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RISK ASSESSMENT OF LEAD IN MILK AND DAIRY PRODUCTS

Abstract. In the present study, a quantitative dietary exposure assessment of lead was conducted using the contamination data of milk and dairy products. Milk and dairy products (n = 120) were analyzed for the presence of toxic elements, such as lead. Milk and dairy products were collected in markets and supermarkets of Shymkent, in accordance to structured sampling plan and analyzed, during the period from January 2016 till October 2017. The usual intake of these food groups was estimated from the results of a social survey of consumption of dairy products. According to a probabilistic exposure analysis, the mean (and P95) lead for milk and dairy products was 0.00138 (0.00318, P95) mg kg^{-1} body weight day^{-1}. These values were below the tolerable daily intake (TDI) levels for lead (0.007 mg kg^{-1} body weight day^{-1}). The absolute level exceeding the TDI for milk and dairy products was calculated, and recorded 0.1% of population.
Key words: risk, lead, hazard, milk, dairy products, heavy metals.

Introduction

Exposure to toxic elements ("heavy metals") causes health problems such as toxicity of the liver, kidneys, hematopoietic system, and nervous system. Metals differ from other pollutants in that they are neither created nor destroyed and occur naturally in the environment. Anthropogenic activity largely contributes to human exposure because metals are bioconcentrated from the environment, people are exposed to toxic elements through a variety of routes, such as second hand exposure to pollution in the workplace, everyday household products [1-3].

Lead is one of the most common and hazardous toxicants. Lead is used in production of batteries, ammunition, metal products (solder and pipes), alloys, pigments and compounds, cable sheathing, and devices to shield X-rays. The risk of lead for a person is determined by its significant toxicity and ability to accumulate in the body. Most of the lead comes from food products (from 40 to 70% in different countries and in different age groups), and also with drinking water, atmospheric air, smoking, with accidental ingestion of lead-containing paint or lead-contaminated soil into the esophagus. With atmospheric air, small amount of lead is supplied 1-2%, but most of this lead is absorbed in the human body. The highest levels of lead are observed in canned foods in tin cans, fresh and frozen fish, wheat bran, gelatin, mollusks and crustaceans. A high content of lead is observed in root crops and other plant products grown on lands near industrial areas and along roads [4-6].

For all food products, the maximum permissible levels of heavy metals are established. The relevant authorities monitor compliance with standards. The presence of each metal in food is controlled by methods of chemical analysis, and in the human body by norms of maximum permissible concentrations [7].

The maximum permissible concentration of lead in tap water is 0.03 mg kg^{-1}. The total content of lead in the human body is 120 mg. TDI - 0.007 mg kg^{-1} body weight [4,5].

In an adult human body, an average of 10% of lead is absorbed, in children 30-40%, 90% of lead is excreted with physiological fluids, the biological half-life is 20 days in blood, and 20 years in bone [3-8].

The mechanism of lead toxic effect is determined in two main directions: 1) blockade of functional sulfhydryl groups of proteins, that leads to inhibition of many vital enzymes; 2) penetration of lead into nerve and muscle cells, formation of lead lactate by interaction with lactic acid, then the formation of lead phosphate, which creates a barrier to the penetration of nerve and muscle cells of calcium ions, and -as result - development of paralysis. Thus, main targets under the influence of lead are hematopoietic, nervous, food systems and kidneys. It noted its effect on sexual function of the body [4, 9-13].

The individual susceptibility to lead poisoning varies widely, and same doses of lead may have greater or lesser effect for different people. Characteristic symptoms of poisoning are pallor of face, loss of attention, poor sleep, tendency to frequent mood changes, increased irritability, aggressiveness, fatigue, and metallic taste in the mouth.

Measures to prevent lead food contamination include departmental and state control of emissions, control over the use of tinned, glazed, ceramic food utensils.

The most consumed group of food products (on average per capita) in Kazakhstan households is milk and dairy products (Statistics Committee of the Ministry of National Economy of the Republic of Kazakhstan).

People of Kazakhstan on average consume 290 kg of dairy products per year per person [14].

The aim of the work is to determine the content of lead in milk and dairy products and the potential risk to the health of population of the South Kazakhstan Region (SKR).

Objects and methods of research

As objects of research, dairy products, sold in markets and supermarkets of Shymkent (SKR), were chosen. In the city, a large part of population satisfies the needs for food products at expense of local and own products.

Sampling and sample preparation were carried out in accordance with the regulatory documentation for each type of product. The lead content in dairy products was evaluated on an inductively coupled plasma mass spectrometer (ICP-MS) device in accordance with ST RK ISO 17294-06 [15].

A total of 120 milk and dairy products samples were selected and analyzed.

The research was carried out in the laboratories of the "Food Engineering" department and in testing regional laboratory of engineering profile "Structural and Biochemical Materials" at M. Auezov SKSU.

A social survey (interview) of the population of Shymkent on consumption of milk and dairy products was conducted. The age of population that participated in survey was 12 years and older.

The usual food intake was expressed as mg kg^{-1} bw day^{-1} using self-reported body weight (bw) data collected during survey.

Three different scenarios were included for the lead dietary exposure assessment in relation to the data treatment of the non-detects (< LOD): lower, medium and upper bound.

Non-detects were considered as zero, 1/2 LOD and LOD for lower, medium and upper bound, respectively.

Calculations of probabilistic exposure assessment were executed using the software *@Risk* for Microsoft Excel version 7 (Palisade Corporation, USA). Best fit was based on chi-square statistics. The probability/probability plots (P/P) and the quantile/quantile plots (Q/Q), resulting from the cumulative distributions, were a parameter if the cumulative distributions corresponded to the theoretical cumulative distributions. First order Monte Carlo simulations were performed considering 10000 iterations. The estimated intake of lead (mean, maximum and percentiles) was determined. Output of exposure was compared to lead TDI [16,17].

Results and discussion

The results of lead content in dairy products produced in SKR are presented in table 1.

The calculation of food contaminants daily load on population was carried out on basis of data from the social survey on volume of consumption of foodstuffs with rations.

The results of the research establish that not all dairy products contain lead.

Based on data of the social survey of Shymkent population (280 people), lead intake with food products was established. Contribution of milk origin products to the total value of the population exposure is determined.

Table 1 - Calculations of concentration of Pb in products (mg kg^{-1}) and consumption product (kg day^{-1} bw^{-1})

Concentration Pb in products, mg kg^{-1}	Consumption milk and dairy products, g day^{-1} (bw, kg)	Consumption milk and dairy products, kg day^{-1} bw
0.03	450 (52)	0.0086
0.02	300 (49)	0.0061
0.01	200 (67)	0.0029
0.02	350 (55)	0.0060
0.3	250 (50)	0.005
0.01	220 (55)	0.004
0.03	200 (58)	0.0034
0.02	180 (65)	0.0027
…	…	…
0.01	100 (55)	0.0018

Recently, studies have reported the concentrations of heavy metals, including Pb, in various milk samples, the results of which showed that the content of heavy metals did not exceed the maximum allowable concentrations specified in the technical regulations [18]. The presence of Pb through plants in milk can arise from environmental sources (region, climate, and soil composition) and anthropogenic sources (by fertilizers and chemical protection of plants) toxic metals come from soil, water. [19]. Since pollutants are able to disperse via air, surface water, and groundwater, heavy metal contamination can be a serious problem in crop production [20].

The overall results of Pb exposure are shown in Tables 2 and 3 (probabilistic).

Since the mean, the 95 percentiles as the maximum exposure are above the TDI value, there is a small risk for the population.

In probabilistic analysis every possible value that each variable can have. The mean of each possible scenario is taken into consideration, therefore allowing a more accurate lead intake estimation. Best fit distributions were formed for lead concentrations in milk and dairy products and all consumption data.

The best fit distributions determined for the upper bound scenario of lead concentrations in products, further applied for the probabilistic calculations are listed in Table 2.

Table 2 - Cumulative distribution of the risk analysis of exposure to Pb

Probabilistic	
Distribution consumption	0.003649 Risk Invgauss (0.003401;0.00688;Risk Shift(0.0001998)
Fraction of consumption	0.058
R and between	1
Distribution Total population	0.002715

Table 3 represent the probabilistic estimates of lead intake (mean, standard deviation, maximum, percentiles) (mg kg^{-1} bw day^{-1}) by population for the upper bound (worst case scenario) of dairy products.

Table 3 showed for lead that 0.1% of population SKR exceeds the TDI of 0.007 mg kg^{-1} bw day^{-1}, potentially indicating that the concentrations found in the analyzed foods cause on daily scale exposure on the health population.

Table 3 - Predictive analysis of Pb estimate for consumption of milk products (mean, percentiles, mgkg^{-1}bwd^{-1}) by the population of Shymkent.

	All Intake (for consumer)
Min	0.000197
SD	0.00092
Mean	0.00138
Max	0.00993
Med (P50)	0.00112
P90	0.00253
P95	0.00318
P99	0.00475
P(X<TDI)	99.9%
Fraction population exceeding	0.1%

The interpretations of risk analysis results are shown in figures 1. The 0.1 % of the population is exposed to concentration of Pb that is above the MPL value of 0.1 mg kg^{-1}: there is possible hazard for the population.

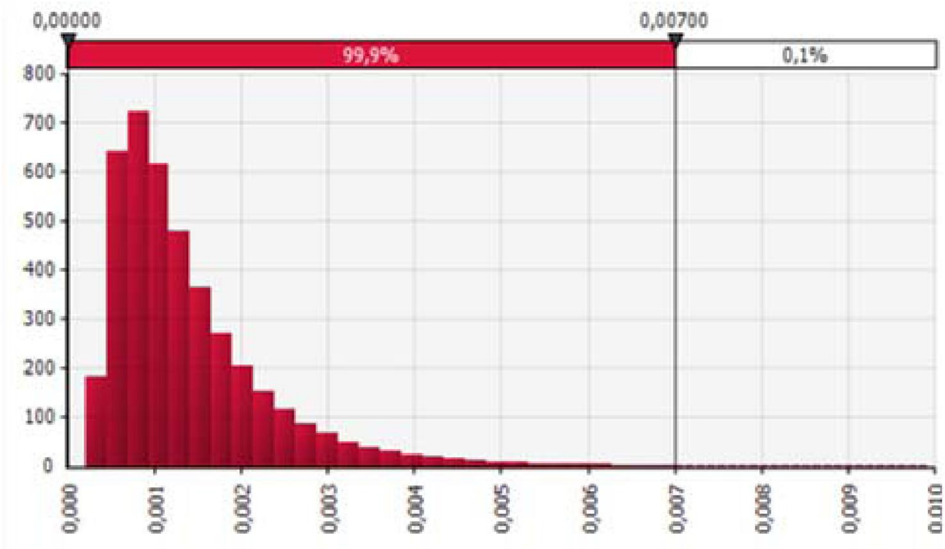

Figure 1 - Predictive risk of consumption of milk and dairy products contaminated by lead (mg kg^{-1} bw day^{-1})

The obtained results show that 0.1% of the population is exposed to possible risk at consumption of milk and dairy products contaminated by Pb.

Conclusion

Thus, levels of lead in milk and dairy products are established, risks of adverse effects of controlled lead coming from finished products produced in SKR are calculated, need to conduct constant monitoring of food safety is confirmed. According to probabilistic impact analysis, the mean (and P95) lead intake for dairy products was 0.00138 (0.00318, P95) mg kg^{-1} body weight day^{-1}. These values were below permissible level of daily intake (TDI) for lead (0.007 mg kg^{-1} body weight day^{-1}). To reduce the risk of population's morbidity by toxic elements like lead, it is necessary to carefully control emissions of industrial enterprises into the atmosphere, soil, water and avoid pastures for animals near industrial centers and major highways.

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СҮТ ЖӘНЕ СҮТ ӨНІМДЕРІНДЕ ҚОРҒАСЫН ТӘУЕКЕЛІН БАҒАЛАУ

Аннотация. Зерттеу барысында сүт және сүт өнімдерінің ластануы туралы мәліметтерді пайдалана отырып, азық-түлік өнімдерінде сандық бағалау жүргізілді. Сүт және сүт өнімдері (n = 120) қорғасын тәрізді улы элементтердің болуы үшін талданды. Шымкенттің нарықтарында және нарықтарында құрылымдық іріктеу жоспарына және талдауына сәйкес 2016 жылдың қаңтарынан 2017 жылдың қазанына дейін сүт және сүт өнімдері жиналды. Осы азық-түлік топтарының әдеттегі тұтынуы сүт өнімдерін тұтынуды әлеуметтік сауалнама нәтижелері бойынша бағаланды. Ыдырау ықтималды талдауына сәйкес сүт өнімдеріне арналған орта (және P95) қорғасын тұтыну тәулігіне 0,00138 (0,00318, P95) мг / кг дене салмағының 1 болған. Бұл мәндер қорғасын үшін тәуліктік қабылдаудың (рұқсат етілген күнделікті тұтыну-РКТ) рұқсат етілген деңгейінен төмен (0,007 мг/кг$^{-1}$ дене салмағының күніне$^{-1}$). Сүт және сүт өнімдері үшін РКТ-дан жоғары болатын абсолютті деңгей есептелді және халықтың 0,1% құрады.

Түйін сөздер: тәуекел, қорғасын, қауіп, сүт, сүт өнімдері, ауыр металдар.

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ОЦЕНКА РИСКА СВИНЦА В МОЛОКЕ И МОЛОЧНОЙ ПРОДУКЦИИ

Аннотация. В настоящем исследовании была проведена количественная оценка содержания свинца в пищевых продуктах с использованием данных о контаминации молока и молочных продуктов. Были проанализированы молоко и молочные продукты (n = 120) на наличие токсичных элементов, как свинец. На рынках и маркетах г.Шымкента в соответствии со структурированным планом выборки и анализом в период с января 2016 года по октябрь 2017 года были собраны молоко и молочные продукты. Обычное потребление этих пищевых групп оценивалось по результатам социального опроса потребления молочных продуктов. В соответствии с вероятностным анализом воздействия, среднее (и P95) потребление свинца для молочных продуктов составляло 0,00138 (0,00318, P95) мг кг$^{-1}$ массы тела в день$^{-1}$. Эти значения были ниже допустимого уровня суточного потребления (ДСД) для свинца (0,007 мг кг$^{-1}$ массы тела в день$^{-1}$). Был рассчитан абсолютный уровень, превышающий ДСД для молока и молочных продуктов, и составил 0,1% населения.

Ключевые слова: риск, свинец, опасность, молоко, молочные продукты, тяжелые металлы.