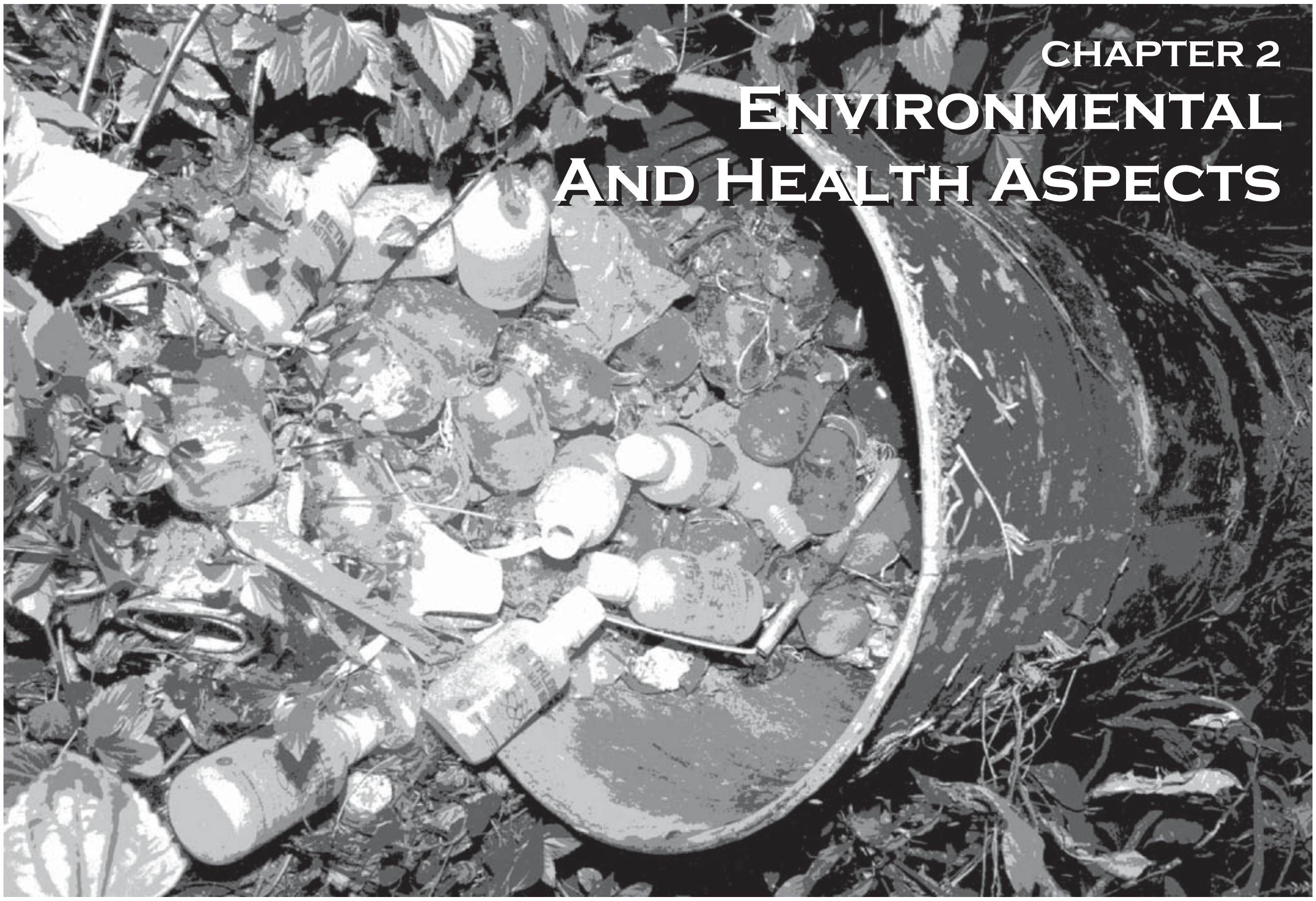
MERCURY IN INDIA

ENVIRONMENTAL AND HEALTH ASPECTS

MERCURY IN INDIA

- Mercury occurs naturally in the environment and thus has a background concentration which is independent of anthropogenic releases. Volcanic sources emit an estimated global total of 60,000 kg of mercury per year.
- The quantity released by burning coal is estimated to 3,000 tonnes per year worldwide, which is about the same amount released through all industrial processes.
- Mercury is commonly found in urban sewage through point source discharges from dental offices and industrial manufacturing processes such as battery fabrication.
- The atmosphere is the dominant transport vector of mercury to most ecosystems. Most of the mercury found in the atmosphere is elemental mercury vapour, which circulates in the atmosphere for up to a year, and hence can be widely dispersed and transported thousands of miles from likely sources of emission.
- Mercury undergoes a series of complex chemical and physical transformations as it cycles among the atmosphere, land and water as part of both natural and anthropogenic activities. Humans, plants and animals are routinely exposed to mercury and accumulate it during this cycle, potentially resulting in a variety of ecological and human health impacts.
- Mercury also has a long retention time in soils. As a result, mercury that has accumulated in soils may continue to be released to surface waters and other media for long periods of time, possibly hundreds of years.
- Fish-eating birds and mammals are more highly exposed to mercury than any other known component of aquatic ecosystems. Adverse effects of mercury on fish, birds and mammals include death, reduced reproductive success, impaired growth and development, and behavioural abnormalities.
- A 1999 study that tested and analysed groundwater samples from eight places in Gujarat, Andhra Pradesh and Haryana revealed that mercury levels were dangerously high in all the samples.
- Although environmental and health concerns of mercury have been well documented in India, there still has been no attempt from the government and the industry to reduce the usage of mercury in various industries and in our day-to-day life.

CHAPTER 2
Environmental And Health Aspects



Mercury occurs as a result of both natural and anthropogenic sources in our environment. The cycle involves different forms and types of mercury as a result of both chemical and biological reactions in aerobic and anoxic microenvironment. Until several years ago, estimates of the natural background level of mercury were unrealistically high due to erroneous data, giving the impression that anthropogenic contributions to the global mercury flux were less than what they truly are.[23] The generation of erroneous data arose because of a lack of sufficiently sensitive instrumentation to measure mercury in soil, water and air. A schematic of the cycle on page 34.

Pathways of Mercury Toxicity

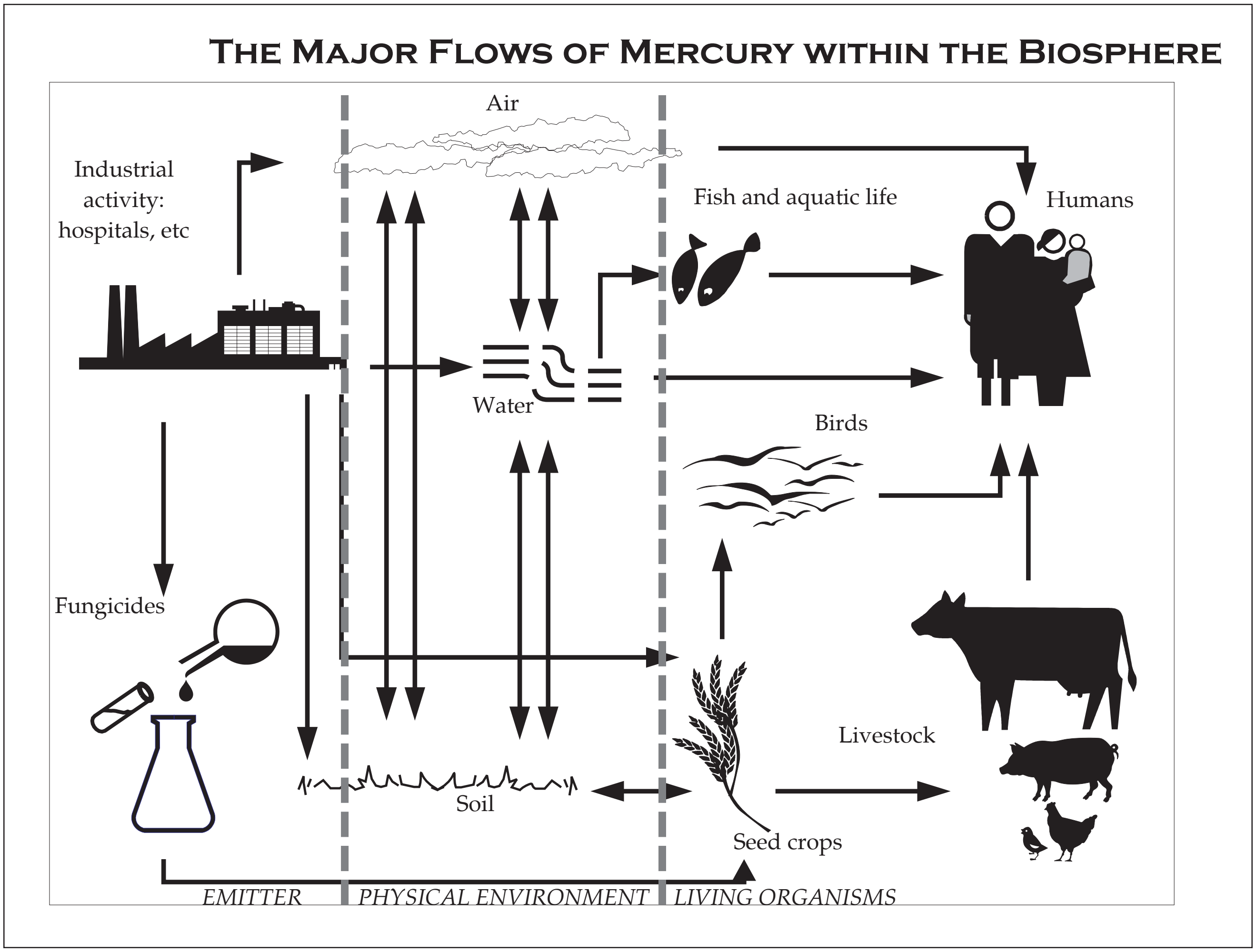
Natural Sources

Mercury occurs naturally in the environment and thus has a background concentration which is independent of anthropogenic releases. Mercury can occur naturally in a variety of valence states and conjugations, such as elemental mercury, dissolved in rainwater or as the ore cinnabar and as an organo metal such as methyl mercury. Moreover, through natural chemical and biological reactions, mercury changes form among these species, becoming alternately more or less soluble in water, more or less toxic, and more or less biologically available.

Because of airborne mercury pathways, there is no part of the globe today untouched by the worldwide increase in both the use and release of mercury by man in this century.

Volcanic Release: Mercury is initially released into the biosphere through volcanic activity. Mercury, present in the earth's crust at a concentration of 0.5 ppm, typically forms the sulphide HgS because of the prevalence of sulphides in volcanic gases. In this fashion it is found naturally in deposits as the red sulphide ore, cinnabar. It is commercially mined in this form. Volcanic sources emit an estimated global total of **60,000 kg of mercury** per year.[24]

Forest Fires Release: Biomass, particularly trees and bushes, accumulate and harbour a substantial fraction of the biosphere's mercury. When forest fires heat these fuels to temperatures well above the boiling point of mercury (357 °C), mercury may be released into the atmosphere. The elemental mercury thus released may be oxidised in the atmosphere over time to ionic mercury, which is also soluble in water and can dissolve in the air's moisture when released in this fashion.



Forest fires and rain are responsible for the transport and deposition of mercury over much of the world's surface, regardless of its source.

Oceanic Release: Mercury is also a component of seawater and is naturally released through the evaporation of elemental mercury from the ocean's surface. Both elemental and ionic mercury are soluble in water, the former to a much lesser degree. As less soluble elemental mercury evaporates, the equilibrium reaction is pulled towards more elemental mercury, which then releases more elemental mercury from the ocean's surface.

Anthropogenic Sources

Mercury is used in a broad array of more than 3,000 manufacturing industries and products. It is released into the atmosphere during various industrial production processes. Though mercury is released in trace amounts in the emissions as well as in effluents, their accumulation in the environment over time is harmful for both flora and fauna.

Thermal Power Plants Release: Coal is known to contain mercury as a result of testing done upon the gas emitted from thermal power plant stacks. The quantity released by burning coal is estimated to be **3,000 tonnes** per year worldwide, which is about the same amount released through all industrial processes.[25] The concentration of mercury in coal varies from as low as **70 µg/g up to 22,800 µg/g (parts per billion)**.[26] During the burning of coal, mercury is initially decomposed to elemental mercury and then, as the gas cools and exits the power plant, the majority of the mercury is quickly oxidised, probably catalytically due to the presence of other metals in the gas, to its water-soluble, ionic form.

Oil Combustion Release: Crude petroleum is known to contain small but measurable amounts of mercury. A study performed on the mass of metals in crude oils from 32 different sources stored in the USA has determined that the average amount of mercury in petroleum is 0.41 ppm.[27] The standard deviation for this average was rather large (0.90 ppm), with one crude oil (Arabian) containing 5.2 ppm mercury. Another study of metals performed on petroleum found mercury concentration rates ranging from 0.03 to 0.1 ppm.[28] Both these studies were performed using old mercury analysis methods, which rely on method detection limits of approximately 0.11 ppm. However, these studies also indicate minimum mercury concentrations in crude oil.

It is unclear whether the mercury present in crude oil is vaporised during the refining process or whether it remains in the refined petroleum. Because of the large volumes of oil consumed, even a small concentration of mercury clearly represents a major source of atmospheric deposition of mercury. More studies with the more sensitive analytical methods developed in the past few years should be undertaken to confirm these figures.

Smelting: The smelting of ores to yield pure metals is thought to release some mercury into the atmosphere. Most metal ores are thought to have higher concentrations of mercury than coal, although the volumes of ore that are smelted each year are low in comparison with the volume of coal burned for power generation.

Chlor-alkali Plants: Elemental mercury is employed as the electrode in the electrochemical production of chlorine gas and caustic soda (sodium hydroxide). Near most paper and pulp facilities, which employ this technology to bleach the paper product white, the sediment is contaminated with high concentrations of mercury.

Mildew Suppression, Laundry facilities: An infrequent and historical point source of mercury contamination has been the use of mercury compounds for mildew suppression by laundry facilities, which have a major problem with moisture and bacterial growth. This contamination source should no longer be a problem because many countries have banned the use of mercury as a fungicide in interior latex paints.

Sewage Treatment: Sewage treatment represents the focal point of today's urban industrial, commercial and domestic liquid waste streams. The secondary treatment of sewage involves de-watering, which necessarily concentrates the solids and all non-volatile contaminants, but does little to treat or remove inorganic dissolved contaminants. Mercury is commonly found in urban sewage through point source discharges from dental offices and industrial manufacturing processes such as battery fabrication. As the sewage is de-watered and the solids concentrated, mercury can be either sequestered by the organic humus of sludge or, if the sludge is caked and dried, can be released into the atmosphere in the drying process.

Pathways of Mercury Toxicity in India

The most significant anthropogenic activities giving rise to mercury (Hg) discharge into the land, water and air in India are:

- Industrial production processes, in particular, the mercury cell chlor-alkali process for production of caustic soda.
- Burning of fossil fuels, for example coal, mineral oil.
- Consumption-related discharges, including munici pal dumps and medical waste incineration.
- Use of agricultural fungicides and seed disinfectants.

All chemical compounds of mercury are toxic to humans, although mercury may have to be oxidised to ionic forms to show toxic effects. The main sources of emission are enumerated in the table below.

Environmental Aspects

Mercury has been used in a wide array of applications due to its unique physical and chemical properties. As a result, the amount of mercury present in the environment is constantly increasing. Studies have indicated that the amount of mercury mobilised and released into the biosphere has increased over the years.

The atmosphere is the dominant transport vector of mercury to most ecosystems. Several types of emission sources contribute to the total atmospheric load of mercury. Once in the air, mercury can be widely dispersed and transported thousands of miles from likely emission sources. The distance of this transport and eventual deposition depends on the chemical and physical form of the mercury emitted.

Mercury undergoes a series of complex chemical and physical transformations as it cycles among the atmosphere, land and water as part of both natural and

MAjor Emitters of Mercury

Mercury	Consumers	Amount (approx)
Mercury in effluents	Chlor-alkali industry (mercury cell process)	100-150 tonnes per annum
Mercury in effluents and soil	Instrument manufacturing industries	Data not available
Mercury in air and fly ash	Coal-based thermal power plants	60 tonnes per annum
Mercury in air and dust	Cement manufacturing plants	Data not available
Mercury in air	Burning of mineral oil	Data not available
Mercury in air and effluents	Disposal of municipal solid waste	Data not available
Mercury in air	Disposal of medical wastes	Data not available

anthropogenic activities. Humans, plants and animals are routinely exposed to mercury and accumulate it during this cycle, potentially resulting in a variety of ecological and human health impacts.

Most of the mercury found in the atmosphere is elemental mercury vapour, which circulates in the atmosphere for up to a year, and hence can be widely dispersed and transported thousands of miles from likely sources of emission. Most of the mercury in water, soil, sediments, or plants and animals is in the form of inorganic mercury salts and organic forms of mercury (for example, methyl mercury).

The inorganic form of mercury, when either bound to airborne particles or in a gaseous form, is readily removed from the atmosphere by precipitation and is also dry deposited. Wet deposition is the primary mechanism for transporting mercury from the atmosphere to surface waters and land. Even after it deposits, mercury is commonly emitted back to the atmosphere either as a gas or associated with particles, to be re-deposited elsewhere. As it cycles between the atmosphere, land, and water, mercury undergoes a series of complex chemical and physical transformations, many of which are not completely understood.

Mercury Emissions and Deposition

Roughly 80 per cent of these emissions are from combustion sources, including waste and fossil fuel combustion. Contemporary anthropogenic emissions are only one part of the mercury cycle.

Releases from human activities today are adding to the mercury reservoirs that already exist in land, water, and air, both naturally and as a result of human activities. The flux of mercury from the atmosphere to land or water at any one location comprises contributions from the natural global cycle, including re-emissions from the oceans, regional sources, and local sources. Local sources could also include direct water discharges in addition to air emissions.

Mercury is a persistent pollutant and its past uses are responsible for the present mercury burden on the environment. One estimate of the total annual global input to the atmosphere from all sources including natural, anthropogenic, and oceanic emissions is 5,500 tonnes.[29]

Studies indicate that the residence time of elemental mercury in the atmosphere may be a year, allowing its distribution over long distances, both regionally and globally, before being deposited on the earth. The residence time of oxidised mercury compounds in the atmosphere is uncertain, but is generally believed to be of a few days or less. Even after it deposits, mercury is commonly emitted back to the atmosphere, either as a gas or in association with particulate to be redeposited elsewhere.

Mercury Methylation and Bio-accumulation

Mercury cycling in the environment is a complex phenomenon that depends on various environmental parameters. Once in aquatic systems, mercury can exist in dissolved or particulate forms and can undergo a number of chemical transformations. Inorganic mercury becomes methyl mercury, which is organic, toxic and persists and travels in the environment.

Mercury also has a long retention time in soils. As a result, mercury that has accumulated in soils may continue to be released to surface waters and other media for long periods of time, possibly hundreds of years.

Mercury methylation is the key process in the entry of mercury into food chains. The transformation of inorganic mercury to methylated mercury in water bodies can occur in both the sediment and the water column.

Methyl mercury accumulation in the freshwater ecosystem is a process of mercury accumulation, which can then be ingested by fish-eating birds, animals and people. In addition, methyl mercury generally comprises a relatively greater percentage of the total mercury content at higher trophic levels. Accordingly, mercury exposure and accumulation is of particular concern for animals at the highest trophic levels in aquatic food webs and for animals and humans that feed on these organisms.

The pattern of mercury deposition worldwide shows that the aquatic ecosystem is more highly exposed to methyl mercury. Fish-eating birds and mammals are more highly exposed to mercury than any other known component of aquatic ecosystems. Adverse effects of mercury on fish, birds and mammals include death, reduced reproductive success, impaired growth and development, and behavioural abnormalities.

Mercury accumulates most efficiently in the aquatic food chain. Predatory organisms at the top of the food chain generally have higher mercury concentrations. Nearly all of the mercury that accumulates in fish tissue is methyl mercury. Inorganic mercury, which is less efficiently absorbed and more readily eliminated from the body, does not tend to bio-accumulate.

Mercury contamination has been documented in mammals such as polar bears, in the aArctic region. These species are at high risk of mercury exposure and impact because they are either fish-eating animals or because they eat animals which feed on fish.

High concentration of mercury in the tissues of wildlife species has been reported at levels associated with adverse health effects in laboratory studies on some species.

However, there is a lack of data and studies to conclude whether fish-eating birds or mammals have suffered adverse health effects due to airborne mercury emissions.

Plants, animals and humans can be exposed to mercury by direct contact with contaminated environmental media or ingestion of mercury-contaminated water and food.

Generally, mercury accumulates up the aquatic food chain, which means that organisms pertaining to higher trophic levels have higher mercury concentration levels. At the top of trophic levels are fish-eating mammals, such as humans, and other fish-eating species.

Environmental Load

The presence of mercury in the environment (air, water and land) in India can be traced back to the 1970s, when various studies conducted showed the presence of mercury in our environmental bodies.

Water

Both surface and ground water have become increasingly contaminated with wastes and pollutants from industry, agriculture and household. Over the years, water pollution has increased the concentration of mercury in Indian waters.

Ground water provides about 80 per cent of drinking water needs in India. A 1999 study tested and analysed ground water samples from eight places in three states — Gujarat, Andhra Pradesh and Haryana — where mercury contamination has been reported. The results are shocking: the mercury levels found are dangerously high in all the samples. The critical areas from where samples were collected were:

Patancheru (Andhra Pradesh): In Patancheru Industrial Area (PIA), Medak district, the level of mercury was *115 times the permissible limit.* In Patancheru, most of the 400 industrial units don't treat their effluents properly, so they dump them in the open or inject them directly into the ground, as suggested by the report. Most of the industrial units here deal with pharmaceuticals, paints, pigments, metal treatment and steel rolling. They use organic and inorganic chemicals as raw materials, which are reflected in appreciable amounts in the effluents.

Panipat (Haryana): In a tested sample of groundwater from Panipat, the mercury level was found to be *268 times the permissible limit.* The presence of chemicals was found to be more than what is permitted for industrial units. Most of the polluting wastewater comes from the 500-odd dyeing and processing units that have mushroomed in the city. It is common knowledge in Panipat that the industrial units involved in dyeing and dye-related operations pump effluents into the ground. Much of the effluents from these units either flow into open drains or on to vacant land. The water never reaches the end of the drains but percolates into the ground much before that.

◆ **Vatva (Gujarat):** "It has been common practice in Gujarat to pump effluents into the ground directly through borewells, a deliberate attempt to kill people," says the 1999 report by *Down to Earth*. Ground water within a range of 30-35 km of the Vatva Industrial Estate (VIE) in Ahmedabad district has been contaminated. In the absence of suitable modes of disposal, indiscriminate discharge of effluents has caused serious pollution of groundwater.

A ground water sample taken from Lali village, about 15 km from Vatva showed that the mercury level was *211 times the permissible limit.* The village is near a seasonal river Khari, which comes through Vatva and only carries industrial effluents and has been reduced to little more than a sewer. Other villages along the bank of the stream face a similar problem. People suspect leaching of effluents of groundwater for the contamination. For years, about 1,500 industrial units in Vatva, manufacturing chemicals such as H-acids, dyes, sulphonic acid and vinyl sulphones, have dumped chemical wastes on their premises or by the roadside.

Ankleshwar (Gujarat): A sample from a well in Sarangpur village in Ankleshwar Industrial Estate (AIE), Bharuch district, revealed that the mercury level was more than *100 times the permissible limit.* Water from a borewell in Bapunagar village near Ankleshwar had *170 times more mercury than the prescribed limit.* The 1605-hectare AIE has about 1,500 industrial units, which manufacture dyes, paints and pigments, pharmaceuticals, chemicals and pesticides, among other things. Effluents from these units have severely contaminated the underground aquifers.

Vapi (Gujarat): The situation in Vapi Industrial Estate (VIE) in Valsad district is no better than the other industrial estates of Gujarat. More than 1,900 industrial

Levels of Mercury (mg/l)

Permissible limit	**0.001**
Industrial Area, Panipat (Haryana)	0.268
Barsai Road, Panipat (Haryana)	0.074
Machua Village, Vatva (Gujarat)	0.115
Lali Village, Vatva (Gujarat)	0.211
Chiri Village, Vapi (Gujarat)	0.096
Sarangpur Village, Ankleshwar (Gujarat)	0.118
Bapunagar, Ankleshwar (Gujarat)	0.176
Pocharam Village, Patancheru (Andhra Pradesh)	0.058

(Source: *Down to Earth*, Aug 31, 1999.)

units have jeopardised the groundwater resources of the area mainly by indiscriminate disposal of hazardous wastes and effluents. A fair share of the effluents is also being dumped into the ground. A sample of water from a borewell in Chiri village, near Vapi, showed a mercury level that was about *90 times more than the prescribed limit.*

Factories in VIE deal with some very hazardous chemicals, including pesticides and other agro-chemicals, organo-chlorine chemicals, dyes, acids like H-acid, liquid chlorine and chlorine gas. Most of these substances have been banned in developed countries. Nearly 32 hand pumps and 65 wells in the area reveal the presence of chemicals. The major source of groundwater pollution is Rata Khadi, a seasonal stream near Chiri, which carries effluents from Vapi to a CETP. The effluents carry organo-chlorines, heavy metals and other toxic chemicals.

Nandesari (Gujarat): The Nandesari Industrial Estate (NIE) near Vadodara is a major production centre for highly toxic chemicals, like H-acid, which are not easily biodegradable. "Disposal of untreated mercury contaminated effluent from caustic soda manufacturers has heavily contaminated the groundwater in Nandesari," says a report submitted by the Union Ministry of Environment and Forests to the World Bank.

NIE is situated along the Mini River, and has about 250 industrial units dealing with chemicals, pharmaceuticals, dyes, pesticides and plastics, among other things. Reckless dumping of effluent and hazardous waste is as common here as in other industrial areas of the state.

Mercury Hot Spots

Beside the above-mentioned places, there are other hot spots where various studies reported mercury pollution and contamination over time:

Ib River (Orissa): The Ib River valley area throws up numerous instances of industrial pollution, and the starting point of this is easily Orient Paper Mills (OPM) of Brajrajnagar in Jharsuguda district.

The mill uses chlorine for bleaching its pulp, and gas leaks are a common occurrence. Bleach plant effluents are a major source of toxicity. This is because OPM uses mercury cell technology, which is a polluting technology, and which is now being progressively replaced by membrane cell technology all over the world. In India, no new plant adopts mercury cell technology.

The Pollution Control Board is aware of the fact that the mill uses mercury cell technology. However, there has been no intervention because the plant is small! But within the electrolysis bleaching plant, there have been many cases of mercury poisoning. The villagers upstream and downstream complain of malaria, diarrhoea, dehydration, a number of water-borne diseases, and skin diseases like scabies.

According to a report prepared by Ib Paribesh, an NGO working in the area for more than four years now, almost all the surface water has become unfit for human consumption. The contamination of groundwater resources has also reached a critical stage.

Rushikulya River (Orissa): A study by the Council of Professional Social Workers (CPSW), Bhuvaneshwar, reports that the Rushikulya River, in Orissa, is polluted by a number of effluents from various industries. However, the most hazardous pollution of Rushikulya is due to the chlor-alkali factory (Jayashree Chemicals Ltd), in Ganjam, which discharges its mercury bearing effluents into the river, causing pollution in Ganjam and its nearby areas. Thousands of acres of agricultural fields have lost their crops. There were tests conducted by a research team of the Department of Botany from the Banaras Hindu University (BHU). The tests reported presence of mercury in fish, trees and river water as an effluent traced to Jayashree Chemicals.

A committee set up by the Orissa Government in 1985 to look into the pollution caused by Jayashree Chemicals also confirms the presence of mercury in the effluent drained into Rushikulya. The Orissa State Pollution Control Board (OSPCB) also complained of the mercury traceable in the effluents of the factory, though it had no estimate of the mercury level in the effluent. The reason stated was that the mercury analyser of the factory was defective.

Kalu River (Bombay): A series of investigations by Ramani Rao and Dr B.C. Haldar for the Institute of Science in Bombay in 1979 have revealed the presence of heavy metals in the aquatic environment of the Kalu River, on the outskirts of Mumbai. The river is recreating another pollution disaster. "The spectre of Minamata stares in the face of the village population that consumes fish and food from or near the Kalu River," says Dr Haldar.

Kalu is a small river which originates in the Western Ghats. It flows through the industrial suburbs of Ambarnath, Ulhasnagar and Kalyan in northeast Mumbai and finally empties into the Arabian Sea. It receives effluents from 150 industrial units. The Institute of Science investigated a stretch of 10 km from Ambivali to Titwala, along which toxic wastes from a rayon factory, a paper mill, a dye factory and a chemical plant pour into the river. During 1978 and 1979, they surveyed the water quality and the effect of pollutants on plants and animal life. Industrial effluents in the river at Ambivali contain metals (mercury, lead, copper, cadmium), chlorides, dyes, organic acids, etc. Sediments, soils and plants along the riverbank showed a fairly high content of mercury, lead, cadmium and copper. "The water at the point of discharge of effluents into the Kalu River has a mercury content equal to that at the centre of the Minamata Bay," emphasises Dr Haldar.

The metallic content of the effluents fluctuates, and at times lead and mercury concentrations rise above the permitted levels. These elements are insoluble in water and sink to the bottom. Certain bacteria in the riverbed convert the insoluble mercury into soluble methyl mercury, which is a deadly poison and can be absorbed by living organisms. Mercury enters the food chain, poisoning the fish and the cattle that graze on the plants in shallow water. "Heavy metal contents of pycreus plants, the most abundant at Ambivali, showed unusually high concentrations. The leaves of these plants contain 3 to 110 ppm of mercury. The rhizomes of the same plants contained 6.9 to 53.3 ppm," reveals the report of the Institute of Science.

There is 5 ppm of mercury in the milk of milch cattle that graze on the pycreus plants. A child drinking a litre of this milk every day consumes 35 ppm mercury in a week. Over a period of several months this can lead to an accumulations of over 0.3 mg of mercury, which is well above the safe level. Further studies carried out by the Institute of Science show that the problem of toxic chemicals may also be spreading to other areas in and around Mumbai.

Kodaikanal (Tamil Nadu): URS Dames & Moore had been commissioned by Hindustan Lever Ltd (HLL) to conduct an environmental site assessment and preliminary risk assessment for mercury at its wholly owned thermometer manufacturing facility located at Kodaikanal, in Tamil Nadu. This followed publicity by Greenpeace and the Palni Hills Conservation Council after their discovery of glass scrap illegally disposed of by the manufacturing facility in a scrap yard in Kodaikanal town.

The thermometer plant in Kodaikanal, one of the largest thermometer-manufacturing factories in the world, has been guilty of dumping mercury-containing glass waste. Till date, the factory has produced 165 million thermometers with 125,000 kg of mercury with a breakage rate of 30 to 40 per cent. The company, in its report to the Tamil Nadu Pollution Control Board, assesses the amount of mercury released into the environment from its factory site in Kodaikanal at *539 kg* (stating a statistical variance of between *43 kg minimum to 1,075 kg maximum).*

The glass scrap from the mercury-contaminated area contained residual mercury and until 1990 was dumped in the compound. During the monsoon season, the mercury used to be washed away into water bodies due to run-off, contaminating the water bodies in the area, especially the rivers.

Bhopal (Madhya Pradesh): The Peoples Science Institute (PSI) in Dehra Dun has found high levels of mercury in the groundwater sources of Bhopal, especially near the closed Union Carbide factory. The water is dangerous for human consumption, as the area of ground water contamination is increasing. Water samples from various localities were taken for testing. Analysis of the samples showed concentrations of mercury as high as 2 ppm in some places, which is above national and international standards.

Golden Corridor (Gujarat): The Paryavaran Suraksha Samiti (PSS) in 2002 collected samples from over 20 villages affected by industrial pollution in the Golden Corridor of Gujarat to investigate the water situation. The samples were also tested and analysed for mercury. The results of mercury concentration in the villages near the industrial areas were shocking: in Haria village and Atul Complex, the mercury level was shockingly high, at 12 ppb – 1200 per cent more than the permissible limit of 0.001 ppm. Another sample in Ankleshwar showed mercury at a high level of 2 ppb – 200 per cent above the standard. Samples in Vadodara-Nandesari ECP Area also showed high mercury levels, at 6 ppb and 1.3 ppb, which are, respectively, 600 per cent and 30 per cent more than the prescribed standards.

Delhi: A recent study conducted by the Environmental Science Department of the Guru Gobind Singh Indraprastha University, reveals that the concentration of contaminants like arsenic, mercury, nitrates, etc, in Delhi's ground water exceeds permissible limits. The study entailed 50 samples of groundwater being lifted from random spots along a 22 km stretch between Palla and Okhla. The mercury concentration in some samples was as high as 4.6 ppm. This alarming presence of mercury in groundwater can be traced to the continuous discharge of sewage and industrial effluents into the Yamuna and, subsequently, into the groundwater aquifer which, being sandy in nature, allows mercury to leach at a rapid rate.

Mercury in Indian Rivers

A brief compilation by the Industrial Toxicology Research Centre (ITRC) of the heavy metal analysis (including mercury) of India's major rivers was presented in 2001 in the 'High Powered Committee on Management of Hazardous Wastes'.

The levels of various heavy metals including mercury were monitored in different water bodies by the ITRC, such as the Ganga river system including the main channel, its tributaries, viz, Yamuna, Gomti, Kalinadi, Ramganga, Ghaghra, Son, Gandak and Hugli estuarine system.

Surface and groundwater sources including minor streams, wells, hand pumps, ponds, reservoirs, lakes, etc, which are used for drinking water supplies in the north and north eastern states of India were also analysed.

Since there are no prescribed permissible limits of heavy metal for surface waters, the levels are compared with those of drinking water. The permissible limit for mercury in drinking water is 0.01 mg/l.

The River Ganga

From 1986 to 1992 water samples were regularly collected each month from 20 different locations: Rishikesh, Haridwar, Garhmukteshwar, Trighat, Buxar, Rajmahal, Behrampur, Palta, Dakshineshwar, Uluberia, as well as upstream and downstream of Kannauj, Kanpur, Allahabad, Varanasi and Patna. During this six-year period, some 1,400 river water samples were analysed for levels of 10 different metals including mercury. The concentration levels for mercury in the river Ganga are shown in the table at the right.

Tributaries of the Ganga River: From 1986 to 1992, water samples were regularly collected each month from the seven major tributaries of the river Ganga and analysed for different metals levels. Concentration levels of mercury are shown in the table on the next page.

Besides, mercury concentration was traced in sediments at the Hugli estuary, revealing a level of mercury of 0.25 mg/l.

Mercury in the Ganga (in mg/l)	
Kanpur upstream	0.02
Kanpur downstream	0.002
Allahabad upstream	0.01
Allahabad downstream	0.1
Varanasi upstream	Not detectable
Varanasi downstream	0.0
Rishikesh	0.08
Haridwar	0.08
Garhmukteshwar	Not detectable
Trighat	Not detectable
Buxar	0.08
Patna upstream	0.0
Patna downstream	Not detectable
Palta	0.00
Behrampur	0.01
Dakshineshwar	0.01
Rajmahal	0.10
Uluberia	0.02
Kannauj upstream	0.01
Kannauj downstream	0.008

Some Case Studies

There were some studies conducted and reports done by various scholars indicating the presence of mercury in the Indian environment, especially in water.

A survey by B.M. Tejam and Dr B.C. Haldar looked for mercury in 30 species of fish from seven sources in the Bombay and Thane environments. The results revealed that the bones of *Tilapia Mozambique, Mugil Dussumieri* and other varieties of fish from Thane and Mumbra creek contain mercury concentration levels higher than 500 µg/g on a fresh weight basis, though the upper limit of mercury concentration in fish has been estimated at 100-200µg/g.

In another study, water samples were collected from 12 spots in Chennai City for finding out the content of mercury, as well as its accumulation in toxic amounts. The samples were analysed by K. Ayyadurai, N. Kamalam and C.K. Rajagopal. The result of the analysis showed amounts of mercury ranging from 2.43 to 32.99 µg/ml. All the spots sampled had non-toxic levels of mercury.

There have been some more studies showing significant amounts of mercury in Indian sea water. There is continuous addition of heavy metals into the marine environment, mostly due to industrial and domestic releases. Dissolved inorganic mercury probably occurs mostly as $HgCl_4$. Its concentration in open ocean water usually lies in the range of 10-50 µg/l, but considerably higher concentrations may occur in inshore waters and especially in polluted estuaries.

A study by P. Kaladharan, V.K. Pillai, A. Nandkumar and P.K. Krishnakumar indicated that the distribution of mercury in the Arabian Sea had a conspicuous pattern showing very low values ranging from below detection level (BDL) to 0.058 µg/l during the pre-monsoon period. It remained more or less the same during the South West monsoon period, with an exceptionally higher level of 0.117 µg/l mercury observed in the shelf waters off Veraval. During the post monsoon season the mercury levels attained were higher than during the previous seasons, ranging from BDL to 0.117 µg/l with some pockets showing higher values.

Stray occurrences of higher levels of mercury were observed both in the southern and northern latitudes during the post monsoon period of 1996 ranging from 0.117 µg/l in the south adjacent to the Cape and Laccadive Sea to a concentration of 0.352 µg/l in the north adjoining the Veraval coast, where a similar higher trend prevailed during the South West monsoon season also. The seasonal average of mercury levels showed

Mercury in Ganga's Tributaries (in mg/l)	
Gomti (Udyarghat)	0.003
Gandak (Patna)	0.02
Ghaghra (Saran)	0.06
Kalinadi (Kannauj)	Not detectable
Ramganga (Kannauj)	0.02
Yamuna (Allahabad)	0.10
Son (Koelwar)	0.05
Hugli estuary water	0.29

a 100 per cent increase during the post monsoon period over the preceding monsoon as well as pre-monsoon seasons. The present study was limited to surface only.

Concentrations of mercury, measured at surface and at different depths in the Laccadive Sea by Sujata Sanzgiri, R. Sengupta and S.Y.S. Singbal ranged from 50-204 µg/l, which agreed with the earlier reported values (11-221µg/l) for the Arabian Sea. A few isolated values were higher than the average but these were low enough to show that the Laccadive Sea waters are currently free from mercury pollution. Average surface mercury concentration in the Laccadive Sea was 91 µg/l (range 60-120 µg/l). In the coastal waters of the Arabian Sea the average value at the surface was 136 µg/l; for the entire Arabian Sea the average surface value was 120 µg/l. Pooling the observations of all the cruises the average concentration at the surface for the northern Indian Ocean would be 106 µg/l.

Again, samples were lifted in Arabian Sea waters and the lowest and highest concentrations observed are 13 and 407 µg/l, respectively, among all the samples analysed from different depths. The values from the surface give an average concentration of 77µg/l.

Vasai creek is an important source of fish farming and is used for many other purposes such as salt pans, agriculture, etc. Due to the recently developed chemical industries, oil and grease spillage from ships and public sewage, the shores and water of Vasai creek are polluted and the water carries all these pollutants. Hence, an interridal collection of water samples was carried out to understand the physico-chemical and microbiological quality of water along with heavy metals in it. R.S. Lokhande and Nilima Kelkar conducted a study to determine the levels of heavy metals (Cd, Cu, Fe, Ni, Mn, Zn, Pb and Hg).

The heavy metals are the most harmful and insidious pollutants because of their non-biodegradable nature. The heavy metal toxicity (Fe, Pb and Hg) of the Vasai creek waters seriously reduces soil fertility and agricultural outputs. It is estimated that the major 18 industries release 7 tonnes of mercury along with other heavy metals yearly into the Ulhas river system.

Health Aspects and Exposure

Epidemics of mercury poisoning – following high level of exposure to mercury in Minamata, Japan, and in Iraq – demonstrated that neuro-toxicity is the health effect of the greatest concern when mercury exposure occurs.

The first cases of mercury poisoning were the people living on the shores of Minamata Bay, Kyushu, Japan. The source of methyl mercury was a chemical factory that used mercury as a catalyst. A series of chemical analyses identified methyl mercury in the factory waste sludge, which was drained into Minamata Bay. Once present in Minamata Bay, the methyl mercury accumulated in the tissue of shellfish and fish that were subsequently consumed by wildlife and humans. Fish was a routine part of these populations' diet.

Through the diet, methyl mercury is almost completely absorbed into the blood and distributed to all tissues including the brain. It also readily passes through the placenta to the foetus and foetal brain.

Fish consumption dominates the pathway for human and wildlife exposure to methyl mercury. Given the current scientific understanding of the environmental fate and transport of mercury, it is not possible to quantify how much methyl mercury the Indian population consumes through fish.

Critical elements in estimating methyl mercury exposure and risk from fish consumption include the species of fish consumed, the concentrations of methyl mercury in the fish and the quantity and frequency of fish consumption.

The Prevention of Food Adulteration Act, 1954, and Rules, 1955, limit the concentration of mercury to 0.5 ppm in fish. Methyl mercury concentration is limited to 0.25 ppm in all types of food items.

A typical Indian consumer eating fish regularly and frequently consumes large amounts of either marine species that typically have much higher levels of methyl mercury than the rest of seafood, or freshwater fish that has been affected by mercury pollution. In both cases, the consumers are highly exposed.

Consumers should be aware of The Prevention of Food Adulteration Act, 1954, and Rules, 1955, that suggest the limitation of contaminated fish's consumption. However, there is no warning against the consumption of certain species of fish contaminated with mercury and methyl mercury.

There is currently a need for research on the actual consumption patterns and estimated mercury and methyl mercury exposure of this sub-population.

Human Exposure Pathways and Health Effects

Humans are most likely to be exposed to methyl mercury through fish consumption. Exposure may occur through other routes as well (for example, the ingestion of methyl mercury-contaminated drinking water, other food sources than fish, and dermal uptake through soil and water). However, fish consumption dominates other contamination pathways for people who eat fish.

There is a great degree of variability among individuals who eat fish with respect to food sources and fish consumption rates. As a result, there is a great deal of variability in exposure to methyl mercury in these populations. The presence of methyl mercury in fish is, in part, the result of anthropogenic mercury releases from industrial and combustion sources. As a consequence of human consumption of the affected fish, there is also an incremental increase in exposure to methyl mercury.

The human exposure routes for mercury are: inhalation, consumption of water, consumption of fish, beef, beef liver, cow's milk, poultry, chicken eggs, pork, lamb, green plants (for example, leafy vegetables, potatoes, fruits, grains and cereals) and ingestion of soil.

Summary

Although environmental and health concerns of mercury have been documented in India to some extent, yet there has been no attempt from the government and the industry to reduce the usage of mercury in various industries and in our day-to-day life. European countries are already on the path of reducing mercury usage. Sometimes industries argue that it is very difficult to find a viable substitute to mercury in thermometer and other measurement-based industries.

Industries such as chlor-alkali and paper industries still use the mercury cell process to produce chlorine in India. The phase out of this obsolete technology is very slow. The government and the industry should both play a proactive role in phasing out these obsolete technologies. The units owned by the public sector, which produce chlorine using mercury cell technology, should lead the way in the phase out in the interim. Besides reducing the usage, it is also important on the part of the industry to follow the standards set up by the government for proper usage and disposal of mercury-related products. Consumers should be made aware of the mercury-containing products that they frequently use and of the hazards related to them. Moreover, proper care should be taken during the handling and disposal of these types of products.

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