## Editorial

The cadmium is a rare element and is present in the natural environment in form of its various compounds, at a relatively low level. Cadmium is widely and increasingly used in industries for corrosion- protection coating, nickel-cadmium batteries and several other applications. It may enter the aquatic and ambient environment as a toxic pollutant from various anthropogenic sources such as zinc, copper and lead mining, various industries, Iron & steel, non-ferrous metals cement production etc, electroplating, phosphate fertilizers, nickel-cadmium batteries, coal utilization and tobacco smoking. In high concentrations, cadmium may affect human health. Cadmium contamination of the fishes was the main cause for the episodal pollution and endemic bone disease "itai-itai" reported from Japan, during which several hundreds of peoples were affected. The cadmium intrusions to the environment can be abated and controlled by adoption of various alternative options, regarding emissions and effluents, thorough adoption of clean technology and implementation of stipulated environmental standards.

At present there is a need for better public awareness about impact of cadmium on the environment and its health implications and the need for strategic management to reduce its environmental toxicity. In the present Newsletter, emphasis has been laid in highlighting various aspects about cadmium and its physico-chemical characteristics, its sources & pathways and its levels in different environmental matrices. The bioavailabilities of cadmium, its geo and bioaccumulation and its toxico-kinetics on human health have been highlighted in the present issue of 'Parivesh'. Regulatory environmental standards of cadmium in different sources have been compiled in this publication for prevention and control of cadmium contamination in the environment.

The efforts made by my colleagues Sh. Bhupander Kumar and Dr. C. S. Sharma under supervision of Dr. S. D. Makhijani and Dr. B. Sengupta for collecting and compiling the information for this newsletter need to be appreciated. We hope the content of the newsletter will be useful to all.

**(J M Mauskar)**

**Chairman**

## INTRODUCTION

Cadmium was discovered by German scientist as a by-product of the zinc refining process during the year 1817. Its name has been derived from the Latin word *cadmia* and the Greek word *kadmeia* . Applications of cadmium for industrial purposes were developed as a corrosion-protection coating on steel and nickel-cadmium batteries in early 20 th century. It is relatively a rare element and is present in the natural environment at relatively low levels. Natural cadmium levels in the atmosphere and earth's crust are 0.1 to 5 ng/m$^3$ and 0.1 to 0.5 µg/g respectively. It is estimated that for every 10 million parts of earth's crust containing about 2 parts of cadmium. Cadmium exposure is recognized to produce toxic effects on humans. Long-term occupational exposure can cause adverse health effects on the lungs and kidney. Cadmium contamination of the environment was established as the main cause for the endemic bone disease, "itai itai" (ouch ouch) reported from Japan, due to which about a hundreds of people were died. Following this increasing scientific interest has been devoted to this element as an environmental contaminant. Initially studies were concentrated on the effects of cadmium on man, while the studies related to the behavior of cadmium in the aquatic environment and its effects on biota were of recent origin. It enters human environment as a contaminant from mining and metallurgy, chemical industries, scrap metal treatment, electroplating, super phosphate fertilizers, cadmium containing pesticides, cadmium-nickel and cadmium-silver storage batteries. It is not an essential metallic element for life, rather it is a poisonous element and especially insidious for human beings, because it is insufficiently eliminated from the body. Like mercury, cadmium has been shown to pose a real health threat to human populations, which receive high level of exposure. Over the years cadmium accumulates in body particularly in bones and culminates in specific disease. There are increasing awareness and regulatory regimes world are to protect the environment as well as human population from the undesirable effects of environmental hazards of cadmium.

## PHYSICAL AND CHEMICAL PROPERTIES OF CADMIUM

Cadmium is a soft, silvery white, easily fusible metallic element. It is slightly malleable, ductile, flexible and heavier than zinc. It is not usually present in the environment as a pure metal but often present as complex oxides, sulphides and carbonates in zinc, lead and copper ores in the natural conditions. Cadmium is readily soluble in nitric acid, slowly in hydrochloric acid and slightly soluble (0.005 wt %) in water. It is having the atomic number 48 and atomic weight 112.41; its density is 8.642 g/cm $^{3}$ at 20°C. Physical properties of Cadmium and some of its important compounds are as below:

| Physical features | Cadmium | Cadmium chloride | Cadmium oxide |
|---|---|---|---|
| Melting point | 320.9 °c | 568 °c | 900 °c |
| Boiling point | 765 °c | 967 °c | 1385 ° |
| Vapor density | 3.9 | 6.3 | - |

## CADMIUM AS MINERAL

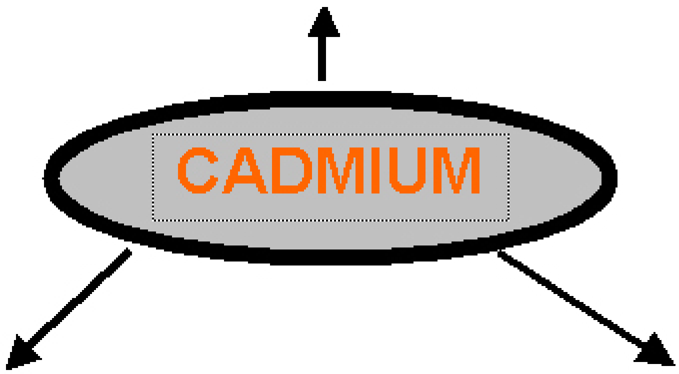
Cadmium is widely Distributed in nature, with an average concentrationof 0.1 to 0.2 mg/kg in earth' crust. It is associated in small amounts with thezinc, lead and copper ores.Cadmium is not recovered as a mining product, but as a by product of the extraction, smelting and refining of other nonferrous metals such as zinc, lead and copper. The average cadmium content of sandstone has been reported to be 0.05 ppm and that of shale as 0.3 ppm. Sedimentary rocks and marine phosphate rocks contain about 15 mg/kg cadmium. Cadmium content of phosphate fertilizers varies between 2 and 200 mg/kg.

| Cadmium interactions with other minerals | |
|---|---|
| **Mineral** | **Interections** |
| Zinc | Cadmium structure is similar to zinc and can replace zinc in the tissues and in enzyme binding sites. Cadmium toxicity is a zinc deficiency. |
| Copper | Cadmium reduces the copper toxicity in high copper persons. |
| Sodium | Cadmium raises the tissue sodium level. This is important because sodium levels are related to adrenal gland activity, which provide an energy boost. This may be reason why smoking may be enjoyable and addictive. |
| Calcium, iron, nganese and Chromium | Cadmium is antagonistic to Ca, Fe, Mn and Cr. For this reason, these minerals can help remove cadmium. |

## PATHWAYS OF CADMIUM TO ENVIRONMENT

### Pathways to Atmosphere

- Combustible waste to municipal waste incineration plants
- Sewage sludge incineration
- Uncontrolled waste burning at dumpsites
- Treatment of scraps and Ni-Cd battery




**Pathways to Aquatic Environment**

- Waste water and Industrial Effluent
- Uncontrolled dumping of waste to water bodies
- Leachate from landfill and Dumpsite
- Runoff from recycling operations

**Pathways to Terrestrial Environment**

- Application of sewage sludge or organic waste to soil
- Uncontrolled dumping of waste on land
- Use of phosphate fertilizers

Natural and anthropogenic sources are the major categorized sources of cadmium missions to the environments such as air, water and soil.

## Natural Cadmium Emissions

Although earth's crust concentration of cadmium is 0.1 to 0.5 mg/kg, but accumulation in sedimentary rocks, marine phosphate and phosphorites may be much as high as 500 mg/kg (WHO 1992). Due to weathering and erosion of rocks, it is estimated that 15000 metric tonnes of cadmium is transported to oceans through rivers (WHO, 1992; OECD, 1994). Volcanic activity and forest fires are also major natural sources of cadmium release to the atmosphere.

| Natural cadmium emissions sources | Emissions (Tonnes/year) | |
|---|---|---|
| **1989** | **2001** | |
| Dust storms | 210 | 24000 |
| Sea salt spray | 60 | 2000 |
| Volcanic emissions | 820 | 1600 |
| Natural fires | 110 | 13000 |
| Vegetation etc. | 190 | - |
| Meteoritic dust | 50 | 0.0002 |
| **Total** | **1300** | **41000** |

*(Source: Niargu, 1989 and Richardson, 2001)*

**Anthropogenic Emissions**

Man- made emissions of cadmium either from the manufacture, use and disposal of cadmium containing products. The cadmium containing products included: <![endif]>

- Nickel- Cadmium Batteries
- Cadmium pigmented plastic, ceramics, glasses, paints and enamels
- Cadmium stabilized Polyvinyl chloride (PVC) products
- Cadmium coated ferrous and Non-ferrous products
- Cadmium alloys
- Cadmium electronic compounds
- Cement
- Phosphate fertilizers

The anthropogenic sources of cadmium emissions to the air are mainly from uncontrolled burning of waste on dumpsites, nonferrous metal production, steel and cement production etc. Oil and coal combustions and the iron and steel production are the largest cadmium emission sources. The aquatic inputs of cadmium are mostly from iron and steel production (40%) and from non-ferrous industry (24.9%).

Municipal solid waste comprises several cadmium sources like iron and steel scrap, gypsum, plastic, cement and other construction debris, non-ferrous metals (Zinc, Lead and Copper), fossil fuel residue and natural substances (grass, plants and food materials). The contribution of Ni-Cd batteries to cadmium emissions from Municipal Solid Waste (MSW) account maximum for cadmium content of municipal solid waste <![endif]>

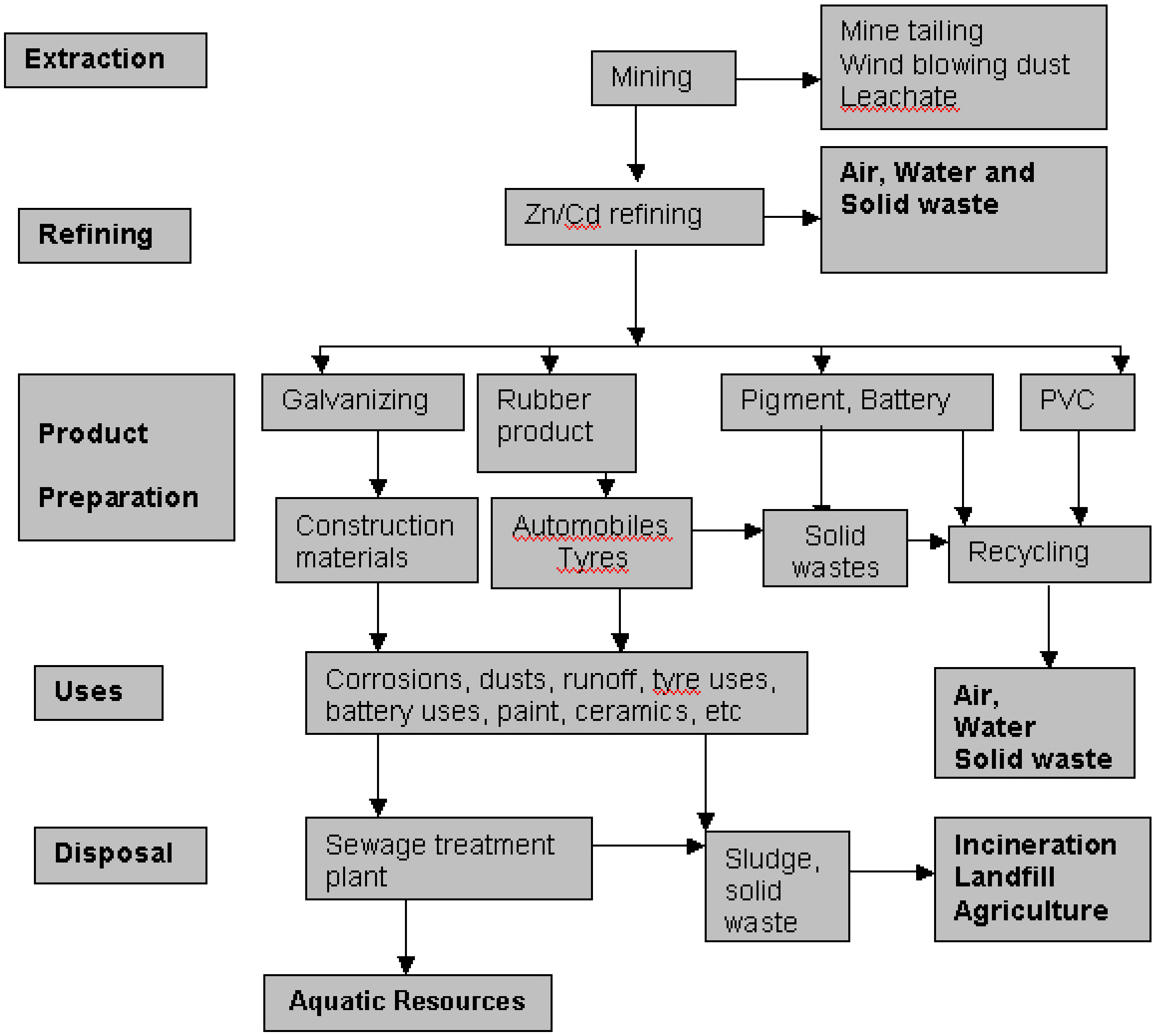



**Fig: Cadmium pathways during mining to end use and disposal**

**Emission from Coal**

Biogenic deposits in form of coal contain remarkable concentrations of metals. The use of coal is increasing both domestically and worldwide, in which the assessment of environmental consequences are very significant. Among these one of the environmental concerns are the toxic metal emissions. Concentrations of various trace metals in coal vary from mines to mines in different country. It is estimated that average concentration of cadmium in coal ash may be more than 5.0 ppm.

**Cadmium Content in Coal from different countries**

| Metal | United States of America | Great Britain | Poland | South Africa |
|---|---|---|---|---|
| Cadmium (mg/kg) | 1.10 | 0.30 | <0.025 | 0.012 |

*(Source: David A. Tillman, 1998.Trace metal emission from coal utilization)*

In power generation the share of coal is 36% globally and it is 60 % in India. The role of coal in electricity generation is likely to increase further due to enhanced energy generation from coal-based power plants. The coal utilization is not the major sources of metal pollution in the atmosphere, however, it is estimated that oil and coal combustion contributes more than 43.5% of cadmium emissions to the environment.

**Phosphate fertilizers**

Cadmium occurs naturally in all phosphate rocks, but its concentration varies considerably. Sedimentary phosphate rocks, which are major row material for phosphate fertilizers, contains between 20 to 200 mg of cadmium per kg of $P_2O_5$. The cadmium concentrations in raw phosphate rocks varies according to their source and location

## ENVIRONMENTAL TRANSPORT OF CADMIUM

Cadmium transports in environment include partitioning of cadmium to various environmental compartments, through atmospheric transport, river transport and ocean transport. The majority of cadmium input partition initially to soils. While some transfer does occur from soils back to the air or water compartments, the next flux into the soil is generally regarded as positive since there is deposition from both air and water onto the soils. Thus most cadmium returns to soil. In soils, cadmium remains bounded to the non-exchangeable fractions, such as clays, manganese and iron oxides limiting its further mobility and transfer. The remaining cadmium emissions may partition between air and water depending on its type of source.

The cadmium emitted to the ambient air can be easily transported alongwith airflow may and impact human health and ecosystem far away from emission source. Anthropogenic activities such as mining, metal production, combustion of fossil fuel increase the cadmium concentration in environment. Cadmium is removed from the atmosphere by two major mechanisms: through dry deposition i.e. uptake by ground surface and through wet deposition i.e. washout with precipitation.

The cadmium inputs to the oceans are atmospheric deposition, river inputs and seabed exploitation for mineral resources. Cadmium is assimilated by phytoplankton and recycled to upper water layer of ocean.

## CADMIUM LEVELS IN ENVIRONMENT

Cadmium levels in the environment vary widely. Since it can be transported continually between various matrices voz. air, water and soil. Cadmium can transform into number of salts such as cadmium oxide, cadmium chloride and cadmium sulphide. The mobility of these salts in the environment affects the ecosystem. Metallic cadmium and CdO powder can be transformed in the environment to the toxic cadmium. Compounds with $Cd^{2+}$ are all stable solids that do not evaporate, although cadmium is found as part of small particles in air.

**Air**

Cadmium chloride, cadmium sulphate and cadmium oxides are the usually available species in cadmium contaminated air. Cadmium in the air is bound to fine particulate matter (<1.0 µm). There are three distinct categories recognized with respect to cadmium concentrations in air viz. (cadmium in ambient air, cadmium in occupational situations and cadmium in indoor air from smoking of tobacco). Cadmium Inputs from these categories may affect human cadmium intake and human health.

**Ambient Air**

The major anthropogenic sources of cadmium in the ambient air are non-ferrous metal smelters and uses of coal for combustion. Cadmium concentration in the surrounding air depends on the population and urbanization of the region. Ambient air cadmium concentrations have been generally estimated as extremely low and may range from 0.1 to 5.0 ng/m$^3$ in rural areas, from 2.0 to 15.0 ng/m$^3$ in urban areas and from 15.0 to 150.0 ng/m$^3$ in industrial areas (WHO 1992, OECD 1994). In urban areas the cadmium level may record higher due to various urban activities, transportation and combustion activities.

**Occupational environment of cadmium in occupational situations**

The major sources are smelting and refining of zinc, lead and copper ores, electroplating, manufacturing of cadmium alloys and of pigments and plastic stabilizers, production of Ni-Cd batteries and wielding. Cadmium air concentrations may be high in certain industrial conditions and leads to higher occupational exposure of workers. Occupational exposure standards for which were formerly lies between 100 to 200 µg/m$^3$ have been made sticker and these now lies between 2 to 50 µg/m$^3$ (ILO 1991).

| Industrial Occupation for Cadmium Exposures |
| --- |
| • Alloys production<br>• Battery production<br>• Electroplating<br>• Enameling<br>• Paint production and use<br>• Phosphorus production<br>• Pigment production and use<br>• Plastic production<br>• Plating |

| **Tobacco smoke** |  |
|---|---|

Environmental tobacco smoke generally during smoking is among the major pollutants in the indoor environment. The presence of toxic metals as chronic inhalation of metals at high concentration can cause respiratory diseases and lung cancer. These metals may include trace concentration of antimony, arsenic, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, selenium etc.

The metal content in the tobacco comes from the soil, which is being concentrated by tobacco plants. Cadmium is used in cigarette paper to make the paper burn slower. These metals are either released into the air by tobacco smoke or are retained in the cigarette ash. It has been reported that the cigarette tobacco contains about 0.5 to 2.0 µg of cadmium and about 10% of the cadmium content is inhaled when cigarette is smoked (WHO 1992). The non smoker may passively inhales significant amount of cadmium alongwith inhaled tobacco smoke while at smoking.

**AQUATIC ENVIRONMENT**

Cadmium may be present in the aquatic environment at relatively low levels as inorganic complexes such as carbonates, hydroxides, chlorides or sulphates, or as organic complexes with humic acids. Even in polluted rivers the cadmium levels in aqueous phase may be significantly low and even sometimes below detection limit. Rivers and lakes in urban areas contain high concentrations of particulate matter and therefore most of the cadmium is adsorbed to suspended particles.

**FRESH WATER**

The cadmium contents of rainwater, fresh water and surface water may vary depending upon specific location. In fresh waters the ratio between particles associated and dissolved forms of cadmium depends on the load of suspended matter.

Irrigation and flooding waters containing suspended solids were implicated for the cadmium pollution in paddy field soils surrounding Jintsu River in Japan, where ‘itai itai’ disease had occurred. The maximum guideline concentration in fresh water is between 0.0002 to 0.002

mg/l (Australian water quality guideline, ANZECC, 1992)

**Cadmium concentrations in Aquatic environment**

| Location | Conc. (mg/l) | Source |
|---|---|---|
| Bellandur Lake, Bangalore | 0.70 | Lokeshwari and Chandrappa, 2006 |
| Matla River, West Bengal | 0.68 | COMAPS, 1990-1999 |
| Saptamukhi River, West Bengal | 0.85 | COMAPS, 1990-1999 |
| Hugli River, West Bengal | 0.59 | COMAPS, 1990-1999 |
| Subernarekha River, West Bengal | 0.47 | COMAPS, 1990-1999 |

Central Pollution Control Board has carried out an extensive study on Yamuna River water during 1999-2005. The maximum concentration of cadmium (0.02 mg/l) was recorded at Agra downstream during the year 2001, while most of the other time the cadmium was founded below detection limit. In sediment, cadmium is mainly associated with small particles of organic materials. Thus high content of cadmium is found in areas, where sedimentation rate of organic particles is comparatively higher.

## GROUND WATER

Ground water is an important source of water, as the surface water is getting scarcer day-by-day. Discharge of municipal wastewater and industrial effluents either onto land or surface water bodies, may percolate through soil and may affect ground water resources. Agricultural usage is also another route through which metallic ions could percolate to the ground water source. CPCB in collaboration with state pollution control boards carried out a study of ground water in various problem areas in the country and observed that cadmium ranged between not traceable to 0.224 mg/l.

**Cadmium in Ground water at some areas (1995-96)**

| Location | State | Cadmium (mg/l) | |
|---|---|---|---|
| | | Minimum | Maximum |
| Korba | Madhya Pradesh | NT | 0.01 |
| Singrauli | Utter Pradesh | NT | 0.01 |
| Gobindpur | Punjab | NT | 0.08 |
| Parwanoo | Himachal Pradesh | NT | 0.062 |
| Kala Amb | Himachal Pradesh | NT | 0.150 |
| Pali | Rajasthan | 0.005 | 0.224 |
| Jodhpur | Rajasthan | <0.005 | 0.042 |
| Nazafgarh | Delhi | NT | 0.013 |

NT- Not traceable

### COASTAL WATER

Metals are natural constituents of seawater and are derived from erosion of ore bearing rocks, volcanoes etc. Rivers and atmospheric inputs also play an important role. In the open sea where the suspended solid are often low more than 99% of the cadmium exists in dissolved form. Among the oceans and seas the lowest concentration of cadmium is reported in the Sargasso Sea and Pacific Oceans while the highest in North Atlantic Ocean. The vertical distribution of cadmium in oceanic waters depicted nutrient like distribution, i.e., low concentration in surface waters which increases with depth.

The cadmium contents in Indian Ocean waters varied between 0.01 and 25 µg/l. However, a maximum of 80 mg/l cadmium has been recorded in the coastal waters off Bombay.

**Cadmium Content in Indian coastal waters**

| Location | Conc. (µg/l) | Source |
|---|---|---|
| Off Bombay | 80.00 | Ganesan *et al.,* 1980 |
| Point Calimere | 0.10-0.60 | Ramachandran *et al.,* 1991 |
| Cuddalore | 2.00-27.0 | Ananthan, *et al.,* 1994 |
| Madras Coast | 1.40 | Somasundaram *et al.,* 1987 |
| River Coovum | 0.98 | Ramachandran *et al.,* 1991 |
| Parangipettai Coast | 2.00-25.0 | Ananthan *et al.,* 1994 |
| East Coast | NT-2.89 | COMAPS |

*Surces: Heavy metal toxicity in the estuarine, coastal and marine ecosystems of India*

*by Mohapatra B.C. and K. Rajendran, COMAPS, 1999-2000)*

## CADMIUM IN SOIL

Cadmium is much less mobile in soils than in air and water. The input of cadmium to the soils is from both natural and anthropogenic sources. Natural sources include underlying bedrock or transported parent material such as alluvium. The cadmium in soils occur at very low levels, but it is added to the soils by other products such as, fertilizers, phosphogypsum, certain zinc additives, biosolids (sewage sludge), manures and other wastes. Cadmium added to the soil remains for a long time and it may take about 100 to 1000 years for leaching of cadmium from the soil to half. The higher concentration of cadmium have been reported in different rocks and ores.

**Cadmium levels in ores and rocks (mg/kg)**

| Igneous, metamorphic and Sedimentary rocks | Zinc ores | Ores for iron & steel | Material for cement | Fossil fuels | Phosphate fertilizers | Copper and lead ores |
|---|---|---|---|---|---|---|
| 0.02-0.25 | 200 - 14000 | 0.1 – 5.0 | 2.0 | 0.5-1.5 | 10-200 | ~500 |

Cadmium in non-agricultural soils generally not affect human health as it could not enter the human food chain but its indirect transfer from non-agricultural soil to agricultural soils via airborne or water transport may affect the food chain. Cadmium in agricultural soils is relatively immobile but become mobile under acidic conditions. The chemistry of cadmium in soil is controlled by the pH. Cadmium mobility increases with a decreasing pH of the soil. The guideline value for cadmium content in agricultural soils is 5.0 ppm.

## Cadmium in compost

Municipal solid waste (MSW) composts contain metals from variety of sources. Batteries, consumer electronics, ceramics, house dusts and paint chips, light bulbs, lead foils, used motor oils, plastics, and some inks and glasses introduce metal contaminants to solid waste. Composts made from these solids waste will inevitably contain cadmium. MSW composts contain more cadmium than found in average soils.

**Cadmium in Port Areas**

The major sources of cadmium in dock waters and sediments are because ofHandling of different metal ores, fertilizers and mining materials. Solid wastes generated in the ports are mainly from ship breaking or repairing process, which includes polyvinyl chloride (PVC) wires, plastic, insulating materials, paints and tiles etc. Regular dredging is being carried out at sea bed near ports and harbors as well as their approach channels to keep them obstruction free for ship and boat movements. Usually the dredged materials may be used for land reclamation or dumped at high sea.

The dredging spoil is often anoxic, may be contaminated with metals and other persistent pollutants originated from various land based activities. Handling of raw materials for phosphate fertilizers and other materials at the ports may contribute cadmium to ports water.

**CADMIUM IN ELECTRONIC WASTE**

Electronic waste (e-waste) is used as a generic term comprising various types of waste containing mainly electronic waste. Common e-wastes include personal computers, monitors, television, cathode ray tubes (CRT), telephones, cell phones, electronic toys, air conditioners, hi-fi sets, VCRs, DVD players, video camera, fax and copy machines, and other home electronics. According to an estimate, there are more than 2 millions of obsolete computers become obsolete currently and these counts may be about to be 315 million worlds over. Expansion of the global market for electrical and electronic products continues to accelerate while the life span of the products is dropping, resulting in a corresponding explosion in electronic wastes.

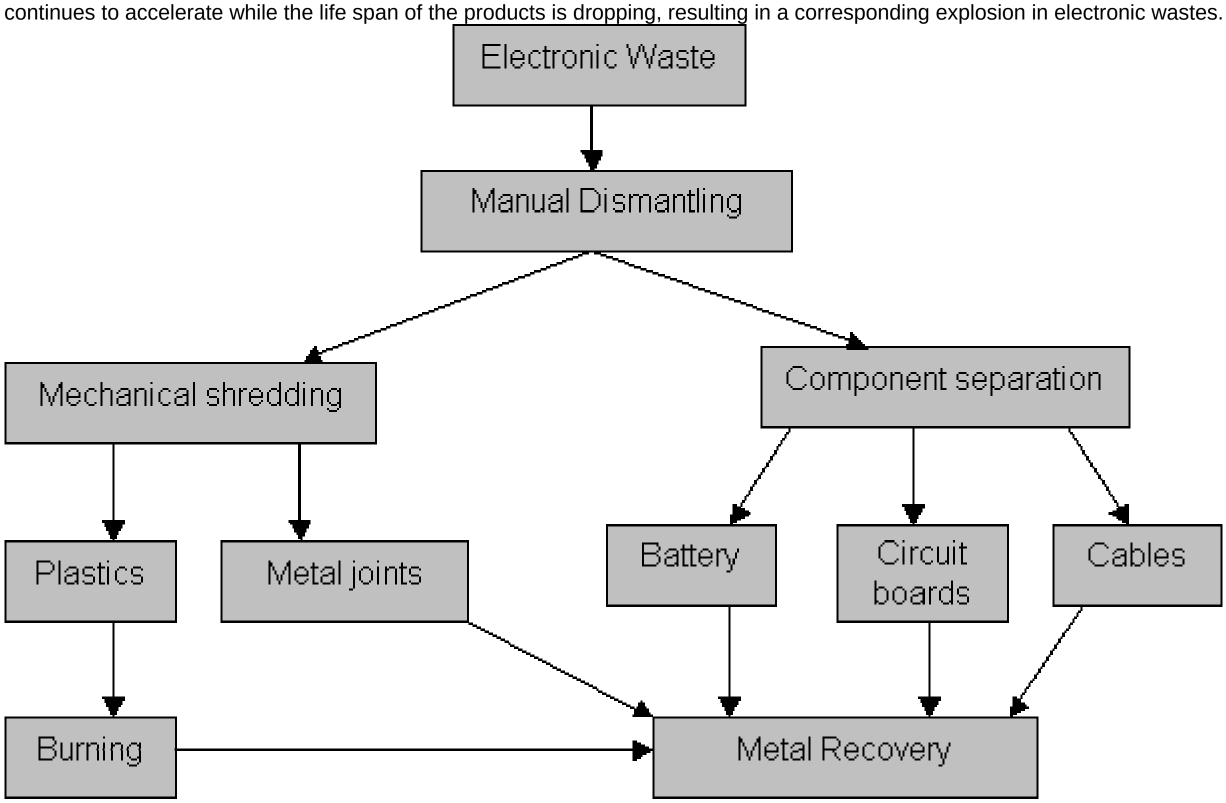



**Fig: Possible sources of metal recovery from e-wastes**
(Source: Green Peace, 2005)

e-waste contain a number of toxic substances, including plastics and heavy metals such as lead, cadmium and mercury, which can cause serious health effects. Cadmium can be found in SMD (surface mount devices) chip resisters, infrared detectors and semiconductors. E-waste often ends up in landfills. It is estimated estimate that 67000 tonnes of computer waste in Canada contributed 1.1 tonnes of mercury, 4.5 tonnes of cadmium and 3012 tonnes of lead into landfills during the year 2005. Cadmium from one mobile phone battery is enough to pollute 600000 liters of water. According to an estimate the average cadmium generation per computer is 2.8 Gms, and every year millions of computers are discarded increasing the risk of toxic metallic waste to the environment. As a precautionary measure the European commission Directive 2002/95/EC restricted maximum concentration value of cadmium in electronic devices to 0.01% by weight.

The UNEP observed that “Every year 20 to 50 million tones of electrical and electronic equipment waste are generated world-wide, which could bring serious risks to human health and the environment. Results confirm that all stages in the processing of electrical and electronic wastes releases quantities of heavy metals to the workplace.

Cadmium occurs in electronics both as cadmium metal in some switches and solder joints while as cadmium compounds in rechargeable batteries, UV stabilizers and in cathode ray tubes. High level of cadmium was also reported in ashes collected from two e-waste burning sites in Delhi viz. Ibrahimpur and Shashtri Park.

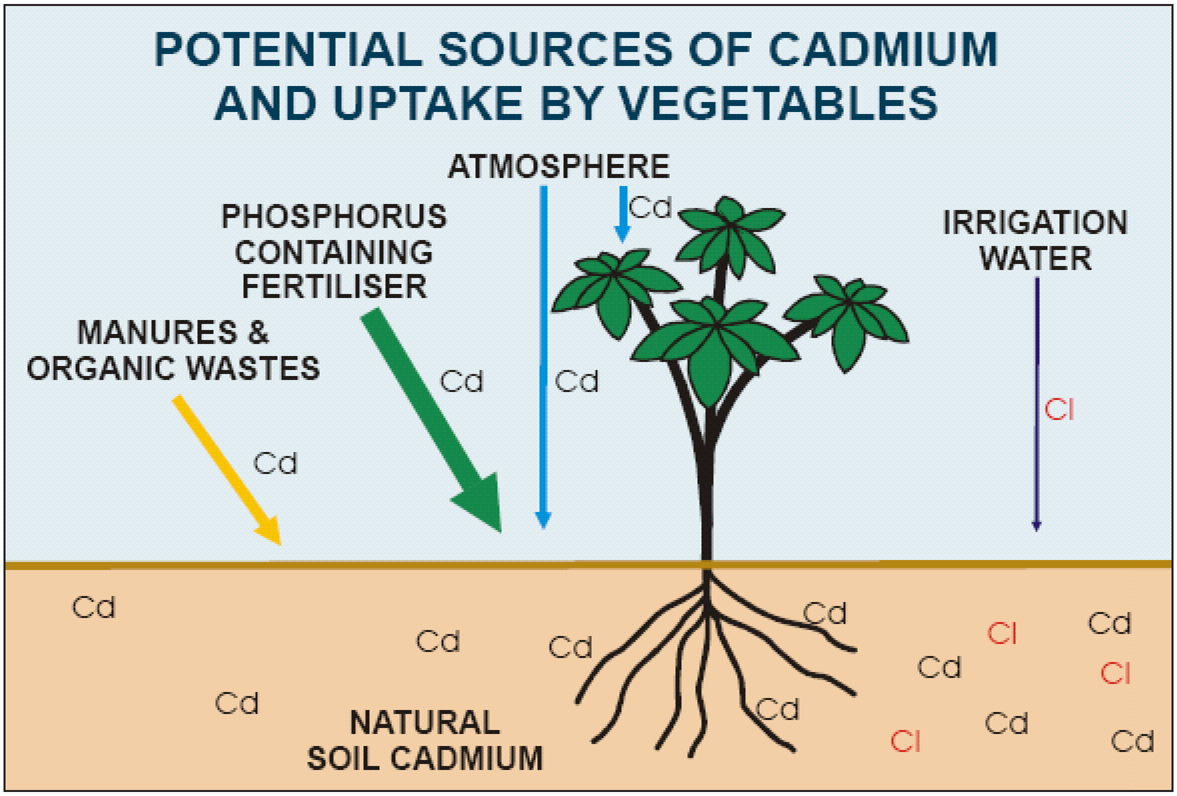
## CADMIUM IN VEGETABLES

Cadmium is taken up from soil by the plant roots. The plants grown in soils that are very sandy, acidic and or low in organic matter more easily absorb cadmium. Cadmium in soil attaches to clay particles and organic matter, sandy soils with low clay content and organic matter induces higher uptake of cadmium. The availability

**Vegetable grouping and risk of cadmium**

| **Roots & Tubers** | **Risk** | **Other crops** |
|---|---|---|
| Garlic, Potato*,<br><br>Carrot, Beetroot,<br><br>Onion | High | Spinach, Silverbeat, Pea, Lettuce, Cabbage |
| Potato* | Medium | Capsicum,Tomato, Cauliflower, Mushroom<br><br>Alfalfa |
| Potato* | Low | Pumpkin, Green Bean,<br><br>Cucumber |

**Potatoes are variety specific*




of cadmium to plants decreases as the soil pH increases. Zinc and cadmium uptake by plants occurs in a similar way and if, soil zinc is low then cadmium will be taken up. Higher Concentrations of chloride in soil mobilizes cadmium and increase uptake by plants. Cadmium may be concentrated in part of the plant such as leaves, roots and tubers, seeds or grain and fleshy fruits. Leafy vegetables such as lettuce, spinach, potatoes and grain foods may concentrate higher concentration of cadmium. According to the study undertaken by Lokeshwari and Chandrappa (2006) on the Impact of metals on vegetation irrigated by Sewage fed lake water near Bangalore; the vegetables were found to cadmium 21 times higher than recommended concentration. Spinach and radish contains 4.0 and 2.5 µg/g of cadmium respectively. The presence of cadmium in cow milk may be because of the fodder containing higher level of cadmium.

**CADMIUM IN FOOD MATERIALS**

The Cadmium levels may vary widely in various foodstuffs. The food should not contain any cadmium however cadmium meat and fish normally contain lower cadmium contents while animal organs such as kidney and liver may exhibit high cadmium values, because of bioaccumulation (WHO 1992). The WHO standard for cadmium in food items is 0.07 mg/day.

Cadmium present in utensils, pottery and trays can be leached out into foods, particularly in foods, which are acidic in nature (fruit juice) due to the presence of organic acids. The additives are added to food to enhance the flavor, taste and to maintain quality but these additives may also contain traces of heavy metals including cadmium. The contaminant include toxic elements like mercury, lead, cadmium, arsenic etc. found in raw food, before processing remain in the food until consumption The food crops grown in industrially polluted soil and soil mixed with from sewage sludge or irrigated with polluted waters may contain increased content ratio of cadmium.

Chemicals accidentally introduced into food from a variety of containers cause rapid illness and at times even death. The incident of cadmium poisoning resulted from the escape of mining wastes over a period of more than 20 years into the river stream of Jintsu in Japan. The river water irrigated soil and crops cultivated were the reason for outbreak of the disease itai itai.

## GEO-ACCUMULATION OF CADMIUM IN SEDIMENTS

Persistent pollutants like toxic heavy metals reaches to the water ecosystem and ultimately settle with bottom sediments in f water bodies. The interaction of dissolved cadmium ($Cd^{+2}$) with suspended particles is the predominant mechanism in the water system. Concentration of cadmium in sediments usually exceeds those in overlaying water. Therefore, high concentrations of toxic metals including cadmium in the sediments are not necessarily the result of pollution, but may be the result of geo-accumulation of organic matter laden with metals.

The sediments of sewage fed ponds may contain substantial amount of cadmium. The accumulation of cadmium in sediments is a typically heterogeneous process, which include physical, chemical and biological activity. The Yamuna river sediment studied during 1999-2005, and most of the observations show that of below detection level.

The characterization of sludges generated from effluent treatment plants of soft drink manufacturing units indicated that cadmium concentration ranged from 5 to 50 mg/kg. The soft drink bottling plant at Palakkad Kerala contained 201.8 mg/kg of cadmium in ETP sludge against the tolerance limit of 50 mg/kg.

## SPECIATION, BIOAVAILABILITY AND TOXICITY OF CADMIUM

Cadmium can exist in various physico-chemical forms such as, $CdCl_2$, $CdCl_3$, $CdCl^+$ and free $Cd^{2+}$. The toxicity, bioavailability, bioactivity, bio-geological distribution / transportation and impact within our body and environment may vary according to physico-chemical form in which cadmium is available. Metallic cadmium and Cadmium Oxide powder are less harmful in the environment than soluble $Cd^{2+}$. Speciation of cadmium determines the mobility of cadmium with respect to partitioning between the water and sediment reservoir.

Bioavailability is the dynamic process, which include exposure and uptake route of cadmium, chemical fluxes for specific biological species and redistribution processes within the species. Bioavailability of cadmium depends on its exchangeable fraction than the presence of total cadmium in the sediments. The Toxicity of cadmium to some terrestrial and aquatic organisms are presented below:

| Terrestrial organisms | Toxicity dose | Aquatic organisms | Toxicity dose |
|---|---|---|---|
| Rat | $LD_{50}$ 88 mg/kg (as $CdCl_2$ ) | Daphnia | 0.1 mg/l (harmful) |
| Rat | $LD_{50}$ 72 mg/kg (as CdO) | Goldfish | LD 0.017 mg/l (9-18 h) |
| Rabbit | $LD_{50}$ 70-150 mg/kg (as $CdCl_2$ ) | Fishes (with out species differentiation) | $LC_{50\ minimal}$ 23 mg/l (>24 h) |
| Guinea pig | LD 150 mg/kg (as CdF) | | $LC_{50\ average}$ 140 mg/l (>24h) |

The amount of exchangeable cadmium held in the sediment is affected by various factors, such as particle size of the sediment, level of organic matter, pH and redox potential of the sediment. Partitioning of cadmium between the adsorbed- in- sediment state and dissolved-in-water state is an important factor which may influence availability of cadmium to food chain. Sediment characteristics and fractionation of geochemical forms (exchangeable, reducible, organic bound, carbonate, oxides and acid extractable) can reveal about biological available form of the cadmium. In aquatic systems, cadmium is absorbed by organisms directly from the water in its free ionic form. The toxicity of cadmium to aquatic organisms is variable and is related to availability of free ionic concentration

#### TOXICOKINETICS OF CADMIUM

he cadmium is transported after absorption through blood bound to albumin in most animals and human being. The cadmium reaches to liver, where it induces synthesis of metallothionein to which it binds. Metallothionein is a low molecular weight intracellular protein available in liver, kidney, intestine and pancreas. The protein is known as important biochemical substance in the regulation of heavy metals particularly cadmium. Cadmium bound metallothionein is released into the circulation, filtered by kidney and reabsorbed by cells of proximal tubules. Cadmium thus accumulates in renal tubular cells, until the synthetic capacity for metallothionein is exceeded. In kidney it may cause proteinuria, hypercalciuria, glucosuria, phosphaturia and aminoaciduria.

#### BIOACCUMULATION OF CADMIUM

The cadmium entering the aquatic ecosystem may not directly impart toxicity to the organisms being in low concentrations; however it can be accumulated in aquatic organisms through bio-concentration, bioaccumulation and the food chain process, and eventually threaten human health because of consumption of fishes and other organism with bio-accumulated concentration of metal species. Bioaccumulation refers to the ability of an organism to not only concentrate, but to continue to concentrate essentially throughout its active metabolic lifetime. The ratio of tissue to ambient concentration would continuously increase during its lifetime. In the aquatic environment algae and suspension feeders absorbs dissolved cadmium. The organism of higher trophic levels in the marine food chain may uptake the cadmium via food dominates, while in fresh water uptake by fish is significant due to a high proportion of the accumulable $Cd^{2+}$ ion.

**Cadmium content in marine biota of some countries (ppm dry weight)**

| Country | Algae | Mussel | Oyster | Gastropods | Crusta- | Fish |
|---|---|---|---|---|---|---|
| Spain | 0.8- 4.0 (b) | 0.5- 8.0 | 2.9- 3.5 | 1.1- 9.0 | 0.7-32.0 | <0.4-4.3 |
| England | 0.2-53.0 (b) | 3.7- 65.0 | 6.0- 54.0 | 3.5-1120.0 | 2.8-33.0 | 0.06-3.96* |
| Australia | - | 4.2- 83.0 | 9.0-174.0 | 2.8- 30.00 | - | 0.05-0.40* |
| Norway | 1.0-13.0 | 1.9-140.0 | - | NT- 51.0 | 1.9-7.0 | <0.01- |
| **Average** | **0.5** | **2.0** | **10.0** | **6.0** | **1.0** | **0.2** |

*ppm in wet weight, (b) blue green algae. *(Source: Michael J. Kennish, 1998)*

Mollusks have ability to accumulate cadmium to the great extent and are therefore widely used as monitoring organisms. Marine organisms are generally reported to contain cadmium concentrations around $10^2$ to $10^4$ times the level than the ambient marine environment. In general molluscs, especially bivalves, are considered as critical groups in the biological transport of cadmium. Predators less resistant to cadmium, feeding mainly on mollusks may especially in cadmium polluted areas be exposed to a massive load of cadmium. The gills represent a considerable surface area and seem to be the most probable entry of dissolved cadmium. Seabirds in general are known to accumulate high level of cadmium.

Studies were conducted on organisms and molluscs of coastal waters of peninsular India indicated cadmium contents as below:

**Concentrations of Cadmium in biotic tissue of organisms from India Ocean**

| | | | |
|---|---|---|---|
| Pilot fish | ND-0.83 | Goat fish | 0.05 |
| Sciaenid | 0.86-1.36 | Lizard fish | 0.05 |
| Sole | 0.35 | Dolphin | ND-0.95 |

*Source: Sengupta R. and S.Z. Qasim, Health of Indian Ocean*

## Cadmium content in some bivalves from Indian coastal waters

| Species | Location | Cadmium (µg/g, dry weight) |
|---|---|---|
| *Perna viridis* (mussel) | North Canara | 0.16- 0.31 |
| *Crassostrea cuculata* (oyster) | North Canara | 1.47-10.90 |
| *Perna viridis* (mussel) | South Canara | 0.54- 0.81 |
| *Crassostrea cuculata* (oyster) | South Canara | 1.93- 2.76 |
| *Meretric casta* (clam) | South Canara | 0.52- 0.89 |
| *Perna viridis* (mussel) | Calicut | ND- 2.00 |
| *Villorita cyprinoides* (clam) | Cochin | 0.50-10.50 |
| *Crassostrea madrasensis* (oyster) | Cochin | 1.15- 2.93 |
| *Perna indica* (mussel) | Vizhinjan | 5.00- 7.50 |
| *Crassostrea madrasensis* (oyster) | Tuticorin | 0.50- 3.00 |
| *Sanguinolaria acuminata (*Mussel) | West Bengal coast | 1.5-1.7 |
| *Meretrix meritrix* (Mussel) | West Bengal coast | 1.5-2.0 |
| *Strigilla splendida* (Mussel) | West Bengal coast | 6.7 |
| *Macoma baltica*(Mussel) | West Bengal coast | 2.6-2.8 |

*Sources: V.K. Pillai et al., 1986, K.Kumar P.K. et al.,1998, COMAPS, 1999-2000*

### CADMIUM EXPOSURE AND HUMAN HEALTH EFFECTS

Cadmium is not an essential element to human life, however its exposure produces adverse health effects on humans health. Humans normally absorb cadmium into the body either by ingestion or inhalation. Absorption of ingested cadmium is poor (about 5%), while almost 50% of inhaled cadmium is absorbed. Factors influencing cadmium absorption are the form in which cadmium is present in the ingested food. Much of the cadmium, which enters the human body through ingestion, derives from terrestrial Cadmium reference values in blood foods. It is estimated that 98% of the ingested cadmium derives from terrestrial foods, while only 1% derives from aquatic foods such as fish and shelfish, and 1% from drinking water. Drinking water guideline value for cadmium is 0.003 mg/l (WHO, 1993).

| Unexposed subjects | |
|---|---|
| Non-smokers | Smokers |
| <27nmol/l (<3µg/l) | <54 nmol/l (<6µg/l) |
| **Occupational exposed subjects: Guideline** | |
| <90nmol/l (<10 µg/l) | >90 nmol/l (>10 µg/l) |

(Source: HMSO, 1986)

| Source-wise Cadmium Exposure to Humans | |
|---|---|
| Phosphate fertilizer | 41.3 % |
| Fossil fuel combustion | 22.0 % |
| Iron and Steel production | 16.7 % |
| Natural sources | 8.0 % |
| Non- ferrous metals | 6.3 % |
| Cement production | 2.5 % |
| Cadmium products | 2.5 % |
| Incineration | 1.0 % |

Source: (Environmental Resources Limited, 1990)

The World Health Organization (WHO, 1993) has established a provisional tolerable weekly intake (PTWI) for cadmium at 7 µg/kg of body weight. This PTWI weekly value corresponds to a daily tolerable intake level of 70 µg of cadmium for average man of 70 kg weight while 60 µg cadmium per day for average women of 60 kg weight. Ingestion of cadmium in food is the major source of cadmium for non-smokers. Uptake of cadmium from smoking could be more than double the daily intake through food. The potential exposures of human beings to cadmium are presented ahead

**Potential Source of Human Exposures to Cadmium**

| Sources | Remarks |
|---|---|
| **EXPOSURE THROUGH AIR** | |
| Smelting of zinc, lead and copper= | Exhausted gases & vapours In roadside air |
| Incineration of plastic and pigments | Stack gases |
| Incineration of rubber goods and tires | |
| Wear tear of rubber tyres | - |
| Burning of motor oils | Motor exhaust |
| Cigarette smoking | Smoke inhalations |
| **EXPOSURE THROUGH WATER AND FLUIDS** | |
| Electroplating | In wash water to sewers |
| Metal alloys | Solution in water or acid fluids |
| PVC | As plasticiser |
| Galvanized iron items | Soft and acid waters dissolved cadmium |
| Cola drinks | From processing |
| Instant coffees | -do- |
| **EXPOSURE THROUGH FOOD STUFFS** | |
| Oysters | Up to 7 ppm, with zinc |
| Canned and dried fish | From canning, drying or smoking |
| Plastic wrappings | Absorbed by food |
| Plated roasting pans | Dissolved by roasting fats |
| Pigmented pottery | Dissolved by acid food and juices |

(Source: , Henry A. Schroeder, 1974,The poisons around Us)

Cadmium dust and fumes are both pulmonary irritants, but freshly generated fumes allow it to reach into lungs more rapidly. The onset of symptoms is frequently delayed for 4 to 10 hours after exposure. Pulmonary oedema may develop therefore rapidly.

## Acute Health Effects

***Skin/Eye:*** Contact with dust or fume may cause local irritation but no tissue damage reported.

***Inhalation:*** Fumes of cadmium (i.e. cadmium oxides) are highly toxic by inhalation. Inhalation may cause series of systematic poisoning and possibly permanent damage to the lungs. Early symptoms of exposure include dryness of the throat, irritation of nose, throat and respiratory tract. After 4 to 10 hours delay a person may develop constriction of chest, persistent cough, and progressive shortness of breath. There may be headache, chills, diarrhea, nausea, vomiting and restlessness. Pulmonary congestion may cause oxygen deficiency and death.

**Sources of cadmium exposure and its Health effects on human beings**

| Sources of cadmium exposure and intake | Health Effects |
|---|---|
| Metal refining, pigments, rubber and plastic additives, fungicides, photographic materials, electroplating alloy production, battery manufacture, tobacco smoking, coal burning etc. | Nausea, vomiting, diarrhea, muscle cramp, salivation, loss of calcium from bones, yellow coloration of teeth (cadmium ring formation), reduction of red blood cells, damage of bone marrow, hypertension, kidney failure following oral ingestion, lung irritation, chest pain, loss of sense of smell after inhalation.<br><br>Implicated in bone deformation, increased incidence of prostate cancer after long term occupational exposure.<br><br>Accumulates in liver and kidney.<br><br>Chronic cadmium poisoning produces proteinuria and affects the proximal tubules of kidney, causing formation of kidney stones. |

***Ingestion:*** Ingestion of excessive quantity of cadmium dust may cause salivation, choking, nausea, vomiting, diarrhea, abdominal pain, dizziness and headache. Convulsions, shock and unconsciousness may occur. Death occurs within 24 hours from shock or after few days due to acute kidney failure.

## Chronic Health Effects

Prolonged exposure to cadmium has been associated with gastrointestinal symptoms, kidney malfunction with excretion of low molecular weight protein (β-2-microglobulin). Chronic exposures may cause loss of smell, occasional ulceration of nasal passages, cough, shortness of breath, sleeplessness, irritability, loss of appetite, and cadmium-yellow fringe on teeth.

Cadmium is primarily bound to metallthionein and these complexes are filtered in the kidney because of which the cadmium accumulates in the renal cortex. Signs of renal dysfunction are the first indications of chronic cadmium toxicity. Cadmium affects the re-absorption capabilities of the proximal tubules and protein in the urine is the first effect to be detected. Later amino acids and glucose in urine, and these appears decreased ability to concentrate urine. There are also abnormalities in the handling of uric acid, calcium and phosphorus, which can lead to kidney stones and osteomalacia. The absorption of the cadmium depends on factors such as the intake of protein, calcium, zinc and vitamin D.

Anaemia has been seen after many years of cadmium exposure, due to deficient absorption of iron from the gut. The disease ***"**Itai-Itai"*, was characterized by osteomalacia with pain in the back and extreme, difficulty in walking and pseudo fractures. It was induced by environmental cadmium exposure primarily in post-menopausal women. Deficiencies in calcium and vitamin D were also important factors. The effect of cadmium on the kidney causes derangement of mineral metabolism, which, influence the development of symptoms along with nutritional deficiencies.

## Effects on Reproduction

Cadmium toxicity includes suppression of testicular function and also act as developmental toxin. The damage to the embryo during pregnancy through the exposure of the mother to the cadmium or any toxin it recognized as Teratogenesis, which is cadmium, induced zinc deficiency. Female rats exposed to cadmium four to five months before mating and gestation, showed damage to offspring.

## Cadmium as Carcinogen

The International Agency for Research on Cancer (IARC) has classified cadmium and certain cadmium compounds as a Group 1 human carcinogens. Chronic obstructive pulmonary disease (COPD) has been associated with long-term high-level occupational exposure by inhalation (WHO 1992, OECD 1994). Some epidemiological studies suggest occupational exposure by inhalation to cadmium may cause prostate and lung cancer in human being. Oral doses of cadmium do not increase tumor rates in animals. However cadmium compounds if injected produced local tumors at the site of injection and testicular tumors in rats. The causes are local irritation and impairment of the vascular system of the testes leading to ischaemia. There is little evidence of an association between oral exposure to cadmium and increased cancer rates in humans. There is no clear evidence that cadmium is mutagenic, however there are reports of induced gene mutation and chromosome abnormalities in mammalian cells.

# PREVENTIVE & CONTROL MEASURES OF CADMIUM CONTAMINATION TO ENVIRONMENT

The cadmium releases to the environment may be prevented and controlled at different levels.

- National level initiatives
- International conventions and treaties
- Source control
- Product control

Several countries have already promulgated national initiative and action, including legislation, to control releases and limitation on use and exposures of cadmium within their territories. The measures to control cadmium release into the environment are summarized below:

**Preventive & control measures of cadmium Contamination to environment**

| Source | Preventive & Control Measure |
|---|---|
| **During production and use of cadmium** | |
| POINT SOURCES | Apply emission control technologies to limit emissions of cadmium from combustion of fossil fuels and processing of mineral materials |
| | Prevent or limit the release of cadmium from industrial processes to the waste water system |
| | Use best available technology to reduce or prevent cadmium releases |
| PRODUCTS | Prevent or limit cadmium contents in products |
| | Limitations on the allowable content of cadmium in bulk materials i.e. phosphate fertilizers |
| | Limitations on the cadmium contents in commercial foodstuffs and feed |
| **During disposal of cadmium containing wastes** | |
| Prevent cadmium waste from being dispose directly to environment, through efficient recycling | |
| Prevent high content cadmium waste from mixing with less hazardous waste i. e. batteries with general waste | |
| Prevention or limitation on cadmium emissions to the environment from incineration | |
| Limitation on cadmium content in sewage sludge and other organic waste used for land application | |
| Limitation on cadmium emissions during road-building, construction etc. | |

**TECHNOLOGIES & PRACTICES FOR CONTROL OF CADMIUM RELEASE TO ENVIRONMENT**

The specific methods for controlling cadmium releases from the sources may be categorized in following broad categories:

- Substitution
- Emission control
- Waste management
- Waste water treatment

**Substitution**

The use of cadmium may be substituted with many alternates under development. The suggested substitutes given below:

**Cadmium applications and alternative options for substitutes**

| Application | Alternatives | Remarks |
|---|---|---|
| Plating | Zinc, aluminum, tin, nickel, silver, gold plating | No alternative for aerospace, mining, offshore and nuclear activities |
| Silver-cadmium alloys for solders | Several alternative solders exist e.g. Sn-Ag solder | - |
| Alloys | Cu-Cd alloys may be replaced by pure copper<br><br>Pb-Cd alloys for cable sheaths may be replaced by aluminum sheaths or normal lead sheaths | Alternatives may be utilized |
| Ni-Cd batteries | Nickel-metal hydride, lithium-ion- polymer etc. | Comparatively costly |
| PVC Stabilizers | Ca/zn compounds may be use for indoor purposes. Pb or organotins may be used for outdoor purposes | Comparatively costly |
| Pigments | Bismuth-vandate and tin-zinc-titanate | Other pigments may be use |

| | | |
|---|---|---|
| Pigments | Gold. Copper, molybdenum and selenide | Gold and copper pigments |
| AgCdO in high power relays | $AgSnO_2$ and AgNi | |

**Emission control**

Combustion of fossil fuels, roasting and smelting of ores, klin operations in cement industry and incineration of wastes releases cadmium into the environment. Cadmium vapors are emitted emit from processes in form of fugitive emissions or through flue gas system. Flue gases pass dust emission controls, the major part of cadmium in the flue gas is bound to the particles, and cadmium emissions depends on the particle size and dust control devices. Emission sources their control measures and percent dust reduction efficiencies are presented below:

| **Performance of dust cleaning devices** | |
|---|---|
| Dust Control Device | Dust after Control ($mg/m^3$) |
| Fabric filter | <10 |
| Fabric filter (membrane) | <1 |
| Dry ESP | <50 |
| Wet ESP | <50 |
| High efficiency Scrubber | <50 |

Source: UNECE, 1999

**Emission Sources, Dust control measure and Reduction Efficiency**

| **Emission sources** | **Dust Control measure** | **Reduction Efficiency (%)** |
|---|---|---|
| **Iron and Steel production** | | |
| Sinter plants | Fabric filter | >99 |
| | Scrubbers | >99 |
| | Cyclone | 60-80 |
| | Electrostatic Precipitator (ESP) | 95-99 |
| Pellet plants | Scrubbers | >95 |
| | ESP+ fabric filter | >99 |
| Blast furnace | Fabric filter / ESP | >99 |
| | Wet scrubbers | >99 |
| | Wet ESP | >99 |
| **Iron Foundries** | | |
| Induction furnace | Fabric filter | >99 |
| Cold blast cupola | Fabric filter | >98 |
| | Fabric filter+ chemisorptions | >99 |
| **Fossil Fuel Combustion** | | |
| Combustion of fuel oil | ESP, Fabric filter | Pb, Cd: 100 |
| Combustion of coal | Fabric filter | Dust: >99<br>Pb: >99<br>Cd: >99 |
| **Cement industry** | | |
| Rotary kilns | ESP | Pb, Cd: >95 |
| Clinker | ESP | Pb, Cd: >95 |
| Cement mills | Fabric filter | Pb, Cd: >95 |
| Crushers | Fabric filters | Pb, Cd: >95 |
| **Glass industry** | | |

| | | |
|---|---|---|
| Direct emissions | Fabric filter | Dust: >98 |
| | ESP | Dust: >90 |
| **Waste Incineration** | | |
| Stack gases | High efficiency scrubbers | Pb, Cd: >98 |
| | Dry ESP | Pb, Cd: 80-90 |
| | Wet ESP | Pb, Cd: 95-99 |
| | Fabric filter | Pb, Cd: 95-99 |

Source: Rentz, et.al. 2004

**Waste Management Practices**

Cadmium in solid waste may be a significant source of cadmium releases to the environment. Control measures for cadmium emissions related to solid waste may be both regulatory and technical measures. The regulatory measure includes guidelines and prohibition of disposal of solid waste on land and waters while Technical control measures may be recycling, biological treatment, land disposal and incineration.

- **Recycling**

The end products may collected for recycling are alloys, cadmium plated items, plastics, pigments and stabilizers. It is estimated that about 17.5 percent of cadmium consumption worldwide recovered through recycling.

- **Biological waste treatment**

The solid waste mainly consist organic materials, such as food waste or garden waste. These waste are increasingly treated biologically, e.g. by composting or fermentation that may be used as fertilizer. The sources of cadmium in compostable solid waste may be waste factions of plastics, atmospheric deposition and zinc wastes.

- **Land filling**

Landfills are a waste management option used for all types of solid waste. The general measure to minimize releases of cadmium from landfills, are to establish top covers liners and approximate treatment of leachate before its discharge to recipient water body.

- **Incineration**

The combustible solid waste sometimes directed to incineration. The fate of metals during incineration depends on the flue gas technology, but it takes place at temperature around 1000 o C. At this temperature cadmium melt and after vaporization adsorbs with the dust particles collected alongwith flue gas treatment devices or ends up in the bottom ash.

**Waste Water Treatment**

Wastewater may be treated by mechanical, biological and chemical treatment techniques. The amount removed from wastewater will be retained in sludge, which is directed to agricultural areas, landfills or incineration. Cadmium can be removed from wastewater through ferric sulphate coagulation at a pH above 8.0 through lime softening or excess lime softening. The cadmium ions are precipitated as cadmium hydroxide at a pH of 10 to 11. Precipitation as sulphide has an advantage of minimum solubility. Since the sludge does not thicken well, the sulphide precipitation is frequently used as a polishing step following hydroxide precipitation.

Chelating ion exchange resins selectively remove many heavy metals in the presence of high concentrations of univalent and divalent cations. The order of selectivity is Cu>Ni>Co>Cd>Fe ++ >Mn>Ca. The heavy metals are removed as weak acidic chelated complexes. This process is suitable for end of pipe polishing and for metal concentration and recovery. Activated carbon and Reverse Osmosis (RO) processes are also employed to remove and recover heavy metals.

**Level of achievable cadmium removal from Industrial wastewater**

| Technology | Achievable concentration (mg/l) |
|---|---|
| Hydroxide precipitation at pH 10-11 | 0.050 |
| Co-precipitation with ferric hydroxide | 0.050 |
| Sulphide precipitation | 0.008 |

**Photovoltaic (PV) solar cell Vs Coal for Electricity generation**

Coal burning routinely generates cadmium because coal contains substantial amount of cadmium. The coal-power plants usually generate waste in form of huge ash or bottom ash. The solar photovoltaic (PV) cells replaces burning coal for electricity generation, preventing substantial cadmium emissions during electricity production.

## SAFETY MEASURES FROM CADMIUM MATERIALS

- **Fire Fighting Measures**

Cadmium is a bluish silver metal that does not burn in bulk. Clouds of fine dust are a fire explosion hazard, however, when cadmium is heated in air, oxide fumes generated. A self-contained breathing apparatus (SCBA) and full protective clothing are required when cadmium is involved in a fire situation. Such fires should not be sprayed with water or foam. Apply dry chemical, dry sand or special powder for extinguish.

- **First Aid Measures during cadmium exposure**

***Eye Contact:*** Flush with warm running water, including under the eyelids for at least 15 minutes.
***Skin Contact:*** Remove dust-contaminated clothing and wash affected areas with soap and warm water. If molten cadmium is contacted then flush contacted area to solidify and cool.
***Inhalation:*** Remove exposed person from exposure area. If breathing has stopped, provide artificial respiration. The affected person may be kept warm and at rest.
***Ingestion:*** If victim is conscious, dilute stomach contents with 2-4 cupful of water or milk. Do not induce vomiting. When vomiting occurs naturally, rinse mouth and repeat water administration.

- **Accidental Release Measures**

Safely control the source of spillage of cadmium bearing material if possible. Restrict accesses to the area until completion of clean up. Molten metal should be solidify before clean up. Close fitting safety goggles may be necessary to prevent eye contact with dust and fumes. Where molten cadmium is involved, heat resistant gloves should be worn.

## REGULATORY ENVIRONMENT STANDARDS FOR CADMIUM

**Drinking Water Standards**

| **Australia**<br>Guideline | **IS:10500**<br>**BIS**<br>Desirable limit | **Japan**<br>**EQS** | **EEC**<br>Maximum admissible concentration | **German**<br>Maximum admissible concentration | **USEPA**<br>Maximum contamination | **WHO**<br>Guideline<br>Value |
|---|---|---|---|---|---|---|
| 0.002<br>(mg/l) | 0.01<br>(mg/l) | 0.01<br>(mg/l) | 0.005<br>(mg/l) | 0.005<br>(mg/l) | 0.005<br>(mg/l) | 0.003<br>(mg/l) |

*BIS: Bureau of Indian Standards, EEC: European Economic Community*

*EQS: Environmental Quality Standards, IS: Indian Standards*

*USEPA: United States Environment Protection Agency*

*WHO: World Health Organization*

**General Standards**

Under Schedule II of the Environment (Protection) Act, 1986, general standards for discharge of effluent into different water bodies are notified.

**Discharge (mg/l) Standards for Cadmium content in effluent**

| Inland surface water | Public Sewer | Marine coastal areas |
|---|---|---|
| 2.00 | 1.00 | 2.00 |

**Guideline Limit for Agricultural Water and Water for Protection of Aquatic life**

CCME (2006) has set the maximum guideline limit of cadmium for agricultural water and for protection of freshwater and marine aquatic life.

| **Agricultural water (µg/l)** | | **Water for protection of aquatic life (µg/l)** | |
|---|---|---|---|
| Irrigation water | Water for livestock | Fresh water | Marine water |
| 5.1 | 80 | 0.017 | 0.12 |

*Source: CCME, 2006)*

**Industry Specific Standards**

The industries produce effluents of varied qualitative quantity and characteristics. In order to reduce the environmental pollution, industry specific standards have been notified by Government of India under schedule I of The Environment (Protection) Act, 1986.

**Industry Specific Standards for Cadmium**

| **Industry** | **Cadmium (mg/l)** |
|---|---|
| Small scale industries (located in the Union Territories) | 2.00 |
| Dye and dye intermediate industries | 2.00 |
| Electroplating industries | 2.00 |
| Inorganic chemical industry (wastewater discharge) | 0.20 |
| Bullion refining | 0.20 |
| Treated effluent quality of CETP<br><br>· Discharge into surface waters<br><br>· Discharge into coastal waters | <br><br>1.00<br><br>2.00 |

**Standards for Coastal Waters**

The developmental activities on the coastal areas have substantial conflict with the uses of coastal waters. In order to reduce to such conflicts and to maintain its uses, the coastal water quality standards have been developed. The heavy metals, mercury, lead and cadmium have been considered for the class SW-I, which includes the saltpans, shell fishing, mariculture and ecologically sensitive areas.

**Water quality standards for cadmium for coastal waters-marine outfalls**

| **Class of Coastal water** | **Standard (mg/l)** |
|---|---|
| SW-I (Salt pans, shell fishing, and ecologically sensitive zone) | 0.01 |

**Environmental Standards for Soil and Sediments**

Guideline values and Probable Effect Level of cadmium in sediments of freshwater and marine water resources presented below:

**Guideline and Baseline values of cadmium for soil and sediments**

| Soils* (µg/g) | | | Shale value** (µg/g) | ISQG*** (µg/g) | | PEL**** (µg/g) | |
|---|---|---|---|---|---|---|---|
| Res. | Ind. | Agri. | Baseline | Freshwater | Marine | Freshwater | Marine |
| 10 | 22 | 1.40 | 0.3 | 0.6 | 0.7 | 3.5 | 4.2 |

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

**Air Quality Standards for Cadmium**

| Ambient Air* (µg/m 3 ) | | | Occupational Exposure Air (µg/m 3 ) | | |
|---|---|---|---|---|---|
| Rural area | Urban area | Ind. Area | PEL** | TLV*** | REL**** |
| 0.0001-0.005 | 0.002-0.015 | 0.015-0.150 | 15-50 | 10 | 2 |

*(Source: * WHO (1992), ** Permissible Exposure Level (Occupational Safety and Health Administration, 2003), *** Threshold Limit Value (American Conference of Government Industrial Hygienists, 2003), **** Recommended Exposure Limit (ACGIH,2003)*

**Standards for Leachate water and compost**

There are various options to reduce the quantum of municipal solid wastes that is reaching to the landfill site, even then a substantial amount of these solid wastes are disposed off at the sanitary landfill sites. In order to restrict the groundwater contamination and to reduce the pollution due to leachate, certain standards have been stipulated under The Municipal Solid Waste (Management and Handling) Rules, 2000 of The Environment (Protection) Act, 1986. This includes the standard for the compost derived from municipal solid wastes also.

**Standards for Cadmium in Treated Leachate for disposal and MSW compost**

| | |
|---|---|
| Disposal of treated leachate into:<br>1. Inland surface waters<br>2. Public sewer | <br>2.00 mg/l as Cd (max)<br>2.00 mg/l as Cd (max) |
| MSW Compost | 5.00 mg/kg as Cd (dry Wt.) |

**Standards for Food, Fish and Fishery**

The Prevention of Food Adulteration Act, 1954 limits the cadmium content 1.50 ppm by weight for all food items. The Ministry of Health and Family Welfare Government of India and the State Health Directorate are responsible for implementing this regulation. Similarly, under Export (Quality Control and Inspection) Act, 1963 the Maximum Residual Limits (MRLs) for heavy metals in fish and fishery products have been promulgated. However, if the MRL fixed by the importing country are more stringent than these prescribed limits, the standard prescribed by import countries need to be complied.

**Residual Limit of Cadmium in Food Products**

| Country/ Organization | Standard * | Product | Concentration (mg/kg, wet weight) |
|---|---|---|---|
| WHO/FAO | CAC | Fish and fishery | 1.00 |

| | | | |
|---|---|---|---|
| | | Leafy vegetables | 0.20 |
| | | Other vegetables | 0.05 |
| | | Stem and rot vegetables | 0.10 |
| | | Potatoes | 0.10 |
| | | Wheat grain | 0.20 |
| Australia | Max. conc | Root, tuber and leafy vegetables | 0.10 |
| | TPHR | Fish and fishery | 5.50 |
| | NHMRC | Fish and fishery | 2.00 |
| East European Union (EU) | - | Fish and fishery | 0.10 – 1.0 |
| Czech Republic | - | Sea fish | 0.20 |
| | | Fresh water fish | 0.10 |
| | | Molluscs | 1.00 |
| | | Crustaceans & gastropods | 0.50 |
| USA | FDA | Fish and fishery | 2.00 |
| Japan | - | Fish and fishery | 1.00 |
| India | - | Fish and fishery | 3.00 |

*(* CAC- Codex Alimentarius Commission, FDA- Food and Drug Administration, USA, NHMRC- National Health Medical Council, TPHR- Tasmania Public Health Regulation)*

**REGULATORY INDIAN LEGISLATION**

**There are series of legislations within country dealing with the impact of pollution upon environment and human health.**

| Indian Legislation for Control of Environmental Contaminations |
|---|
| **Environmental** |

| |
|---|
| • The Poison Act, 1919<br>• The Workmen's Compensation Act, 1923<br>• The Factories Act, 1948<br>• The Industries (Development and Regulation) Act, 1951<br>• The Mine and Minerals (Regulation and Development) Act, 1957<br>• The Water (Prevention and Control of Pollution) Act, 1974<br>• The Air (Prevention and Control of Pollution) Act, 1981<br>• The Environment (Protection) Act, 1986<br>• Hazardous Waste (Management and Handling) Rules, 1989<br>• Banning and Restriction on Hazardous Substances Rules, 1989<br>• Manufacture, Storage and Imports of Hazardous Chemicals (MSIHC) Rules, 1989 |
| **Food and Food Products** |
| • The Prevention of Food Adulteration Act, 1954<br>• The Export (Quality control and Inspection) Act, 1963 |
| **Others** |
| • The Insecticide Act, 1968<br>• The Public Liability Insurance Act, 1991<br>• Chemical Accidents Rules, 1996 |

## CADMIUM AND THE FUTURE

The health effects of cadmium are well recognized and well, but the toxicant metal is invariably present in useful products or in controlled wastes. Nickel-cadmium batteries are essential and irreplaceable in many consumer applications, particularly those requiring high power, long lives and good temperature performance. Rechargeable Ni-Cd batteries can replace thousands of primary non-rechargeable batteries, and significantly reduce the total amount of waste. The material in recyclable Ni-Cd batteries can be recovered for reuse and recycled in the production of new Ni-Cd batteries.

From ecological point of view, it is important to develop and maintain functional products with long service lives to minimize the input into the world's waste stream. Cadmium pigments and stabilizers are important additives in certain specialized plastics, glasses, ceramics and enamels to achieve bright colors with long service lives. Inferior substitute that produce, shorten service lives will only increase the volume of the waste. The cadmium applications in chemically products are very stable and highly insoluble.

Cadmium coated components provide outstanding corrosion resistance along with low electrical resistivity, good galvanic comparability, good plating coverage, and solderability. For these reasons cadmium coated products are preferred for a wide range of critical and safety related applications in the aerospace, electrical, defence, mining, nuclear and offshore industries. In addition, cadmium coated wastes and products are easily recycled.

It will not be advisable with respect to the cadmium and cadmium products as it is one of the useful metal too. From environmental viewpoint the recovery of cadmium from cadmium products would ensure that cadmium would be kept out of the waste stream and out of the environment, but it will also conserve limited resources of cadmium. It is therefore necessary to encourage the industries to collect and recycle cadmium-containing products, which would contribute to the sustainable and safe use of cadmium.

## REFERENCES


1. ATSDR, 1999: Toxicological profile for cadmium. Agency for Toxic Substances and Disease Registry, US Department of Health & Human Services.
2. COMAPS, 1990-1999: Decadal Monitoring Profile, West Bengal Coast
3. Cadmium and compounds fact sheet, 2005: Department of Environment and Heritage, Australia.
4. Canadian Council of Ministers of the Environment (CCME). 2002.Canadian Sediment quality guidelines for the protection of aquatic life: Summary tables. Updated 2002 In: Canadian environmental quality guidelines, 1999.
5. Codex Alimentarius Commission. 1984. Contaminants: Joint FAO/WHO standards program. Codex Alimentarius, Vol. XVII. 1 st ed. pp. 1-33. Rome Italy.
6. Canadian Council of Ministers of the Environment (CCME). 2006.Canadian Sediment quality guidelines for the protection of aquatic life: Summary tables. Updated 2006 In: Canadian environmental quality guidelines, 1999.
7. Environmental Resources Limited, 1990: Evaluation of the sources of human and environment contamination by cadmium. Consumer Protection and Nuclear Safety, London.
8. FAO/WHO, 2001: WHO Technical reports series 901. Geneva,
9. Green peace, 2005: Recycling of electronic waste in China and India
10. HMSO, 1986: Health and Safety Executive, 1986: Cadmium: Health and Safety Precautions: Guidance Note EH 1. London HMSO.
11. Horn, G., 1988: Recycling of NiCd batteries: Some practical aspects. Cadmium Association London, UK,
12. Henry A. Schroeder, 1974: The poison Around Us, Toxic metals in food, air and water.
13. http://minerals.usgs.gov./ minerals /pubs/mcs/2006/mcs2006.pdf , April 2006
14. http://www.atsdr.cdr.gov/Toxprofiles/phs5.html
15. http://www.Lumen.luc.edu/lumen/
16. http://www.onlybatteries.com/showitems.asp
17. ICdA, 2005: Cadmium market and trends- September 2005. International Cadmium Association, Brussels, Belgium.
18. International Labour Organization (ILO), 1991: Occupational Exposure Limits for Airborne Toxic substances, III rd Ed., Occupational Safety and Health Series No. 37.
19. Lokeshwari, H. and G.T. Chandrappa, 2006: Impact of heavy metal contamination of Belladur Lake on soil and cultivated vegetation. Current Science, 91(5), 622-627.
20. Managing cadmium in vegetables, 2000: State of New South Wales, Department of Primary Industries.
21. Nriagu, J.O.,1989: A global assessment of natural sources of atmospheric trace metals. Nature, 338, 47-48.
22. Oosterhuis, F.H., Brouwer, F.M. and Wijinants, H. J., 2000: A possible EU wide charge on cadmium in phosphate fertilizers: Economic and environmental implications. Institute for Environmental Studies, Amsterdam, The Netherland
23. OECD, 1994: Risk reduction monograph No. 5: Cadmium. OECD Environmental Monograph Series No. 104. OECD Environment Directorate, Paris, France.
24. Recharge @ rechargebatteries.org
25. Richardson , G.M., Garrett, R., Mitchell, I.,Mah-Paoulson, M., and Hackbarth, T., 2001: Critical review on natural global and regional emissions of six trace metals to the atmosphere.
26. Rentz, O., Wenzel, S., Deprost, R. and Karl, U., 2004: Material for consideration in the discussion concerning the protocol on heavy metals to Convention on long range Transboundry Air pollution. Karlsruhe, Germany.
27. Turkian, K.K. and Wedepohl, K.H. 1961: Geol. Soc. Am. Bull., 72:175 .
28. USGS, 2002: Cadmium Statistics. In: Historical statistics for mineral commodities in the United States, U.S. Geological Survey, Reston.
29. USGS, 2006: Mineral commodity summaries 2006. (Http://minerals.usgs.gov./minerals/pubs/mcs/2006/mcs2006.pdf.April2006)
30. UNECE, 1999: To the 1979 Convention on long range Transboundry Air pollution on Heavy metals, Done at Aarhus, Denmark.
31. www.nrcan.gc.ca/mms/cmy/com_e.html .
32. www.cadmium-management.org.au

33. webmaster@pca.state.mn.us
34. World Health Organization (WHO), 1992: Environmental Health Criteria 134 – Cadmium International Programme on Chemical Safety (IPCS) Monograph.
35. WITESKA, M., 2001: Changes in the common carp blood cell picture after acute exposure to cadmium. Acta Zoologica Lilunica, Vol. 11(4), 366-371