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RESEARCH ARTICLE

Potential Harmful Effects of Heavy Metals in Milk and Milk Products on Human Health; A Systematic Review

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ABSTRACT

Milk and dairy products are a major source of nutrition, especially for children, because they contain almost all of the nutrients. Consumption of milk and dairy products is high in developed countries and accounts for about 10%-20% of daily calories. Heavy metal poisoning is associated with a number of diseases, but if these heavy metals are found in milk, which is the main food of the vulnerable age group, the severity of the condition becomes even greater. For this review study, keywords such as "Heavy metals", "Milk, milk products, Safety", and "Toxicity" were used. The databases searched for in those articles were "Google Scholar", "SID", "Scapus", "PubMed", "Science Direct", and "ISI" search engines. The degree of heavy metal toxicity depends on their chemical form of metals. Some forms of metals are rapidly excreted and do not have the opportunity to be absorbed and stored in body tissues, accordingly they are not very toxic, while some forms of metals are highly toxic and lethal. These forms are slowly excreted from metals and can be absorbed and accumulated in fish muscles and other organs. Heavy metals cause harmful effects such as carcinogenesis, malformations, damage to the nervous system, damage to the reproductive system and infertility in men, liver failure and cardiovascular disease, and so on. Therefore, The purpose of this review study, Potential Harmful Effects of Heavy Metals in milk and milk products on Human Health.

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Abbreviations

Fe - Iron
Zn - Zinc
Cu - Copper
As - Arsenic
Pb - Lead
Cd - Cadmium
Ni - Nickel
Cr - Chromium
Co - Cobalt
ICP-OES - Inductively coupled plasma-optical emission spectrometry
EU - European Union
FDA - Food and Drug Administration
WHO - World Health Organization

Introduction

Milk and dairy products (cottage cheese, cheese, butter, etc.) one of the most important products in the human diet (1). Milk and its products are considered as a nearly complete food, since they are good sources of

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protein, fat and major minerals (2). On average, mineral elements account for 4 % of total body mass and part of every tissue, liquid, cell and organ in human body (3). Milk plays an important role in human health, especially for infants and children. Milk is a product that is used in diets and therapies and it contains all the necessary nutrients and vitamins for humans (4, 5). Milk contains about 250 different nutrients that include compounds such as proteins, milk fats, carbohydrates, minerals and vitamins are easily digestible (6). Major minerals in milk include Ca, P, Mg, K and Na (3). All the essential minerals can be found in milk because, by definition, it contains the nutrients needed for youthful growth table 1 (7). In addition it provides the human body with vitamins A, C and D. In general, humans need about 300-400 kg of milk and dairy products annually to supply the body with salts and nutrients (8, 9).

Table 1. Concentrations of trace elements in milk (3)

Mineral element	**Milk**
Sulphur (mg/100 g)	32
Iron (µg/100 g)	30-70
Copper (µg/100 g)	2-30
Manganese (µg /100 g)	1.3-4
Zinc (µg/100 g)	74-145
Iodide (µg/100 g)	2-6
Selenium (µg/100 g)	1.3-1.7
Fluoride (µg/100 g)	11-21
Cobalt (ng/100 g)	50-130
Nickel (µg/100 g)	0.4-6
Molybdenum (µg/100 g)	2.4-6
Boron (µg/100 g)	19-95
Bromide (µg/100 g)	154-293
Chromium (µg/100 g)	1-4
Nitrate (µg/100 g)	20-1240
Aluminium (µg/100 g)	46

However, the content of trace elements in milk depends on the content of these elements in beef, which varies considerably from country to country (3). Milk can carry many foreign biotic substances (pesticides, antibiotics, drugs, heavy metals and various environmental pollutants) as a mammary gland excretion, which is a dangerous factor for human health (10). Heavy metal contamination causes environmental concerns, such as entering the food chain and contaminating food, which can be harmful to human health. Unfortunately, in industrial areas, heavy metals can be easily transported through them. Milk and milk-based products have adverse effects on humans. Heavy metals such as cadmium, lead, arsenic, etc. have many toxic effects such as acute syndrome and neurotoxic effects (11, 12).

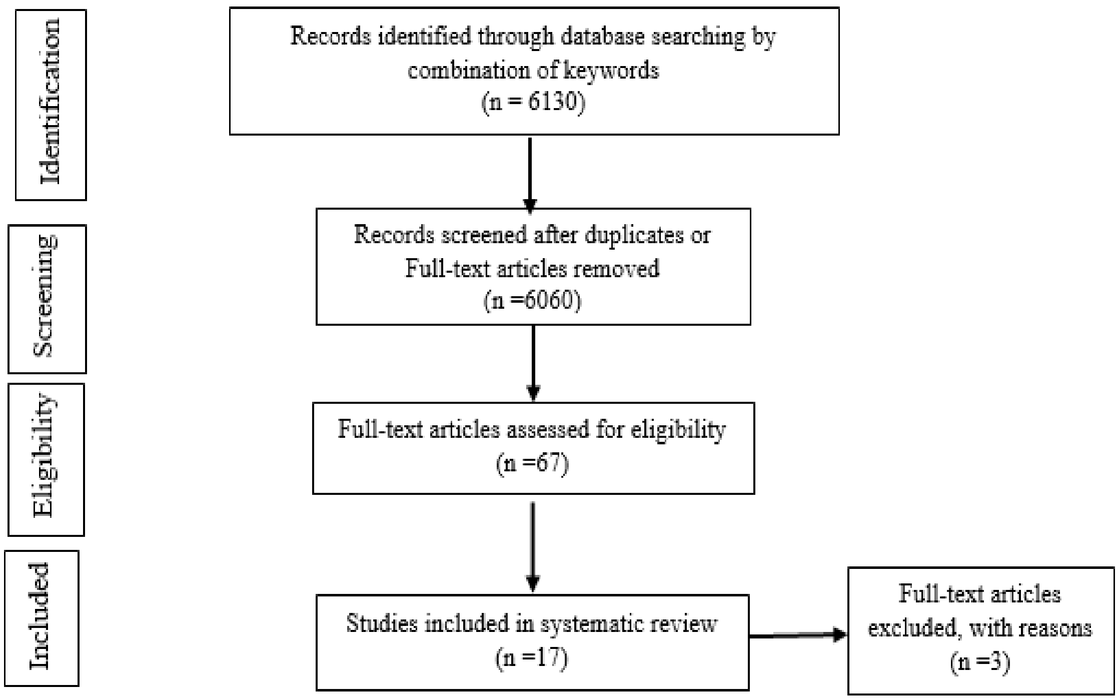
Methodology

Database Study

A complete the databases searched for in those articles were “Google Scholar”, “SID”, “Scapus”, “PubMed”, “Science Direct”, and “ISI” search engines. search was done for articles published that included the search term containing Iranian medicinal plants, medicinal plants, Tooth decay, essential oils, and extracts, Dental caries, Prevention of dental caries in their title. This study focused on published articles papers from 2011 to 2021.

Study Assortment

Articles were selected in total. The chosen papers were published from 2011 to 2021. (Figure 1).



Flowchart 1. The criteria and the number of entry and exit articles

Result

Sources of Heavy Metals in Milk

Heavy metals are commonly found in nature and their concentration in food is increasing day by day. Heavy metals have been contaminated with canal water, soil and agricultural products (13). In addition, it is due to the use of untreated wastewater and industrial effluents to irrigate crops. Studies show that by consuming contaminated food, animals add small amounts of metals to milk through the animal's body (14, 15). Metals may contaminate animal milk through tools and machinery used in milk processing and distribution. For this reason, processed milk has been reported to have higher concentrations of heavy metals than raw milk. In addition, heavy metals may enter milk through feed from infected livestock through irrigation canals with sewage or sewage, the use of pesticides and fungicides, and the presence of industries near feed areas (16).

Toxic Effects of Heavy Metals

In recent years, with increasing population, the demand for land use has increased and the problem of environmental pollution has intensified in the world (17). Source of Heavy Metal Contamination Human activities such as metal mining, smelting, foundry, landfill, automobile and road construction. As well as agricultural activities such as the use of pesticides, fertilizers and insecticides and natural causes such as volcanic activity, metal corrosion, soil erosion, and geological weathering (18). Toxicity of the metal can be defined as the harmful health effects of consuming too much of a certain metal. Metal poisoning through milk is a more serious problem than other foods due to the increased consumption of milk by vulnerable age groups, i.e. infants and the elderly, which is between 30 and 150 kg per year (19). Ni, Co and Cu have been reported to have some positive effects on human health, but certain overdoses may pose health risks, while lead, Cd and Hg are toxic metals that are harmful even at low doses. Evidence shows that a wide range of heavy metals such as lead, cadmium, arsenic, mercury and nickel, etc. cause toxic side effects including teratogenic and mutagenic effects, carcinogenicity, lung problems, liver and kidney damage, heart (19) table 2.

According to World Health Organization (WHO), heavy metals concentration which are considered to regulatory limits in milk table 2.

Table 2. Toxicity and Regulatory limits (16, 19-21)

Metals	Effect	Source	Regulatory limits (FAO/WHO) µg/ml
Lead (Pb)	Mutagenic effects, carcinogenicity such as lung cancer and bladder cancer, neurotoxic effects, memory loss, hemolytic anemia	Fossil burning, production of lead acid batteries, paints, PVC pipes, batteries, agricultural tools.	0.02
Cadmium (Cd)	Neurodegenerative disorders, ESRD, breast cancer, prostate cancer, demineralization of bones, diabetes.	Burning vapors (from products containing cadmium, phosphate fertilizers, color pigments, PVC products, smoking) and the process of photography and engraving, plated parts, batteries, paints, plastics, optical conductors, synthetic rubber, etc.	0.01
Arsenic (As)	Arsenicosis, psychological effects, decreased mental function, hypertension, risk of cardiovascular disease, carotid atherosclerosis and diabetes mellitus, lung cancer, carcinogenicity.	Water, soil, pesticides, herbicides, insecticides, environmental disinfectants, metal alloys, industrial waste, fossil fuels, etc.	0.1
Mercury (Hg)	Central nervous system disorders, autism, heart and kidney damage, respiratory problems, carcinogenic effects, hair, loss, Headache, lack of concentration, memory loss	smelters, coal, air, soil, water, fertilizers, caustic soda, batteries, emissions from volcanoes, weathering of rocks	1.0
Copper (Cu)	Vomiting, eye irritation, dizziness, liver and kidney damage, oral irritation, anxiety, difficulty swallowing, brain damage and death	Photovoltaic cells, soil, atmosphere, tanning, fertilizers, Copper wires, plating, coins, pipes, fertilizers, wood preservation, chemical tests for sugar detection in Fehling solution, etc.	5
Nickle (Ni)	Carcinogenicity, lung cancer, bladder cancer, lung problems, asthma, allergic reactions, respiratory failure, heart disorders, dizziness.	Chemical industries, food processing industries, forest fires, volcanic emissions, incineration of waste, combustion of coal Soil, air, water, pans & pots etc.	Not Reported
Cobalt (Co)	Carcinogens such as skin, mouth and lung cancer, asthma and bronchitis, edema, liver and kidney damage, nausea and vomiting, heart problems	Metal tools, electrodeposited alloys, varnishes, printing inks, oil-based paints, in air by industrial burning etc.	Not Reported

Some studies indicate the some metals cause many serious diseases such as cancer (19, 22, 23). Briffa et al. has reported that heavy metals accumulate in the human body due to their bioaccumulation properties and cause diseases such as brain damage, kidney and liver problems, lung cancer, skin cancer and heart failure (22). Perveen et al. has shown that heavy metal contaminants may affect drinking water quality, the food chain, and the environment (24). Zhou et al. reported that Industrial activities cause contamination of lead and cadmium in milk (25). Mostafidi et al. has shown that the measured amounts of lead, cadmium and nickel in all samples of camel milk were less than acceptable for cow's milk. However, changes in the mineral content of camel milk can be due to feed, lactation stage, milk collection time, drought conditions and environmental conditions (26). Harmankaya et al. indicated that Heavy metal contents of creams were found low compared with individually biscuit and gofret wafers (27).

Conficoni et al. Italian industrial ice cream samples were not positive for lead and tin (28).

Data Derivation

In current study was evaluated a Prevalence of Heavy metals in milk and milk products samples from various countries. Details of heavy metal affecting the Human Health and the major results has been shown in the Table 3.

Table 3. Prevalence of Heavy metals in milk and milk products samples from various countries during 2011–2021 (mg/Kg).

Country	Year	Sample	Milk type	Cd	Pb	As	Hg	Cu	Unit	Method	Ref
Egypt	2014	75	examined full cream milk powder	0.09±0.02	0.05±0.01				mg/kg	Flame Emission Atomic Absorption Spectrophotometer	**(29)**
Egypt	2014	75	examined skimmed milk powder	0.03±0.01	0.03±0.01				mg/kg	Flame Emission Atomic Absorption Spectrophotometer	**(29)**
Egypt	2014	75	examined infant milk formula	0.04±0.003	0.03±0.01				mg/kg	Flame Emission Atomic Absorption Spectrophotometer	**(29)**
Egypt	2015	60	milk chocolate	0.040 ± 0.0171	0.1074 ± 0.0343	0.0038 ± 0.0028	ND		mg/L	Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES)	**(30)**
Egypt	2015	60	mikl Strawberry	0.024 ± 0.0060	0.1064 ± 0.0459	0.0057 ± 0.0070	ND		mg/L	Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES)	**(30)**
Egypt	2015	60	milk Banana	0.022 ± 0.0041	0.1067 ± 0.0549	0.0047 ± 0.0052	ND		mg/L	Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES)	**(30)**
Ethiopia	2012		milk					0.206 ± 0.024	mg/L	Flame Atomic Absorption Spectrometer (FAAS)	**(31)**
Italy	2010	50	Artisanal ice cream	0.036	0				mg/kg	ICP-optical emission spectroscopy	**(28)**
Italy	2010	50	Industrial ice cream	0	0.056				mg/kg	ICP-optical emission spectroscopy	**(28)**
India	2020	34	milk	0.022±0.012	0.062±0.01			0.105±0.025	mg/L	inductively coupled plasma-mass spectrometry	**(32)**
Iran	2016	25	camel milk	0.34±0.14	5.31±1.95				µg/L	ICP-OES	**(26)**
Ethiopia	2014	10	milk					0.087–0.122	µg/L	Flame Atomic Absorption Spectrometer	**(33)**
Pakistan	2015	480	milk	0.001	0.014			0.738	mg/kg	flame atomic absorption spectrophotometry	**(16)**
Iran	2013	250	raw milk	1.11 ± 0.51	14.0 ± 2.67			427 ± 174	µg/kg	ICP-OES	**(34)**
Iran	2013	250	pasteurized milk	1.0 ± 0.49	9.59 ± 1.99			378 ± 159	µg/kg	ICP-OES	**(34)**
Iran	2013	250	cheese	1.25 ± 0.58	14.5 ± 2.5			428 ± 155	µg/kg	ICP-OES.	**(34)**
Iran	2013	250	yoghurt	0.99 ± 0.4	7.54 ± 1.76			399 ± 125	µg/kg	ICP-OES	**(34)**
Iran	2013	250	doogh	0.84 ± 0.47	7.2 ± 1.29			320 ± 86	µg/kg	ICP-OES	**(34)**
Iran	2014	60	Pasteurized Milk	3.94	12.5	2.28	21.16		µg/L	ICP-OES	**(10)**
Iran	2014	60	Cheese	5.4	18.21	4.28	27.27		µg/L	ICP-OES	**(10)**
Iran	2014	60	Yogurt	4.79	16.56	3.34	23.81		µg/L	ICP-OES	**(10)**
Iran	2014	60	Yogurt drink	4.06	14.34	2.95	20.35		µg/L	ICP-OES	**(10)**
Bangladesh	2014	90	milk	0.053±0.022	0.033±0.006			0.163±0.031	ppm	Flame Atomic Absorption Spectroscopy (FAAS)	**(35)**
Egypt	2014	22	Milk	0.051 ± 0.005	0.214 ± 0.021			0.0953 ± 0.0413	ppm	flame atomic absorption spectrophotometer	**(36)**
Egypt	2014	20	Kareish cheese	0.09 ± 0.009	0.43 ± 0.029			0.087 ± 0.026	ppm	flame atomic absorption spectrophotometer	**(36)**
Egypt	2014	21	Butter	0.057 ± 0.005	0.49 ± 0.021			0.60 ± 0.104	ppm	flame atomic absorption spectrophotometer	**(36)**
Egypt	2014	14	Rice pudding	0.067 ± 0.01	0.1999 ± 0.029			0.102 ± 0.013	ppm	flame atomic absorption spectrophotometer	**(36)**
Egypt	2011	100	milk	0.245±0.128	3.141±1.454			1.448±0.623	µg/g	atomic absorption spectrometer	**(37)**
Turkey	2012	144	raw milk	0.006	0.004	0.003		1.130	mg/kg	inductively coupled plasma mass spectrometry (ICP-MS)	**(38)**
Croatia	2010	157	raw milk	2.58±2.91	47.45±77.6	31.5±85.25	4.34±9.02	890.15±1819.05	µg/l	graphite furnace-atomic absorption spectroscopy	**(39)**
Mitrovica	2014		raw milk	0.032	0.703				mg/l	atomic absorption spectrophotometry	**(40)**
Iran	2012	1440	raw milk	0.3 ± 0.3	12.9 ± 6.0		3.1 ± 0.3		Ng/g	atomic absorption spectrophotometry	**(41)**
Iran	2012	1440	ewe milk	1.6 ± 1.2	14.9 ± 7.8		3.1 ± 0.3		Ng/g	atomic absorption spectrophotometry	**(41)**

Conclusion

The purpose of this study is to document and compare the results of previous studies on the prevalence of heavy metals in milk and milk products in different parts of the world. Studies show that industrial and agricultural activities are the most common sources of pollutants entering the food chain. Heavy metals can cause acute and chronic diseases and endanger human health. Children and the elderly are exposed to heavy metals due to the high consumption of milk and dairy products. In developing countries, due to fewer regulations and poor enforcement by law enforcement agencies, the level of heavy metals in milk and dairy products has increased. In contrast, developed countries are less prone to heavy metal pollution problems. In general, stronger assessments of milk heavy metals are needed in developing countries.

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Conflict of Interest

There is not any conflict of interest.

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