HAZARDOUS METALS AND MINERALS POLLUTION IN INDIA: SOURCES, TOXICITY AND MANAGEMENT

A POSITION PAPER

August 2011

Indian National Science Academy
Bahadurshah Zafar Marg, New Delhi

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PREFACE

Indian National Science Academy (INSA) is a leading science academy of India, affiliated to the International Council of Scientific Unions. It has a societal programme as well as a science policy cell to identify and analyse national issues where scientific and technological advice may be possible. Last year the issue of "Nutrition security for India–issues and the way forward", a burning problem in India, was discussed in a symposium and a position paper prepared. This was followed by a more focussed paper on "Micronutrient deficiencies—priorities for research and action". The idea of these papers is to present to the government, the stake holders and the public, the problem and suggest remedial measures based on Science and Technology. Effort is made to draw expertise from within and outside the fellowship, and make a considered statement.

Environmental degradation has become a major societal issue thanks to uncontrolled anthropogenic activity, besides natural factors. Entry of toxic heavy metals and minerals in human system mainly through contaminated water, food, and air, leads to overt and insidious health problems. A rapidly developing country like India needs to be aware of these problems and find preventive and remedial solutions for management. Sometimes expensive high-tech remedial measures are not easy for a country like India, and hence emphasis has to be on prevention. Indigenous research towards mitigation and remediation has to be encouraged, keeping in mind India's unique problems of poverty, crowding and malnutrition.

On November 30.and December 1st, 2010, a panel discussion on the subject of "Hazardous metals and minerals pollution in India: sources toxicity and management" was held in INSA, New Delhi. The draft position paper based on presentations and discussions during the meeting was circulated among the INSA fellowship and other experts. The present draft is a distilled statement which not only analyses the problem in terms of its origin and health consequences, but also gives suggestions for its management (mitigation and remediation). While hazardous limits have been fixed for many pollutants, this is an evolving process and the best dictum is zero tolerance. This may not be easy to achieve but that has to be the way forward. The paper also provides citations.

My gratitude to all the participants in the panel discussion and the reviewers for their very valuable inputs; to INSA presidents (Dr. M Vijayan and Dr. Krishan Lal) and Vice president Dr. R Rajaraman for interest and useful suggestions; Dr. GV Subrahmanyam, Advisor, MoEF, for advise in preparing the programme; Mr. S Sahni, advisor, Policy cell, INSA, Dr. Alok Moitra, ES, INSA, and Dr. Seema Mandal, OI/C Societal programmes, for valuable help.

MAHTAB S BAMJI
Panel Discussion Convener,
and Vice President, Science and Society

EXECUTIVE SUMMARY

The major hazardous metals of concern for India in terms of their environmental load and health effects are lead, mercury, chromium, cadmium, copper and aluminium. Their source is mostly anthropogenic- industrial activity, vehicles, etc. Natural causes like seepage from rocks, volcanic activity and forest fires can also contribute. Minerals like fluoride and arsenic salts are of natural origin, but human activity can also aggravate the situation.

In general heavy metal toxicity can cause chronic degenerative diseases the symptoms being mental disorders, pain in muscle and joints, gastro intestinal disorders, vision problems, chronic fatigue, and susceptibility to fungal infections. Sometimes the symptoms are vague and difficult to diagnose at early stage. Geno-toxicity and cancers can also occur. Industrial workers and populations living near the polluting industry are more susceptible and have to be monitored. Malnourished people and pregnant women are vulnerable.

Crippling effects of fluoride and arsenic toxicity due to non-availability of safe water for drinking and farming, has become a major public health problem, which defies simple solutions.

Management priority should be to mitigate the problem. Once the metal is out of the rock it is difficult to put it back. Physico-chemical as well bioremediation solutions are being tried to reduce the environment load, preferably at the site of generation. While large industries should be forced to set-up their own effluent treatment plants, common effluent treatment facilities can be considered for smaller industries, provided they are maintained. Pollution from items such as medical devices containing mercury, and CFL bulbs can be mitigated by salvaging them after use, at collection centres, and recycling. Haphazard disposal as is the case now will prove to be very harmful. Mercury- free alternatives should be encouraged.

At the end of the paper, a list of specific recommendations for mitigating the problem has been provided. Specific inputs that came from reviewers after the panel discussion in August 2010 have been indicated as boxed items.

GENESIS

The Indian National Science Academy (INSA) has recently initiated a formal Science and Society Programme. The purpose is to identify issues which have societal relevance, discuss them using scientific evidence and come out with recommendations which can be communicated to the government/implementing agencies etc.

Environment pollution particularly from hazardous heavy metals and minerals (fluoride arsenic salts) is an important societal problem. Many of these elements being stable are bio-accumulative, and deriving their safe limits is very difficult. Also toxicity of metals depends largely on its chemical form and oxidation state. Hence toxicity studies without taking the speciation may not reveal its actual hazard.

Some elements like Fe, Zn, Cu, Co, Cr, Mn, Ni, are needed in small quantities for human metabolism, but may be toxic at higher levels. Others like lead, mercury, cadmium, and arsenic etc. have no beneficial role and are positively toxic. Small amounts of fluoride help to prevent dental caries, but excess is harmful. Toxicity of these is of considerable concern in India because of their environmental burden. This was the theme of a panel discussion organised on November 30-December 1 2010, at the INSA. The resource persons were all eminent scientists and environment engineers. The programme giving the names of the participants and the themes covered is appended. (Appendix 1, Programme).

The position paper is based on the presentations in the panel discussion and comments on the draft paper from the panellists as well as other scientists who reviewed the paper. (Appendix 1 and 2).

SOURCES OF HAZARDOUS METALS AND MINERALS

Environmental pollution from hazardous metals and minerals can arise from natural as well as anthropogenic sources. Natural sources are: seepage from rocks into water, volcanic activity, forest fires etc. Pollution also arises from partitioning of polluting elements (which are concentrated in clay minerals with high absorption capacities), between sedimentary rocks and their precursor sediments and water. (Sisir Sen, personal communication). With rapid industrialization and consumerist life style, anthropogenic sources of environmental pollution have increased. The pollution occurs both at the level of industrial production as well as end use of the products and run-off. These toxic elements enter the human body mostly through food and water and to a lesser extent through inhalation of polluted air, use of cosmetics, drugs, poor quality herbal formulations particularly 'Ayurvedic/Sidha bhasamas', (herbo-mineral preparations) and `Unani' formulations, and even items like toys which have paints containing lead.

Heavy Metals and Aluminium

Table 1 lists the industrial sources of heavy metals.

Table 1: Sources of heavy metals (Source: Gautam SP, CPCB, New Delhi)

Metal	Industry
Chromium (Cr)	Mining, industrial coolants, chromium salts manufacturing, leather tanning
Lead (Pb)	lead acid batteries, paints, E-waste, Smelting operations, coal- based thermal power plants, ceramics, bangle industry
Mercury (Hg)	Chlor-alkali plants, thermal power plants, fluorescent lamps, hospital waste (damaged thermometers, barometers, sphygmomanometers), electrical appliances etc.
Arsenic (As)	Geogenic/natural processes, smelting operations, thermal power plants, fuel burning
Copper (Cu)	Mining, electroplating, smelting operations
Vanadium (Va)	Spent catalyst, sulphuric acid plant
Nickel (Ni)	Smelting operations, thermal power plants, battery industry
Cadmium (Cd)	Zinc smelting, waste batteries, e-waste, paint sludge, incinerations & fuel combustion
Molybdenum (Mo)	Spent catalyst
Zinc (ZN)	Smelting, electroplating

Besides the industrial sources of lead, listed in table 1, lead exposure also occurs through gasoline additives, food can solder, ceramic glazes, drinking water system, cosmetics, folk remedies, and battery/plastic recycling industry[1]. According to some work done at the DPSAR university, New Delhi many brands of cosmetics like talcum powder, lipsticks, shampoos, 'kajal' and hair colours contain heavy metals. (SS Agarwal)

Ash dumps from thermal power plants, contain many polluting metals and complexes, which are carried to nearby water bodies and ground water. Volatile complexes such as those from Uranium, enter the atmosphere via chimney emissions. The U content of coal may be as low as 0.2 ppm, but considering the millions of tons of coal that is burnt it is an important pollutant. (Sisir Sen, personal communication).

In recent years the use of energy-saving CFL bulbs has gone up enormously. Thus, according to a recent report the production of CFL bulbs has increased from 19 million in 2002 to 500 million in 2010. Each bulb contains 3-12 mg of mercury. With no system to recover these bulbs and safe disposal, these can prove to be a major health hazard. (For details see Down to Earth, February 1-15, page 29, 2011).

The major heavy metal contaminated sites in India, are given in table 2.

Table 2: Major heavy metals contaminated sites in India
(Source: Gautam SP, CPCB, New Dellhi, RC Murty*, Indian Institute of Toxicology Research, personal communication)

Chromium	**Lead**	**Mercury**	**Arsenic**	**Copper**
Ranipet, Tamil Nadu	Ratlam, Madhya Pradesh	Kodaikanal, Tamil Nadu	Tuticorin, Tamil Nadu	Tuticorin, Tamil Nadu
Kanpur, Uttar Pradesh	Bandalamottu Mines, Andhra Pradesh	Ganjam, Orissa	West Bengal	Singbhum Mines, Jharkhand
Vadodara, Gujarat	Vadodara, Gujarat	Singrauli, Madhya Pradesh	Ballia and other districts, UP*	Malanjkahnd, Madhya Pradesh
Talcher, Orissa	Korba, Chattisgarh			

Data of CPCB show that Gujarat, Maharashtra and Andhra Pradesh contribute to 80% of hazardous waste (including heavy metals) in India.

Apart from industries, roadways and automobiles contribute substantially to the environmental burden of heavy metals since particulate matter in traffic emissions include heavy metals like lead, cadmium and arsenic. Exposure to traffic emissions, especially diesel exhaust may enhance asthma, allergen responsiveness and inflammation, leading to atherosclerotic vascular disease. Role of metal per se in this pathology is however not clear.[2, 3]. With the use of unleaded petrol, the burden of lead has decreased.

Aluminium pollution is associated with bauxite mining. With steady increase in demand for aluminium in India, its anthropogenic pressure is increasing. India ranks sixth in bauxite mining and 8th in aluminium production. The state of Orissa is worst affected.

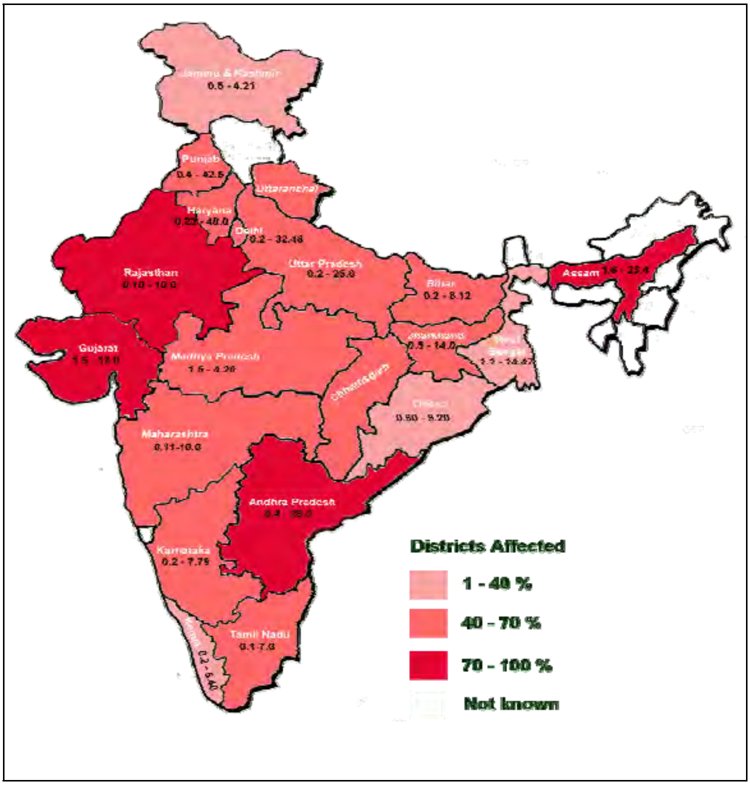
'Significant concentration of total and hexavalent chromium is observed in many wells located in the close vicinity of some of the industries in the industrial area of Ranipet, in Tamil Nadu. The sources are clusters of tanneries and other industries located in the area. The concentration of total chromium in these wells varies between 3.1 to 246 mg/L whereas the concentration of hexavalent chromium varies between 2.1 to 214 mg/L which far exceed the concentration of 0.05 mg/L prescribed under Indian Standards Specification for Drinking water quality. The ground water in these areas is therefore, severely contaminated with hexavalent chromium. Based on the detailed laboratory scale studies and techno-economic evaluation, an in-situ bioremediation (biotransformation) option was recommended by NEERI for implementation of bio-remediation of contaminated ground water in the critically polluted area' [Ref. Tamil Nadu Pollution Control Board: 'Revised Action Plan for Critically polluted Area – Ranipet', Nov, 2010]. (Personal communication, AK Ghosh).

Village Khanpur in Rania area of Kanpur Dehat also revealed high levels of hexavalent chromium in groundwater ranging from 1.05 to 35.34 ppm [Personal communication Krishna Gopal, IITR].

Fluoride

Natural sources contribute to the bulk of environmental load of fluoride and arsenic. In India, 19 out of 35 states and Union territories have ground water highly contaminated with fluoride, with levels exceeding 1.0 mg/L and going up to 48mg/L.[4,5].

A map of fluoride prevalent states in India is given below. In states like Andhra Pradesh, Gujarat and Rajasthan, 70-100% districts contain high fluoride levels in food and water. According to AK Susheela, black rock salt (CaF2) commonly used as flavouring agent in road side, as well as processed and home-cooked foods contributes significantly to the ingestion of fluoride. It contains 157 ppm F--. Public awareness in this regard is needed. Dental products, anti-depressant and anti - cholesterol drugs used for long term treatment are important sources of fluoride. Industries using fluoride salts/hydrofluoric acid pollute the work environment and are a source for high ingestion/inhalation of fluoride dust and fumes by the Industrial workers.



Source: Ref. 4,5.

Arsenic

Pockets in West Bengal, Bihar, UP, Assam and Chhatisgarh are the major states affected by arsenic contamination of water, West Bengal being by far the worst affected. Ground water of 9 out of 16 districts of West Bengal is heavily contaminated with arsenic, affecting 26 million people[6]. In a U.P. Jal Nigam/IITR survey of 66671 samples of water from hand pumps in 20 districts of U.P., 42% were found to contain > 10 ppb arsenic of which 2610 (4%) had > 50 ppb arsenic. Children ingest arsenic through pica behaviour.

While the high burden of environmental pollution in developed countries like India is due to high level of resource consumption, in developing countries like India it is due to outdated technologies, over exploitation of natural resources and weak environment regulations and enforcement.

TOXICITY DUE TO METALS AND MINERALS

In general, heavy metal toxicity can cause chronic, degenerative conditions. General symptoms include: headache, short-term memory loss, mental confusion, sense of unreality, distorted perception, pain in muscles and joints, and gastro-intestinal upsets, food intolerances, allergies, vision problems, chronic fatigue, fungal infections etc. Sometimes the symptoms are vague and difficult to diagnose.

Lead (Pb)

Absorption of Pb from different sources is dependent on the amount of Pb presented to portals per unit time and the physical and chemical state in which Pb is presented. It is also influenced by factors such as age and physiological status. In adults, almost 20-30% and in children almost 50% lead is absorbed through the GI track. Depending on the particle size, lead can enter through lungs. While organic lead is well absorbed through the skin, inorganic lead is not. Since lead is chemically similar to calcium, body handles it like calcium. In the body lead is distributed throughout-bone, teeth, liver, lung, brain and spleen; bone being the major accumulator. Lead can cross blood brain barrier as well as placental barrier. Excretion occurs through urine and faeces. Dose and duration dependent genotoxic effects have been observed[7].

Nutritional iron deficiency enhances Pb toxicity, raising concern that pregnant women and young children in whom iron deficiency anaemia is high, may be more susceptible to Pb toxicity[8]. Pb absorption is increased considerably with fasting or in persons whose diet is deficient in calcium, iron, phosphorous or zinc. In children the blood lead level (BLL) above 10 μg/dl is labelled as poisoning. Recent studies from Hyderabad also show abnormal cognitive functions in children at levels > 10 μg/dl. A study done in Hyderabad showed high blood lead levels in neonates and mothers in general population[9,10].

In general Pb is excreted very slowly from the body. Its biological half-life estimated at 10 years, facilitates accumulation in the body. Almost 90% lead is bound to red blood cells. Lead has high affinity for SH groups and hence it impairs the activity of zinc-dependent enzymes like δ-aminolevulinic acid dehydratase (ALAD) which is involved in haem synthesis. As low as 10 μg/dL BLL is known to inhibit the ALAD activity. Apart from haemoglobin, cytochrome synthesis, steroid metabolism, membrane integrity, synthesis of active metabolite of vitamin D in renal tubular cells (conversion of 1-hydroxyvitamin D to 1,25-hydroxyvitamin D) are also affected.

Tables 3 and 4 give the general signs and symptoms of lead toxicity, and relationship with dose[11].

Table 3: General signs and symptoms of lead toxicity

- Fatigue
- Irritability
- Lethargy
- Paresthesis
- Myalgias
- Abdominal pain
- Tremor
- Headache
- Vomiting
- Weight loss
- Constipation
- Loss of libido
- Motor neuropathy
- Encephalopathy
- Cerebral edema
- Seizures
- Coma
- Severe abdominal cramping
- Epiphyseal lead lines in children (growth arrest)
- Renal failure

Table 4: Range of lead-induced effects in humans at different blood levels

Blood lead levels	Adults	Children
10 µg/dL	Hypertension may occur	Crosses placenta Impairment IQ, growth Partial inhibition of heme synthesis
20 µg/dL	Inhibition of heme synthesis Increased erythrocyte protoporphyrin	Beginning impairment of nerve conduction velocity
30 µg/dL	Systolic hypertension Impaired hearing	Impaired vitamin D metabolism
40 µg/dL	Infertility in males Renal effects Neuropathy Fatigue, headache, abd pain	Haemoglobin synthesis inhibition
50 µg/dL	Anaemia, gastro-intestinal disorder, headache, tremor	Colicky abdominal pain, neuropathy
100 µg/dL	Lethargy, seizures, encephalopathy	Encephalopathy, anemia, nephropathy, seizures

Lead is a confirmed carcinogen in animals (AK Ghosh, personal communication).

Mercury (Hg)

Mercury occurs in three forms:

Elemental: liquid at room temperature, but volatizes readily. It is rapidly distributed in the body through vapour, but poorly absorbed through GI track.

Inorganic: Poorly absorbed through GI tract, but can be caustic. Dermal exposure results in toxicity.

Organic: Lipid soluble. It is well absorbed via GI tract, lungs and skin. Can cross placenta and into breast milk.

Anaerobic organisms bio-transform the inorganic form to methyl mercury which gets bio-accumulated in food chain. It's the most toxic form of mercury. Adverse health effects depend on its chemical form, route of and duration of exposure. Enzymes, receptors, membranes and structural proteins are affected. There is multiple organ failure. Some of the symptoms of mercury poisoning are summarised.

- At high concentrations, vapour inhalation produces acute necrotizing bronchitis, pneumonitis, and death.
- Long term exposure affects central nervous system (CNS).
  - Early: insomnia, forgetfulness, anorexia, mild tremor
  - Late: progressive tremor and erythrism (red palms), emotional lability, and memory impairment
  - Salivation, excessive sweating, renal toxicity (proteinuria, or nephrotic syndrome)
  - Gastrointestinal ulceration or perforation and haemorrhage are rapidly produced, followed by circulatory collapse.
  - Breakdown of mucosal barriers leads to increased absorption and distribution to kidneys (proximal tubular necrosis and anuria).
  - Acrodynia (Pink disease) usually from dermal exposure
  - maculopapular rash, swollen and painful extremities, peripheral neuropathy, hypertension, and renal tubular dysfunction.
  - Signs progress from paresthesias to ataxia, followed by generalized weakness, visual and hearing impairment, tremor and muscle spasticity, and then coma and death.
- Teratogen with large chronic exposure
  - Asymptomatic mothers give birth to severely affected infants
  - Infants appear normal at birth, but psychomotor retardation, blindness, deafness, and seizures develop over time.

Thus, exposure to inorganic and organic mercury is associated with genotoxicity, Teratogenicity, and embryo toxicity. In the GI track, acute poisoning results in sloughing away of the mucosa with pieces of intestinal mucosa appearing in the stool. In chronic intoxication there is mercury line at the gingival border similar to the `lead line'.

> A classical example of mercury poisoning due to consumption of fish contaminated with methyl mercury from industrial waste is that of Minamata disease, reported from Minamata in Japan in 1956. "Symptoms include ataxia, numbness in the hands and feet, general muscle weakness, narrowing of the field of vision and damage to hearing and speech. In extreme cases insanity, paralysis, coma and death follow within weeks of onset of symptoms. A congenital form of the disease can also affect foetus in the womb".
>
> -- A second outbreak of Minamata disease occurred in Niigata Prefecture in 1965".[12]

A study conducted at AIIMS, New Delhi showed poor understanding among health professionals, particularly the technical and nursing staff, regarding the hazards of mercury in hospital devices and equipment. These workers continued to prefer mercury containing equipment like thermometers, manometers etc. despite availability of alternative digital devices. (YK Gupta).

Cadmium (Cd)

Tobacco smoke is an important source of cadmium exposure. Smoking one pack a day, can imbibe 5-10 times the amount of cadmium obtainable through a regular diet. Food is a poor source of Cadmium. It is transported in blood, bound to metallothionin. Urinary excretion is slow, Biological half life can be up to 30 years. Highest concentration is found in kidney and liver. The problem of cadmium toxicity in India is not known. The disease Itai itai is caused by cadmium contamination associated with a diet low in calcium and vitamin D. Cadmium affects lungs, kidneys, liver and skeletal system. It binds to sulfhydryl groups, displacing other metals from metalloenzymes, disrupting those enzymes. Cadmium competes with calcium for binding sites on regulatory proteins. Lipid peroxidation has been demonstrated. Cadmium has been classified as a suspected human carcinogen (AK Ghosh, personal communication)

Arsenic (As)

Arsenic tends to accumulate in keratin- rich tissues like nails, hair and skin. Inorganic arsenic is converted to organic arsenic (biomethylation to monomethyl arsenic- MMA or DMA) in the liver. This may represent a process of detoxification. 30-50% of inorganic arsenic is excreted in about 3 days through urine. Trivalent forms of As bind to sulfhydryl groups leading to inhibition of enzymatic systems. Arsenic affects energy transduction reactions like Krebs cycle and oxidative phosphorylation, and ATP production is inhibited. Endothelial damage, loss of capillary integrity, capillary leakage, volume loss, finally result in shock. Table 5 lists the symptoms of arsenic toxicity. (AK Jain).

Table 5 Symptoms of acute arsenic toxicity

Bodily system affected	Symptoms or signs	Time of onset
Systemic	Thirst	Minutes
	Hypovolemia, Hypotension	Minutes to hours
Gastrointestinal	Garlic or metallic taste	Immediate
	Burning mucosa	Immediate
	Nausea and vomiting	Minutes
	Diarrhoea	Minutes to hours
	Abdominal pain	Minutes to hours
	Hematemesis	Minutes to hours
	Hematochezia, melena	Hours
	Rice-water stools	Hours
Hematopoietic system	Haemolysis	Minutes to hours
	Hematuria	Minutes to hours
	Lymphopenia	Several weeks
	Pancytopenia	Several weeks
Pulmonary (primarily in inhalational exposures)	Cough	Immediate
	Dyspnea	Minutes to hours
	Chest Pain	Minutes to hours
	Pulmonary edema	Minutes to hours
Liver	Jaundice	Days
	Fatty degeneration	Days
	Central necrosis	Days
Kidneys	Proteinuria	Hours to days
	Hematuria	Hours to days
	Acute renal failure	Hours to days

Acute exposure can even result in death.

Chronic exposure can result in poisoning of the nervous system, liver damage, and peripheral vascular disease, leading to gangrene of the lower limbs. This condition is commonly known as `black foot disease'. Chronic exposure to As is also associated with leukaemia, kidney and bladder cancers, dermatitis, hyper pigmentation, and arsenical keratosis. Arsenic acts as a non-genotoxic carcinogen. However, it affects DNA methylation and repair.

Studies of Giri and colleagues show that there is a genetic predisposition to arsenic toxicity. Thus although large numbers are exposed to arsenic through drinking water, only 15-20% show arsenic-induced skin lesions. Though both skin lesions and non skin lesions group had higher degree of damage, those with the skin lesions showed greater degree of health effects, and immunological, haematological and genetic damage than those not showing skin lesions.[13,14]

Fluoride (F)

Toxicokinetic studies show that absorbed fluoride is distributed into two compartments. Fluoride in blood and soft tissues has short half life of few hours, but that in hard tissues like bone and teeth has long half life of eight years. Accumulation in these two tissues is dose and age dependent. Unlimited accumulation of fluoride in bones is the main cause of the disease, skeletal fluorosis. Fluoride toxicity can be acute due to exposure to a single massive dose, as happens with industrial workers (industrial fluorosis) or chronic (endemic fluorosis) due to continuous ingestion of water and food containing high amounts of fluoride. In both the types, teeth and bone are the primary targets. However, fluoride does not spare soft tissues and causes non-skeletal fluorosis. As mentioned earlier, endemic fluorosis is a serious problem in many parts of India.

The characteristic feature of dental fluorosis is dental mottling. The clinical features of skeletal flourosis are; muscular skeletal dysfunction, arthralgia, arthritis, fixed flexion deformities, restricted movement of joints, stiffness of the spine, and sometimes paraplegia. The progression is slow[15]. In more recent years, a variant of skeletal fluorosis – genu valgum or knock nee has been reported from some parts of the world including India, in younger individuals. Its aetiology is not fully understood.

Though ingestion of high amounts of fluoride through water and food is the main factor in the causation of endemic fluorosis, other factors- probably dietary, also play a role. Thus, In the US, ingestion of even 8 ppm fluoride containing water, over 15 years did not lead to fluorosis. On the other hand in India levels above 1 ppm are considered unsafe. The role of nutrition status is apparent from the fact that even in the fluorotic regions, the poor and malnourished are the worst affected.

MANAGEMENT OF POLLUTION FROM METALS AND MINERALS

The saying "prevention is better than cure" applies to environmental pollution as it does to diseases. Polluted environment in any case leads to disease and ill health. Thus technological options should not just be confined to remediation strategies, but concentrate on mitigation strategies through reduction–either by total replacement of heavy metals/minerals by alternatives or refining the existing technologies for reducing the requirement.

Remediation Technologies

Release within safe limits has to be through three complementary functions: 1) Technological 2) Management (implementation) and 3) Regulatory. Once the metal is out of the earth's crust, it is difficult to put it back into earth despite efforts being made. Technologies for reduction should be cost- effective and affordable. Most industries use engineering technologies for remediation based on physico-chemical methods. Bioremediation methods using plant and microbial systems have also been developed for detecting pollution as well as for remediation.

Technological functions involve development of the treatment scheme whereby the quantity and concentration in the waste/effluent is brought within the stipulated safe limits. The form in which the metal is present will also influence its entry into the food chain and hence the effort should be to convert to less toxic form. Technologies for treatment of gaseous emissions and liquid effluents to reduce the burden of metals to safe levels are available. For particulate matter in gaseous emissions the technologies are: use of cyclones, electrostatic precipitators bag filters, scrubbers singly or in combination. For liquid effluents, physico-chemical processes like settling, neutralisation, precipitation, flocculation, filtration etc are adopted. Overall strategy is to reduce the metallic burden in gaseous or liquid media by converting it into solid form and then either recycle it or put it back in to earth after chemical treatment and fixing it in a matrix from where it cannot leach out.

The responsibility of Management is to ensure that the right technologies are adopted and monitor the end result. Regulations are in place to regulate the release of toxic metals in the environment to ensure safety and health of the workers as well as the public in general. However, the question is how much is safe? What are the safe limits? The current regulatory limits are based on some gross evidence to judge health hazard. More work is needed to determine the safe limits using more refined cellular, molecular and functional (neurological, carcinogenic, reproductive health etc) parameters. Microbial, Plant, Animal and Human systems have been tried to detect toxic substances. At present, the guidelines for management of tailings from beneficiation plants and slags from smelters which are not categorised as hazardous waste but which are generated in large volumes are yet to be prepared.

Suggestions for further action:

i. Recycling/reprocessing of wastes containing toxic metals needs to be given greater emphasis not only from environmental and health considerations but also as a resource conservation measure.

ii. Monitoring of air, water and soil in the vicinity of the toxic metal processing units needs to be carried out more rigorously for the specific metal.

iii. Tailings dumps and process wastes lying in locations close to the processing units need to be remediated on priority.

iv. Guidelines for proper management of tailings and slags containing toxic metals should be prepared taking into consideration techno- economic feasibility.

v. Health monitoring of workers engaged in the processing of toxic metals/compounds should be carried out regularly.

In India, small industries in unorganised sector contribute to a great deal of pollution. Common treatment plants can help. So far, in India, 22 Common Treatment, Storage and Disposal Facilities in 10 states have been established-7 in Gujarat, 4 in Maharashtra, 3 in UP, 2 in AP, and 1 each in HP, MP, Punjab, Tamil Nadu and West Bengal. (CPCB, New Delhi). For a vast rapidly industrialising country like India this number seems to be very small. In Hyderabad a common effluent treatment plant (CETP) has been set up for treating effluents from several small electroplating industries. (Madhusudhan Rao, APPCB). Proper working of CETSPs has to be ensured. Past experience of Andhra Pradesh is however not encouraging (YS Murty, former member secretary PCB, AP, personal communication). Most plants do not work efficiently. While small industries would need common treatment plants, large industries should have their own treatment plants and discharge waste in to sewers after treatment, rather than burden the carrying capacity of the common treatment plants.

NEERI, has developed several technologies for water and land sectors for waste management as well as a kit for testing the quality of water.

For recovery of heavy metals like mercury from medical devices and CFL bulbs, suitable collection centres need to be set up, and some refund given. As it is, no such mechanism exists and with increasing use of CFL bulbs, haphazard disposal can be dangerous. Replacement of CFL bulbs with LED bulbs needs to be considered. In medical devices like thermometers and BP apparatus, digital devices should replace the mercury-based sphygmomanometers.

Phytotechnologies to reduce the burden of heavy metal load

The techniques in Bioremediation/Phytoremediation include the application of appropriate plants for in-situ risk reduction through contaminant removal, detoxification or containment in contaminated soil, sediments, and ground water. This strategy/approach can be used along with or, in some cases, in place of mechanical cleanup methods. Cleanup can be accomplished to certain level within the reach of plants' roots. Such sites need to be maintained and monitored (watered, fertilized, and monitored). Microflora associated with plants; endophytic bacteria, rhizosphere bacteria and mycorrhizae have the potential to degrade organic compounds in association with plants and this process is termed rhizoremediation. Bioremediation processes can also be accessed through a multifaceted approach such as: Natural attenuation, sensing environmental pollution, metabolic pathway engineering, applying phyto- and microbial diversity to problematic sites, plant-endophyte partnerships and systems biology; plant physiology, agronomy, microbiology, hydrogeology, and engineering are combined to select the proper plant and conditions for a specific site. The specific application will depend on the mobility, solubility, degradability, and bioavailability of the contaminant(s) of concern[16,17]. Metal resistance mechanisms and their phytoremediation potential has been investigated in wide range of experimental model systems such as *Scenedesmus quadricauda, S. bijugatus, Chlamydomonas reinhardtii, Sorghum bicolor, Zea mays, Brassica juncea; Ceratophyllum demersum, Vallisneria americana* and *Lemna trisulca* and phytomass derived products as adsorbents for toxic metals[17].

Genetically modified plants for phytoremediation

Both microorganisms and higher plants have been genetically modified for detoxification of soils contaminated with heavy metals or minerals. Following are some examples: (i) Ralstonia eutropha (a natural inhabitant of soil) was transformed using a mouse gene encoding metallothionein, which was expressed on the surface of the cell surface thus helping in sequestering of cadmium from the soil; (ii) Transgenic plants of *Arabidopsis thaliana* were produced for detoxification of soils contaminated with either aluminium, or arsenic or mercury. For aluminium detoxification, a gene encoding citrate synthase (CSb) was used, while for arsenic, genes encoding arsenic reductase (ArsC) and glutamylcysteine synthase (gamma-ECS) were used. Similarly, for mercury detoxification, genes encoding mercury reductase and organomercurial lyase (merA and merB) were used (for details see, Gupta, 2010).[18]

Apart from phytoremediation, plants can also be used to detect metal pollution. A system based on the plant *Hordeum vulgare* has been developed at Baharampur University by Panda and colleagues.

Management of Natural Burden of Arsenic and Fluoride

In areas where water has high load of minerals like arsenic and fluoride, alternative sources- (canal water, rain water harvesting) would have to be provided not only for drinking water but also for farming. Technologies for de-fluoridation of drinking water have been developed.

There are thousands of villages in the endemic states in India with excess fluoride problem. The water quality assessment undertaken by NEERI during 1970-1990 revealed that physico-chemical parameters of the samples varied widely within the same village in all the 19 endemic states, then surveyed. Based on the results, the water sources are classified into different groups and potential technologies suggested in table 6[19].

Table 6: Potential technologies suggested by the National Environment Engineering Research Institute (NEERI), Nagpur[19]

	Parameters Groups		Suggested Technologies
Group 1	Dissolved solids, mg/L	above 5000	Water Transportation
Group 2	Dissolved solids, mg/L Chlorides, mg Cl/1 Sulphates, mg SO_4/1 Nitrates, mg NO_3/1 Fluorides, mg F^-/1	above 2000 above 1000 above 400 above 100 above 1.5	Water Transportation Reverse Osmosis Electro dialysis
Group 3	Dissolved solids, mg/L Chlorides, mg Cl/1 Sulphates, mg SO_4/1 Nitrates, mg NO_3/1 Fluorides, mg F^-/1	below 2000 above 1000 above 400 above 100 above 1.5	Reverse Osmosis Electro dialysis
Group 3	Dissolved solids, mg/L Chlorides, mg Cl/1 Sulphates, mg SO_4/1 Nitrates, mg NO_3/1 Fluorides, mg F^-/1	below 1000 below 250 below 200 above 45 above 1.5	Ion-Exchange
Group 5	Dissolved solids, mg/L Chlorides, mg Cl/1 Sulphates, mg SO_4/1 Nitrates, mg NO_3/1 Alkalinity, mg $CaCO_3$ Fluorides, mg F^-/1	below 2000 below 1000 below 400 below 45 below 200 above 1.5	Activated Alumina Technology
Group 6	Dissolved solids, mg/L Chlorides, mg Cl/1 Sulphates, mg SO_4/1 Nitrates, mg NO_3/1 Alkalinity, mg $CaCO_3$ Fluorides, mg F^-/1	below 2000 below 1000 below 400 below 45 above 200 above 1.5	Nalgonda Technology for fluoride removal

Issues Related with Quality of Water

All societies, particularly in the developing world are seriously concerned about the availability of safe water for human consumption. The growing population and fast urbanization has posed several serious challenges to solve water related problems in rural as well as urban areas. The Millennium Development Goal (MDG) 7C states: "Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation".

The availability of adequate quantity of water is the first very important need of the society. It is true that sustained efforts of the last decade at international level have enabled access to safe drinking water to about 1 billion additional people in the world. However, quality of water is also of paramount importance. There are continuous efforts through international organizations like World Health Organization (WHO) and the International Bureau of Weights and Measures (BIPM) through its Consultative Committee on Quantity of Matter (CCQM) have devised standards for ensuring quality of safe drinking water and methodology of achieving the same through a chain of Testing and Calibration Laboratories in each country. The measurements have to be made as per globally acceptable techniques and methods with well calibrated equipments. The laboratories are accredited by an organization like National Accreditation Board for Testing and Calibration Laboratories (NABL) in India. This ensures that all the measurements made in a country are traceable to national standards maintained at the National Metrology Institute (NMI) of the country, National Physical laboratory in our case. It is the responsibility of the NMI to ensure traceability of national standards to the international standards.

For safe drinking water WHO through efforts of its expert groups has identified nearly 100 contaminants and have specified their safe limits. In India the documentary standard of water is the responsibility of the Bureau of Indian Standards (BIS). The standard IS 10500 defines the permissible level of contaminants in the water for human consumption.

To ensure that the determination of contaminants in laboratories is as per international practices Certified Reference Materials (CRMs) are used to calibrate the equipments and to validate the experimental techniques employed. Certified Reference Materials are prepared with specified quantity of a contaminant in water, like a toxic element such as lead, mercury or arsenic. These are generally prepared and certified by NMIs like NPL in India in collaboration with laboratories which have expertise in this field. In the Indian CRM programme standards of toxic elements and other contaminants like fluoride in water were taken up in the first phase. Already more than twenty CRMs have been prepared through the joint efforts of about 30 top laboratories of the country. To ensure that the CRMs are as per international standard this group gets involved from time to time in international inter-comparison programme.

It may be mentioned that International organizations like International Council for Science (ICSU), Global Network of Academies (IAP) and others have been quite actively involved in this field.

The G8 Summit of industrially advanced countries seeks inputs from their apex science academies to support programmes of societal relevance. Generally, the Science Academies of G8 +5 countries including India after consultations recommend areas which need urgent action at the highest political level. In March 2011 a meeting of the Academies took place at Paris. President N. Sarkozy of France met the Academy Presidents and other delegates and mentioned that their recommendations will be considered with all seriousness during the Summit. The Academies have recommended support in the following two areas:

- Water and Health; and
- Education for a Science Based Global Development

The Joint Statements duly signed by Presidents of all the participating Academies have been released simultaneously on 19 May 2011 in their respective countries. INSA had also released it and besides media, sent copies to Hon'ble Ministers of External Affairs and Science & Technology. Copies were also sent to Secretaries of Departments of Science & Technology, Biotechnology, Health Research and Scientific and Industrial Research (DG CSIR).

Dr KRISHAN LAL, *President INSA*

CONCLUDING REMARKS AND RECOMMENDATIONS

While anthropogenic activities are the major source of heavy metal pollution, natural sources contribute significantly to the burden of arsenic and fluoride. Apart from industries, road runoff is also an important source.

The toxic elements enter the body mainly through water, food and air. Cosmetics, dental products, some drugs, particularly Ayurvaid and Unani drugs also contribute. More research is needed to assess the extent to which these products affect human health. Public awareness should be created. There should be monitoring and control over the concentration of heavy metals in cosmetics.

The existence of metals in nano form or otherwise should be determined. Toxicity of metals bearing nano particles is a domain where systematic research needs to be carried out to establish or negate toxic factors.

Susceptibility to toxicity is influenced by age, physiological status, nutrition status and genetic factors. More research is needed to study these interactions, particularly since malnutrition is rampant in India. Where specific interactions are known: e.g. lead and calcium, fluoride and calcium, populations exposed to these toxic substances (factory workers, communities living near the factories) should receive periodic health check-up and nutritional support.

Health monitoring of workers engaged in industries handling toxic metals/ minerals should be carried out regularly and nutritional support where necessary provided.

Since toxicity is insidious, mechanisms for early detection of the problem at sub-clinical level through proper surveillance systems are needed. More research is needed to identify and develop bacteria, plant, and fish- based tests. Functional consequences which may not be too obvious, like effects on reproductive, neurological – cognitive and other functions have to be identified, through more research on animals and humans under controlled conditions.

India often employs standards of safety developed in the western countries. Considering the genetic diversity and rampant malnutrition, would these apply to India? What is the safe level? Is tolerance developed over prolonged exposure adaptation or compromise? Since fixing standards is a very costly and laborious process, regulatory agencies like the MoEF and PCB, tend to follow the standards developed by developing countries, with modifications to suit the local conditions like body weight, nutrition status etc. The best approach should be to revise the standards periodically and upgrade treatment technologies to meet the standards. A new approach is to develop Environment specimen banks (ESB) which can be drawn upon periodically for testing using upgraded technologies.

There should be harmonization of heavy metal standards which are usually risk based and adopted in developed countries. Dichotomy in standards may not be appropriate in this era of globalization. Wherever possible, and techno-economically feasible, source remediation should be practiced. Cleaner technology options avoiding the use of toxic heavy metals and minerals should be explored, documented and shared with Indian industries with a view to adopt cleaner technologies.

Anthropogenic pollution can be at the stage of fabrication or end use. Instead of pollute and clean; mitigation strategies should receive high priority. Regulatory standards for emission and discharges from process plants should be strictly enforced.

Recycling/reprocessing of wastes containing toxic metals needs to be given greater emphasis not only from environmental and health considerations but also as a resource conservation measure.

Monitoring of air, water and soil in the vicinity of the toxic metal processing units needs to be carried out more rigorously for the specific metal.

Regional accredited laboratories for analyzing pollutants in various environmental compartments should be set up to help regulatory bodies.

Guidelines for proper management of tailings and slags containing toxic metals should be prepared taking into consideration techno- economic feasibility.

Tailings dumps and process wastes lying in locations close to the processing units need to be remediated on priority. Phytorestoration enhances ecological capital and provides biodiversity of choice suitable for the region where such restoration measures are undertaken.

In India, small industries in unorganised sector contribute to a great deal of pollution. While CETP are needed to help small industries, larger ones should set up their own treatment plants and discharge the treated effluent in sewers. Subsidies can be considered for industries which invest in clean technologies. There should be continuing research to develop cost- effective technologies for reduction and replacement. As it is, lot of pollution in India is due to outdated production technologies.

For recovery of heavy metals like mercury from medical devises and CFL bulbs, suitable collection centres need to be set up, and some refund given. As it is, no such mechanism exists and with increasing use of CFL bulbs haphazard disposal can be dangerous.

Attempt should be made to replace CFL bulbs with LED (Light emitting diode) bulbs

Mercury-based medical devices and equipment should be totally phased out, since digital options are available.

Presently there is emphasis on production and use of private vehicles-two wheelers, cars. This should change with emphasis on cleaner public transport systems to reduce the burden of road run off. CNG should replace petrol and diesel.

Use of diesel should be confined to public transport and transport of goods. Manufacture of diesel cars should be stopped. Rich are taking the benefit of the subsidy on diesel.

Periodic (six monthly) examination of water quality, particularly for detection of fluoride and arsenic is necessary in newer alluvium and flood plain areas in different parts of India.

Water supplied by urban municipalities and rural panchayats, should be free of (or contain within safe levels) of biotic and abiotic toxicants including heavy metals and minerals. Inexpensive devises for purifying water at household level have to be developed.

Creation of public awareness is very important. Greater interaction between scientists, technologists and media is needed to achieve that. School education can be a mechanism for creating awareness

Since India is at the stage of development transition, wasteful, consumerist, lifestyle which eats up resources and adds to pollution burden should be discouraged.

We need to remember an old Native American proverb that "We did not inherit the Earth from our Ancestors, but borrowed it from our Children”. Their future has to be considered, before plundering the earth and contaminating it.

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PROGRAMME

Day 1, November 30, 2010		
10-10.30 am	Registration and tea	
10.30-11 am	Inauguration–Professor M. Vijayan, President INSA	
11 am-1pm	Aetiology and magnitude of the problem	
Session 1	Chair: SS Agrawal, Delhi Pharmaceutical Science & Research University	
	SP Gautam, CPCB, New Delhi	Hazardous metal pollution in India–an overview
	AK Susheela, Fluorosis research and rural development foundation, New Delhi	Fluoride Sources, Toxicity and Management
	PB Rastogi, MOEF, New Delhi	Hazardous metals and minerals pollution in India-sources, magnitude, toxicity, rules and regulations applicable and use of clean technology
	B Madhusudhan, AP State Pollution Control Board, Hyderabad	Pollution potential and containment of hazardous metals from electroplating industries
	Ashok K Giri, IICB, Kolkata	Arsenic Contamination in Groundwater: Health Effects, Genetic Susceptibility, Route of Exposure and Mitigation
1-2 Pm	Lunch	
2-3.30 pm	Effects of heavy metals and minerals toxicity on health	
Session 2	Chair: AK Jain, Institute of Pathology, New Delhi	
	PK Nag, NIOH Ahmedabad	Hazardous, occupational exposure to heavy metals
	YK Gupta, AIIMS, New Delhi	Mercury Pollution in healthcare Sector: Problems and Solutions
	Kaiser Jamil, BMMRC, Hyderabad	Hazards of metal toxicity in human health
3.30-4.00 pm Tea Break		
4-5.30 pm	Dinesh Kumar, NIN, Hyderabad	Current trends in environmental lead exposure and its impact on pregnant women, neonates and children
	BB Panda, Berhampur University, Behrampur	Plant bioassays to monitor and assess aluminium pollution: problems and prospects
	Pushpa Dhar AIIMS, New Delhi	Modulation of oxidative stress marker levels and apoptotic marker expression by exogenous alpha lipoic acid (ALA) in rat hippocampus following sodium arsenite exposure during early postnatal period
	Rita Singh, University of Delhi, New Delhi	Reproductive health Concerns: The Impact of Environmental heavy metals and minerals on Reproductive Health of Women/Men
Day 2, December 1, 2010		
10.00-10.30 am Tea		
10.30am-1 pm	Scientific and technological approaches to reduce the burden of heavy metals and minerals load Chair: Dr RK Garg	
	RK Garg, Rare Earths (Retd)., Mumbai	Environmentally Sound Management of Toxic Metal Waste
	MNV Prasad, University of Hyderabad, Hyderabad	SWEET (Soil and Water Efficiency Enhancing Technologies) phytotechnologies to reduce the burden of heavy metal load.
	Tapan Chakrabarti, NEERI, Nagpur	Scientific and Technological Approaches to Reduce the Burden of Heavy Metals and Mineral Loads
	Rajeev Betne, Toxic Link, New Delhi	Scientific and Technological Approaches to Reduce the Burden of Heavy Metals and minerals load
	Mahtab S Bamji, Convener	Concluding remarks

APPENDIX II

List of reviewers besides the participants in the panel discussion

Name	Designation
Gupta PK	INSA Hon. Scientist and Hon. Professor, Dept. of genetics and plant breeding, Chaudhary Charan Singh University, Meerut
Kesavan PC	MS Swaminathan Research Foundation, Chennai
Krishan Lal,	President INSA, Former Director, NPL, New Delhi
Murthy RC FNA	Indian Institute of Toxicology Research, Lucknow
Murty YS	Former Member Secretary, Pollution Control Board, AP, and Advisor EPTRC, AP
Pakshirajan Kannan	Department of Biotechnology and Centre for the Environment, Indian Institute of Technology Guwahati
Rai LC,	Centre of Advanced Study in Botany, Banaras Hindu University
Rajaraman R,	JNU, New Delhi
Ram S Sharma	INSA Honorary Scientist, Sanganer (RHB), Jaipur
Rao UR FNA	Department of Space, ISRO
Sen Sisir	Former Professor and Dean, IIT, Kharagpur