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Health impacts of the potentially toxic metals present in milk, dairy products, chocolates, alcoholic and non-alcoholic beverages: A review

O.P. Bansal
Chemistry Department, D.S. College, Aligarh-202001

Abstract:
Milk and dairy products are one of the essentials foods for the human and are the main source of nutrition for young mammals till other types of food is not digested by them. Consumption of the non-alcoholic and alcoholic beverages is becoming a socio-economic status irrespective of age and sex globally. Chocolates and candies which provide not only joy and pleasure are nutritious energy source is the ingredient of several foods, i.e. cakes, cookies, breads ice creams, etc. are consumed by all the citizenry also act as stimulant, relaxant, and antidepressant.
The potentially toxic metals are present in all the organic material and living organisms and are indestructible and indelible. These metals are accumulated in the soils, groundwater,fruits,and crops mainly green leafy vegetables. With the increasing accumulation of the potentially toxic metals in the environment, agricultural emission, accumulation in the raw food materials, milk, dairy products, beverages, chocolates, and candies are contaminated with the toxic metals. The survey of the literature reveals that most of the samples of milk, dairy products, non-alcoholic, alcoholic beverages, chocolates, and candies contain Cd and Pb beyond their permissible limit.
The aim of the present study was to summarize the concentration of the potentially toxic metals in animal milk, maternal mother milk, dairy products, non-alcoholic and alcoholic beverages, and in the chocolates, and candies, and their impact on human.
***(Keywords:** Milk, Dairy products, Beverages, Chocolates, Potentially toxic metals)*

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I. Introduction

With the development of civilization human starts not only agricultural activities, but also domesticated animals for milk, fur, and their meat. Milk, awhite fluid which is produced by the mammary glands of the mammals (cow, buffalo, goat, sheep, and camel) is the main source of nutrition for young mammals till other types of food is not digested by them.As milk and other dairy products contain essential nutrient proteins, amino acids, vitamins, lactose, minerals, essential fatty acids, immunoglobulins, antimicrobial in balanced ratio milk and other dairy products are the important components of our diet [Kowalska et al., 2020; Sarsembayeva et al., 2020]. The amount of these components in the milk varied from with animal species and breeds within the species. Milk is the human's first food which provides all the necessary nutrients needed for growth and biological functions at the early stages of life. Globally the milk and dairy industries have a turn over about 442 billion US dollars and growing by a rate of 5.2% annually. As per estimate the worldwide milk consumption in 2017 was 216million metric tons and is expected to become 234million metric tons in 2021. Globally average milk consumption is 100 kg/year/person.

To reduce home activities, increase mobility and flexible itinerary of workers the consumption of the ready-to–eat food has been increased globally irrespective of age, sex and socio-economic status. The ready–to-eat food contains fruit juices, nutritional drinks and beverages. Non–alcoholic soft drinks which include carbonated drinks, juice drinks, fruit juices, sports and energies drinks were commercially introduced in 1884 in the USA as energy source. Juices which are natural products are the sources of vitamins (C, folic acid), minerals, fibres, and antioxidants needed for different activities by human [Owolade et al., 2017]. Carbonated drinks contain water, carbon dioxide and flavours [Izah et al., 2017]. The alcoholic beverages which are generally consumed are beer and wines made from different plant materials. Global consumption of non-alcoholic beverages was 682.52 billion litres in 2016 and expected to become 803.02 billion litres by 2021, while consumption of alcoholic beverages are expected to become 244.62 billion litres in 2021 from 235.4 billion litres in 2017. The global market of alcoholic and non-alcoholic beverages in 2019 was approximately 2630 billion US dollars.

Candies and chocolates which provide not only joy and pleasure are nutritious energy source as have fast metabolism and can be easily digested are regularly eaten. These act as stimulant, relaxant, and antidepressant. The unconstrained eating of these increases the obesity and dental complications. The Candies have high glycine index which increases blood sugar in the body causing diabetes. Cocoa powder associated with chocolates contains thebromine and phenethylamine alkaloids have physiological impacts on the consumers [Abt et al., 2018].Globally 7.3 million tons of the Chocolates are consumed valued approximately 100 million US dollars. Europe is the leading consumer of the Chocolates; in Switzerland consumption is 19.4 pounds (ca. 9 kg) per capita followed by Germany (17.8 pounds (ca. 8 kg) per capita), Ireland (17.4 pounds (ca. 8 kg) per capita) UK (16.8 pounds (ca. 8 kg) per capita) and Sweden (14.6 pounds (6.62 kg) per capita). USA consumes approximately 30 % of the global chocolates.

Due to urbanization, industrialization advanced agricultural activities, irrigation of the crops/fodder by the sewage water; use of sewage sludge, pesticides, fertilizers in agriculture the contamination of food products with undesirable toxic substances as potentially toxic metals, mycotoxins, dioxins is increasing globally which is of the major concern for the health of animals and citizenry [Ismail et al., 2019; Eleboudy et al., 2017]. Potentially toxic metals/metalloid arsenic, lead, cadmium, nickel, mercury, chromium, cobalt, and zinc beyond their permissible limit even in very small amount in body of animal or human became toxic. The toxicity of these metals is due to disruption of the normal cellular processes and due to bio accumulation; these metals adversely affect soft tissues' viz., kidney, liver, and central nervous system. The laboratory studies has shown that due to production of reactive oxygen species and oxidative stress metals As, Cd, Pb, Cr and Hg have as toxic and carcinogenic in human and animals.

A number of researchers [Lahiji et al., 2016;Ziarati et al., 2018; Singh et al., 2019; Babu et al., 2018] have reported the presence of potentially toxic metals (mainly Cd, Pb, As, Cr and Ni) in the animal milk, maternal mother milk and in the dairy products. The presence of potentially toxic metals in all types of alcoholic and non-alcoholic beverages globally has been reported by the number of scientists [Abdel-Rahman et al., 2019; Anastacio et al., 2018; Meshref et al., 2014]. Potentially toxic metals Cd, Pb, Ni beyond their permissible limits in chocolates and candies due to their raw materials have been reported by number of food scientists [Devi et al., 2016; Kongor et al., 2016; UdayPrakash et al., 2014; Chavez et al., 2016]. During this review the concentration of the potentially toxic metals in animal milk, maternal mother milk, dairy products non-alcoholic and alcoholic beverages, and in the chocolates, and candies, and their impact on human is summarized.

II. Potentially toxic metals:

Potentially toxic metals are naturally occurring metals whose specific gravity (density) is 5 times than that of water and atomic weight ranges in between 64 -201. These metals cannot be easily degraded so persist for a long period. Metals Cu, Zn, Co, Cr, Mn and Fe are required in small amount by all the living organisms (plants, animals, and humans) for various biochemical and physiological functions. As these metals participate in the redox reactions and are an important part of enzymes are termed as essential metals but when the concentration of these metals crosses permissible limit they became toxic. Metals Pb, Hg, Cd and As (metalloid) are highly toxic non-essential metals and have no biological role in the living organisms

III. Sources of Potentially toxic metals contaminants within the environment:

After World War II because of increase in urbanization, industrial growth, mobility and transport the amount of the potentially toxic metals in the environment is increasing [Toth et al., 2016; Su et al., 2014]. The main sources of the environment contamination by potentially toxic metals are:

3.1 Natural:

The natural sources of potentially toxic metals in the environment is rock weathering in the rocks these metals are present in the form of hydroxides, sulphides, phosphates, silicates, organometallic compounds and as chelated with organic compounds, forest fires (plants accumulates these pollutants), volcanic eruptions (earth crust have vast amount of these metals),biogenic sources and wind born soil particles.

3.2 Anthropogenic activities:

The global population is increasing and expected to be 9.7 billion inhabitants by 2050 to fulfil their basic needs industrial manufacturing of products like to cement production, iron industry, steam power plants, glass production, paint, and tanning industries is increasing, these industries are one of the major causes of the environmental pollution because of anthropogenic activities. Other human activities which cause the release of these pollutants in the different compartments of the environment are the agricultural activities (use of sewage sludge as manure, irrigation by sewage wastewater, use of the fertilizers, and pesticides) mining, and metallurgical processes, garbage and waste mud incineration facilities, combustion of fuels, surface emission and traffic and runoffs. The main route of the groundwater and aquatic contamination by potentially toxic metals are the leaching from toxic industrial waste dumps, municipal landfills and leaching of agricultural chemicals from soils into the upper aquifers [Sharma et al., 2017]. Potentially toxic metals (Cr, Cd, Cu, Zn, Ni, Mn, Pb and As) are present as impurities in fertilizers and pesticides, which are continuously applied within the fields to increase crop growth. Sewage sludge and irrigation of crops by sewage water is the another cause of introduction of these metals in the soils. As the concentration of potentially toxic metals within the environment is continuously increasing, and therefore, the soil retention capacity of those metals is decreasing resultant is that these metals are absorbed by the plants and leached to ground water.

IV. Routes of Contamination:

4.1 Routes of contamination of Milk and Dairy Products:

The main routes of contamination of the milk and dairy products by potentially toxic metals are:

4.1.1 Uptake of these potentially toxic metals by the animals:

Routes of uptake of those toxic metals by the animals are(Batool et al., 2016):

(i) Ingestion: It occurs via gastrointestinal route i.e. through the mouth by eating contaminated green fodder, drinking water, veterinary medicines and other feeds.

(ii) Dermal: Dermal uptake means absorption through skin

(iii) Inhalation: Inhalation uptake occurs via inhalation of the polluted air as dust fumes or contaminatedvapours.

4.1.2Other Sources of contamination:

(i) Machines associated with processing and distribution (Anetta et al., 2012; Riaz et al., 2015).

(ii) Water, equipment, and containers used in processing and cooking;

(iii)Materials used for packaging and store.

4.2 Routes of contamination of Beverages:

The presence of the potentially toxic metals in the soft drinks and synthetic fruit juices are due to contamination of its major constituents, i.e. water, sweeteners, carbon dioxide, antioxidants, colouring, preservatives.The fruit juices are contaminated by these metals as natural fruits and ground water contain the potentially toxic metals beyond the permissible limit because of the accumulation of these metals in the soils in which they are grown.

In most of the alcoholics beverages active ingredient is plant material, viz., beers are produced from hops and cereals plant material. The bio accumulation of these metals in the plant material occurs via uptake from the soils. The major route of accumulation of these metals in soils is use of fertilizers, pesticides, contaminated surface water, sewage sludge and sewage water.

Other sources are processing and packaging.

4.3 Routes of contamination of Chocolates and Candies:

(i) Cocoa beans are used for the chocolate production. Chocolate products are contaminated by potentially toxic metals by uptake of these metals by Cocoa tree from the soils which are contaminated due to natural and anthropogenic activities.

(ii) Industrial processes by which products are passed.

(iii) Material and printed colour ink used for protection, handling and marketing. Colourful Wrappings used for packing of candies. The metals from printed surface migrate to productsvia blocking, rubbing, peeling and diffusion.

V. Potentially toxic metals within the Milk and Dairy Products:

Milk quality and the composition depends on the cattle, its breed, diet provided, chemical composition of the soil of the area, the water used for irrigation of the crops. Bio accumulation of these metals in the lactating animals adversely affects milk quality and production. The amount of the potentially toxic metals in the bovine milk depends on lactation period of the animal, animal feed composition seasonal variations, climatic conditions, and environmental contamination [Kabir et al., 2017; Mahmoudi et al., 2017]. The survey of literature have revealed that metals/ metalloids Cd, Cu, Zn, Pb, Ni, As and Fe are presenting in all the studied samples of animal (cow, buffalo, camel, sheep, goat) milk andin the milk products most of the samples were beyond permissible limit. These metals are also present in the maternal breast milk. Table 1, denotes the concentration of these potentially toxic metals in milk and milk products.

VI. Potentially toxic metals in the alcoholic, non-alcoholic drinks and fruit juices:

Carbonated drinks, besides juices, energy drinks, and probiotic drinks are called as non-alcoholic beverages. Carbonated drinks are the most consumed non-alcoholic drinks. Due to environmental pollution, surface, and ground water contamination, use of contaminated fruits the potentially toxic metals such as cadmium, lead, mercury arsenic, and zinc are found in the soft drinks [Engwa et al., 2016]. The Minister of state for Health in the Indian Parliament reported that soft drinks like Sprite, Mountain Dew, UP, Pepsi and Coca Cola contains toxic metals Cadmium, Chromium, and lead [Woyessa et al., 2015] which have a significant health impact on humans [Yadav et al., 2017]. Krstic (2019) in his studies found that more than half of the grape, pear, apple, and fruit blends samples contain elevated concentration of these metals. They also reported that intake of half a cup—are enough to accumulate these metals in humans beyond permissible limit. Besides water, sugar, and alcohol, inorganic as well as organic compounds are present in the alcoholic beverages wine and beer. The composition of these beverages and contamination by toxic metals is influenced by many factors such as specific production area: plant varieties, soil and climate, surface, and ground water, culture, beverages making, transport and storage [Fathabad et al., 2018; Orutugu et al., 2015]. Most of the samples of alcoholic beverages contain Cd and Pb beyond permissible limit. The concentration of these metals in Non-alcoholic and alcoholic drinks are given in Table2.

Potentially toxic metals in the chocolates and Candies:

The cocoa beans fruit (Theobroma cacao L); one of the major components of the chocolate occupies the third place in the world market of raw materials after the sugar and coffee. A review of literature denotes that cocoa based chocolates and candies have higher amount of potentially toxic metals than in sugar based chocolates and candies [Samsuddin et al., 2016], the higher concentration of these metals in the chocolates, and candies are due to accumulation of these metals in the raw materials, i.e. cocoa beans, cocoa butter, and cocoa solids [Anyimah-Ackah et al., 2019; Prakash et al., 2014]. Material and printed colour ink used for protection, handling and marketing of these products passes these toxic metals in chocolates and candies via blocking, rubbing, peeling and diffusion. A survey of literature denotes that the entire local made and most of the imported chocolates and candies contain Pb and Cd beyond their permissible limits. The concentration of these metals in the different samples of chocolates, Candies, and cocoa are given in Table 3.

Toxicity of probably toxic metals:

As metals arsenic, chromium, Cadmium, lead and mercury are highly toxic these metals in environment affects public health most. The degree of the toxicity of these metals to citizenry depends on the dose, contact pattern, age, gender, nutritional status of the citizenry. As these metals disrupt endocrine system they act as carcinogenic [Orr and Bridges,2017; Mallozzi et al., 2016]. World Health Organization reported that in the year 2015 approximately 8.8 million deaths were due to cancer globally one of the reasons of these deaths is the presence of these toxic metals beyond permissible limit.When these metallic ions interact with DNA and nuclear proteins they damage DNA causing structural changes, cytotoxicity, oxidative stress, damages of antioxidants, enzyme inhibition [Bhattacharya et al., 2016; Hernández-García et al., 2014]. The mixture of these toxic metals adversely affects the immune and Hematopoietic systems in human and animals [Fowler et al., 2004]. Yadav et al., (2017) have reported that accumulation of these metals in the body beyond the permissible limit adversely affects human bone health. Li et al. [2018] have also reported that the major reason for the human bone diseases is the presence of the potentially toxic metals beyond their permissible limit.

The toxicity of these metals is:

Metal	Source	Toxicity Mechanism	Toxicity Organ	Effects/ Diseases
Cd	Earth crust, battery industries	Tumor-suppressor proteins, DNA repair disruption, dysfunctions of sexual glands, displace vitamin C and E from their metabolically active sites, disruption of the mineral balance within the body. decrease in absorption of Calcium by intestine	Liver, Lungs Kidney, Prostate ,	Anaemia, hair loss, Itai-Itai disease hypertension, Carcinogen, pulmonary adenocarcinoma, Proteinuria, Osteoporosis, Kidney stones, endocrine disruption, neuro-developmental toxicity.
Pb	Earth crust, battery industries, fossil fuels, mining, and paint industry. Out of 4 million tonnes used per annum three million tonnes is discharges in the environments	DNA repair disruption and reactive oxygen species mediation	Nerve , kidney, Red Blood cells	Carcinogen, fatigue, anaemia, loss of appetite, weight loss and headache, insomnia, miscarriages, infertility, lowering of active Vitamin D3 level, decrease in the secretion of γ–carboxyglutamic acid containing protein, affects central nervous system, renal, cardiovascular, neurological, and Musculoskeletal Systems, disrupts biosynthesis of Haemoglobin, metabolism of Fe, Zn and Cu, and of vitamin D within the body, causes cognitive impairment, acts as nephrotoxicants, when present with Cd and As in human, and other animal causes

				hepatotoxic (damage to the liver). Causes hyperactivity, dense lines in the bones and delayed mental development in the children
Cr	Used in chrome plating, leather tanning, paint pigments, wood treatments. The annual output of Cr globally is approximately7.5 million tons.	Damages DNA and proteins with the production of superoxide ion, hydrogen peroxide, and hydroxyl radical	Skin, bones and Kidney	Cr (III) an essential dietary nutrient, required to regulate insulin and for normal glucose metabolism. Cr (III) deficiency is associated withcardiovascular disease,decreased sperm count,impaired fertility, glucose tolerance and maturity-onset diabetes. Excess of Cr (III) and presence of Cr (VI) causes dermatitis, allergic and eczematous skin reactions, skin and mucous membrane ulcerations, nasal ulcers, asthma, bronchial carcinomas, gastro-enteritis, hepatocellular deficiency, renal oligo-anuric deficiency and supresses the secretion of Collagen-Type I which helps in the healing of bone fracture.
As	Metal smelting, pesticides, contaminated food and water	Alters DNA methylation, cell proliferation, promotes tumour, genotoxicity, oxidative stress, co-carcinogenesis, disrupts sulfhydryl containing enzymes, enhance hydrolysis of ATP molecules. Arsine causes haemolysis .	Skin, lung, kidney	Carcinogen,Hyperpigmentation, Keratosis, headaches, dermatitis, muscular weakness, loss of hairs and nails, nausea, abdominal pain, neuropathy, Lung, liver, kidney and skin cancer, mitochondrial damages, histological changes, decreased antioxidant power of kidney, death of neuronal cells, cognitive dysfunction, Alzheimer's disease.Cognitive impairment, deafness, hypertension, anaemia dementia, hematemesis
Cu	Earth crust, Pesticides, fossil fuels, power plants	Cell metabolism, iron metabolism Haem synthesis, bones development, normal functioning of Liver	Kidney, liver, central nervous system	An essential metal plays important role in metabolism, synthesis of red blood cell, bone development, maintains the strength of the skin, blood vessels, and connective tissues in the body. Deficiency in citizenry cause's anaemia, low number of leucocytes, defects in animal tissue and osteoporosis in infants, causes hematemesis, jaundice, and melena, damage to central nervous system, Wilson disease (a genetic disease), liver and kidney problems when accumulates beyond its permissible limit.
Zn	Earth crust, industrial activities, such as mining, coal and waste combustion, steel processing, fertilizers, pesticides	Plasma membrane, the metal-regulatory transcription factor (MTF)-1, induces the expression of thionein, oxidation of thiols by reactive oxygen (ROS) or nitrogen (RNS) to form oxidized protein thionin (Tox).	Brain, prostate, liver,the gastrointestinal tract, kidney, skin, lung, brain, heart, and pancreas	An essential metal helps in blood clotting, wound healing, proper thyroid functioning, prostaglandin, bone mineralization, sperm production, protein synthesis, DNA synthesis, RNA transcription, cell activation plays a crucial role in number of metallo-enzymes viz, dehydrogenase, alkaline phosphatase, Carbonic anhydrase, leucine amino peptidase, superoxide dismutase. Acts as anti-inflammatory. Over exposures to zinc in human causes dry or pharyngitis, chest tightness, headache, increased indices of pulmonary inflammation, nausea, decrease in the activity of copper metallo-enzyme, decreased HDL-cholesterol level, immunotoxicity, and gastrointestinal effects.
Hg	It is estimated that annually 5,500 tons of mercury enter the global. Coal-fired utility boilers, ocean emission are the major sources.Mercury is also used for the extraction of the gold from river beds.	inactivate proteins and enzymes involved in synaptic and neuromuscular transmission	Skin, Kidney, Brain	Cardiovascular diseases, hypertension, renal dysfunction, Alzheimer's disease , skin, and nose irritation, damage to central nervous system, hearing, speech and visual disorders, neurotoxic effects including death of neuronal cells, cognitive dysfunction, anorexia, Polyuria, polydipsia, albuminuria, Constipation, diarrhoea, generalized distress
Ni	Earth crust, volcanic eruptions, ocean floors, ocean water, steel and other alloys industries, electroplating.	Depletion of glutathione levels and deactivation of the proteins by bonding to the sulfhydryl groups of proteins, inhibition of ATPase activity	Lungs, skin	Excess uptake of nickel by human causes asthma, pneumonia, allergies, heart disorder, skin rashes and miscarriage. Chances of development of carcinoma, nose cancer, larynx cancer and prostatic adenocarcinoma are enhanced, causes hypoxic cellular environment by depletion of

				iron from the cell

VII. Conclusions

- The survey of literature denotes that agriculture and industries are the most sources of contamination of the food chain.
- Worldwide most of the milk samples, dairy products, alcoholic and non-alcoholic beverages, chocolates, and candies have potentially toxic metals Cd and Pb beyond their permissible limits.
- Milk and dairy products which contain almost all the essential constituents (proteins, vitamins, minerals essential fatty acids) are the major components of the citizenry.
- Potentially toxic metals Cd, Cr, Pb, As and Ni are accumulated in the plant materials via soils pass into the milk and dairy products.
- The contamination of beverages by potentially toxic metals is through the raw materials used for beverages drink production i.e. water and other plant materials.
- The higher concentration of Cd, Pb, and Cr, in the chocolates and candies are due to raw materialsi.e.cocoa beans, cocoa butter and due to packaging materials.
- A number of biological and biochemical processes are disrupted in the physical body by accumulation of those metals. These metals also cause developmental abnormalities in the children.

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Table 1: The concentration of different potentially toxic metals in Milk and Dairy products

Sample	Source	Concentration of metal								Reference
		Cd	Cr	Cu	Zn	Pb	Ni	As	Fe	
Milk	Tabriz, Iran	2.34-6.07ng/g		141.7-241.2ng/g		6.06-10.83ng/g		3.25-7.54ng/g	2764.3-3151.3ng/g	Beikzadeh et al., 2019
Yoghurt		3.14-8.83ng/g		276.2-423.5		5.54-19.34ng/g		6.65-10.84ng/g	2412.4-4115.7ng/g	
Industrial Kashk		1.54-13.45ng/g		115.9-565.4ng/g		2.16-19.62ng/g		4.35-20.35ng/g	2588.4-5014.3ng/g	
Traditional Kashk		5.23-9.97ng/g		416.4-923.6ng/g		7.97-32.72		7.66-28.41	4491.4-6402.3ng/g	
Raw milk samples	Hamadan City Iran	0.36ng/g		9.77ng/g	253.7ng/g	32.83ng/g				Sobhanardakani 2018
Pasteurized Milk		5.57ng/g		8.41	90.12ng/g	25.54ng/g				
Cow Milk	Serbia	0.01ug/g	0.018ug/g	4.40 ug/g	60.21 ug/g	0.08 ug/g	0.119ug/g	0.058ug/g	283.9 ug/g	Davidov et al., 2019
Milk	Poland	0.000-0.001ug/g		0.31-1.033ug/g	4.83-15.84 ug/g	0.012-0.234 ug/g				Sujka et al., 2019
Kefir (Milk Product)		0.000-0.004ug/g		0.087-1.25 ug/g	1.925-15.68 ug/g	0.004-0.156 ug/g				
Butter Milk		0.000-0.002ug/g		0.188-1.72ug/g	2.18-8.51 ug/g	0.005-0.039 ug/g				
Yoghurt		0.000-0.0067ug/g		0.099-0.930ug/g	0.01-9.52 ug/g	0.015-0.099 ug/g				
Cream		0.001-0.0026ug/g		0.02-1.140ug/g	2.05-5.42 ug/g	0.006-0.036 ug/g				
Cheese spread		0.000-0.0066ug/g		0.082-3.74/g	5.16-56.44 ug/g	0.015-0.340 ug/g				
Cottage Cheese		0.000-0.003 ug/g		0.41-3.94 ug/g	5.39-53.72 ug/g	0.03-0.38 ug/g				
Milk	Egypt	0.00-0.06 ug/g		0.041-0.336 ug/g	0.42-1.42 ug/g	0.143-0.737 ug/g				Khalil et al., 2018
Buffalo Milk		0.013-0.06 ug/g		0.041-0.079 ug/g	0.417-0.961 ug/g	0.159-0.733 ug/g				
Cow Milk		0.027-0.036 ug/g		0.111-0.133 ug/g	0.683-1.128 ug/g	0.209-0.430 ug/g				
Goat Milk		0.00-0.03 ug/g		0.254-0.336 ug/g	0.967-1.368 ug/g	0.143-0.254 ug/g				
Sheep Milk		0.004-0.029 ug/g		0.148-0.315 ug/g	0.649-1.42 ug/g	0.147-0.737 ug/g				
Milk Products										
Kareish		8-14 ng/g		155-193 ng/g	2365-3796 ng/g	174-178 ng/g				Khalil et al., 2018
Domiati		14-21 ng/g		48-206 ng/g	1026-2598 ng/g	111-174 ng/g				
Mish		14-16 ng/g		61-183 ng/g	842-1057 ng/g	164-173 ng/g				
Samna		11-15 ng/g		10-83 ng/g	93-634 ng/g	163-179ng/g				
Cow Milk	Dhaka Bangla Desh	0.0-0.081 ng/g	0.165-1.533 ng/g	0.042-1.778 ng/g		0.0-0.204 ng/g			0.25-0.949 ug/g	Muhib et al., 2016
Cow milk (1to 5 yr of lactation)	Bangladesh	0.034 ug/g	6.378 ug/g	0.124 ug/g	0.176 ug/g	0.092 ug/g	0.112 ug/g	0.012 ug/g	7.642 ug/g	Kabir et al., 2017
Milk	Bushehr, Iran	0.0765 ug/g		0.1038 ug/g	7.31 ug/g	0.2523 ug/g				Hashemi et al., 2017.
Yoghurt		0.083 ug/g		0.110 ug/g	7.67 ug/g	0.2731 ug/g				
Cheese		0.1076 ug/g		0.0965 ug/g	10.23 ug/g	0.5465 ug/g				
Butter		0.0623 ug/g		0.731ug/g	6.01 ug/g	0.6631 ug/g				
Cream		0.1324 ug/g		0.458 ug/g	7.81 ug/g	0.6123 ug/g				
Dough		0.0566 ug/g		0.1106 ug/g	6.40 ug/g	0.1435 ug/g				
Cow Milk	Punjab Province, Pakistan	0.0014-0.0041 ug/g		0.041-0.093 ug/g		0.014-0.033 ug/g	0.018-0.073 ug/g			Ismail et al., 2019
Buffalo Milk		0.0001-0.0073 ug/g		0.021-0.082 ug/g		0.018-0.041 ug/g	0.026-0.062 ug/g			
Goat Milk		0.0001-0.0041 ug/g		0.018-0.141 ug/g		0.007-0.021 ug/g	0.009-0.067 ug/g			
Buffalo Milk	Palghar, Maharashtra		0.014-1.606ug/mL		0.111-7.23ug/mL	0.065-0.137 ug/mL	0.04-0.749 ug/mL			Nirgude&Bhagure, 2015
Buffalo Milk	Hyderabad				3.96 ug/mL	0.22 ug/mL				Shailaja et al., 2014

Goat Milk	Hosur (Tamilnadu)	0.016-0.03ug/mL				0.052-0.064 ug/mL	0.069-0.097 ug/mL	0.056-0.082 ug/mL		Dhanalakshmi et al., 2013
Milk and Milk Products	Vadodara	0.23-1.51 ug/mL			2.28 ug/mL					Chandrakar et al., 2018
Cow Milk						0.03ug/g		0.12 ug/g		Castro-Gonzalez et al., 2017
Cheese						0.11 ug/g		0.17 ug/g		
Milk whey						0.07 ug/g		0.16 ug/g		
Milk						2.12-37.36 ug/L				de Oliveira et al., 2017
Goat milk	Indonesia					50-80ng/g		70-110ng/g		Wanniatie et al., 2019
Goat Milk	China	0.425 ng/g	11.7 ng/g	0.208ug/g	3.11 ug/g	7.97 ng/g	38.3 ng/g	4.27 ng/g	1.08 ug/g	Chen et al., 2020
Cow Milk		0.767 ng/g	15.0 ng/g	0.165ug/g	4.36ug/g	23.4 ng/g	81.9 ng/g	4.61 ng/g	1.45 ug/g	
Buffalo Milk		0.676 ng/g	7.94 ng/g	0.209ug/g	4.00 ug/g	17.3 ng/g	62.4 ng/g	3.81 ng/g	1.01 ug/g	
Camel Milk		0.786 ng/g	13.6 ng/g	0.248ug/g	5.81 ug/g	18.2 ng/g	131 ng/g	8.06 ng/g	1.29 ug/g	
Yak Milk		0.254 ng/g	1.85 ng/g	0.522ug/g	4.76 ug/g	4.31 ng/g	66.8 ng/g	1.12 ng/g	2.54 ug/g	
Raw Milk	Iran	1.1 ng/g		427 ng/g	571 ng/g	14 ng/g				Shahbazi et al., 2016
Pasteurized Milk		1.0 ng/g		378 ng/g	447 ng/g	9.59 ng/g				
Cheese		1.25ng/g		428 ng/g	586 ng/g	14.5 ng/g				
Yoghurt		0.99 ng/g		399 ng/g	431 ng/g	7.54 ng/g				
Dough		0.84 ng/g		320 ng/g	369 ng/g	7.2 ng/g				
Milk	Chittoor		0-0.002 ug/g	0.15-0.68 ug/g		0-0.004 ug/g				Babu et al., 2018
Cow Milk	Khyber-Pakhtunkhwa Pakistan	0.076ug/g	0.034ug/g	0.141ug/g	3.136ug/g	0.0 ug/g	0.13ug/g		0.692ug/g	Ahmad et al., 2017
Buffalo Milk		0.117ug/g	0.032ug/g	0.223ug/g	4.356ug/g	0.0 ug/g	0.15ug/g		0.960ug/g	
Goat Milk		0.074ug/g	1.152ug/g	0.212ug/g	3.345 ug/g	0.0 ug/g	1.15ug/g		0.950ug/g	
Sheep Milk		0.01ug/g	0.044ug/g	0.151ug/g	3.113ug/g	0.0 ug/g	0.34ug/g		0.592ug/g	
Camel Milk		0.102ug/g	0.024ug/g	0.06ug/g	5.15ug/g	0.0 ug/g	0.22ug/g		1.580ug/g	
Milk	Egypt	0.008-0.104 ug/g		0.0036-0.9312 ug/g	2.73-18.16 ug/g	0.055-0.409 ug/g			2.96-45.62 ug/g	Meshref et al., 2014
Cheese		0.01-0.162 ug/g		0.0002-0.53 ug/g	3.40-17.57 ug/g	0.194-0.650 ug/g			1.76-14.74 ug/g	
Butter		0.011-0.094 ug/g		0.059- 1.692 ug/g	2.82- 8.89 ug/g	0.328-0.751 ug/g			5.07-13.14 ug/g	
Cow Milk	Kazakhstan	0.0025-0.0029 ug/g				0.008-0.001ug/g		0.00 ug/g		Sarsembayeva et al., 2020
Cheese		0.0496-0.057 ug/g				0.009-0.016 ug/g		0.00 ug/g		
Camel Milk	Riyadh&Qassim, Iran	0.013-0.026 ug/g		0.18-0.22 ug/g	1.13-1.19 ug/g	0.54-0.59 ug/g	1.51-2.1 ug/g		0.68-0.79 ug/g	Soltan et al., 2017
Sheep Milk		0.026 ug/g		0.20-0.38 ug/g	0.95-1.0 ug/g	0.68-0.88 ug/g	0.8-2.21 ug/g		0.93-3.2 ug/g	
Camel Milk	Iran	0.09-0.72 ug/L	0.0-0.03 ug/L	0.32-0.74 ug/mL	10-156 ug/mL	2.26-8.28 ug/L	0.45-0.69 ug/L		0.47-15.51 ug/mL	Mostafidi et al., 2016
Cow Milk	Argentina	0.024-0.037 mg/L	0.086 mg/L	0.133-1.275 mg/L					1.432 mg/L	Bousbia et al., 2019
Human Milk	USA			71-5-317.1 ug/L	0.15-1.61 mg/L	0.41-2.1ug/L		2.4-6.02 ug/L	0.84-1.85 mg/L	Klein et al., 2017
Human Milk	Poland			82.9252.42 ug/L	0.2-2.02 mg/L	0.52-1.44ug/L		3.03-7.9 ug/L	0.8-1.38 mg/L	
Human Milk	Argentina			89.52-419.09 ug/L	0.25-2.01 mg/L	0.21-1.69 ug/L		2.54-9.08 ug/L	0.71-1.51 mg/L	
Human Milk	Namibia			55.6-208.83 ug/L	0.03-3.75 mg/L	1.92-2.48 ug/L		4.08-11.2 ug/L	0.74-2.97 mg/L	
Maternal Breast Milk	Turkey			0.08-2.02 mg/L	0.45-15.8 mg/L	<1ug/L		<1ug/L	0.45-5.11 mg/L	Altun et al., 2018
Maternal Breast Milk	Pakistan							0.092-1.24 ug/L		Khan et al., 2018
Permissible limits	Milk	0.03-0.4 ug/g	0.025ug/g	0.1-0.7 ug/g	1-3 ug/g	0.02-0.04 ug/g	0.01 ug/g	0.01-0.05ug/g		
	Dairy products	0.03-0.5 ug/g	0.03-0.05 ug/g	0.3-0.9 ug/g	1.5 ug/g	0.02-0.05 ug/g	0.01 ug/g	0.01-0.03 ug/g		

Table 2: The concentration of different potentially toxic metals in alcoholic,Non -alcoholic drinks and fruit juices

Sample	Source	Concentration of metal								Reference
		Cd	Cr	Cu	Zn	Pb	Ni	As	Fe	
Carbonated drinks	Ogun state Nigeria	0-0.26 mg/L	0-0.027 mg/L	0-3.25 mg/L	0.11-7.38 mg/L	0-0.45 mg/l	0-0.30 mg/L	0.0-0.14 mg/L	0.57-1.73 mg/L	Salako et al., 2016
Alcoholic drinks		0.0-0.104 mg/L	0.0-0.002 mg/L	0.001-0.671 mg/L	0.11-0.220 mg/L	0-0.211 mg/L	0.184-0.273 mg/L	0.0-0.12 mg/L	1.09-2.45 mg/L	
Alcoholic drinks	Ibom State Nigeria			3.16-6.21 mg/L	0.325-5.0 mg/L	3.0-6.75 mg/L			6.0-28.5 mg/L	Udota and Umoudofia, 2011
Carbonated Drinks	Egypt	0.0 ug/g	0.0ug/g	0.06-0.21ug/g		0.0 ug/g	0.0-0.24ug/g		1.56-20.34 ug/g	Abdel-Rahman et al., 2019
Fruit Juices		0.0 ug/g	0.0ug/g	0.17-0.56ug/g		0.0 ug/g	0.15-0.53 ug/g		3.48-43.88 ug/g	
Yoghurt fruit juices		0.0 ug/g	0.0ug/g	0.17-0.23ug/g		0.0 ug/g	0.23-1.37 ug/g		3.17-8.59 ug/g	
Soft Drinks	Nigeria	0.27-1.28 mg/L		0.1-2.44 mg/L	2.24-5.89 mg/L	0.21-0.63 mg/L		0.16-0.53 mg/L		Oyekunle et al., 2019
Soft Drinks	Nigeria	0.000-0.01 mg/L		0.04-0.79 mg/L	0.11-2.28 mg/L	0.0-0.04 mg/L		0.0-0.01 mg/L	0.08-0.55 mg/L	Ogamba et al., 2016
Juices	Nigeria	0.08-0.12 mg/L	0.06-0.57 mg/L	0.01-0.03 mg/L		0.20- 1.21 mg/L			0.50-1.88 mg/L	Adegbola et al., 2015
Beer	Nigeria	0.003-0.008 mg/L	0.17-0.34 mg/L	0.04-0.08 mg/L	0.08-0.15 mg/L	0.023-0.045 mg/L	0.04-0.10 mg/L		0.23-0.56 mg/L	Ubuoh, 2013
Alcoholic Beverages	Nigeria	0.06-0.07 mg/L	0.15-0.35 mg/L		0.14-0.40 mg/L	2.13-4.70 mg/L			0.72-4.22 mg/L	Okareh et al., 2018
Soft drinks	Nigeria	<0.001-0.010 mg/L		0.040-0.790 mg/L	0.190-2.28 mg/L	0.001-0.040 mg/L		<0.001-0.016 mg/L	0.080-0.550 mg/L	Ogunlana et al., 2015
Fruit Juices	Iran	0.89-3.44 ng/g				27.87-66.1 ng/g		1.14-18.36ng/g		Fathabad et al., 2018
Orange Juices		0.01-0.05 mg/L				0.2-1.19 mg/L		2.01-2.56 ug/g		Savic et al., 2015
Juices	Romania	0.12-1.42 ug/L				1.02-75.68 ug/L		0.001-4.36 ug/L		Dehelean and Magdas, 2013
Juices	Saudi Arbia	0.01 -0.0157 ug/g				0.02-0.0264 ug/g				Enani and Farid, 2011
Juices	Iraq	0.01-2.40 ug/g				0.01-0.09 ug/g				Al-Mayaly, 2013
Juices	Egypt					0.03-1.20 ug/g				Hassan et al., 2014
Commercial Packaged Fruit Juices	Iran	0.00-0.085 mg/L				0.043-1.96 mg/L	0.008-1.73 mg/L			Mohammadi and Ziarati, 2015.
Soft Drinks		0.0-0.03 mg/L	0.0-0.08	0.09-2.2 mg/L	0.15-2.42 mg/L	0.0-0.05 mg/L			0.14-3.81 mg/L	Magomya et al., 2015
Non-alcoholic Drink	Nigeria	0.003-0.131ug/g	0.0 ug/g	0.043-0.123ug/g		0.381-0.729 ug/g	0.222-0.893 ug/g			Ogidi et al., 2020
Alcoholic Drinks		0.034-0.120 ug/g	0.0 ug/g	0.02-0.142 ug/g		0.479-0.701 ug/g	0.222-0.478 ug/g			
Juices	Nigeria	0.0-1.49 ng/L				0.17-3.39ng/L				Goodwill et al., 2015
Beer	USA		33-45 ug/L	29-150 ug/L	45-530 ug/L				5000 ug/L	Markovski et al., 2018
Carbonated Drinks	India					0.51-5.34 mg/L				Razeenakarim, 2017
Fruit Juices						0.30-0.40 mg/L				
Wine	Brazil	1.74-5.25 ug/L		1.0-10.3 ug/L	4.64-69.3 ug/L	4.57-17.9 ug/L				Maciel et al., 2019
Wine	Nigeria	0.011-0.037mg/L			0.017-0.088 mg/L	0.120-0.295 mg/L			0.404-1.645 mg/l	Gazuwa et al., 2017
Fermented Beverages	Ethiopia	0.005-2.37 mg/L	0.07-0.09 mg/L	0.04-1.15 mg/L	1.32—10.95 mg/L	<0.01-0.13mg/L	0.07-4.73 mg/L		0.008-0.028 mg/L	Debebe et al., 2017
Wine	Europe	0.0-0.0184 mg/L			0.0-4.63 mg/L	0.0-1.25 mg/L				Plota-Wasylka et al., 2017
Wine	Italy	0.26-7.2 ug/L			95-978 ug/l					Dumitriuet al., 2019
White Wine	Croatia		0.0-93 ug/L	9-2874 ug/L	370-2100 ug/L	3-189 ug/L	0.0-84 ug/L			Blesic et al., 2017
Red Wine			00.0-732 ug/L	3-1056 ug/L	357-1860 ug/L	0.0-58 ug/L	0.0-489 ug/L			
Permissible	Non-alcoholic drinks	0.003ppm	0.05ppm	2-5ppm	0.5-10ppm	0.02-0.2	0.02-0.07	0.02-0.05	0.3 ppm	
limits						ppm	ppm	ppm		
	Alcoholic Drinks	0.003 ppm	0.05 ppm	1-2 ppm 0.02-0.07 ppm	3 ppm	0.01ppm	0.02-0.07 ppm	0.01 ppm	0.3 ppm	

Table 3: The concentration of different potentially toxic metals in Chocolates, candies and Cocoa

Sample	Source	Concentration of metal (ug/g)								Reference
		Cd	Cr	Cu	Zn	Pb	Ni	As	Fe	
Chocolates and Cocoa	Saudi Arabia	0.001-0.08	0.18-0.66	0.61-9.74		0.033-0.123	0.27-3.17	0.01-0.046		Salama2018
Cocoa based Candies	India	0.0-2.73		0.01	0.03-11.11	0.0-4.0	0.0-5.65			Devi et al., 2016
Milk based Candies		0.0-0.85		0.01	0.00-7.53	0.15-5.74	0.0-3.93			
Sugar based Candies		0.10-0.98		0.0-0.81	0.0-8.02	0.93-3.58	0.0-2.43			
Mix Candies	Imported (USA, Malaysia, Colombia)	0.0-0.05		0.01-3.50	0.01-20.80	0.0-0.60				
Candies and Chocolates	Nigeria	0.001-0.2	0.4-3.0		1.7-12.3	0.08-2.3	1.4-7.9		0.05- 1.49	Iwegbue et al., 2011
Chocolates	Hissar, India	0.17		0.0	2.52	2.0	0.84			Khaiwal, 2018
Chocolates	Tiruchirappalli, India						0.041-5.16	0.03-0.90		Prakash et al., 2014
Soft Candies							0.036-3.46	0.10-4.50		
Hard Candies							0.075-5.47	0.01-2.88		
Dark Chocolate	USA	0.02-1.29				0.002-0.11				Abt et al., 2018
MilkChocolate		0.004-0.31				0.002-0.07				
Cocoa Powder		0.01-3.15				0.02-0.38				
Chocolates and Candies	China		ND – 10.8mg/g	3.0 – 4.2 mg/g	ND – 42.5mg/g		ND – 305.0 mg/g		ND – 102.5mg/g	Ochu,2012
Cocoa Powder	Italy	0.153-0.159				0.417		0.260		Dico et al., 2018
Chocolates		0.016				0.133		0.012		
Cocoa Powder	Poland					0.575				Kruszewski et al., 2018
Chocolates						0.585				
Chocolates Powder	Colombia	209-235.7 ng/g								Chaparro-Acuñaet al., 2017
Cocoa Powder	Ghana	0.017-0.20			49-58	0.32-0.52		<0.006		Vītolaet al., 2016
Permissible Limits		0.05-0.1 ppm	0.05-0.15 ppm	16-20 ppm	18-32 ppm	0.1 ppm	0.05 ppm	0.002 ppm		

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