DOI: 10.12731/2658-6649-2022-14-4-89-104
UDC 641.1:632.15

APPROACHES TO RATIONAL NUTRITION OF THE POPULATION OF INDUSTRIALIZED REGIONS EXPOSED TO AEROGENIC IMPACT OF AROMATIC HYDROCARBONS

M.A. Zemlyanova, Y.V. Koldibekova, E.V. Peskova

In the process of sustainable development of regions, negative consequences arise in the form of (1) depletion of natural and energy resources, (2) reduction of biological diversity, (3) violation of the stability of ecosystems, and (4) pollution of environmental objects, including atmospheric air. The constant prolonged chronic aerogenic impact of aromatic hydrocarbons on the human body can make a significant contribution to the formation of additional morbidity and mortality in the population. The ability to neutralize and correct the effect of these compounds is ensured not only by continuous monitoring of the quality of atmospheric air and its impact on human health but also by specifically selected food rations. The analysis of modern theoretical data of international and Russian scientific literature was conducted within the methodological approaches to organizing food for the population in conditions of chemical pollution of atmospheric air. We searched for scientific information in bibliographic and abstract databases. Besides, we presented the average long-term data on (1) the content of benzene and phenol in the atmospheric air and blood in children living under conditions of high chemical aerogenic load with these substances; (2) the state of the antioxidant and conjugation-elimination functions of the benzene biotransformation system; (3) the assessment of the secretion of proteolytic digestive enzymes; and (4) the state of liver cells and excretory-concentration function of the biliary tract. There are examples of food products, the systematic inclusion of which in the diet accelerates the modification and elimination of chemicals; moreover, it has a membrane-stabilizing, hepatoprotective, and antioxidant effect. Acceleration of biotransformation and elimination of toxic substances can be done by including food products with a high content of fiber and pectins in the diet. The acceleration of the metabolism of toxic substances can be carried out by including in the diet foods with a high content of fiber and pectins, polyunsaturated fatty acids, and antioxidant vitamins. The importance of the availability of special diets for all groups of the population

living in industrially developed regions under conditions of aerogenic chemical load, including aromatic hydrocarbons, is shown to minimize the negative impact of human-made chemicals and prevent diseases caused by an increased level of atmospheric air pollution.

Keywords: *air pollution; aromatic hydrocarbons; biotransformation rational nutrition*

For citation. *Zemlyanova M.A., Koldibekova Y.V., Peskova E.V. Approaches to Rational Nutrition of the Population of Industrialized Regions Exposed to Aerogenic Impact of Aromatic Hydrocarbons. Siberian Journal of Life Sciences and Agriculture, 2022, vol. 14, no. 4, pp. 89-104. DOI: 10.12731/2658-6649-2022-14-4-89-104*

ПОДХОДЫ К РАЦИОНАЛЬНОМУ ПИТАНИЮ НАСЕЛЕНИЯ, ПРОЖИВАЮЩЕГО В ПРОМЫШЛЕННО РАЗВИТЫХ РЕГИОНАХ, В УСЛОВИЯХ АЭРОГЕННОГО ВОЗДЕЙСТВИЯ АРОМАТИЧЕСКИХ УГЛЕВОДОРОДОВ

М.А. Землянова, Ю.В. Кольдибекова, Е.В. Пескова

В процессе устойчивого развития регионов возникают негативные последствия в виде истощения природных и энергетических ресурсов, сокращения биологического разнообразия, нарушения стабильности экосистем, и загрязнения объектов окружающей среды, в том числе атмосферного воздуха. Постоянное длительное хроническое аэрогенное воздействие ароматических углеводородов на организм человека может внести существенный вклад в формирование дополнительной заболеваемости и смертности населения. Возможность нейтрализовать и скорректировать действие этих соединений обеспечивается не только постоянным мониторингом качества атмосферного воздуха и его влияния на здоровье человека, но и специально подобранными рационами питания. В работе проведен анализ современных теоретических данных зарубежной и российской научной литературы в рамках методологических подходов к организации питания населения в условиях химического загрязнения атмосферного воздуха. Поиск научной информации осуществлялся в библиографических и реферативных базах данных. Приведены средние данные многолетних наблюдений о содержании бензола и фенола в атмосферном воздухе и крови у детей, проживающих в условиях высокой химической аэрогенной нагрузки этими веществами, о состоянии антиок-

сидантной и конъюгационно-элиминационной функций системы биотрансформации бензола, об оценке секреции протеолитических пищеварительных ферментов, о состоянии клеток печени и экскреторно-концентрационной функции желчевыводящих путей. Приведены примеры пищевых продуктов, систематическое включение которых в рацион ускоряет модификацию и выведение химических веществ, оказывает мембраностабилизирующее, гепатопротекторное и антиоксидантное действие. Ускорение биотрансформации и выведения токсичных веществ может быть осуществлено путем включения в рацион пищевых продуктов с высоким содержанием клетчатки и пектинов. Ускорение метаболизма токсичных веществ может быть осуществлено за счет включения в рацион продуктов с высоким содержанием клетчатки и пектинов, полиненасыщенных жирных кислот и витаминов-антиоксидантов. В исследовании показана важность наличия специальных рационов питания для всех групп населения, проживающих в промышленно развитых регионах в условиях аэрогенной химической нагрузки (в том числе ароматических углеводородов) для минимизации негативного воздействия техногенных химических веществ и профилактики заболеваний, вызванных повышенным уровнем загрязнения атмосферного воздуха.

Ключевые слова: *загрязнение воздуха; ароматические углеводороды; биотрансформация; рациональное питание*

Для цитирования. *Землянова М.А., Кольдибекова Ю.В., Пескова Е.В. Подходы к рациональному питанию населения, проживающего в промышленно развитых регионах, в условиях аэрогенного воздействия ароматических углеводородов // Siberian Journal of Life Sciences and Agriculture. 2022. Т. 14, №4. С. 89-104. DOI: 10.12731/2658-6649-2022-14-4-89-104*

Introduction

Sustainable socio-economic development of the constituent entities of the Russian Federation presupposes economic growth, an increase in production capacity, the development of modern technologies, and an improvement in the quality of life of the population [2]. At the same time, in the process of sustainable development of regions, negative consequences arise in the form of (1) depletion of natural and energy resources, (2) reduction of biological diversity, (3) violation of the stability of ecosystems, and (4) pollution of environmental objects, including atmospheric air. According to the Report of the Government of the Russian Federation "On the state of sanitary and epidemiological well-being of the population in the Russian Federation in 2019," about 80 million people in 41 constituent entities of the Russian Federation (55.4% of the

population) are exposed to chronic chemical loads, including air pollution [19], which has a particular impact on the morbidity and mortality of the urban population associated with environmental factors [1; 13]. In this regard, creating and maintaining a comfortable and safe environment for human life is relevant for the population living in large urbanized cities under conditions of a stable impact of emissions of pollutants that negatively influence health.

Aromatic hydrocarbons are typical chemical air pollutants in large industrial regions of Russia. The negative impact of these chemicals during exogenous intake can affect all ages and social groups of the population living in areas where the established maximum permissible concentrations are exceeded [7; 25]. Long-term chronic load of aromatic hydrocarbons, which are by their nature (synthesized, semi-synthetic, etc.) foreign substances (xenobiotics) for the human body, leads to the dysfunction of organs and systems due to the specific toxic effect of the substance [26]. Several international scientists identified the formation of reactive oxygen species (superoxide anions, hydroxyl radicals, hydrogen peroxide) as a single pathogenetic mechanism of the cellular effect of aromatic hydrocarbons, which cause oxidative stress [26]. This process can damage DNA, mitochondrial dysfunction, and redox homeostasis imbalance. Then, this process can result in multicellular and multi-tissue damage, ultimately leading to many non-communicable diseases [32]. Most of the representatives of aromatic hydrocarbons, in addition to a high level of general toxic effects on the human body, have specific toxic effects (carcinogenic, mutagenic, sensitizing, etc.), which in the conditions of their chronic intake with atmospheric air aggravates the effect on the body's detoxification system and leads to the depletion of its reserves, reducing the degree of proper decontamination of toxic substances. Consequently, one can observe the development of various morpho-functional disorders on the part of the leading organs and systems of the human body [32].

It is possible to level and correct the impact of aromatic hydrocarbons through constant monitoring of the quality of atmospheric air and its impact on human health and specific preventive measures. One of these preventive measures is a specially grounded diet. Such a diet contributes to the provision of conditions for normal physical and mental development, prevention and reduction of the incidence rate, and, therefore, an increase in the quality of life of the population [16]. The implementation of a daily, regulated intake of specially selected food components provides substrate and energy support for the functioning of universal defense mechanisms at the cellular and organ levels, a decrease in the absorption of xenobiotics and their metabolites in the gastrointestinal tract, and a decrease in the level of their deposition and accelerated excretion from the body [10; 16].

These metabolic transformations during the process of biotransformation of endogenous and exogenous chemicals into more polar (hydrophilic) compounds involve specific systems of proteins (enzymes) that successfully function only in combination with minerals, vitamins, phospholipids, and other compounds obtained by the body with food [11; 21]. Unadjusted diets, taking into account the chemical load on the population, can serve as an additional reason for the development of new diseases or aggravation of the existing ones, including the diseases of the digestive system, cardiovascular, oncological, and other diseases, which are the most common in the structure of diseases of the population. In this regard, in Russia, as in many countries of the world, it is relevant to develop a balanced diet as a measure of prevention of the development of the most common non-infectious diseases associated with exposure to external chemical factors in the population of urbanized areas [4; 22;27; 30].

Materials and Methods

The study aims to consider approaches to rational nutrition of the population living under aerogenic exposure to aromatic hydrocarbons. The substantiation of approaches to rational nutrition of the population in conditions of increased external chemical load with aromatic hydrocarbons is based on data from the international and Russian scientific literature and our accumulated experience. We searched for scientific information in bibliographic and abstract databases, such as Scopus (Elsevier Publishing House), MedLine (resource of the EBSCOhost Research Databases platform), Web of Science (resource of the Web of Science Core Collection platform), and Russian Index of Scientific Citations (platform eLIBRARY.RU). To obtain unique data for the Perm Krai for 2012–2019, we surveyed about 5,000 children aged 3–7 living in conditions of chronic aerogenic exposure to aromatic hydrocarbons (observation group) and those living without exposure to these substances (control group).

The assessment of the chemical pollution of atmospheric air by the content of benzene and phenol was carried out by environmental monitoring specialists for the same period. The results obtained were evaluated in accordance with SanPiN 1.2.3685-21 “Hygienic standards and requirements for ensuring the safety or harmlessness of environmental factors for humans.” We determined aromatic hydrocarbons in children’s blood by gas chromatography in accordance with the methodological guidelines MUK 4.1.765-99 [9]. The proposed approaches to rational nutrition of the population living under aerogenic exposure to aromatic hydrocarbons are based on the modern concepts of biotransformation, metabolism, and maintenance of homeostasis [5; 8; 24;31].

Using unified biochemical and enzyme-linked immunosorbent methods with commercial test systems, we studied the state of the antioxidant function of the glutathione system of the organism by (1) the activity of serum superoxide dismutase and glutathione peroxidase, (2) catalase of blood erythrocytes, (3) conjugation-elimination function, (4) the content of glutathione reductase, (5) glutathione-S-transferase, and (6) glucose-6-phosphate dehydrogenase in the blood serum. The study and assessment of the secretion of proteolytic digestive enzymes in the stomach were done according to the level of gastrin, pepsinogen I, and pepsinogen II in the blood serum, liver enzymes – according to the content of alanine aminotransferase [ALAT], aspartate aminotransferase [ACAT]; bile pigments – according to the level of total and direct bilirubin.

Results

The assessment of the chemical pollution of atmospheric air by the content of aromatic hydrocarbons in industrialized territories showed an excess of the average daily maximum permissible concentrations up to 3.3 times for benzene (0.1–0.3 mg / m^3) and phenol (0.003–0.01 mg / m^3), for toluene – up to 1.3 times (0.6–0.8 mg / m^3) and no excess for these substances in the control areas.

In the blood of about 25% of the examined children, the concentration of benzene was set at a level from 0.001 mg / dm^3 to 0.026 mg / dm^3; in 65% of children, phenol was established at a level of 0.01–0.34 mg / dm^3, which is up to 9 times higher than the indices in the blood of children of the control group (0.012 ± 0.008 mg / dm^3; $p = 0.002$).

The study of the complex of intracellular enzymes of the first and second stages of biotransformation of the presented aromatic hydrocarbons proves the tension passing into the stage of depletion of the antioxidant and conjugation-elimination functions of the glutathione system in children of the observation group. The levels of glutathioperoxidase and glutathione reductase in blood serum increased 1.5–1.9 times compared to those in the control group ($p = 0.0001$-0.005). At the same time, in 45% of the studied samples, a 5-fold increase in the concentration of glucose-6-phosphate dehydrogenase in children was recorded relative to the control group ($p = 0.021$). Besides, there was a 1.3–2.3-fold decrease in the level of glutathione-S-transferase and superoxide dismutase in children of the observation group relative to these indicators in the control group ($p = 0.005$-0.038), which indicates a relatively low conjugation with active products of the metabolism of aromatic compounds.

The violation of the secretion of proteolytic digestive enzymes is evidenced by an increase of up to 1.5 times in the level of pepsinogen I and, on the con-

trary, a decrease of up to 1.2 times in the gastrin of children of the observation group compared to the comparison group ($p = 0.037$).

The results of the study of the level of liver enzymes and bile pigments in the blood serum in children of the observation group in comparison with the control group showed their significant increase by 1.6–2.0 times ($p = 0.007$-0.036), which may indicate dysfunction of the biliary tract.

Discussion

Acceleration of biotransformation and elimination of aromatic hydrocarbons can be carried out by including foods with a high content of fiber and pectins with sorption properties in the diet: cereals (buckwheat, pearl barley, barley, oatmeal, etc.); fruits (apples, prunes, quince, figs, dates, plums, pears, etc.); vegetables (potatoes, carrots, white cabbage, cauliflower, peas, eggplants, etc.); whole-grain bread [6; 12]. At present, in addition to pectin, a high sorption effect of dietary fiber, maltodextrins, and a number of polysaccharides was shown. An increase in the rate of elimination of aromatic hydrocarbons can be achieved by including nonessential and irreplaceable glucogenic amino acids, betaine, polyunsaturated fatty acids, a complex of fat- and water-soluble vitamins, thioctic acid, and trace elements in the diet. These substances are contained in meat, eggs, fish, cottage cheese, dairy, and other products, the list of which is presented in the collective monograph of G. G. Onishchenko and Zaitseva N. V. [14; 18]. In addition to the sorbing activity, these substances have the properties of prebiotics that improve the vital activity of beneficial flora in the intestine and enhance the nonspecific resistance of the organism [15].

Micro and macro elements (Fe, Ca, Mg, P, Ca, K, etc.) have detoxifying properties concerning aromatic hydrocarbons, preventing their accumulation in depot organs [12; 17]. The detoxification of aromatic hydrocarbons in the body is enhanced by bioflavonoids contained in sufficient quantities in vegetables, fruits, and herbs, namely, ellagonic acid – in raspberries, strawberries, blackberries; catechins – in tea and coffee; indoles and glycosinolates – in cabbage; turnips, rutabagas, horseradish, isothiocyanates, and polysulfides – in onions and garlic; chloragenic acid – in apples, quince, peaches, and sunflower seeds [17]

In addition, special attention should be paid to maintaining the protective and barrier function of the intestinal walls, the integrity of the mucous-epithelial layer [28] due to the daily intake of dietary fiber and pectins to maintain the microbial composition [3].

Toxic metabolites of aromatic hydrocarbons (for example, phenol) are characterized by the ability to disrupt the enzymatic activity of the hepatocyte membrane

due to the activation of oxidation processes [29]. In this regard, to ensure hepatoprotective and membrane-stabilizing effects, it is necessary to include in the diet vitamin C, folic acid, potassium, calcium, iron, terpenes, monoterpenes, D-glucaric acid, beta-carotene, lycopene [20], and the flavonoid, which has the highest concentration of the hepatoprotector naringin [23]. Foods with antioxidant and anti-inflammatory properties include grapefruit, blueberries, cranberries, grapes (grape seeds), containing flavonoids (anthocyanins, flavonols) and catechins [20; 23].

Further chemical and medico-biological studies of the content of toxicants in human biological media, the level of intracellular enzymes of biotransformation of aromatic hydrocarbons, proteolytic digestive enzymes of the gastrointestinal tract and the activity of hepatocytes will make it possible to analyze and evaluate the effectiveness of correction of the diet in the exposed children.

Conclusion

Analysis of the international and Russian scientific literature in the field of rational nutrition as well as the accumulated experience of our own studies of the body's response to the effects of aromatic hydrocarbons, make it possible to emphasize the need to use specially selected food rations for all groups of the population exposed to a high level of chemical aerogenic environmental load, including aromatic hydrocarbons. Nutritional approaches as a preventive measure are necessary to reduce and prevent the development of non-communicable diseases associated with increased levels of air pollution. In-depth hygienic and laboratory-clinical studies of actual nutrition, nutritional status, and health of various population groups will expand the theoretical knowledge of the use of special diets to reduce the negative impact of toxic substances on the human body under conditions of high chemical load.

References

1. Andreeva E. E., Onishchenko G. G., Kleyn S.V. Gigiyenicheskaya otsenka prioritetnykh faktorov riska sostoyaniya okruzhayushchey sredy i zdorov'ya naseleniya g. Moskvy [Hygienic assessment of priority risk factors of environment and health condition of the population of Moscow]. *Analiz riskov dlya zdorov'ya* [Health Risk Analysis], vol. 3, pp. 23-34.
2. Vagin V. S., Sheina S. G., Chubarova K. V. *Printsipy i faktory ustoychivogo razvitiya gorodskikh territoriy* [Principles and factors of sustainable development of urban areas], 2015. URL: http://naukovedenie.ru/PDF/91EVN315.pdf
3. Shuldyakov A., Barylni Y. B., Lyapina E. P., Ramazanova K. H., Filippova N.V. Razvitiye depressivnykh rasstroystv v svyazi s mikrofloroy kishechnika i diyetich-

eskimi faktorami (obzor) [Depressive disorders development in connection with gut microflora and dietary factors (review)]. *Saratovskiy nauchno-meditsinskiy zhurnal* [Saratov Journal of Medical Scientific Research], 2016, vol. 12, no. 2, pp. 168-174.

4. World Health Organization. *Nedoyedaniye* [Malnutrition], 2021. URL: https://www.who.int/ru/news-room/fact-sheets/detail/malnutrition
5. Ushakov I. B., Esaulenko I. E., Popov V. I., Petrova T. N. Gigiyenicheskaya otsenka vliyaniya regional'nykh osobennostey pitaniya na zdorov'ye studentov [Hygienic assessment of the impact of regional peculiarities of nutrition on health of students]. *Gigiyena i sanitariya* [Hygiene and Sanitation], 2017, vol. 96, no. 9, pp. 909-912.
6. Zhdanova-Zaplesvichko I. G., Zemlyanova M. A., Koldibekova Yu. V. Biologicheskiye markery nekantserogennogo negativnogo vozdeystviya na tsentral'nuyu nervnuyu sistemu detey v zone vozdeystviya vybrosov alyuminiyevogo proizvodstva [Biological markers of non-cancerogenic negative impacts on the central nervous system of children in the area of exposure to aluminum production emissions]. *Gigiyena i sanitariya* [Hygiene and Sanitation], 2018, vol. 97, no. 5, pp. 461-469.
7. Korolev A. A. *Gigiyena pishchevykh produktov: uchebnik dlya studentov vuzov* [Food Hygiene: A textbook for University Students]. Moscow, Center Academy, 2006, 528 p. URL: https://studopedia.org/3-35947.html
8. Mazhaeva T. V. Vliyaniye pitaniya na uroven' fizicheskogo razvitiya doshkol'nikov v usloviyakh neblagopriyatnogo vozdeystviya okruzhayushchey sredy [Influence of nutrition on the level of physical development of preschoolers in conditions of adverse environmental impact]. *Ural'skiy meditsinskiy zhurnal* [Ural Medical Journal], vol. 2, no. 80, pp. 53-56.
9. Federal Center for State Sanitary and Epidemiological Supervision of the Ministry of Health of Russia. Gazokhromatograficheskiy metod kolichestvennogo opredeleniya predel'nykh i aromaticheskikh uglevodorodov (benzola, toluola, etilbenzola, o-, -m-, p-ksilola) v biologicheskikh sredakh krovi [Gas chromatographic method for the quantitative determination of saturated and aromatic hydrocarbons (benzene, toluene, ethylbenzene, o, -m-, p-xylene) in biological media blood]. *Opredeleniye khimicheskikh soyedineniy v biologicheskikh sredakh, MUK 4.1.765-99* [Determination of chemical compounds in biological media, MUK 4.1.765-99], Moscow, 2000, URL: https://files.stroyinf.ru/Data2/1/4293743/4293743471.pdf
10. Churnosov M. I., Polyakova I. S., Pakhomov S. P., Orlova V. S. Molekulyarno-geneticheskiye mekhanizmy biotransformatsii ksenobiotikov [Molecular and genetic mechanisms of xenobiotic biotransformation]. *Nauchnyy vestnik BelGU*

Seriya: Meditsina Apteka [Scientific bulletin of BelSU Series: Medicine Pharmacy], 2011, vol. 6, no. 111, pp. 223-228.

11. Novikov V. S., Karkishchenko V. N., Shustov E. B. *Funktsional'noye pitaniye cheloveka v ekstremal'nykh usloviyakh* [Functional human nutrition under extreme conditions]. Saint-Petersburg, Polytechnic-print, 2017, 339 P. URL: https://search.rsl.ru/ru/record/01009368451
12. Novikova M. V., Sultaeva N. L. Razrabotka spetsializirovannykh pishchevykh produktov s biologicheski aktivnymi dobavkami [Development of specialized food products with biologically active additives]. *Servis v Rossii i za rubezhom* [Service in Russia and Abroad], 2012, vol. 2, no. 29, pp. 10-18.
13. Onishchenko G. G. Gorodskaya sreda i zdorov'ye cheloveka [The urban environment and human health]. *Gigiyena i sanitariya* [Hygiene and Sanitation], 2007, vol. 5, pp. 3-4.
14. Onishchenko G. G., Zaitseva N. V. (eds). *Analiz riska zdorov'yu v strategii sotsial'no-ekonomicheskogo razvitiya gosudarstva* [Health Risk Analysis in the Strategy of the State Social and Economic Development]. Perm, Perm National Research Polytechnic University, 2014, 738 p.
15. Lisovitskaya E. P., Patieva S. V., Timoshenko N. V., Patieva A. M. Otsenka analiticheskikh kharakteristik razlichnykh vidov pektinovykh veshchestv v tekhnologii konservov dlya profilakticheskogo pitaniya lyudey [Assessment of analytical characteristics of various types of pectin substances in canned food technology for preventive nutrition of people]. *Vse o myase* [All About Meat], 2016, vol. 3, pp. 32-35.
16. Baytlesova L. I., Dzhubayalieva A. K., Gumarova A. K., Sukhanberdina F. H., Kabaeva S. M. Pitaniye naseleniya v usloviyakh ekologicheskogo neblagopoluchiya [Nutrition of the population in conditions of ecological trouble]. *Problemy pedagogiki* [Problems of Pedagogy], 2018, vol. 3, no. 35, pp. 6-9.
17. Rembovskiy V. R., Mogilenkova L. A. Yestestvennyye protsessy obezvrezhivaniya khimicheskikh veshchestv, zagryazniteley okruzhayushchey cheloveka sredy [Natural processes of detoxification of chemicals, pollutants of the human environment]. *Biomeditsinskiy zhurnal* [Biomedical Journal], 2015, vol. 16, pp. 216-239. URL: http://www.medline.ru/public/art/tom16/art19.html
18. Federal Service for Surveillance on Consumer Rights Protection and Human Welfare. *Alimentarnaya profilaktika narusheniy antioksidantnoy, kon"yugatsionnoy i eliminatsionnoy funktsiy glutationovoy sistemy u detey, svyazannykh s vozdeystviyem aromaticheskikh uglevodorodov, MR 2.4.8.0076-13 20* [Alimentary prevention of disorders of the antioxidant, conjugation and elimination functions of the glutathione system in children associated with exposure to aromatic hydrocarbons, MR 2.4.8.0076-13 20], Moscow, 2013. URL: https://base.garant.ru/70585164/

19. Federal Service for Surveillance on Consumer Rights Protection and Human Welfare. *O sostoyanii sanitarno-epidemiologicheskogo blagopoluchiya naseleniya v Rossiyskoy Federatsii v 2020 godu. Gosudarstvennyy doklad* [On the state of the sanitary-epidemiological well-being of the population in the Russian Federation in 2020. State report], Moscow, 2020. URL: https://www.rospotrebnadzor.ru/upload/iblock/5fa/gd-seb_02.06-_s-podpisyu_.pdf
20. Shtina I. E., Luzhetsky K. P., Ustinova O. Yu. Otsenka tekhnologii profilaktiki narusheniy fizicheskogo razvitiya i gipotrofii u detey (ye44-46), svyazannykh s vozdeystviyem metallov (svinets, marganets, nikel', kadmiy, khrom) [Evaluation of children prevention technology physical development disorders and malnutrition (e44-46) associated with exposure metals (lead, manganese, nickel, cadmium, chromium)]. *Obshchestvennoye zdorov'ye i zhiznennaya sreda* [Public Health and Life Environment], vol. 4, no. 289, pp. 38-42.
21. Rebezov M. B., Naumova N. L., Alkhamova G. K., Lukin A. A., Khairullin M. F. Ekologiya i pitaniye, problemy i resheniye [Ecology and nutrition, problems and solution]. *Fundamental'nyye issledovaniya* [Fundamental Research], 2011, vol. 8-2, pp. 393-396.
22. Bueno M. B., Fisberg R. M., Maximino P., Pádua Rodrigues G., Fisberg, M. Nutritional risk among Brazilian children 2 to 6 years old: A multicenter study. *Nutrition*, 2013, vol. 29, pp. 405-410. URL: https://www.sciencedirect.com/science/article/abs/pii/S0899900712002754?via%3Dihub
23. Gupta V., Kohli K., Ghaiye P., Bansal P., Lather A. Pharmacological potentials of citrus paradise-An overview. *International Journal of Phytotherapy Research*, 2011, vol. 1, pp. 8-17. URL: https://www.researchgate.net/publication/306150016_Pharmacological_potentials_of_Citrus_paradisi-an_overview
24. Gwaltney-Brant S. M. Chapter 8 Nutraceuticals in Hepatic Diseases. *Nutraceuticals*, 2021, vol. 1, pp. 117-129. https://doi.org/10.1016/B978-0-12-821038-3.00008-2
25. Hennig B., Ettinger A. S., Jandacek R. J., Koo S., McClain C., Seifried H., Silverstone A., Watkins B., Suk A. W. Using nutrition for intervention and prevention against environmental chemical toxicity and associated diseases. *Environmental Health Perspectives*, vol. 115, no. 4, pp. 493-495. https://doi.org/10.1289/ehp.9549
26. Koutsoukas A., St Amand J., Mishra M., Huan J. Predictive toxicology: modeling chemical induced toxicological response combining circular fingerprints with random forest and support vector machine. *Frontiers in Environmental Science*, 2016, vol. 4, no. 11, pp. 1-9. https://doi.org/10.3389/fenvs.2016.00011
27. Lazarevic K., Stojanovic D., Bogdanović D. Energy and nutritional value of the meals in kindergartens in Nis (Serbia). *Roczniki Państwowego Zakładu Higieny*, 2014, vol. 68, no. 2, pp. 127-131. URL: https://www.researchgate.net/

publication/266251660_Energy_and_nutritional_value_of_the_meals_in_kindergartens_in_Nis_Serbia
28. Lir D. N., Perevalov A. Ya., Tapeshkina N. V., Sherstobitova A. V., Misharina E. A. Analyzing nutrition rations at pre-school children facilities in a large industrial city in Russia. *Health Risk Analysis*, 2020, vol. 1, pp. 52-58.
29. Madrigal-Santillán E., Madrigal-Bujaidar E., Álvarez-González I., Sumaya-Martínez M. T., Gutiérrez-Salinas J., Bautista M., Morales-González Á., González-Rubio y M. G-L., Aguilar-Faisal J. L., Morales-González J. A. Review of natural products with hepatoprotective effects. World Journal Gastroenterol, 2014, vol. 20, no. 40, pp. 14787-14804. URL: https://www.wjgnet.com/1007-9327/full/v20/i40/14787.htm
30. Morales-Ruan M. D. C., Villalpando S., Garcia-Guerra A. Iron, zinc, copper and magnesium nutritional status in Mexican children aged 1 to 11 years. *Salud Pública de México*, 2012, vol. 54, no. 2, pp. 125-134. URL: https://pubmed.ncbi.nlm.nih.gov/22535171/
31. Saghir S. A., Ansari R. A. Metabolism (Biotransformation). Reference *Module in Biomedical Sciences*, 2019, vol. 4, pp. 24-35. https://doi.org/10.1016/B978-0-12-801238-3.11365-0
32. Zhang S., Khan W. A., Su L., Zhang X., Li C., Qin W., Zhao Y. Predicting oxidative stress induced by organic chemicals by using quantitative Structure-Activity relationship methods. *Ecotoxicology and Environmental Safety*, 2020, vol. 201, pp. 1-8. URL: https://pubmed.ncbi.nlm.nih.gov/32512417/

Список литературы

1. Андреева Е. Е., Онищенко Г. Г., Клейн С. В. Гигиеническая оценка приоритетных факторов риска среды обитания и состояния здоровья населения г. Москвы // Анализ риска здоровью. 2016. № 3. С. 23-34.
2. Вагин В. С., Шеина С. Г., Чубарова К. В. Принципы и факторы устойчивого развития городских территорий, 2015. URL: http://naukovedenie.ru/PDF/91EVN315.pdf
3. Взаимосвязь факторов питания и микрофлоры кишечника с развитием депрессивных расстройств / Шульдяков А. А., Барыльник Ю. Б., Ляпина Е. П., Рамазанова К. Х., Филиппова Н. В. // Саратовский научно-медицинский журнал. 2016. Т. 12. № 2. С. 168-174.
4. Всемирная организация здравоохранения. Неполноценное питание, 2021. URL: https://www.who.int/ru/news-room/fact-sheets/detail/malnutrition
5. Гигиеническая оценка влияния на здоровье студентов региональных особенностей их питания / Ушаков И. Б., Есауленко И. Э., Попов В. И., Петрова Т. Н. // Гигиена и санитария. 2017. Т. 96. № 9. С. 909-912.

6. Жданова-Заплесвичко И. Г., Землянова М. А., Кольдибекова Ю. В. Биомаркеры неканцерогенных негативных эффектов со стороны центральной нервной системы у детей в зоне влияния источников выбросов алюминиевого производства // Гигиена и санитария. 2018. Т. 97 № 5. С. 461-469.
7. Королев А. А. Гигиена питания : учеб. для студ. высш. учеб. заведений. М.: Академия, 2006, 528 с. URL: https://studopedia.org/3-35947.html
8. Мажаева Т. В. Влияние питания на уровень физического развития дошкольников в условиях неблагоприятного воздействия окружающей среды // Уральский медицинский журнал. 2011. Т. 2. № 80. С. 53-56.
9. Министерство здравоохранения Российской Федерации. Газохроматографический метод количественного определения ароматических (бензол, толуол, этилбензол, о-,м-,п-ксилол) углеводородов в биосредах (кровь): МУК 4.1.765-99. Определение химических соединений в биологических средах. М.: Министерство здравоохранения Российской Федерации, 2000, 4 с. URL: https://files.stroyinf.ru/Data2/1/4293743/4293743471.pdf
10. Молекулярные и генетические механизмы биотрансформации ксенобиотиков / Чурносов М. И., Полякова И. С., Пахомов С. П., Орлова В. С. // Научные ведомости белгородского государственного университета. серия: медицина. Фармация. 2011. Т. 16. № 111. С. 223-228.
11. Новиков В. С., Каркищенко В. Н., Шустов Е. Б. Функциональное питание человека при экстремальных воздействиях. С.: Политехника-принт, 2017, 339 с. URL: https://search.rsl.ru/ru/record/01009368451
12. Новикова М. В., Султаева Н. Л. Разработка специализированных продуктов питания с биологически активными добавками // Сервис в России и за рубежом. 2012. Т. 2. № 29. С. 10-18.
13. Онищенко Г. Г. Городская среда и здоровье человека // Гигиена и санитария. 2007. № 5. С. 3-4.
14. Онищенко Г. Г., Зайцева Н. В. Анализ риска здоровью в стратегии государственного социально-экономического развития. П.: Пермский национальный исследовательский политехнический университет, 2014, 738 с.
15. Оценка аналитических характеристик различных видов пектиновых веществ в технологии консервов для профилактического питания людей / Лисовицкая Е. П., Патиева С. В., Тимошенко Н. В., Патиева А. М. // Все о мясе. 2016. № 3. С. 32-35.
16. Питание населения в условиях экологического неблагополучия / Байтлесова Л. И., Джубаялиева А. К., Гумарова А. К., Суханбердина Ф. Х., Кабаева С. М. // Проблемы педагогики. 2018. Т. 3. № 35. С. 6-9.
17. Рембовский В. Р., Могиленкова Л. А. Естественные процессы детоксикации химических веществ, загрязнителей среды обитания человека // Био-

медицинский журнал. 2015. № 16. С. 216-239. URL: http://www.medline.ru/public/art/tom16/art19.html
18. Федеральная служба по надзору в сфере защиты прав потребителей и благополучия человека. МР 2.4.8.0076—13 Алиментарная профилактика нарушений антиоксидантной, конъюгационной и элими-национной функций глутатионовой системы у детей, ассоциированных с воздействием ароматических углево-дородов, 2013. URL: https://base.garant.ru/70585164/
19. Федеральная служба по надзору в сфере защиты прав потребителей и благополучия человека. "О состоянии санитарно-эпидемиологического благополучия населения в Российской Федерации в 2020 году", 2020. URL: https://www.rospotrebnadzor.ru/upload/iblock/5fa/gd-seb_02.06-_s-podpisyu_.pdf
20. Штина И. Е., Лужецкий К. П., Устинова О. Ю. Оценка эффективности технологии профилактики нарушений физического развития и недостаточности питания (е44-46), ассоциированных с воздействием металлов (свинец, марганец, никель, кадмий, хром), у детей // Здоровье населения и среда обитания – ЗНИСО. 2017. Т. 4. № 289. С. 38-42.
21. Экология и питание. проблемы и пути решения / Ребезов М. Б., Наумова Н. Л., Альхамова Г. К., Лукин А. А., Хайруллин М. Ф. // Фундаментальные исследования. 2011. № 8-2. С. 393-396.
22. Bueno M. B., Fisberg R. M., Maximino P., Pádua Rodrigues G., Fisberg, M. Nutritional Risk among Brazilian Children 2 to 6 Years Old: A Multicenter study // Nutrition, 2013, vol. 29, pp. 405-410. URL: https://www.sciencedirect.com/science/article/abs/pii/S0899900712002754?via%3Dihub
23. Gupta V., Kohli K., Ghaiye P., Bansal P., Lather A. Pharmacological potentials of citrus paradise-An overview // International Journal of Phytotherapy Research, 2011, vol. 1, pp. 8-17. URL: https://www.researchgate.net/publication/306150016_Pharmacological_potentials_of_Citrus_paradisi-an_overview
24. Gwaltney-Brant S. M. Nutraceuticals in Hepatic Diseases // Nutraceuticals, 2021, vol. 1, pp. 117-129. https://doi.org/10.1016/B978-0-12-821038-3.00008-2
25. Hennig B,. Ettinger A. S., Jandacek R. J., Koo S., McClain C., Seifried H., Silverstone A., Watkins B., Suk A. W. Using nutrition for intervention and prevention against environmental chemical toxicity and associated diseases // Environmental Health Perspectives, 2007, vol. 115, no. 4, pp. 493-495. https://doi.org/10.1289/ehp.9549
26. Koutsoukas A., St Amand J., Mishra M., Huan J. Predictive toxicology: modeling chemical induced toxicological response combining circular fingerprints with random forest and support vector machine // Frontiers in Environmental Science, 2016, vol. 4, no. 11, pp. 1-9. https://doi.org/10.3389/fenvs.2016.00011

27. Lazarevic K., Stojanovic D., Bogdanović D. Energy and nutritional value of the meals in kindergartens in Nis (Serbia) // Roczniki Państwowego Zakładu Higieny, 2014, vol. 68, no. 2, pp. 127-131. URL: https://www.researchgate.net/publication/266251660_Energy_and_nutritional_value_of_the_meals_in_kindergartens_in_Nis_Serbia
28. Lir D. N., Perevalov A. Ya., Tapeshkina N. V., Sherstobitova A. V., Misharina E. A. Analyzing nutrition rations at pre-school children facilities in a large industrial city in Russia // Health Risk Analysis, 2020, vol. 1, pp. 52-58.
29. Madrigal-Santillán E., Madrigal-Bujaidar E., Álvarez-González I., Sumaya-Martínez M. T., Gutiérrez-Salinas J., Bautista M., Morales-González Á., González-Rubio y M. G-L., Aguilar-Faisal J. L., Morales-González J. A. Review of natural products with hepatoprotective effects // World J Gastroenterol, 2014, vol. 20, no. 40, pp. 14787-14804. URL: https://www.wjgnet.com/1007-9327/full/v20/i40/14787.htm
30. Morales-Ruan M. D. C., Villalpando S., Garcia-Guerra A. Iron, zinc, copper and magnesium nutritional status in Mexican children aged 1 to 11 years // Salud Pública de México, 2012, vol. 54, no. 2, pp. 125-134. URL: https://pubmed.ncbi.nlm.nih.gov/22535171/
31. Saghir S. A., Ansari R. A. Metabolism (Biotransformation) // Reference Module in Biomedical Sciences, 2019, vol. 4, pp. 24-35. https://doi.org/10.1016/B978-0-12-801238-3.11365-0
32. Zhang S., Khan W. A., Su L., Zhang X., Li C., Qin W., Zhao Y. Predicting oxidative stress induced by organic chemicals by using quantitative Structure-Activity relationship methods // Ecotoxicology and Environmental Safety, 2020, vol. 201, pp. 1-8. URL: https://pubmed.ncbi.nlm.nih.gov/32512417/

DATA ABOUT THE AUTHORS

Marina A. Zemlyanova

Federal Scientific Center for Medical and Preventive Health Risk Management Technologies of the Federal Service for Surveillance on Consumer Rights Protection and Human Wellbeing
82, Monastyrskaya Str., Perm, 614045, Russian Federation
zem@fcrisk.ru
ORCID: https://orcid.org/0000-0002-8013-9613

Yuliya V. Koldibekova

Federal Scientific Center for Medical and Preventive Health Risk Management Technologies of the Federal Service for Surveillance on Consumer Rights Protection and Human Wellbeing

82, Monastyrskaya Str., Perm, 614045, Russian Federation
koldibekova@fcrisk.ru
ORCID: https://orcid.org/0000-0002-3924-4526

Ekaterina V. Peskova
Federal Scientific Center for Medical and Preventive Health Risk Management Technologies of the Federal Service for Surveillance on Consumer Rights Protection and Human Wellbeing
82, Monastyrskaya Str., Perm, 614045, Russian Federation
peskova@fcrisk.ru
ORCID: https://orcid.org/0000-0002-8050-3059

ДАННЫЕ ОБ АВТОРАХ

Землянова Марина А.
Федеральный научный центр медико-профилактических технологий управления рисками здоровью населения Федеральной службы по надзору в сфере защиты прав потребителей и благополучия человека
ул. Монастырская, 82, г. Пермь, 614045, Российская Федерация
zem@fcrisk.ru

Кольдибекова Юлия В.
Федеральный научный центр медико-профилактических технологий управления рисками здоровью населения Федеральной службы по надзору в сфере защиты прав потребителей и благополучия человека
ул. Монастырская, 82, г. Пермь, 614045, Российская Федерация
koldibekova@fcrisk.ru

Пескова Екатерина В.
Федеральный научный центр медико-профилактических технологий управления рисками здоровью населения Федеральной службы по надзору в сфере защиты прав потребителей и благополучия человека
ул. Монастырская, 82, г. Пермь, 614045, Российская Федерация
peskova@fcrisk.ru

Поступила 28.03.2022 Received 28.03.2022
После рецензирования 05.04.2022 Revised 05.04.2022
Принята 10.04.2022 Accepted 10.04.2022