Guidance Note No.15/2020

Metal Contaminants in Foods - *Potential Risk and Mitigation measures*

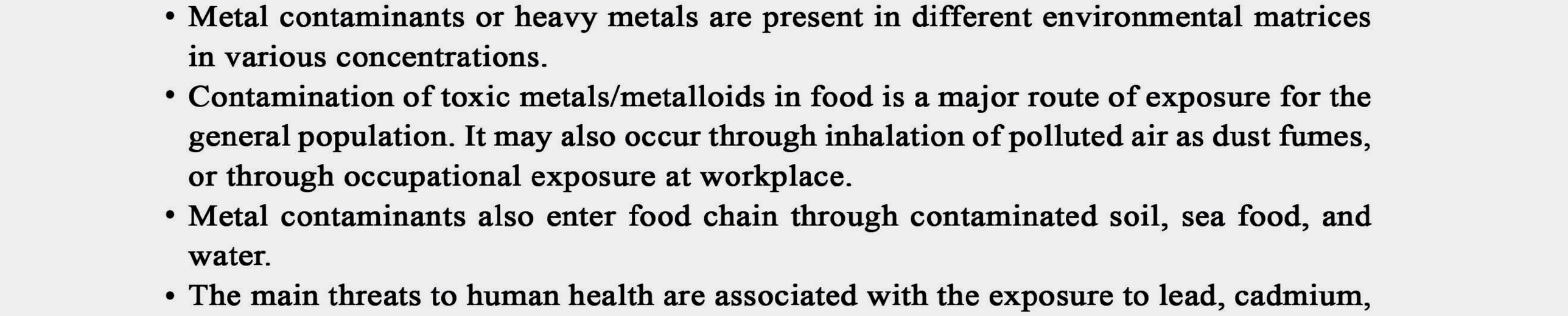
SUMMARY

Metal contamination in foods is a global health concern. Metallic contaminants including arsenic, cadmium, lead and mercury exist naturally in the earth's crust and can be found at various levels in the environment and subsequently enter the food chain. Each of these contaminants also form compounds with other organic entities, which vary in chemical properties and levels of toxicity to humans when ingested. Long term use of contaminated water for irrigation can cause accumulation of these metals in soil which can be translocated to food crops and thus enter the food chain.

Awareness with regard to heavy metal contamination in food has increased worldwide. Chemical exposure incidents in communities need utmost attention to curb metal toxicity. Internationally, to protect against high exposures of metal contaminants, the Codex Alimentarius Commission has set limits for these metals in food commodities. At the national level, FSSAI has also prescribed maximum limits for metal contaminants in various foodstuffs. This guidance note briefly describes the sources, exposure pathways, toxicity and measures that could be undertaken by the stakeholders in assuring safe food to the consumers.

KEY TAKEAWAYS

- **Metal contaminants or heavy metals are present in different environmental matrices in various concentrations.**
- **Contamination of toxic metals/metalloids in food is a major route of exposure for the general population. It may also occur through inhalation of polluted air as dust fumes, or through occupational exposure at workplace.**
- **Metal contaminants also enter food chain through contaminated soil, sea food, and water.**
- **The main threats to human health are associated with the exposure to lead, cadmium, mercury and arsenic.**
- **Food Safety and Standards (Contaminants, Toxins and Residues) Regulation, 2011, has specified maximum limits of metal contaminants in different food categories.**
- **Guidance to industry and other relevant stakeholders on heavy metal exposure, its deleterious effects and proper management is needed.**



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Introduction

1. Metals such as lead, arsenic, cadmium, mercury find their way in foods. At high levels, these metals can be toxic, but eliminating them entirely from our food supply is not always possible because these metals are found in the air, water and soil and then taken up by plants as they grow.

2. There is a global health concern associated with metal contamination because of their toxicity even at low concentrations. Heavy metals can contaminate food commodities as a result of anthropogenic activities such as mining, smelting, use of phosphate fertilizers, industry or car exhausts which have resulted in their diffusion and accumulation in the food. The main threats to human health from heavy metals are associated with exposure to lead, cadmium, mercury and arsenic.

Metal contaminants of concern in human diet

3. Concerns regarding toxicity of metals exist primarily due to their bioaccumulation in the tissues of the body where they are taken up and stored faster than they are excreted. Secondly, their presence in the body disrupts normal cellular processes, leading to toxicity in a number of organs. Four heavy metals, namely lead, arsenic, cadmium and mercury, are of particular concern in food. Ingestion of such metals from food and water is a major route of exposure for the general population. In order to protect human health it is necessary to control the levels of these toxic metals in foodstuffs.

Exposure pathways of heavy metals

4. Human exposure to metals occur through consumption of contaminated food stuffs, sea foods, and drinking water, through inhalation of polluted air as dust fumes, or through occupational exposure at workplace. These metals can be taken up through several routes. The chain of contamination usually follows from industry, to the atmosphere, soil, water, foods and then human. Some heavy metals such as lead, cadmium, mercury, arsenic can enter the body through the gastrointestinal route that is, through the oral ingestion after consuming food including fruits, vegetables, drinking water or other beverages. Some metals can enter the body by inhalation while others such as lead can be absorbed even through the skin.

Lead

5. Lead is a ubiquitous heavy metal with no physiological function. Exposure to lead occurs mainly at occupational sites, production of lead-acid batteries or pipes, metal recycling industries and foundries. Therefore, it may get into soil and flow into water bodies which can be taken up by plants, and human exposure occurs via food or drinking water. The water supplies get contaminated through lead pipes, where lead is used as a construction or welding material. The contamination of food can occur through food containers containing lead, e.g. storage in lead-soldered cans, ceramic

vessels with lead glazes and leaded crystal glass. The lead gets accumulated in fish and shellfish in addition to offal (liver and kidney) of animals. It can settle on soil or be absorbed by plants grown for fruits or vegetables. The amount of lead in a food product should not be high enough to raise a person's blood lead level to a point of concern. To control this, the regulatory agencies like FDA have established a maximum daily intake for lead, called the Interim Reference Level (IRL) at 3 µg per day for children and 12.5 µg per day for adults.

Toxicity of Lead

6. Lead poisoning occurs mainly by ingestion of food or water contaminated with lead. Lead affects almost every organ in the body. The nervous system is the most affected target in lead toxicity, both in children and adults. Infants and young children may undergo behavioural problems, learning deficits and lowered intellectual quotient. Long-time exposure to lead has been reported to cause anaemia, damage to kidneys, reproductive and immune systems. Severe damage to brain and kidneys, both in adults and children, were found to be linked to exposure to high lead levels even resulting in death.

Mercury

7. Mercury is a toxic heavy metal present in the environment both in organic and inorganic form. It is the only metal which is liquid at room temperature. Inhaled elemental mercury is retained in lungs and gets distributed in the plasma and erythrocytes to almost equal degree. It can pass the blood brain barrier and the placenta. Oxidation to mercuric form, the toxicological relevant form is fast. Methylmercury is the most toxic form and is found at significant levels in fish and seafood. The industrial release of inorganic mercury into marine environments results in its uptake by marine microorganisms which then convert the inorganic mercury, which is less toxic, into the more toxic methyl mercury. It is accumulated in food chain due to its low rate of breakdown, reaching potentially toxic levels in species at the top of the food chain which forms part of the human diet. The major potential dietary sources of exposure to methylmercury are fish and shellfish.

Toxicity of Mercury

8. Excessive exposure to mercury is associated with a wide spectrum of adverse health effects including damage to the central nervous system and the kidneys. Organic forms of mercury can cross the placental barrier between the mother and the unborn baby, and epidemiological studies in exposed populations of humans and toxicological studies in animals have shown that this can result in a range of neurological disturbances from impaired learning to clear brain damage

Cadmium

9. Cadmium has a high phyto-accumulation index because of its low adsorption coefficient and high soil-plant mobility and thereby may enter the food chain. Its uptake by plants depends on soil factors such as pH, Cadmium: Zinc ratio etc. Zinc limits the cadmium uptake and thus protects the food chain. However, rice has unusual capacity to exclude zinc which helps transfer of high level of cadmium from soil to plant in bioavailable form. Highest levels of cadmium are found in the offal (kidney and liver) of mammals and in mussels, oysters and scallops. Certain wild mushrooms may also contain high levels. These foodstuffs are however minor contributors to overall intake of cadmium.

Toxicity of Cadmium

10. The principal toxic effect of cadmium is on kidneys. It is also involved in lung damage and skeletal changes in occupationally exposed populations. Cadmium is relatively poorly absorbed in the body, but once absorbed it is slowly excreted, like other metals, and accumulates in the kidney causing renal damage. Its uptake in the intestine occurs in two phases i.e. lumen to mucosa and mucosa to blood. It is also evident that these are influenced by interaction with other metals and proteins. Iron deficiency increases cadmium absorption.

Arsenic

11. People are exposed to elevated levels of inorganic arsenic through various sources. The greatest threat to public health from arsenic originates from contaminated groundwater. Rice plants take up more arsenic, approx. 10 folds, as compared to other cereal crops. Arsenic-contaminated water used for irrigation and food preparation is the source of the high arsenic content detected in cultivated grains and vegetables and in cooked food. Terrestrial foods typically contain low levels of arsenic but arsenic in rice is elevated when grown on arsenic-rich groundwater and soil, arsenical pesticides, phosphate fertilizer, processing industries, and through pollution from mining activities.

Toxicity of Arsenic

12. People affected with arsenicosis generally show symptoms of skin lesions like pigmentation, keratosis or melanosis which could range anywhere between moderate to severe. Symptoms of early acute toxicity include muscular pain, nausea, vomiting and rice-watery stool diarrhea. Severe toxicity is known to cause kidney failure, seizures and finally death due to shock

Regulatory status

13. Regulations have been established in many countries for metal contaminants in foods. Internationally, Codex Alimentarius Commission has set limits for metal contaminants in foods under the "General standard for contaminants and toxins in food and feed (CXS 193-1995)" which serves as the reference standard for international trade in food.

Provisions under Food Safety and Standards Act, 2006

14. The maximum limits for metal contaminants are prescribed under Food Safety and Standards (Contaminants, Toxins and Residues) Regulations, 2011 (FSSR). These Regulations are available on FSSAI website (www.fssai.gov.in). The regulations establish maximum levels (MLs) for various metal contaminants in a range of foodstuffs. Maximum limits of some of the major food categories covered above are reproduced below:-

Name of metal contaminant	Article of food	Parts per million by weight
Lead	Brassica vegetable excluding Kale, Leafy vegetables (excluding spinach)	0.3
	Bulb vegetables, Fruiting vegetables, cucurbits and Root & tuber vegetables	0.1
	Foods not specified	2.5
Arsenic	Foods not specified	1.1
Cadmium	Rice Polished	0.4
	Brassica, Bulb and fruiting vegetables, cucurbits	0.05
	Leafy vegetables	0.2
	Other foods	1.5
Mercury	Fish	0.5
	Predatory Fish (Tuna, Marlin, Sword Fish, Elasmobranch)	1.0
	Non predatory fish, Cephalopods, crustaceans, molluscus	0.5
	Other Foods	1.0

*For specific limits please refer the Regulations.

Test methods for determination of metal contaminants in food

15. Various analytical methods are employed in analysis of metal contaminants in food. The analytical methods include Atomic Absorption Spectrophotometer, Inductively Coupled Plasma-Optical Emission Spectrometer, Spectrophotometer, colorimetric method, and titrimetric method. The detailed methodology for sample preparation, extraction, and analysis is provided in the Manual of methods of analysis of foods- Metals.

The Manual of methods of analysis of foods- Metals is available on FSSAI website (www.fssai.gov.in).

Competent Laboratories to carry analysis of heavy metals in various

16. FSSAI Notified NABL Accredited Food Testing Laboratories are having the quality system in place and are competent to carry out the food test under their scope of accreditation which also includes heavy metal analysis. The details of those laboratories are available on FSSAI website (www.fssai.gov.in). FSSAI is also implementing a Central Sector Scheme for "Strengthening of Food Testing System" in the country where it has provided the State Food Laboratories with various food testing instruments. Under the same, ICP-MS has been installed in the following State Food Laboratories for analysis of heavy metals in foods. Any further update in this regard may be obtained from FSSAI website.

S.No.	State/UT	Name of the Laboratory
1	Assam	State Public Health Laboratory, Guwahati
2	Delhi	Food Laboratory, Department of Food Safety, Delhi
3	Goa	Food and Drugs Laboratory, Goa
4	Gujarat (Vadodara)	Food and Drug Laboratory, Vadodara
5	Gujarat (Rajkot)	Regional Food Laboratory, Rajkot
6	J & K (Jammu)	Public Health Laboratory, Patoli, Jammu
7	Karnataka (Bangalore)	Karnataka State Food Laboratory, Bangalore
8	Kerala (Kozhikode)	Regional analytical Laboratory, Malaparamba, Kozhikode
9	Manipur	State Public Health Food Testing Laboratory, R&D Wing Complex, Medical Directorate, Lamphel
10	Meghalaya	Food Testing Laboratory, Pasteur Hills, Shilong
11	Nagaland	State Public Health Laboratory, Kohima
12	Punjab	State Food Lab Punjab, Food & Drug Testing Building at Kharar, SAS Nagar
13	Telangana	State Food Laboratory, Nacharam, Hyderabad
14	Uttar Pradesh	Govt. Public Analyst Laboratory, Aliganj, Lucknow
15	West Bengal	State food Lab West Bengal, Kolkata

Risk Reduction Measures foods

- **Guidance to the Regulatory Bodies and other relevant organizations**

i. The regulatory bodies may devise effective surveillance and response systems for preventing metal contaminants entering the food supply chain.

ii. Use of unregulated chemicals including fertilizers and pesticides should be properly monitored.

iii. Identification of the type of neighborhood activities including e-waste, battery recycling or illegal waste dumping, and taking strict measures against their non compliance, if any.

iv. Wastewaters from industries should be treated effectively before discharge into the natural water bodies.

v. Guidelines for irrigation water quality should be established.

vi. Regular diet surveys need to be conducted. Such data will be valuable for public health impact.

vii. Technologies for mitigation such as immobilization, soil washing, and phyto remediation may be considered for cleaning up heavy metal contaminated soils.

viii. High-arsenic water may be used for the purpose of flushing and cleaning.

ix. The levels of potentially toxic metals in various environmental media such as air, water and soil should be accessed and monitored regularly.

- **Guidance to the Food Industry**

i. Comply with the specified maximum limits of metal contaminants under Food Safety and Standards (Contaminants, toxins and Residues) Regulations, 2011.

ii. Comply with the requirements for food contact materials used for processing and packaging such as ceramic dishes that may contain lead and cadmium.

iii. Implementation of Good Manufacturing Practices and Good Hygiene Practices, and identification of critical control points in the food manufacturing process where food has exposure to any kind of metals.

iv. Sampling and testing of potentially contaminated foods by FSSAI notified accredited food laboratories.

v. Awareness and training of the personnel in food industry regarding discharging contaminated water without proper treatment of the effluents.

vi. Industrial waste shall meet the standards prescribed before discharge.

- **Effective ways to reduce exposure by the consumers**

i. Consumers should opt for a balanced diet, and not depend on a selective diet.

ii. Cooking should be carried out in appropriate utensils.

iii. Lead may be avoided as plumbing material in drinking water lines.

iv. The fresh vegetables or fruits grown in the vicinity of water bodies having industrial effluents should be avoided.

References

Related FSSAI Standards and other Regulations

- Food Safety and Standards (Contaminants, Toxins and Residues) Regulations, 2011
- The Manual of Methods of Analysis of Foods- Metals

Other sources

- General Standard for Contaminants and Toxins in Food and Feed (CODEX STAN 193-1995).
- Tchounwou PB, Yedjou CG, Patlolla AK, Sutton DJ. Heavy metal toxicity and the environment. Exp. Suppl. 2012;101:133–164
- Morgan, J N,. Effects of processing of heavy metal content of foods., Adv. Exp. Med. Biol. 1999;459:195-211.
- Food Safety Authority of Ireland (2009) Mercury, Lead, Cadmium, Tin and Arsenic in Food, Toxicology Factsheet Series.
- Fowler, B., Alexander, J. and Oskarsson, A. (2015). Handbook of Toxicology of Metals. 4th ed.
- WHO (2018) Arsenic, WORLD Health Organization, Geneva
- Hajeb, P., Sloth,J.J.,Shakibazadeh,Mahyudin,N.A., and Afsah- Hejri,L.,Toxic Elements in Food: Occurrence, Binding, and Reduction Approaches, Comprehensive Reviews in Food Science and Food Safety, 2014,13:4
- Wani AL, Ara A, Usmani JA. Lead toxicity: a review. Interdiscip Toxicol. 2015;8(2):55–64.