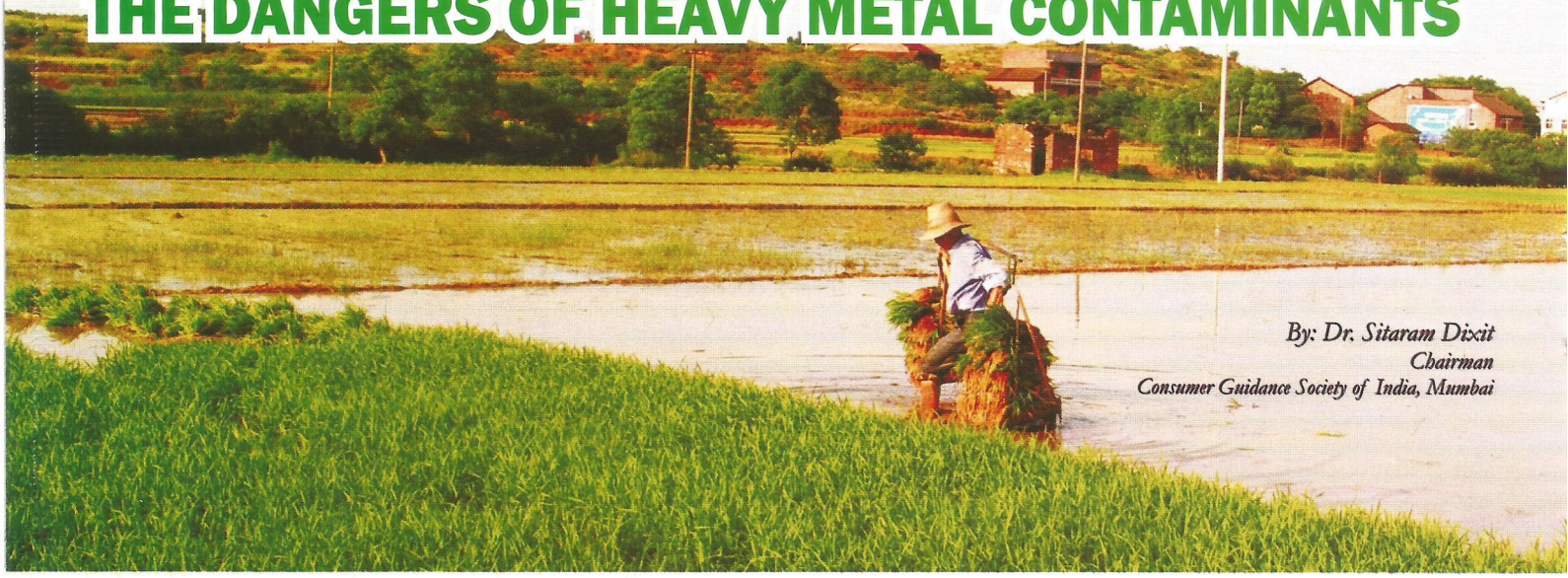
CONSUMERS BEWARE !
THE DANGERS OF HEAVY METAL CONTAMINANTS



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Exposure to metals like lead, cadmium, mercury, tin, and arsenic threaten life and human health. So many international bodies including the World Health Organization (WHO) regularly carry out extensive studies and review of their effects on human health. Heavy metals have been in use by humans for thousands of years, and in spite of understanding several of their ill effects on human health, the usage continues; sometimes even flourishing, particularly in less-developed nations. Normally humans absorb trace amounts of these elements through food, drinking water, air, etc.

Food contains a wide range of metals such as sodium, potassium, iron, calcium, boron, magnesium, selenium, copper, zinc, etc., that are essential in trace quantities for the up-keep of our cellular processes: a key to maintaining the metabolism of the human body. However, at high concentrations these very metals can cause poisoning, resulting in impaired mental and central nervous function, as well as damage to vital organs. Long term exposure may result in slowly progressing physical, muscular, and neurological degenerative conditions, including cancer. Metals that have no functional effects in the body can surely be harmful to our health if we regularly consume foodstuffs containing them.

In recent years, a number of consumer products around the world have had links to heavy metal contamination. Very recently in India, excess lead in Maggie noodles and the eventual ban on its consumption has again highlighted the importance of strict quality control of food products. All this very clearly emphasises that only a strong regulatory agency can take concrete steps to detect and minimise the presence of hazardous heavy metals in food, and to aid in preventing us from inadvertently ingesting these harmful elements that can impair our health and well-being.

WHAT IS A HEAVY METAL?

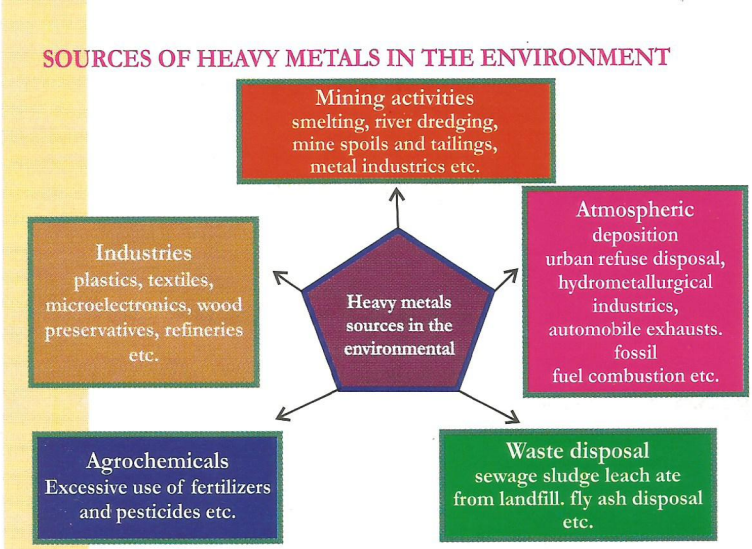
We define heavy metals as those metals that have a specific density of more than 5g/cm3 or their high atomic weight. In this context, the major threat to human health is from our exposure to lead, cadmium, mercury, tin and arsenic (arsenic is a metalloid; however, we usually classify it as a heavy metal). Extensive studies on these metals and their adverse effects on human health are available, along with regular reviews by international bodies and WHO.

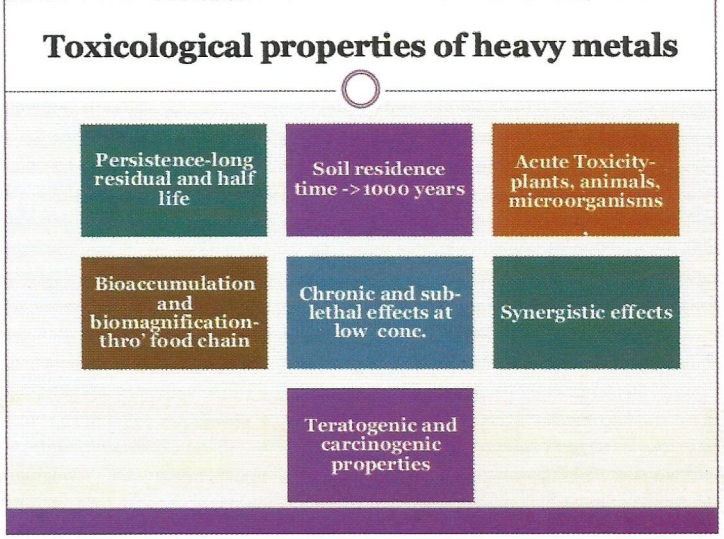
Heavy metals have been in use for thousands of years; for example, lead has been in use for over 5000 years, in building materials, pigments for glazing ceramics, water pipes, etc. Ancient Romans made use of lead acetate to sweeten old wine, probably some of them consuming even as much as a gram of lead a day. Early Romans made use of mercury as a salve to alleviate teething pain in infants, and as a remedy for syphilis. Claude Monet used cadmium pigments extensively in the mid 1800s, in his art. Humans have been well aware of the adverse health effects of heavy metals for a long time now, but still use and expose themselves to heavy metals, sometimes even increasing their use and exposure in specific areas. Common examples are use of mercury in gold mining, arsenic in wood preservation, tetra-ethyl lead as an additive to petrol, etc.

Atmospheric emissions of heavy metals still tend to be the greatest concern in terms of human health, more due to the larger quantity, the wider-spread dispersion, and the maximum potential for human exposure. Lead emissions are mainly from road transport and so uniformly distributed over space. We can associate cadmium emissions primarily with non-ferrous metallurgy and fuel combustion, whereas the spatial distribution of anthropogenic mercury emissions reflects mainly the level of coal consumption in different regions.

Exposure of people to potentially harmful chemicals could happen through physical and biological agents in air, food, water or soil. However, the key to exposure is contact, between the agent and the outer boundary of the human body, like the airways, the skin, or the mouth. We define exposure as a function of concentration and time, an event that occurs at the boundary when there is contact between a human and the environment containing a contaminant of a certain concentration for a specific interval of time. In short, for exposure to happen, coexistence of contaminants and people has to occur. Metals are natural components of the Earth's crust and can be naturally present in food or can enter food through our industrial and agricultural processes.

Chemically, these elements can exist as a pure metal, viz., tin or lead, or compounds formed by combination of a metallic element with a non-metallic element; for example a





combination of sodium with chlorine (sodium chloride or common salt) or oxygen (an oxide).

Other potentially toxic metal contaminants in food and water include chromium and uranium; workplace metal contaminants include beryllium and nickel. However, we do not find these metallic elements normally in food at levels that could cause toxicity. Nickel contamination in foodstuffs could be generally possible if we make use of hydrogenated oils and fats (viz., Vanaspati) in food preparations. However, in this paper we limit our discussion to only mercury, lead, cadmium, tin, mercury and arsenic.

TOXICITY OF HEAVY METALS

The two main aspects regarding toxicity of these metals are:

1. They have no known metabolic function, but when present in the body they disrupt normal cellular processes, leading to toxicity in a number of organs.

2. Heavy metals mercury and lead accumulate in biological tissues, getting stored in the liver or the kidney. Since heavy metals excrete at a slow rate in comparison to their uptake, bio-accumulation occurs; this happens in humans and all animals, including food animals like fish and livestock. Thus it becomes necessary to control toxic metal levels in foodstuffs to protect human health.

MERCURY

Prehistoric cave paintings made use of the mercury compound cinnabar (HgS) to produce red colors. In ancient Greece, metallic mercury (as well as white lead) found use as a cosmetic to lighten the skin. Apart from prehistoric uses, mercury also finds use as diuretic [calomel (Hg2Cl2)]. Mercury amalgam still finds use in filling teeth in many countries. Metallic mercury usage in thermometers, barometers and instruments for measuring blood pressure is common.

Mercury electrodes find major use in the electrochemical process of manufacturing chlorine in the chloralkali industry. The largest occupational groups exposed to mercury are dental care personnel. Excessive exposure to mercury causes damage to the central nervous system (neurotoxicity) and the kidney.

Different forms of mercury (I.e., mercury metal, inorganic mercury salts such as mercuric chloride and organic forms of mercury such as methyl mercury) produce different toxicity patterns. The general population exposed to low levels of mercury in their diet relates to the potential neurotoxicity of the organic forms of mercury, viz., methyl mercury, especially in young children. Organic forms of mercury can cross the placental barrier between the mother and the baby in the womb. Epidemiological studies in human and toxicological studies in animals by international expert bodies show that toxicity can result in neurological disturbances, ranging from impaired learning to obvious brain damage. Acute mercury exposure may result in lung damage. Chronic poisoning leads to neurological and psychological symptoms, such as tremors, changes in personality, restlessness, anxiety, sleep disturbance and depression. However, these symptoms are reversible after cessation of exposure. Metallic mercury may cause kidney damage, which is also reversible after exposure has stopped. Metallic mercury is an allergen, causing contact eczema. Mercury from amalgam fillings may sometimes give rise to oral lichen in some individuals, who get relief on removal of these fillings. Due to the blood-brain barrier there is no central nervous involvement related to inorganic mercury exposure.

Inorganic mercury when converted to organic methyl mercury becomes very stable and accumulates in the food chain. Commonly people ingest mercury via food, with fish being a major source of methyl mercury exposure. Dental amalgams release mercury vapours, with the release rate increasing by chewing. Mercury in urine is primarily due to recent exposure to inorganic compounds, whereas blood mercury is due to exposure to methyl mercury. Methyl mercury poisoning with latency of 1 month or longer after acute exposure may cause nervous system damage, the earliest symptoms being parestesias and numbness in the hands and feet. Later, coordination difficulties and concentric constriction of the visual field could develop along with auditory symptoms. High doses may lead to eventual death. The biggest health risks from methyl mercury exposure are from high fish consumption. Intake of mercury from consumption of fish may also increase the risk of coronary heart disease.

LEAD

Consumption of food containing lead is the major source of exposure for the public. Short-term exposure to high levels of lead causes brain damage, paralysis (lead palsy), anaemia and gastrointestinal symptoms. Longer-term exposure causes damage to the kidneys, reproductive and immune systems, in addition to effects on the nervous system. Low-level lead exposure affects the intellectual development in young children and, like mercury, can cross the placental barrier and accumulate in the foetus. Infants and young children are more vulnerable to the toxic effects as they absorb lead more readily. Even short-term, low-level exposures to lead can affect neurobehavioral development of young children. The general population gets exposure to lead from air and food. Earlier, lead in foodstuff originated from pots used for cooking and storage, and use of lead acetate to sweeten port wine. During the last century, lead emissions to ambient air have further polluted our environment, mostly originating from leaded petrol.

However, increasing use of unleaded petrol could decrease blood lead levels in the general population. Occupational exposure to inorganic lead occurs in mines, smelters, while welding lead-painted metal, in battery plants, in the glass industry, etc.

Airborne lead gets deposited on soil and water, and reaches humans via the food chain. Also, our lungs absorb the inhaled inorganic lead. Ten to fifteen percent of lead comes from food. In the case of children, almost fifty percent could be through the gastrointestinal tract. Lead binds itself to erythrocytes in our blood. Elimination is slow and principally via urine. Lead accumulates in the skeleton, and is released very slowly. The half-life of lead in blood is about 1 month and in the skeleton, 20-30 years. In adults, inorganic lead does not penetrate the blood-brain barrier, whereas this is not the case in children. Their high gastrointestinal uptake and their permeable blood-brain barrier make children especially susceptible to lead exposure and subsequent brain damage.

Organic lead compounds penetrate body and cell membranes. Tetra-methyl lead and tetra-ethyl lead penetrate the skin easily. These compounds may also cross the blood-brain

Toxic diseases of heavy metals

- Aluminium has been associated with Alzheimer's and Parkinson's disease, senility, and presenile dementia.
- Arsenic exposure can cause cancer, abdominal pain, and black foot disease.
- Cadmium exposure produces kidney damage and hypertension
- Lead and mercury may cause joint diseases and ailments of the kidneys, circulatory system, and nervous system
- Nickel can cause damage to lung, liver and kidney.
- Chromium can cause lung damage and cancer.

barrier in adults, who thereupon suffer from lead encephalopathy (sleeplessness and restlessness).

The symptoms of acute lead poisoning are headache, irritability, abdominal pain and various symptoms related to the nervous system. Children may exhibit behavioural disturbances, learning and concentration difficulties. In severe cases of lead encephalopathy, the affected person may suffer from acute psychosis, confusion and reduced consciousness. People with long-time exposure may suffer from memory deterioration, prolonged reaction time and reduced ability to understand. Individuals with average blood lead levels below 3?mol/l are likely to show signs of peripheral nerve symptoms, with reduced nerve conduction velocity and reduced dermal sensibility.

In less serious cases, the most obvious sign of lead poisoning is disturbance in hemoglobin synthesis, and long-term lead exposure may lead to anemia. Blood lead levels in children below 10?g /dl could be so far acceptable, but recent data indicate that certain genetic and environmental factors can increase the detrimental effects of lead on neural development, thereby rendering certain children more vulnerable to lead neurotoxicity. Lead is a 'possible human carcinogen' and may cause lung and stomach cancer.

1. Since there is a risk to the foetus in particular, pregnant women should avoid a high intake of fish, such as shark, swordfish and tuna; and fish (such as pike, walleye and bass) taken from polluted fresh water.
2. Avoid amalgams in dental fillings.
3. Avoid use of leaded petrol and phase out any remaining uses of lead additives in motor fuels.
4. Do not use any lead based or glazed food containers, which may leach lead into food.
5. Abandon the use of lead-based paints.

CADMIUM

The principal effect of cadmium is its toxicity to the kidney. It also causes lung damage (including induction of lung tumours) and skeletal changes in occupationally exposed populations. Although cadmium is poorly absorbed into the body, it also is excretes very slowly accumulating in the kidney causing renal damage, and is a secondary suspect in causing prostate cancer, kidney cancer, and renal cell carcinoma. The kidney of food animals is a major source of cadmium in human diet even though we find lower levels in many other foods.

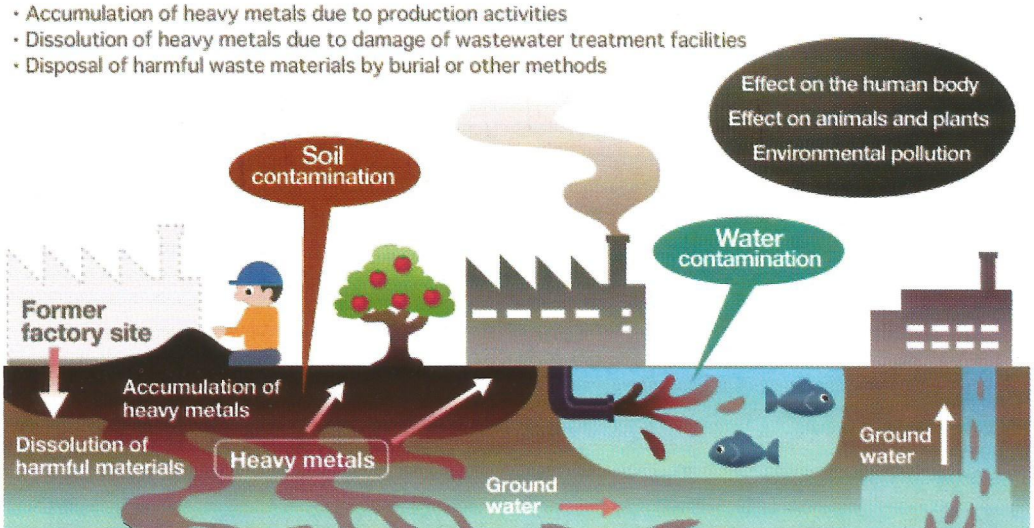
Cadmium occurs naturally in ores together with zinc, lead and copper. Cadmium compounds find use as stabilizers in PVC products, colour pigment, several alloys and, now most commonly, in rechargeable nickel-cadmium batteries.

Metallic cadmium is as an anti-corrosion agent (cadmiation) and is present as a pollutant in phosphate fertilizers. Cadmium-containing products are rarely recycled. When dumped together with other household waste, it only contaminates the environment, especially so during waste incineration. Natural cadmium along with industrial emissions, application of fertilizer and sewage sludge to farmlands, leads to soil contamination, and increased cadmium uptake by crops and vegetables especially at low pH 4. Cigarette smoking is also a major source of cadmium exposure causing significant increases in blood cadmium (B-Cd) levels. Cadmium concentrations in smokers on an average are 4-5 times higher than people who do not smoke. Food however, is the most important source of cadmium exposure as it is present in most foodstuffs, although concentrations vary greatly with individual intake due to differences in dietary habits. Women usually have lower daily cadmium intakes, due to lower energy needs.

Nutritional factors, like iron status, influences gastrointestinal absorption of cadmium. B-Cd generally reflects the current exposure, and partly lifetime body burden unlike urine (U-Cd) cadmium concentration that is largely due to the body burden, being proportional to the cadmium concentration in the kidney. Smokers and people living in contaminated areas have higher urinary cadmium concentrations, with smokers having almost double the levels.

TIN

Tin is comparatively less toxic than mercury, cadmium and lead. The presence of tin in food in higher levels is largely in canned foods due to incorrectly manufactured tins, where tin present in the can leaches into the food. This occurs more in the case of acidic foodstuffs (canned tomatoes), consumption of which can result in gastrointestinal irritation and stomach upsets in some individuals at concentrations above 200 mg/kg. Organotin compounds reach humans primarily through a diet of fish and fish products. These compounds are widely prevalent in the aquatic environment due to their agricultural use as antifouling agents and biocides. Tin is used in canned foods to protect the steel base from corrosion both externally (aerobic conditions) and internally when in contact with foods (anaerobic). Although the use of can lining lacquers enables a satisfactory



packing, improper lining can cause enough damage.

Highly pigmented foods like beetroot, berries, etc., can have their colours bleached by tin dissolution. The tin in canned food is likely to be in the form of inorganic tin salts rather than tin in covalently bound organometallic compounds.

The tin content of canned foods depends on whether the can is lacquered or food is stored in opened cans; the presence of oxygen; reducible organic compounds; the pH of the food; the presence of plant pigments; the storage conditions (i.e., time & temperature); food additives, etc.

The chemistry of the food products can greatly change due to internal corrosion in plain tinplate cans. The point to note is that fruits, vegetables, and tomatoes themselves have significant natural variation in pH (acid type) and concentration, dependent on variety, maturity, time/ place/ conditions of harvest, soil chemistry, and agricultural practices that are difficult for a canner to control. These ultimately affect the level of tin uptake by the packed product. Acidic foods are more aggressive to the tin coating in metal cans and canned acidic foods have higher tin contents. Tomato-based products tend to have high levels of tin as nitrate in the food accelerates corrosion of the tin. Tin concentrations of canned foods increase with storage time and temperature.

ARSENIC

Arsenic exists both in inorganic and organic forms, and in different valence states. Arsenic is a widely distributed metalloid, occurring in rock, soil, water, and air. Inorganic arsenic is present in groundwater used for drinking in several countries all over the world (e.g., Bangladesh, Chile and China). We generally find organic arsenic compounds (arsenobetaine) in fish, which may increase human exposure. Smelting of non-ferrous metals and the production of energy from fossil fuels are the two major industrial processes that lead to arsenic contamination of air, water and soil. Other contamination sources are the manufacture and use of arsenical pesticides and wood preservatives. General population exposure to arsenic is mainly via intake of food and drinking water. Food is the most important source, but in some areas, arsenic in drinking water is a significant source of exposure to inorganic arsenic. Absorption of arsenic in inhaled airborne particles is highly dependent on the solubility and the size of the particles. Soluble arsenic compounds are easily absorbed from the gastrointestinal tract. However, inorganic arsenic is extensively methylated in humans, and the metabolites are excreted in the urine. Inorganic arsenic is significantly more toxic than organic arsenic compounds like dimethylarsinate. Likewise, trivalent forms of arsenic viz., arsenic trichloride, are more toxic than the pentavalent arsenates. Pentavalent arsenates become toxic only after metabolic conversion to the trivalent form of arsenic.

Chromium also behaves in a similar way as arsenic. Inorganic arsenic exposure causes cancer and is classified as a human carcinogen. Continual low-level exposure to arsenic causes skin, vascular and nervous system disorders. Intake of large quantities leads to gastrointestinal symptoms and severe disturbances of the cardiovascular and central nervous systems, eventually leading to death.

In survivors, we may observe bone marrow depression, haemolysis, hepatomegaly, melanosis, polyneuropathy and encephalopathy. Ingestion of inorganic arsenic may induce peripheral vascular disease, which in its extreme form leads to gangrenous changes. People exposed to arsenic via drinking water show excess risk of mortality from lung, bladder and kidney cancer, the risk increasing with increasing exposure. There is also an increased risk of skin cancer and other skin lesions, such as hyperkeratosis and pigmentation changes. Studies on various populations exposed to arsenic by inhalation, such as smelter workers, pesticide manufacturers and miners in many different countries consistently demonstrate significant increase in lung cancer. Studies show that the lung cancer risk increases with increasing arsenic exposure. The latest WHO evaluation concludes that arsenic exposure via drinking water can relate to cancer in the lungs, kidney, bladder, skin, etc., sometimes even observing precancerous skin lesions.

Uncertainties in the estimation of past exposures are important when assessing the exposure-response relationships, but it would seem that drinking water containing arsenic concentrations of approximately 100 µg/l have led to cancer at these sites, and that precursors of skin cancer have been associated with levels of 50-100µg/l. The relationships between arsenic exposure and other health effects are less clear. There is relatively strong evidence for hypertension and cardiovascular disease, but the evidence is only suggestive for diabetes and reproductive effects and weak for cerebrovascular disease, long-term neurological effects, and cancer at sites other than lung, bladder, kidney, and skin.

CONCLUSION

The Food Safety & Standards Act 2006 sets maximum levels for heavy metals in individual foodstuffs. For other food contact materials, including those made from metal and alloys, regulation sets a general requirement that migration of substances should not endanger the health of consumers. Food operators/ manufacturers are responsible for the safety of food they produce, transport, store or sell.

They must also ensure that their products comply with the legislative limits for heavy metals as laid down by law. Codex Alimentarius adopts a code of practice for the prevention and reduction of inorganic tin contamination in canned foods. It is important that all food operators should identify the 'Critical Control Points' (CCPs) in their processes along their food operators' chain, to enable them to develop and apply proper HACCP systems to ensure that there are no unforeseen sources of metal contamination.

An important point we have to note is that, it is the responsibility of food operators to test their products for mercury, lead, cadmium, tin, and arsenic content at the point of sale, carrying out sampling and analysis in accordance with the principles outlined in official protocols in accredited laboratories, and to comply with the requirements of regulations.