STANDARDS

Chronic exposure of mercury results in fertility impairment and adverse pregnancy outcomes. Foetuses are at high risk from methyl-mercury poisoning. Methyl mercury can cross the placenta barrier and cause foetal brain damage without any symptoms in the expectant mother. New born babies may experience mental and physical disabilities as well as delayed development of motor and verbal skills. High level of prenatal methyl mercury exposure causes mental retardation and other neurological disturbances *Anon 2005*. Various guidelines standards have been prescribed for exposure to mercury by various international agencies.

Table 11: Guidelines and Standards for Chronic Mercury Exposure

S. No.	Environment Component	Guidelines Standard	Agency
1.	Air (Elemental)	0.2 mg/m^3 0.3 mg/m^3	Agency for Toxic Substance and Disease Registry (ATSDR), USA
2.	Air (Inorganic)	1.0 mg/m^3	WHO
3.	Drinking water	1 mg/l (total Hg) 2 mg/l (Inorganic Hg)	WHO EPA
4.	Food (Methyl Mercury)	0.1 mg/kg/day 0.3 mg/kg/day 1.0 mg/g	EPA ATSDR FDA
5.	Chronic Oral Intake (Inorganic)	0.3 mg/kg/day	EPA

Source: Donald T, Wigle 2003, Child Health and the Environment, Oxford University Press, USA, pp 100-135.

6.0 SUBSTITUTION OF MERCURY - MERCURY FREE ALTERNATIVES

Most of the mercury that enters the environment comes from anthropogenic use of mercury. The substitution of mercury with mercury free alternatives is one of the preventive actions against mercury release to environment and its toxicity. Increased awareness is required for substitution of mercury with mercury free alternatives for major uses of mercury such as dental amalgam, tilt switches, thermometers, lamps, pigments, batteries, reagents and barometers. The mercury alternatives available are detailed below:

Table 12: Alternatives available for Mercury Commercial Use

S. No.	Product or Application	Available Alternatives	Cost Effectiveness
1.	Mercury cell process in chlor-alkali industry	Membrane technology	Higher investment costs for conversion but lower operational, waste treatment and disposal costs
2.	Mercury used in dental amalgam	Gold, silver, ceramic, porcelain, polymers, composites, glass ionomers amalgam fillings	While some are less expensive and easy to apply, others are more expensive and difficult to apply
3.	Mercury based batteries	Mercury free batteries	Cost of mercury free batteries may be higher or about the same but their usage is preferable to costly cleaning of mercury contaminated wastes
4.	Laboratory use	It is possible to restrict mercury use in school or university laboratories to a few controllable uses	The alternatives are generally no more expensive
5.	Thermometers	Other liquids, gas, electric and electronic sensors	More expensive but one electronic thermometer may replace several broken mercury ones
6.	Pressure measuring and control equipments	In pressure gauges, switches and transmitters, mercury can be substituted using flexible membrane, piezoelectric crystals and fibre-optic pressure sensors in barometers and manometers, mercury can be replaced by other liquids or gases	Electrical and electronic instruments are slightly more expensive but alternatives based on gas, other liquid or mechanical spring show no significant price difference
7.	Tilt switch Electronic switch Reed switch Proximity sensor/switch	Mechanical or micro switch Solid state and optical switch Solid state and electro-optical switch, semi-conductor Inductive, capacitive, photo-electric sensor, ultrasonic	No significant price differences
8.	Artisanal gold extraction Pesticides and biocides	Non-mercury electrolytic process, Minataur process Processes not requiring chemical pesticides and biocides or use easily degradable substances	Not more expensive Cost is roughly comparable and environmental benefits are considerable
9.	Energy-efficient lamps (Compact Fluorescent Lamps)	Currently there are no mercury-free efficient alternatives to the energy-efficient lamps	-

Source- Global Mercury Assessment, UNEP Chemicals, December 5, 2002

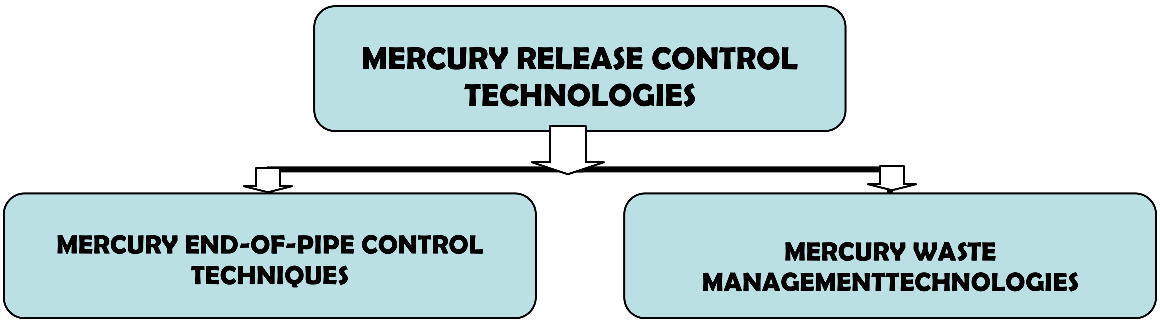
Table 13: Mercury Containing Chemicals and their alternatives

S. No.	Chemical	Alternatives
1.	Mercury (II) oxide	Copper catalyst
2.	Mercury chloride	None identified
3.	Mercury (II) chloride	Magnesium chloride/sulfuric acid or zinc, freeze dying
4.	Mercury nitrate for anti-fungal uses	Ammonia/ copper sulphate, mycin
5.	Mercury iodide	Phenate method
6.	Zenker's solution	Zinc formalin
7.	Mercury (II) sulphate	Silver nitrate/ potassium/ chromium (III) sulphate

Fig. 21: **Mercury Free Digital Thermometer** **Mercury Free Alkaline Batteries**

7.0 MERCURY RELEASE CONTROL TECHNOLOGIES AND PRACTICES

Mercury is released into the environment both from intentional as well as unintentional use. The specific methods for controlling mercury releases from the sources vary widely, depending upon local circumstances, but generally grouped in two major categories:



7.1 MERCURY END-OF-PIPE CONTROL TECHNIQUES

This is the most effective method in controlling unintentional mercury release to the environment. The various pollution sources & their respective control techniques are summarized below:

Table 14: Mercury Pollution Sources & Control Techniques

S. No.	Air Pollution Sources	Control Techniques
AIR POLLUTION SOURCES		
1.	Mercury mining & smelting	Conditioning of mercury vapour in refrigeration unit followed by electrostatic precipitator (EP)
2.	Mercury battery cell	Electro static Precipitator/Bag house
3.	Chlor-alkali industry	Process change/ use of ventury scrubber
4.	Pulp & paper	Process change, restriction in use of mercury
5.	Incineration	Sort the waste portion containing mercury prior to incineration
WATER POLLUTION SOURCES		
1.	Chlor-alkali industry	Process change/ properly designed tailing system
2.	Mining & smelting/battery	Ion exchange/ neutralization & sedimentation with/ without precipitation
3.	Pulp & paper	Process change/ restriction in use of mercury
4.	Solid waste disposal	Restriction on dumping of solid waste without pretreatment like recycling/ sanitary landfill etc.
SOIL POLLUTION SOURCES		
1.	Use as herbicide & insecticide	Restriction of use in agriculture
2.	Airborne mercury particulate deposition	Air pollution control measures
3.	Solid waste dumping	Restriction on dumping of solid waste without pretreatment like recycling/ sanitary landfill etc.

7.2 Mercury Waste Management

Mercury wastes, including those residues recovered by end-of-pipe technologies, constitute a special category of mercury releases, with the potential to affect environment and populations far from the sources of the mercury emissions. Mercury waste management consists of rendering mercury content of the waste, chemically inert followed by controlled landfillind or it may not treat the waste prior to the landfill.

Low concentrations of mercury in waste are generally permitted in normal landfills, while some countries only allow waste with higher mercury concentrations to be deposited in specific landfills that are designed with enhanced release control technologies to limit mercury leaching and evaporation i.e. sanitary landfill. The cost of disposal of mercury waste in environmentally sound manner is quite high. The strict environmental norms in western countries force the mercury waste producers to switch to mercury alternatives in which they wouldn’t have to produce and deal with mercury waste. The recycling and recovery of mercury from wastes can limit the need for new mercury mining and reduce the problem of mercury mine waste dumping.

8.0 DECONTAMINATION & RESTORATION OF MERCURY POLLUTED AREAS

The process of decontamination involves binding the mercury in the waste to inorganic and organic materials, which are slowly buried by the ever-occurring sedimentation process. Various decontamination solutions are as below:

i.) Removal of mercury containing sediments by dredging or pumping

The dredging operation must ensure that the disposal of the dredged material should be handled in such a manner that the mercury contamination is not leached back into the surface waters or percolated into underground aquifers.

ii.) Removal of mercuric ions using

a) Granulated slag of steel plant
About 1 gm of granulated slag can efficiently remove 70 mg of mercuric ions in a week.

b) Fly-ash from a coal-fired boiler
Fly ash can effectively adsorb mercuric ions from aqueous solution at pH 4.0.

c) EDTA along with activated charcoal and coconut shell carbon

d) Steamed hoof powder (size< 53µ)

e) Aluminium or other active metals
This method involves adding aluminium or some other metal, which will actively react with mercury to form an amalgam and thereby removing it from the biological methylation cycle.

iii.) Making the mercuric unavailable to be biologically converted into dimethyl mercury

iv.) The removal of dimethyl mercury in limnetic ecosystems through vaporization into the atmosphere

When the pH of water is alkaline, then dimethyl mercury exists rather than mono methyl mercury. Then, this dimethyl mercury can be easily volatilized into the atmosphere.

v.) The biological removal of mercury in aquatic ecosystems

Few species of microorganisms such as *Pseudomonas aeruginosa*, *Proteus* spp. and *Escherichia coli* can easily convert mercuric ions into elemental mercury in aquatic media, which being volatile in nature is removed from the water body.

vi.) Bury the mercury contaminated sediments with sand or other materials (clay)

Layers of selected inorganic sediments from 3 to 8 cm in depth can be effectively used to bury the mercury contaminated sediments and thereby decontaminate the area.

vii.) Cover the bottom of mercury contaminated lakes with a plastic coating

This method would not only isolate the mercury contamination already accumulated in lake / reservoir bottom sediments, but would also prevent problems associated with sediment migrations.

9.0 LEGAL MECHANISM & ENVIRONMENTAL STANDARDS FOR MERCURY POLLUTION CONTROL

9.1 United States and at International level

Mercury regulations in United States are regulated through multiple federal and state statues, as well as multiple agency jurisdictions. The United States Environmental Protection Agency (USEPA) regulates mercury in pesticides, and mercury releases into the environment through air, water and land disposal limits. The US Food and Drug Administration (FDA) regulate mercury in cosmetics, food and dental products. The Occupational Safety & Health Administration (OSHA) regulates mercury air exposures in the workplace. Unlike the separate regulatory structure created for Poly Chlorinated Biphenyls (PCB's) under the Toxic substances Control Act (TSCA), no statute, at a federal level, has strategically identified mercury as a sole source of concern.

To understand how existing mercury regulations influence the full spectrum of economic activities that involve mercury it is helpful to first distinguish between regulations that have a direct effect on sources from those that have an indirect effect on sources Use or release related regulations have a direct effect on sources that use mercury or release mercury into the environment. These regulations in United States specify, for individual mercury sources, the costs and/or conditions associated with using and releasing mercury during production or disposal.

Environmental Standards

Environmental standards are numeric criteria that specify a maximum acceptable concentration for different media, based on scientific or risk-based criteria. For instance, mercury standard exists for water, sludge, fish tissue, drinking water, and several other media. These standards provide a yardstick against which to measure the effectiveness of mercury release regulations.

Table 15: Environmental Standards for Mercury in United States

S. No.	Media	Mercury Standard	Explanation
1.	**Ambient Water**	• 0.144 µg/l for ingestion of both water and aquatic organisms; • 0.146 µg/l for ingestion of only aquatic organism. • 2.4 µg/l for freshwater acute exposure; change with GLI) • 0.012 µg/l for freshwater chronic exposure; • 2.1 µg/l for marine acute exposure; • 0.025 µg/l for marine chronic exposure. (50 FR 30791)	Established under Clean Water Act §304(a). Ambient water criteria varies by state
2.	**Drinking Water**	• Maximum contaminant level = 0.002 mg/l (40 CFR 141.62)	Maximum contaminant level for mercury established under the Safe Drinking Water Act.
3.	**Air**	• No ambient standard.	-
4.	**Sludge**	• 0.17 mg/kg (dry wt) and 17 kg/hectare cumulative loading for sludge applied on agricultural, forest and publicly accessible lands. • 0.17 mg/kg (dry wt) and .85 kg/hectare annual loading rate for sludge sold or distributed for application to a lawn or home garden. • 0.57 mg/kg (dry wt) for sludge sold or distributed for other types of land disposal • 0.100 g/kg (dry wt) for sludge disposed in lined or unlined facilities (40 CFR 503).	-
5.	**Compost**	• No federal standards.	EPA Minnesota has mercury concentration limits in compost.
6.	**Fish**	• 1 µg/g (1 mg/kg or 1 ppm)	FDA action level for methyl mercury
7.	**Ground water**	• 2 µg/l	-
8.	**Bottled Water**	• . 0.002 mg/l (21 CFR 103.35)	-
9.	**Hazardous Waste**	• TCLP = 0.2 mg/l or 0.2 ppm (40 CFR 261, 24, 264)	Land disposal (Subtitle D, non-hazardous landfills) prohibited unless leachate contains less than 0.2 mg/l.

Table 16 : Regulatory Environmental Standards for Mercury in Drinking Water

IS: 10500 BIS Desirable Limit	EEC Maximum admissible concentration	German Maximum admissible concentration	WHO Guidelines Value
0.001 mg/l	0.001 mg/l	0.001 mg/l	0.001 mg/l

BIS : Bureau of Indian Standards
EEC : European Economic Community
WHO : World Health Organization

Table 17: Guideline Limit of Mercury for Water for Protection of Aquatic Life

CCME (2006) has prescribed the maximum guideline limit of mercury for protection of freshwater and marine aquatic life as detailed below:

Mercury state	Water for Protection of Aquatic Life (µg/l)	
Inorganic mercury	0.026	0.016
Methyl mercury	0.004	-

Source: CCME, 2006

Table 18: Guideline and Baseline Values Standard for Soil and Sediments

Guideline value and Probable effect level of mercury in sediments of marine and fresh waster are compared with world shale value below:

Soils* (µg/g)			Shale ** Value (µg/g)	ISQG***		PEL**** (µg/l)	
Residential	Industrial	Agricultural	Baseline	Fresh Water	Marine	Fresh Water	Marine
6.6	50	6.6	0.4	0.17	0.13	0.486	0.70

* *Guideline Value (CCME, 1999)*
** *World Shale Value (Turkian & Wedepohl, 1961)*
*** *Interim Sediment Quality Guideline (CCME, 2002)*
**** *Probable Effect Level (CCME, 2002)*

a) Mercury Use Regulations in United States

Regulations associated with mercury use in commence impose costs, conditions and / or restrictions associated with obtaining, selling, using or transporting mercury. Mercury use regulations affect only these facilities that use mercury as an input. They do not affect these sources that release mercury incidentally as a by-product.

Mercury in Commerce	▪ Excise taxes and import taxes directly affect the cost of using mercury as an input in manufacturing processes. ▪ Regulations governing mercury sales from National Defence Stockpile influence the amount of mercury available for purchase. ▪ Transportation requirements impose restrictions on mercury transport.
Mercury in Products	▪ Mercury product regulation has health based reasons to eliminate mercury from products. ▪ Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and the Federal Food, Drug and Cosmetic Act (FFDCA) regulations have control on mercury in products.
Reporting Requirements	▪ Facilities that exceed threshold planning quantities for mercury under SRA title 111 regulations. Quantity must be reported to local emergency planning commission. ▪ Mohican has regulations to report the quantities of chemicals used under the Part 9 rules of Act, 245.

9.2 Occupational Exposure Limit in Japan

Occupational exposure limit (OEL) for mercury vapour have been established in Japan and other countries. The Japan Society for Occupational health (JSOH) recommended the OEL for mercury vapour to be 0.025 mg/m^3 in 1998. The recommendations of OEL in other countries are stated in the Table 19.

Table 19: Occupational exposure limit (OEL) for Mercury

Country	Unit	OEL
ARAB Republic of Egypt TWA	mg/m^3	0.05
Austria MAK	mg/m^3	0.05
Australia TWA	mg/m^3	0.1 Skin
Belgium TWA	mg/m^3	0.1 Skin
Denmark TWA	mg/m^3	0.05 Skin
Finland TWA	mg/m^3	0.05
Sweden TWA	mg/m^3	0.05 vapour
Switzerland TWA	mg/m^3	0.05 Skin
Turkey TWA	mg/m^3	0.1 Skin

Biological exposure indices (BEI) have also been established. JSOH recommends a mercury level of 35 μg/g creatinine in urine samples for biological monitoring. A lower OEL of methyl mercury (0.01 mg Hg/ m^3 has been established in most of the countries including Japan.

9.3 International Convention Agreements

The following are the international agreements dealing directly with Mercury regulations:

- The Convention on Long – Range Transboundary Air Pollution and its 1998 Airbus Protocol on Heavy Metals (LRTAP Convention).
- The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention).
- The Convention on the Protection of the Marine Environment of the Biotic Sea Area (Helsinki Convention).
- The Basel Convention on the Control of Transboundry Movements of Hazardous Waste and their disposal.
- The Rotterdam Convention on the Prior Inferred Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade.
- The Stockholm Convention on Persistent Organic Pollutants (Stockholm Convention).

It has been realized that mercury pollution is not a problem of small region and also it is very difficult to tackle alone. Thus, a number of governments have found it beneficial to cooperate across national borders in order to address the adverse impacts of mercury on health and the environment in a specific sub-region or region. To fulfill this aim number of actions plans have been started,

- Arctic Council Action Plan (ACAP)
- Great Lakes Bi-national Toxics Strategy
- New England Governors/ Eastern Canada Premiers Mercury Action Plan
- Nordic Environmental Action Programme
- North American region Action Plan on Mercury
- North Sea Conferences
- Coordinating Body on the Sea of East Asia-UNEP/ GEF project on reversing environmental degradation trends in the South China Sea and Gulf of Thailand
- Governor Blagojevich's Mercury Pollution Reduction Plan.

9.4 International Organizations & Mercury Control Programmes

Mercury pollution has now become a global phenomena and thus with growing concern number of international organizations have mandate to address the impacts of mercury on health and environment. The leading organizations are International Agency for Research on Cancer (IARC), International Labour Organization (ILO), International Programme on Chemical Safety (IPCS), Organization of Economic Co-operation and Development (OECD), United Nations Environment Programme (UNEP), and World Bank group. All these programmes and organizations cover worldwide except OECD, which is applicable to only member states.

- IARC addresses the evaluation of carcinogenic of chemicals, including health effect of mercury to humans. It also evaluates individual chemicals, provide information and issue guidelines.
- ILO addresses occupational health and safety issues linked with use of chemicals, including small-scale mining activities and mercury. It also issues guidelines and emphasize on capacity building.
- IPCS deals with health and environmental aspects of mercury and provide information regarding risk and precautionary measures.
- OECD focuses on mercury and mercury compounds releases, products, wastes etc. It also provides the recommendation for reducing the mercury in waste.

- UNEP addresses heavy metals, including mercury and provide guidelines to deal with these metal pollution.

- UNIDO and World Bank both emphasize on environmentally sustainable industrial activities and provides with information, guidelines and capacity building in this activity.

9.5 LEGAL MECHANISMS & MERCURY REGULATIONS AT NATIONAL LEVEL

Hazardous substances pervade modern industrialized societies. Indian industry generates uses and discards toxic substances. Toxic substances are extensively regulated in Indian constitution, since its 42nd Amendment came into force in 1976.

The implementing arms of the Central Government, particularly the Pollution Control Boards, have been actively working in cooperation with industries to control the quality and quantity of wastes from different industrial units. This objective is implemented as below:

- Laying down a set of rules on the expert recommendations to control the environmental pollution.

- Adopting international conventions and recommendations concerning the prevention of occupational risk.

- Observing the codes of practice and guidelines on prevention.

9.5.1 Environmental Legislation Related to Mercury

The various legislations governing the mercury emission/ discharge directly or indirectly to the environment have been enacted. The enforcing agencies and details of these legislations are presented below:

Table 20: Environmental Legislation related to Mercury in India

S. No.	Legislations	Objectives	Comments
1.	The Water (Prevention & Control of Pollution) Act, 1974 (amendment 1988)	To provide for the prevention, control and abatement of water pollution, and the establishment of central and state boards to implement that objective	It specifies areas affected by water pollution in the country and prohibits the use of streams or wells for disposal of polluting matter but doesn't concern with the disposal of sludge.
2.	The Water (Prevention & Control of Pollution) Cess Act/ Rules, 1978	Act was primarily intended to levy and collect a cess for the abatement of pollution whereas rule specifies quantity of water to be consumed by industries.	Rule specifies the maximum quantity of water to be used for the production of caustic soda by mercury cell process
3.	The Environment (Protection) Act/ Rules, 1986	Act provides for the protection and improvement of environment by giving Central Government powers to take measures whereas Rules regulate environmental pollution, with power given to Central & State Pollution Control Boards	Mercury is included in the standards of all the major emitting industries, but there are no regulations or standard for thermal power plants emitting mercury in the air.

S. No.	Legislations	Objectives	Comments
4.	The Hazardous Wastes (Management & Handling) Rules, 1989 & amendment 2000, 2003	To establish a control mechanism for the management of hazardous wastes	Mercury included in the waste category
5.	The Manufacture, Storage and Import of Hazardous Chemical Rules, 1989 (amendment 2000)	Formed to regulate hazardous chemicals in the country	Chemicals included according to the degree of toxicity
6.	The Municipal Solid Wastes (Management & Handling) Rules, 2000	Regulates municipal solid waste	Standards set for mercury in groundwater, composts and leachate
7.	The Central Insecticides Act, 1968	Regulates the import, manufacture, sale transport, distribution and use of insecticides to prevent risk to people and animals	Prohibits the import of most mercury based agro-chemicals

ENVIRONMENTAL STANDARDS RELATED TO MERCURY

Central Pollution Control Board (CPCB) has developed National standards for effluents and emission standards under the statutory powers of the Water Act, 1974 and the Air Act, 1981.

Emission Standards

Chlor-alkali (Caustic soda)	Emissions	Standard (Concentration in mg/m^3, normal)
Mercury Cell Process	Mercury (from hydrogen gas holder stack)	0.2 mg/m^3

Effluent Standards

Industry	Effluents	Standard (Concentration not to exceed)
Dye and dye intermediate industries	Mercury	0.1 mg/l
Pharmaceutical industry (Bulk drugs)	Mercury	0.1 mg/l
Pesticide manufacturing and formation industry	Heavy metals mercury	0.1 mg/l
Inorganic Chemicals Industry (waste water discharge)	Mercury	0.1 mg/l
Organic chemicals manufacturing industry	Mercury	0.1 mg/l

9.5.2 *Occupational Health Legislations*

The legislation deals and prescribes relief and protection measures to workers, working in the hazardous environment. The legislations included into this category are summarized ahead:

Table 21: Occupational Health Legislations

S. No.	Legislation	Objective	Comments
1.	The Workmen's Compensation Act, 1923	To provide the workers compensation by their employers in case of personal injury by accident	Diseases caused by mercury or its toxic compounds are included but this become useless because generally mercury poisoning occurs after the retirement of the worker.
2.	The Factories Act, 1948 (Amendment 1987)	Covers all the aspects of health and safety of workers	Permissible limits of exposure to the mercury in the work environment have been specified.
3.	The Public Liability and Insurance Act/Rules, 1991	Act provides for public liability insurance for the purpose of providing immediate relief to the person affected by the accident and rule provides the list of chemicals with quantities for application of the Act.	The schedule provides reimbursement of medical expenses incurred but only mercury fulminate is included in the list.

10.0 RECOMMENDATIONS

It is globally and nationally realized that mercury is one of the most toxic heavy metals and has serious impacts on human health. The import of mercury and its illegal trade has shown a tremendous increase in the past few years, because of its increasing demand in domestic market. Mercury from a variety of industrial, occupational, household and health care uses as well as local and global mercury sources is posing serious health risk.

Ministry of Environment & Forests (MoEF) & Central Pollution Control Board (CPCB) have taken up several programmed to facilitate switchover to cleaner technologies. CPCB has been constantly advising to all State Pollution Control Boards (SPCBs) to make the segregation of mercury-contaminated bio-waste a condition for granting authorization to the healthcare centres. The new healthcare establishments will have to ensure the mercury-laden waste is properly segregated, treated and disposed of.

The regulation and safeguard for handling mercury are still inadequate. To deal with the problem of mercury in the control, apart from various legislations regulatory measures are to be strengthened further. It is also recommended that following measures should be adopted to deal with the problem.

- The restriction and ban on the usage of elemental mercury and mercury compounds through disincentives like high taxes and import duties, and provide incentives (lower or zero taxes or import duties) for commercial uses of mercury alternatives.

- Regulation on recycling and recovery of mercury from various products and also prohibition on disposal of mercury bearing products along with garbage and disposal to landfills.

- Strong measures should be taken to reduce and/or eliminate mercury in wastes through sound mercury waste management.

- Emission standards for mercury and suitable cost effective environmental monitoring have to be strengthened.

- During Mercury spills following precautions are necessary:

  - ➢ The people and pets have to be moved away from the mercury spill area. To minimize the mercury that vaporizes, turn off heaters and air conditioners. Ventilate the area by opening windows.

  - ➢ Vacuum cleaner should not be used to clean up mercury spill. Mercury will normally contaminate the vacuum cleaner, but the heat from the cleaner will also evaporate the mercury to surrounding environment.

  - ➢ Always wear rubber gloves while handling mercury.

  - ➢ All jewellery and watches have to be removed, while handling mercury spill, as mercury will bind with the metal.

- Phase-out mercury containing instruments or chemicals and replace them with safer alternatives.
- Adopt mercury inventorization in the hospital to assess the mercury usage and plan a phase out strategy.
- The policy on mercury usage, handling procedures, safe guards, spill clean up, etc. needs to be formulated.
- Introduce reporting formats to report and register only mercury spills/ leaks.
- Post hazard and warning information in the work area.
- The workers should be trained to dispose off mercury when spilled
- Establish mercury waste management in hospitals to ensure that no mercury enters the sewage system/municipal bins and biomedical waste. All the waste should be dealt with hazardous waste.
- Curricula should have special emphasis on hazardous substances and pollution prevention. The curricula of medical, nursing, dental, paramedical schools, etc. should be considered for adding this information on.

- Awareness programmes should be launched to educate the population about the risk and impact of mercury.

REFERENCES

BOOKS

1. D'Itri, Patricia A.; D'Itri, Fran M., Mercury Contamination – A Human Tragedy; Wiley – Interscience-1977.

2. D'Itri, F. M. The Environmental Mercury Problem, CRC Press-1972.

3. Environmental Health Criteria 1, Mercury, Published under the joint sponsorship of UNEP & WHO, Geneva 1976.

4. Glass, Gary E., Bioassay Techniques & Environmental Chemistry, EP Agency, Minnesota, Ann Arfor Science Publishers, 3rd Edition-1975.

5. Hartung Felf, Dimman Bentram D., Environmental Mercury Contamination; An Urban Science Publishers Incorporation, 3rd Edition, 1974.

6. Hutzinger O., The Handbook of Environmental Chemistry Vol. 1 Part A – The National Environment & the Bio-geochemical Cycles, Springer-Verlag Berlin Heidelberg, New York, 1980.

7. Hutzinger O., The Hand book of Environmental Chemistry Vol. 3 Part A – Anthropogenic Compounds, Springer-Verlag Berlin Heidelberg, New York, 1980.

8. Mercury – Environmental Aspects, EHC 86, Published by WHO, Geneva 1989.

9. Mercury, inorganic, EHC 118, Published by WHO, Geneva, 1991.

10. Methyl Mercury, EHC 101, Published by WHO, Geneva, 1990.

11. Mitra, S., Mercury in the Ecosystem, Trans Tech Publications-1986.

12. Safe, S. and Hutzinger, O., Mass Spectrometry of Pesticides and Pollutants, CRC Press-1973.

13. Vernet, J. P., Heavy Metals in the Environment; Institute F.A. Forel, University of Geneva, Versoir, Switzerland, 1991.

REPORTS

14. Global Mercury Assessment –United Nations Environmental Programme (UNEP), December, 2002.

MAGAZINES

15. Anon. Lurking Menace, Toxic Links, New Delhi, 2005, pp 19-21.

16. Jamwal, Nidhi, Mercury Rising, Down To Earth, November, 30, 2003, pp 15-16.

17. Jamwal, Nidhi, Slow but sure, poisons, Down To Earth, November 15, 2004, pp 32-33.

18. Yadav, Kushal PS, Danger Zone, Down To Earth, September 15, 2000, pp-20-21.

CPCB PUBLICATIONS

19. COINDS/6/1981-82, Minimal National Standards : Caustic Soda (Mercury Cell Industries)

20. Parivesh Highlights-2000, April, 2001.

21. PROBES/12/1982-83, Mercury Transfer to Environment From Chlor - Alkali Industry - A Case Study

22. PROBES/27/1985, Zonal Committee's Report on Assessment of Pollution Control Measures in Chlor-Alkali Industries (Mercury Cell

23. PROBES/30/1985-86, Performance Study of Ion - Exchange Resin Treatment System for Mercury Removal from Wastewater at Gujarat Alkalies & Chemical Ltd. Baroda, Gujarat

24. PROBES/92-2002-03, Assessment of Industrial Pollution

25. PROBES/97/2002-2003 Environment Management in Selected Industrial Sectors-Status & Need

WEBSITES

26. www.cpcb.nic.in

27. www.chem.unep.ch

28. www.epa.gov

29. www.envfor.nic.in

30. www.inchem.org

31. www.webhealthcenter.com

JOURNALS

31. Agrawal, Manju and H.D. Kumar, 1978, Physico-chemical and Psychological Assessment of Two Mercury-polluted Effluents, Indian Journal of Environmental Health, Vol. 20 (2), pp 141-155.

32. Amin_Zokil, Elhassani S, Majeed M A, Clarkson TW, Doherty RA, Greenwood M, 1974, Intra-Uterine methyl mercury poisoning in Iraq. Pediatrics 54, 587-95.Hiroshi Satoh (2000). Occupational and Environmental Toxicology of mercury and its compounds, Industrial Health 38, 153-164.)

33. Ayyadurai, K and *et.al*., 1994, `Studies on Heavy Metal Pollution in the Finfish, Oreochromis mossambicus from River Cauvery, Indian Journal of Environmental Health, Vol. 36 (2), pp 99-103.

34. Ayyadurai, K and *et..al*., 1983, `Mercury Pollution in Water in Madras City' Indian Journal of Environmental Health (IJEH), Vol. 25 (1), , pp 15-20.

35. Bhattacharyya, K. G. and Sarma Nikhileswar, 1993, `Using Flyash to Remove Mercury (II) from Aqueous Solution, IJEP, Vol. 13(12), pp 917-920.

36. Choudhuri, J. Mandal A., Sudhukhan, P. C., Ghosh, S. and Ghosh, D. K., 1996, `Accumulation of Mercury in Edible Fish from Wetlands of Calcutta, IJEM, Vol. 38(4), pp. 261-268.

37. Clarkson TW, 1992; Mercury: Major issues in environmental health: Environ Health Perspect 100: 31-8.

38. Docter, P. B. and Ghosh, S. K., 2001, `Toxicity Assessment of Textile Dye Contaminated Effluents Before and After the Treatment, IJEP, Vol. 21 (5), pp 431-433.

39. Harada M, 1978. Congenital Minamata disease intrauterine methyl mercury poisoning. Teratology 18, 285-88.

40. Loomba, Komal and Pandey, G. S., 1992, `Removal of Mercury from Chloralkali Plant Effluent Using Granulated Slag of Steel Plant', IJEP, Vol.12(7), pp 528-530.

41. Mohan, Brij, 1992, `Toxic Effects on Industrial Workers due to Occupational Exposure of Mercury', IJEP, Vol. 12(2), , pp 105-109.

42. Nag, J. K. and Das, A. K., 1994, `Study of Metal Parameters in the District of Banbura, IJEP, Vol. 14(6), pp 453-456.

43. Nagalakshmi, R., Priya, G. K. Nagarjan, Prabavathi, Venkataraman, G. and Samdas, S., 2000, `Strategies of Environmental / Friendly Shielded Metal Arc Welding, IJEP, Vol.20(4), , pp 252-262.

44. Panigrahy, P. K., Panda, U. C., Nayak, B. B. and Acharya, B. C. 2002, `Evaluation of Mercury Content in Estuarine and Coastal Sediments of Rushjikulya Ganjan, IJEP, Vol. 22(9), , pp 998-1002.

45. Pank, Mee, Jungand Bhargava, D. S. 1992, `Environmental Impacts of Solid Waste Incineration, IJEP, Vol. 12(6), pp 401-408.

46. Prasad, Surendra and Nigam, Prem C., 1989, `Mercury Catalyzed Exchange Reaction of Hexacyano ferrate (II) and its application in Trace Element Determination in Environmental Pollution; Indian Journal of Environmental Pollution (IJEP), Vol. 9(2), pp 113-117.

47. Rao, M. Subba and Gadgil, K. 1996, `Effect of Toxic Metals and their Complexes on BOD Values in Wastewater Analysis' IJEP, Vol. 16(11), pp 801-804.

48. Sahesta, S. K., Kaur, Harinder and Sahesta, H. S., 1996, `Mercury Contamination of Drinking Water Near Thermal Power Plant, IJEP, Vol. 16(9), pp 676-678.

49. Sarma, Nikhileswar and Sarma, R., 1994, `Combined Paper Mill Effluent Treatment by Water Hyacinth' IJEP, Vol. 14(9), pp 678-681.

50. Sengar, C.B.S. and Kumar, Animesh, 1991, `Sampling and Analytical Techniques for the Determination of Mercury and its Compounds in the Environment. A Review, IJEP, Vol. 11 (11), , pp 843-852.

51. Sharma, R. K. and Kothari, R. M., 1992, `Toxicity of Water and Wastewater, IJEP, Vol. 12 (4), pp 291-296.

52. Shiva Samy, P., Muthumari, R., Viola. T. Shanmugam, P. N. Lakshmi and Shanthi, S., 2000, `EDTA Assisted Removal of Heavy Metal Ions by Adsorption on Activated Charcoal and Coconut Shell Carbon, IJEP, Vol. 20(10), , pp 761-771

53. Srivastava, R. K. Ayachi, A. K. and Sehgal, Vandana, 2001, `Absorption of Mercury on Fly ash', IJEP, Vol. 21(6), pp 543-545.

54. Shrivastava, V. S., 1996 `Heavy Metals in Industrial Wastewater & Sludge by ICP – Atomic Emission Spectrophotometer, IJEP, Vol. 16(5), , pp 328-329..

55. Tiwaree, R. S. & Bhargava, D. S., 1992 `Trace Metals (Cd, Pb & Hg) in the Environment, IJEP, Vol. 12(4), , pp 241-250.

56. Tyagi, Poonam, Buddhi, D., Choudhury, Rubina and Sawhney, R. L., 2000 `Degradation of Ground Water Quality due to Heavy Metals in Industrial Areas of India – A Review, IJEP, Vol. 20(3), , pp 174-181.

57. Vanmathi, G. and Gopalakrishnan, S., 2000 `Heavy Metals in Tuticorin Coast, IJEP, Vol. 20(6), pp 447-451.

58. Watanabe C, Satoh H, 1996, Evolution of our understanding of methyl mercury as a health threat. Environmental Health Perspectives 104, 367-79.).