



Comparative Assessment of Arsenic Contamination in Raw Milk, Infant Formulas and Breast Milk



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Abstract

Rapidly growing urbanization and increased industrialization has led to introduction of numerous detrimental toxicants into the environment. Such toxicants which are hazardous to human health, ultimately become a part of our food chain and accumulate in human body, in levels exceeding permissible limits. One of the most common food toxicants is heavy metals out of which Arsenic ranks 1st in the list of top 20 hazardous substances. Arsenic intake has been found to induce skin, liver, bladder and lung cancers, disturb GIT, cause fatigue, arrhythmia, bruising, nerve impairment, hyperkeratosis, hyperpigmentation of skin, gangrene, cyanosis and black foot disease. Milk and milk-based products from different milch animals that make up one of the most nutritious categories of food are reported for being contaminated with Arsenic, worldwide. Arsenic is introduced in milk from human and other milk producing animals by the intake of arsenic contaminated water or through their feed. On the other hand, breast feeding is reducing day by day due to a false verdict that it is unsafe for infants whereas infant formula milk is safer, as heavy metals like arsenic become a part of human milk in areas with high arsenic content in drinking waters. Therefore, this review highlights various studies determining arsenic contamination in raw milk, infant milk formulas as well as breast milk, in an attempt to create awareness regarding which mode of infant nutrition is safest to choose.

Keywords: Arsenic; Heavy Metals; Milk Contamination; Infant formulas; Breast feeding

Introduction

From farm to fork, food is subjected to numerous potential hazards of physical, chemical and microbiological nature, making it quite a challenge to ensure that the food is not at all toxic for human consumption [1,2]. Toxicity is a condition when a micronutrient or additive or any toxic compound exceeds its safety limit and causes adverse health effects. The trace elements in different foods are of significant interest because of their essential (as micronutrients) or toxic nature. Although there are many potential toxins related to foodstuff but heavy metals are quite common and abundant. Heavy metals are the metals which have high density (more than 5 g/cm³) and are dangerous for human consumption if exceeding their safety limits. According to the list of "Top 20 Hazardous Substances" compiled by the U.S. Environmental Protection Agency and the Agency for Toxic Substances and Disease Registry (ATSDR), heavy metals including Arsenic (As), Lead (Pb), Mercury (Hg), and Cadmium (Cd) stand on 1st, 2nd, 3rd and 4th position, respectively. Arsenic is of prime importance as it is a common yet potent water contaminant and from there it transfers to different food by coming in contact directly or indirectly. This heavy metal has been reported to pose multiple adverse effects on human health as well.

Milk and milk-based products make up one of the most nutritious category of foods rich in protein and minerals, a great

source of calcium and magnesium, as well as trace amounts of essential elements such as iron, copper and zinc. Since, the primary form of feed at infant level to almost all ages is milk, therefore milk and milk-based products have always been valued for their significant role in body growth and development. Unfortunately, the rapidly increasing urbanization and growing industrialization have immensely polluted the environment and consequently milk and milk-based products have been highly contaminated with several toxic substances particularly heavy metals that may pose detrimental effects to human health [3]. Milk is also being contaminated with arsenic. Arsenic is introduced in milk from human and other milk producing animals by the intake of arsenic contaminated water or through their feed. This is known to exceed the safety limits i.e. 0.1 mg/ml. Breast feeding is reducing day by day due to false consideration that it is not safe for infants whereas infant formula milk is safer, as heavy metals like arsenic becomes a part of human milk in areas with high arsenic content in drinking waters. This review paper is written to shed some light on this issue and highlight the studies that indicate the arsenic contamination in milk.

Heavy Metals

Heavy metals are the metals whose specific gravity exceeds 5g/cm³ in their standard state. The most toxic heavy metals are

namely Arsenic, Lead, Mercury, and Cadmium ranked 1st, 2nd, 3rd, and 4th in the list, respectively. Presence of these heavy metals is to be measured in parts per million (ppm), and the obtained values are to be compared to the Provisional Tolerable Weekly Intake (PTWI) for toxic metals as set by the FAO. Heavy metals that contaminate milk might originate from the milking utensils, milking personnel, milk processing, contaminated water used for agricultural purposes and animal fodder, as well as the immediate surroundings of milch animal [2].

Heavy Metals Toxicity

The toxicity of heavy metals results due to the long-term exposure to low contamination sources in our environment, including in the air we breathe, water and food we consume. Lead, chromium, nickel, cadmium and cobalt are the common heavy metals that might contaminate cows and other environments, disrupt milk at different levels and cause numerous problems. The contamination of milk products with heavy metals might be a consequence of the contamination of the basic cow milk that has been exposed to contaminated atmosphere including feed or poor water source. Moreover, contamination of raw milk might occur during its production. Cadmium, mercury and lead are quite hazardous to human health therefore they are referred to as a major menace to humans when consumed along with food [2]. Another study named as "Lead and Mercury in Breast Milk", has reported the presence of Mercury in breast milk as well as bovine milk in substantially higher amounts as compared to those observed in common infant formulas. Whereas the Levels of lead in breast milk are relatively lesser than that found in milk-based infant formulas [4].

Health Risks Associated with Heavy Metals

Heavy metals belong to a class of pervasive toxicants that prevail everywhere in land, air and water. Among all the toxicants, arsenic (As) and mercury (Hg) were considered to be unusual, since they exist in a series of different chemical species with diverse toxicities to human beings [5]. Heavy metals when accumulate in the body might cause various diseases including nervous system disorders, renal failure, genetic mutations, types of cancers, neurological disorders, respiratory disorders, cardiovascular diseases, immune system weakening and infertility. Lead causes onset and development of various cancers, central nervous system disorders, anemia, renal, hepatic and cardiac damage, compromised immune system as well as weakened GIT tract. Lead can also cause encephalitis and hepatitis. Whereas Cadmium deposits in body tissues just like the liver and kidneys, causing anemia, as well as elevated blood pressure. Cadmium is also a potent carcinogen that can readily induce tumor development particularly in the prostate and lungs.

Health Risks Linked with Arsenic

Arsenic toxicity has emerged as a worldwide health issue that has affected masses of people because of its high prevalence in land, air and water resources, as well as absorption in food

crops. The maximum permissible limit for arsenic in milk established by European Union Commission is about 0.1 mg/ml (European Union 2006). The organic forms of arsenic such as monomethylarsenic (MMA), dimethylarsenic (DMA), arsenobetaine and arsenocholine have been observed to be relatively nontoxic in comparison to its inorganic forms arsenite (AsIII) and arsenate (AsV) that have been categorized as Type 1 carcinogens by the International Agency for Research on Cancer (IARC) [6]. Comprehensive data is present to validate the oral-toxicity of inorganic arsenic along with its various carcinogenic and non-carcinogenic effects. Its intake has been reported to cause generalized body fatigue, disturbed GIT, arrhythmia, bruising and nerve impairment. The most distinctive effects that are observed as a result of prolonged oral exposure of arsenic are hyperpigmentation of the skin and hyperkeratosis. Other non-carcinogenic effects might include peripheral vascular effects such as gangrene, cyanosis, blackfoot disease and various other cardiovascular effects including circulatory problems as well as increased blood pressure. Oral exposure to inorganic arsenic has also been observed to increase the risk of cancer in the skin, liver, bladder and lungs [7]. Previous century witnessed a massive, endemic disease just due to contamination of drinking water with arsenic, called Hydroarsenism Chronic Regional Endemic that is associated with a specific type of skin cancer.

A number of factors are responsible for severity of toxicity of arsenic in humans. These factors include age, sex, nutritional status, concentration, dose and duration of exposure to arsenic. Arsenic exposure during gestation period has been observed to pose detrimental effects on development of fetus through irreversible faltering of thioredoxin reductase, methyltransferases and DNA repair enzymes. Human arsenic toxicity has also been associated with epigenetic changes like DNA methylation, histone modification and RNA interference whereas chronic arsenic exposure might result in an increased risk of diabetes mellitus. Arsenic is the first metalloid which is directly associated with adverse pregnancy outcomes (APO) and even induces lung, skin and urinary bladder cancers [8,9]. Long-term exposure to As might result in arsenicosis—a term that refers to arsenic related health effects including internal cancers (lung, kidney, bladder), skin problems, skin cancers, diseases of the blood vessels of the legs and feet, hyperkeratosis, hyperpigmentation, hair hypomelanosis and Mees's lines [10]. The actual mechanism behind how arsenic induces cancers is yet not completely understood. While certain studies declare arsenic toxicity to be affective on child intelligence (e.g., perceptual reasoning, verbal comprehension and working memory) as well [11].

Arsenic in Breast Milk

Mothers' milk is the basic source of nutrition of the offspring; therefore, it is indispensable to ensure that the composition of human milk is safe enough for the infant. Lately, the presence of lead, cadmium and mercury in human milk, has been reported as well. Due to prevalence of arsenic rich bedrock in widespread

areas of the world, ground water is often detected with high concentration of arsenic and travels through the entire food chain to ultimately become a part of mother's milk as well. Native Andeans living in a village at the northwest of Argentina have been reported with high concentrations of arsenic (200µg/l) in the drinking water. Whereas, low concentrations of arsenic were detected in the breast milk and urine of the nursing babies in relation to the high level of maternal exposure. This shows that inorganic arsenic is not found in breast milk to a significant extent. Therefore, there is a quite valid reason for long breast-feeding periods for newborns [12].

A study revealed that in Izmir, breast milk was observed to be considered toxic for suckling infants, but still less than the cow's milk. Therefore, the point to ponder is that arsenic contamination through breast or cow's milk is relatively higher in babies living in areas with higher thermal activity or in regions where ground water has higher arsenic concentration (Ulman, C. et al.,1998). In another study atomic absorption spectrometry was used to measure level of arsenic in 64 samples of breast milk collected from Ankara, Turkey and the arsenic level appeared to be below the limit of quantification (LOQ, 7.6µg/l) in all samples [13]. The probable effects of arsenic contamination for nursing new-borns and infants, were also analyzed by Sternowsky & Moser [14] with a Perkin-Elmer Type 403 hydride-generation atomic absorption spectrometer, equipped with an arsenic EDL-lamp using 36 breast milk samples obtained from three different regions of Germany. Arsenic was not detectable, i.e. below 0.3µg/l, in majority of samples whereas the greatest concentration of 2.8µg/l was obtained in a sample from the rural area. It was revealed that Arsenic concentrations did not vary in samples obtained before and after nursing nor with the age of the infant.

Khan & Ismail [15] also determined arsenic concentration in breast milk samples collected from all over Pakistan. The results of the study indicated the presence of arsenic in the mother milk samples within the range of 0.092-1.240mg/L, while the mean as level was 0.504 ppb. The concentration of arsenic in the mother milk was found to be within the safe limits. Although, Breastfeeding is the primary preventive measure that can be given to the child at birth, the ratio of exclusively breast milk fed babies for their first six months has dropped from about 20% in 1998 to 16% in 2003 [12].

Arsenic in Milk and Milk Products

Arsenic is considered as one of the inevitable contaminants for human beings and is well known as a toxic element since ancient times. Humans are exposed to many chemical forms of both inorganic and organic arsenic but the highly stable organic forms are apparently nontoxic. Arsenic content of foods is generally less than 1 mg/kg, with the exception of seafood in which arsenic is predominantly in the organic form [16]. Prolonged, chronic exposure to inorganic arsenic through breathing, drinking or ingestion has been linked to, skin, lungs and urinary bladder cancer

[17]. In past decade, almost 13,000 Japanese infants have been afflicted with contaminated milk powder, majorly in the western part of the country where industrialization was considerable. Affected infants reported diarrhea, fever, skin pigmentation, whereas more than 100 died from acute poisoning [4].

Carrera et al, 2004 also determined the concentration of arsenic in cow milk samples collected from Cordoba. The arsenic was found to be in the range of 0.3-10.5 ng/g. Dakeisi et al, 2006 analyzed the concentration of arsenic in milk powder as well. The level of arsenic contamination in milk powder was found to be in the range of 4-7mg/l. In 2005, ANTUNOVIĆ et al, used a hybrid technique on an atomic absorption spectrophotometer to determine the arsenic content of milk and the results revealed that arsenic concentrations in ewe milk varied depending on the lactation stage. Concentration of arsenic was lower in colostrum at 2nd lactation day (As:0.011mg/kg) as compared with milk on the 10th (As: 0.025 mg/kg), 30th (As: 0.028 mg/kg) and 60th (As: 0.029mg/kg) lactation day. Licata & Trombetta [18] assessed the milk from 40 cows bred on various farms in Calabria to determine the load of heavy metal contamination in them. Quantitative analyses performed using an atomic absorption spectrophotometer with graphite furnace; followed by hot vapor generation technique showed the mean concentration of as in samples was about (37.90µg/kg). In 1999 arsenic levels were determined in cow milk samples collected at the most important dairy farms of the Comarca Lagunera in Coahuila and Durango, Mexico, a region naturally rich in Arsenic. Arsenic concentrations found in milk ranged from <0.9 to 27.4 ng g-1. Using a pharmacokinetic approach, it was found that the cow's milk biotransfer factor for arsenic was up to 6×10^{-4} [19].

The concentration of Arsenic in Philippine's infant formula milk for 6-12 months old was also analyzed by Cruz, Din [20] using Atomic Absorption Spectrophotometry and results were compared with an existing standard for permissible quantities of arsenic in food products as set by the World Health Organization. All the infant formulas tested showed up to be negative for Arsenic. Another study was conducted to determine arsenic concentration in 32 raw cow milk samples collected from traditional and industrial sites of Arak City, Markazi Province, Iran using an atomic absorption spectrometer. The residual amounts of as were found out to be lower than permissible limits established by Codex Alimentarius [2].

Therefore, considering the stated previous studies, we cannot conclude that all the infant formula milk available in markets worldwide, contains toxic heavy metals or not. However, this study can be further utilized as a reference or a foundation for future in-depth analysis of heavy metal contamination in various foods. This review can also help create awareness among consumers, manufacturers, and the professionals in the health care system because of its cumulative display of important statistics regarding heavy metal contamination in foodstuff.

Conclusion

Milk is no doubt affected by the heavy metal contaminated water sources, yet the above discussed studies showed that human milk is still the safest of all, as arsenic levels do not vary significantly even if one is taking arsenic contaminated water in daily routine, however it may be a potent risk on a long term basis. Furthermore, safety of milk obtained from different animals with respect to arsenic contamination showed that if it is taken from a sheep, it is least susceptible to Arsenic toxicity even from a place with higher Arsenic content in water, but the cow milk is most susceptible. In a nutshell the misconception of breast milk being unsafe and infant formulas being safer is under question and the studies show that breast milk is the safest among all other milk sources.

Conflict of Interest Disclosures

There are no conflicts to report.

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