RESEARCH ARTICLE

Risk assessment of the rural population health from exposure to polluted food products

Emiliya R. Valeeva, Natalya V. Stepanova, Firziya M. Kamalova, Alfiya I. Ziyatdinova, Dmitry A. Semanov, Farida I. Serazetdinova

Department of Medicine, Institute of Fundamental Medicine and Biology, Kazan Federal University, 18 Kremlyovskaya St., 420008 Kazan, Republic of Tatarstan, Russian Federation

Abstract

Aim and Scope: In the diet of the rural population, milk, dairy products, meat and meat products, fish, bread, and bread products make the largest contribution to the exposition of cadmium, arsenic, and mercury. The cardiovascular, hormonal, central nervous, immune, reproductive systems, blood, and kidneys are most at risk. Non-carcinogenic risk for imported food products is determined by the systems: Blood, hormonal, central nervous, and reproductive. **Materials and Methods:** Statistical analysis of the obtained data was implemented operating system Windows 2007 with the application of standard application program packages Excel 2007 and "Statistics v.6.0". **Result and Discussion:** Comparative analysis of the obtained data revealed that the Republic of Tatarstan had higher indices in the content of pollutants in the fruit and vegetable products. As the result of our studies, we excluded such pollutants as aflatoxin, copper, zinc, sulfur, dioxide, iron, peroxidase, and desoxynivalenol, which were revealed on one occasion or the studies failed to register them.[27] **Conclusion:** The levels of the toxic substances' content in basic food products consumed by the population of the Republic of Tatarstan did not exceed the maximum allowable concentration for the period from 2004 to 2014.

Key words: Non-carcinogenic risk, nutrition, pollutants, rural population health

INTRODUCTION

Nutrition is the primary factor determining the public health worldwide. In the year of 2000, the 53rd session of the World Health Assembly adopted a resolution calling on the World Health Organization and its Member States to recognize food safety as an essential public health function.[1]

Environmental pollution with toxic elements such as lead, cadmium, arsenic, and mercury interferes with the population health and is one of the most acute ecological problems not only in Russia but also all over the world. Food products are ranked as the leading ones when assessing the contribution of the chemical load factors information of the population health.[8] To assess the hazard associated with the effect of chemical substances polluting the food products, the risk assessment methodology is used. The risk assessment also serves as the scientific basis for risk analysis, risk minimization measures, risk elimination, and distribution of information about risk.[9-11] The WHO carries out scientific risk assessments focused on determination of safe limit values of the chemical substances' concentration. These assessments are used as the fundamentals when developing national and international standards in the field of the food products security directed toward the consumer health protection and creating conditions for fair trade in Russia as well, and the Republic of Tatarstan, in particular, risk.[12-15]

Important state documents in the field of safe nutrition are adopted in Russia. They are as follows: "Food Security Doctrine" (The RF Government Executive Order of January

Address for correspondence:
Emiliya R. Valeeva, Institute of Fundamental Medicine and Biology, Kazan Federal University, 18 Kremlyovskaya St., 420008 Kazan, Republic of Tatarstan, Russian Federation.
E-mail: Val_med@mail.ru

Received: 27-11-2017
Revised: 05-12-2017
Accepted: 10-12-2017

30, 2010, No. 120),[16] "Fundamentals of the State Policy of the Russian Federation on Healthy Nutrition of the Population for the Period up to 2020 (The RF Government Executive Order No. 1873- p of October 25, 2010),[17] and "On Recommended Rates of Consumption of the Major Food Groups" (The RF Order of the Ministry of Healthcare and Social Development No.593n of August 2, 2010 "On Approval of Recommendations on the Rational Standards of Consumption of Food Products Conforming to the Contemporary Requirements for Healthy Nutrition,"[18] where the primary role of nutrition in the population health maintenance and promotion was approved.

The system of risk assessment based on monitoring of factors and the population health will allow obtaining quantitative and qualitative characteristics of the factor effect on the health well before the manifestations and consequences of this effect. The experience in the application of the risk assessment and management methodology in many regions of Russia showed that it could significantly enhance the effectiveness and reliability of the activities on the provision of sanitary and epidemiological welfare of the population in our country.[19,20]

If assessments of risks associated with the effect of pesticides, veterinary drugs and food additives are usually confirmed by, then there are less data on the toxicology of pollutants in food products. The issues of various pollutant loads of the food products and their effect on the population in different regions of Russia are also poorly studied. This aspect of the problem is of great importance because the population nutrition can vary considerably in different regions. Selection of the population groups, in which ingestion of pollutants with food intake will exceed the established hygienic regulations, will allow carrying out their in-depth examination for revealing the status of a pre-existing disease or diseases, which are possibly associated with the given specific factors. Moreover, such approach will allow moving to a novel monitoring system - monitoring of pollutant load on the population on the whole and on certain groups, primarily on the risk groups.[21,22]

Agriculture of the Republic of Tatarstan is one of the leadings in RF. Possessing 3.8% (7.86 million ha) of the farmland of Russia, the Republic produces 3.4% of its total agricultural products. Agriculture of the Republic of Tatarstan is under the authority of the Ministry of Agriculture of the Republic of Tatarstan. The total acres of the farmland as of 2014 made 3682.6 thousand ha. The Republic of Tatarstan is an area of risk farming for growing of heat- and moisture-loving crops. Nevertheless, the Republic, using 2.3% of the farmland of Russia, produces 5% of its agricultural products. The farmland occupies 4.4 million ha of lands (65% of the territory of the Republic of Tatarstan), 77% of them being an arable land, and 23% - feed acreages (pastures and hayfields). Agriculture of the Republic of Tatarstan gravitates toward economically more developed regions, such as the North-West, North-East, and South-East ones. Almost 60% of the gross agricultural outputs are produced in them. Zones of the suburban farming were formed around big cities and industrial hubs. The Republic of Tatarstan specializes in growing of corn, sugar beets, and potatoes, as well as in production of meat, milk, and eggs. The leading branches of agriculture are the plant cultivation and the livestock farming.[2-7]

Due to this fact, the assessment of consequences of the effect of pollutants contained in food products is urgent for the population health in the Republic of Tatarstan.[23]

The aim of the work is to study the levels of the food products pollution with toxic elements with account of the food habits of the rural population in the Republic of Tatarstan**.**

MATERIALS AND METHODS

To study the quality of food products, the research data of the laboratory of the Federal State-Funded Health Care Institution (FBHI) "Center for Hygiene and Epidemiology in the Republic of Tatarstan (Tatarstan)" and the data on consumption of the main product groups based on the results of sampling studies of the household budgets on the whole in the Republic of Tatarstan were used.[20] A questionnaire survey of 950 males and females living in rural settlements on nutrition study and the priority of the products consumed was carried out based on the findings of a sampling study performed in three municipal settlements of the Republic of Tatarstan (Leninogorsky District - the South-East region; Cheremshansky District - the Zakamsky region; and Sabinsky District - Predkamsky/the Kama River region). A total of 260 thousand samples of alimentary raw materials and food products were analyzed for the period from 2004 to 2014.

The risk assessment was carried out according to the data of the regional information fund of social and hygienic monitoring, and results of the research carried out on the basis of an accredited laboratory of the Federal State-Funded Healthcare Institution "The Center of Hygiene and Epidemiology in the Republic of Tatarstan" in keeping with Guidelines P 2.1.10.1920-04.[21]

Exposure calculations and contribution of each of the product groups to total exposure value were carried out according to the formulas (1) and (2):

$$Exp = \frac{\sum_{i=1}^{N} (C_i M_i)}{BW} \quad (1)$$

Where Exp is the value of pollutant exposure, mg/kg body weight/day (mg/kg body weight/week, mg/kg body weight); C_i is the pollutant content in the i^{th} product, mg/kg; M_i is the consumption of the i^{th} product, kg/day (kg/week, kg/year); BW is the human body weight, kg (standard value is 70 kg); N is the total amount of products included in the study.

The product contribution to the total value of pollutant exposure was calculated according to following formula:

$$C_{ontr} = \frac{C_k M_k}{\sum_{i=1}^{N} (C_i M_i)} \quad (2)$$

Where Contr is the contribution of the k^{th} product to the total exposure value; C_i is the pollutant content in the i^{th} product, mg/kg; and M_i is the consumption of the i^{th} product, kg/day (kg/week, kg/year).

Non-carcinogenic risk (route of ingestion: Per os) is assessed by calculating the hazard quotient (HQ):

HQ = I/RfD,

Where I is an average daily dose substances by oral intake, mg/kg, and RfD is a reference (safe) dose.

To assess the total effect of chemical substances, the total hazard index (THI) is used:

HI = HQ1 + HQ2 +... + HQn,

Where HQq, HQ2, and HQn are the HQ of the 1^{st}, 2^{nd} … n^{th} chemical substances. The calculation of HI is usually performed only for the substances, affecting the same body organs and systems. To assess the non-carcinogenic risk, the approach based on safe (reference) doses and THI was used. The non-carcinogenic risk was assessed based on the values of the upper limit of the 95% CI of the results of studies carried out on the basis of an accredited laboratory of the FBHI "Center for Hygiene and Epidemiology in the Republic of Tatarstan" according to guidelines regulating the carrying out of the population health risk assessment in the RF.[21] The study of the pollutants' toxicity was carried out on the basis of chronic daily ingestion of a substance (the peroral route). Characteristics of the total toxic effects were made based on HQ of certain substances and THI for the substances with synergistic effects. Due to the fact that distribution of quantitative EFs was significantly different from a normal distribution, a median (Me) and the 95^{th} percentile (Perc) were used for their presentation.

The nutrition pattern of the rural population is given according to the data of the sampling study in three municipal settlements of the Republic of Tatarstan on the basis of a questionnaire survey according to a specially made chart. A total of 950 subjects took part in the survey, 43.6% of them being males, and 56.4% - females. Results of the questionnaire survey of the rural population were analyzed by descriptive statistics methods for generalization of data obtained within the frames of the sampling study. The procedure was reduced to grouping and summarizing of the findings and tabulation and thereafter to the determination of percentage indices for description of the distribution frequency for each variable in reduction to 100, and proportions are used in a similar way for reduction of data to unity 1. The confidence interval of indices, which we determined, was in the range of 95.0% correct prediction probability for the obtained data transfer on the general rural population of the Republic of Tatarstan.[24-26]

RESULT AND DISCUSSION

The basic product groups with sufficiently high content of toxic substances are on the list of the consumer basket of the rural population in the Republic of Tatarstan, and their consumption volumes are sufficiently high [Table 1].

Hygienic assessment of the content of lead, mercury, cadmium, arsenic, nitrates, and nitrites in seven food groups for the period from 2004 to 2014 in the Republic of Tatarstan was carried out with the account of methodical approaches recommended by the Federal Service for Surveillance of Consumer Rights Protection and Human Well-being.[28] Milk

Table 1: The content of pollutants in fruit and vegetable products depending on the place of production (mg/kg)

Place of production	Percentile	Pollutant				
		Lead	Mercury	Cadmium	Arsenic	Nitrates
The Republic of Tatarstan	50th	0.14405	0.02692	0.10851	0.25405	436.4
	90th	0.54911	0.22341	0.42927	1.72545	705.0
Other regions of the Russian Federation	50th	0.010	0.003	0.000	0.040	90.9
	90th	0.102	0.015	0.009	0.080	977.6
Non-CIS countries	50th	0.010	0.015	0.000	0.050	36.5
	90th	0.154	0.015	0.023	0.106	820.1
CIS countries	50th	0.010	0.003	0.000	0.035	73.0
	90th	0.135	0.008	0.003	0.080	1232.6
MAC		0.4	0.02	0.03	0.2	60–2000

(1) The Republic of Tatarstan. (2) Other regions of the RF. (3) Non-CIS countries. (4) CIS countries. MAC: Maximum allowable concentration

Table 2: Levels of the toxic substances' content in basic local food products consumed by the population of the Republic of Tatarstan (2004–2014) mg/kg

Product group name	Local products							
	Cadmium		Arsenic		Mercury		Lead	
	Me	95 Perc	Me	95 Perc	Me	95 Perc	Me	95 Perc
MAC	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Meat and meat products; poultry, eggs and processed foods	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
Milk	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Fish	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Cereals	0.0186	0.0186	0.0186	0.0186	0.0186	0.0186	0.0186	0.0186
Sugar	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
Fruit and vegetable products	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165
Oilseed raw materials	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 3: Level of the toxic substances' content in the basic imported food products consumed by the population of the Republic of Tatarstan (for the period from 2004 to 2014) mg/kg

Product group name	Imported products							
	Cadmium		Arsenic		Mercury		Lead	
	Me	95 Perc	Me	95 Perc	Me	95 Perc	Me	95 Perc
MAC	0.05	0.1	0.03	0.5	0.05	0.1	0.03	0.5
Meat and meat products, poultry, eggs and processed foods	0.011	0.763	0.011	0.044	0.002	0.003	0.116	0.168
Milk	0.006	0.008	0	0.045	0.001	0.003	0.017	0.162
Fish	0.038	0.011	0.08	0.369	0.013	0.030	0.241	0.193
Cereals	0.003	0.044	0	0.006	0	0.001	0.140	1.734
Sugar	0.005	0013	0	0.047	0	0.003	0.12	0.146
Fruit and vegetable products	0.012	0.042	0.007	0.018	0.001	0.004	0.185	0.140
Oilseed raw materials	0.0020	0.018	0	0.030	0	0.03	0.044	0.04

and dairy products, vegetable oil and other fats, meat and meat products, sugar, fish, vegetables, melons and gourds, and bread and baked products were studied according to their priority [Tables 2 and 3].

On combined ingestion of pollutants through alimentary tract, the total HI of developing non-carcinogenic effects made 16.2 (95% perc) in local products and 4.6 (95% perc) in imported products.

CONCLUSION

The analysis, which we carried out, showed that the non-carcinogenic risk from the pollution of local food products was formed due to the effect of cadmium, arsenic, and mercury.[29] The systems, which were most vulnerable to the total non-specific effect, were the cardiovascular system (HI) - 3.6; the hormone system with hazard index (HI) - 2.7; the central nervous system with HI - 2.4; the immune system (HI = 1.45); the blood (HI = 0.88); the kidneys (HI = 0.79); and the reproductive system (HI = 0.71). As far as the effect of the imported food products, the functional systems were arranged in the following way: The blood (HI=0.48), the hormones (HI = 0.81), the central nervous system (HI = 0.52), and the reproductive system (HI = 0.41).

ACKNOWLEDGMENTS

This work was funded by the subsidy allocated to Kazan Federal University for the state assignment in the sphere of scientific activities 19.9777.2017/8.9.

REFERENCES

1. WHO. The WHO Global Food Security Strategy. WHO; 2003. Available from: http://www.who.int/publications/list/9241545747/fr. [Last accessed on 2017 Jul 01].
2. WHO. Estimates of the Global Burden of Food borne Diseases. WHO; 2015. p. 255. Available from: http://www.who.int/foodsafety/areas_work/

foodborne-diseases/ferg/en. [Last accessed on 2017 Jul 01].
3. WHO. Estimates of the of Food Borne Diseases: Food Borne Diseases Burden Epidemiology Reference Group 3007-2015. p. 255. Available from: http://www.apps.who.int/iris/bitstream/10665/199350/1/9789241565165_eng.pdf. [Last accessed on 2017 Jul 01].
4. Fukudaa K. Food safety in a globalized world. Bull World Health Organ 2015;93:212.
5. Fetter VV. Human health risk assessment of the chemical contamination of food products and raw foods. Health Risk Anal 2013;4:54-9.
6. Robertson A, Tirado C, Lobstein T, Jermini M, Knai C, Jensen JH, *et al.* Food and health in Europe: A new basis for action. WHO Reg Publ Eur Ser 2004;96:i-xvi, 1-385.
7. Principles and Guidelines for the Conduct of Microbiological Risk Assessment. CAC/GL 30-1999.
8. Working Principles for Risk Analysis for Food Safety for Application by Governments. CAC/GL 62-2007.
9. FAO/WHO. Expert Committee on Food Additives (JECFA). Toxicological Evaluation of Certain Veterinary Drug Residues in Food/Prepared by the Sixty-Second Meeting of the Joint. FAO/WHO; 2004. Available from: http://www.apps.who.int/iris/bitstream/10665/43088/1/9241660538.pdf. [Last accessed on 2017 Jul 19].
10. FAO/WHO Food Standards Programme. Codex Alimentarius Commission Procedural Manual 20th ed. Rome: World Health Organization Food and Agriculture Organization of the United Nations, FAO/WHO; 2011. p. 220. Available from: http://www.ftp.fao.org/codex/Publications/ProcManuals/Manual_20e.pdf. [Last accessed on 2017 Jul 18].
11. Bories G, BrantomP, de Barberà JB, Chesson A, Cocconcelli PS, Debski B, *et al.* Scientific opinion of the panel on additives and products or substances used in animal feed (FEEDAP) on a request from the European commission on the safety evaluation of ractopamine. EFSA J 2009;1041:1-5.
12. Food Security Doctrine of the Russian Federation (Approved by the Decree of the President of the Russian Federation of January 30, 2010; No. 120).
13. Fundamentals of the State Policy of the Russian Federation on Healthy Nutrition of the Population for the Period up to 2020 (Approved by the Russian Federation Government Executive Order, 2010; No. 1873 p. Of October 25,).
14. Order of the Ministry of Healthcare and Social Development of the Russian Federation (Minzdravsotsrazvitiya of Russia). On Approval of Recommendations on the Rational Standards of Consumption of Food Products Conforming to the Contemporary Requirements for Healthy Nutrition. Moscow: Order of the Ministry of Healthcare and Social Development of the Russian Federation (Minzdravsotsrazvitiya of Russia); 2010.
15. Ivanov VP, Vasilieva OB, Polonikov AV. Scientific-methodological bases of assessment of population health risk in complex ecological-hygienic studies of territories. Hum Ecol 2012;11:85-8.
16. Unguryanu TN. Hygienic assessment of food products quality in Novodvinsk. Hum Ecol 2010;12:10-7.
17. Stepanova NV, Valeeva ER, Fomina SF, Kamalova FM, Ju AT, Faizullina RA. Heavy Metals: Effect Issues (using the City of Kazan as an Example) Part1. Kazan: Publishing and Printing Complex LLC "Brig"; 2015. p. 140.
18. Tsunina NM, Ayupova LV. Population Health Risk Assessment from Contamination of Food Products with Contaminants (c.d.*Samara, c.d.Togliatti). Vol. 1. Health Risk Analysis; 2014. Available from: http://www.journal.fcrisk.ru/2014/1/7. [Last accessed on 2017 Jul 19].
19. Stepanova NV, Valeeva ĒR. Main trends in children's population health in the republic of tatarstan. Gig Sanit 2015;94:92-7.
20. Per Capita Consumption of Major Food Products [Electronic Resource]. UISIS. Government Statistics. Available from: https://www.fedstat.ru/indicator/31346. [Last accessed on 2017 Jul 10].
21. Federal Center of the State Committee for Sanitary and Epidemiological Supervision (Gossanepidnadzor) of the Ministry of Health of the Russian Federation. Guidelines on the Population Health Risk Assessment on Exposure to Chemical Substances Polluting the Environment. Vol. 14. Moscow: Federal Center of the State Committee for Sanitary and Epidemiological Supervision (Gossanepidnadzor) of the Ministry of Health of the Russian Federation; 2004. p. 62.
22. Hygienic Requirements for the Safety and Nutritional Value of Food. Moscow: SanPiN 2.3.2.1078-01 Resolution of the Chief State Sanitary Doctor of the Russian Federation; 2001. p. 36. Available from: http://www.docs.cntd.ru/document/901806306. [Last accessed on 2017 Jul 15].
23. Federal Center of Hygiene and Epidemiology of the Russian Federal Service for Surveillance of Consumer Rights Protection and Human Well-being. Uniform Sanitary Epidemiologic and Hygienic Requirements for Goods Subject to Sanitary and Epidemiological Control (Supervision). Moscow: Federal Center of Hygiene and Epidemiology of the Russian Federal Service for Surveillance of Consumer Rights Protection and Human Well-being; 2010. p. 707.
24. Sewalem N, Elfeky S, Fatma E. Phytoremediation of lead and cadmium contaminated soils using sunflower plant. J Stress Physiol Biochem 2014;10:122-34.
25. Gomes AR, Justino C, Rocha-Santos T, Freitas AC, Duarte AC, Pereira R. Review of the ecotoxicological effects of emerging contaminants on soil biota. J Environ Sci Health A Tox Hazard Subst Environ Eng 2017;19:1-16.
26. Mc Evoy JD. Emerging food safety issues: An EU perspective. Drug Test Anal 2016;8:511-20.

27. Mancini FR, Busani L, Tait S, La Rocca C. The relevance of the food production chain with regard to the population exposure to chemical substances and its role in contaminated sites. Ann Ist Super Sanita 2016;52:505-10.
28. Alves S, Tilghman J, Rosenbaum A, Payne-Sturges DC. U.S. EPA authority to use cumulative risk assessments in environmental decision-making. Int J Environ Res Public Health 2012;9:1997-2019.
29. Martí-Cid R, Llobet JM, Castell V, Domingo JL. Dietary intake of arsenic, cadmium, mercury, and lead by the population of Catalonia, Spain. Biol Trace Elem Res 2008;125:120-32.

Source of Support: Nil. **Conflict of Interest:** None declared.