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ASSESSMENT OF SOIL AND PLANTS IN PRIVATE GARDENS OF AN INDUSTRIAL CITY

In this study, ecological evaluation of the soils of the private gardens located in the industrial area and in the suburban rural area was given. The results of physical and chemical analysis of soil samples were summarized, and the obtained data were statistically processed. Soil and vegetable samples for analysis were taken from private gardens located in the city near «Kazzinc» LLC. In addition, samples were collected from the outskirts of the city – Akhmirova village for comparative analysis. These samples were prepared for chemical investigation to determine the content of Zn, Pb, Cu, and Cd.

The findings revealed that the levels of heavy metals in the soils of the industrial area are several times higher than those in the suburban rural area. The average values of the analyzed metals in the industrial soils across all studied regions exceed the safe levels accepted in Kazakhstan. In the samples taken in the industrial area, the content of all investigated heavy metals was 2 to 8 times higher than the internationally recommended safe level. Despite being grown in the same environmental conditions, vegetables have different accumulation levels of heavy metals. However, it should be noted that high concentrations of heavy metals in the soil affect their content in plants. The highest levels of heavy metals were found in vegetables grown in the industrial area, while the lowest levels were observed in the suburban area.

Key words: industrial zone, suburban rural area, private gardens, soil and vegetables.

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Өнеркәсіптік қаланың жеке бақшаларындағы топырақ және өсімдіктердің бағалау

Бұл зерттеу жұмысында өндірістік кешенге жақын және қала маңында орналасқан ауылдағы жеке меншік бақшалардың топырақтарына экологиялық баға берілді. Топырақ сынамаларына жүргізілген физикалық және химиялық талдау нәтижелері қорытындыланып, алынған деректер статистикалық өңдеуден өткізілді. Анализдерді жүргізуге арналған топырақ және көкөніс үлгілері қала ішінде «Қазмырыш» ЖШК -не жақын маңда орналасқан жеке бақшалардан алынды. Сонымен қатар салыстырмалы талдау жүргізу үшін қала шетінен- Ахмер ауылынан сәйкесінше үлгілер жинақталды. Бұл үлгілер химиялық талдауға дайындалып, құрамында Zn, Pb, Cu және Cd мөлшері анықталды.

Зерттеліп отырған аймақтардың топырағында талданған ауыр металдардың мөлшері өндірістік аймақта Ахмер ауылынан қарағанда бірнеше есе жоғары екендігі анықталған. Барлық зерттелген аймақтардағы топырақтардағы талданған металдардың алынған орташа мәндері Қазақстанда қабылданған қауіпсіз деңгейден жоғары. Өндірістік аймақта алынған сынамаларда барлық зерттелген ауыр металдардың мөлшері халықаралық ұсынылған қауіпсіз деңгеймен салыстырғанда 2-ден 8 есеге дейін жоғары болды. Бірдей экологиялық жағдайда өсірілгендігіне қарамастан, көкөністердің ауыр металдардың жинақтау деңгейі әр түрлі болды. Дегенмен, топырақтағы ауыр металдардың жоғары болуы өсімдік құрамына тұра әсер еткенін атап өткен

жөн. Ауыр металдардың ең көп мөлшері өндірістік ауданда өсірілген көкөністерде, ең азы – қала маңындағы ауданда анықталды

Түйін сөздер: өнеркәсіптік аймақ, қала маңындағы ауыл, жеке бақшалар, топырақ және көкөністер.

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Оценка почвы и растений
в частных огородах промышленного города

В исследовании дана сравнительная характеристика почв частных огородов, расположенных вблизи промышленного комплекса и в пригородном селе Ахмирова. Результаты физико-химического анализа образцов почвы были обобщены и полученные данные обработаны статистически. Пробы почвы и овощей для анализа были взяты из частных садов, расположенных в городе вблизи ТОО «Казцинк». Кроме того, для сравнительного анализа были собраны пробы на окраине города – село Ахмирова. Эти образцы были подготовлены к химическому анализу и определено содержание Zn, Pb, Cu и Cd.

Установлено, что содержание тяжелых металлов в почвах исследуемых территорий в несколько раз выше в промышленной зоне, чем в почвах села Ахмирова. Средние значения анализируемых металлов в почвах всех изучаемых регионов превышают предельно-допустимый уровень, принятый в Казахстане. В пробах, взятых на садовых участках вблизи промышленной территории, содержание всех исследованных тяжелых металлов от 2 до 8 раз превышало рекомендованный международными стандартами безопасный уровень. Несмотря на то, что овощи выращиваются в одинаковых условиях окружающей среды, они имеют разный уровень накопления тяжелых металлов. Однако следует отметить, что высокая концентрация тяжелых металлов в почве влияет на содержание их в растениях. Наибольшее количество тяжелых металлов обнаружено в овощах, выращенных в промышленной зоне, а наименьшее – в пригородной зоне.

Ключевые слова: промышленный комплекс, частные огороды, пригородные сельские районы, почва и растения.

Introduction

The rapid development of industry in the city of Ust-Kamenogorsk leads to environmental pollution with heavy metals. The smoke released from the chimneys of industrial giants contains more than a hundred pollutants. They not only pollute the air, but also increasingly accumulate in the soil from year to year. According to research by Woszczyk M. and others, the level of soil pollution in Ust-Kamenogorsk with heavy metals was estimated from medium to very high[1]. However, residents of the city and suburbs plant vegetables in their private gardens and use them in large quantities in their daily diet. The importance of vegetables as a source of micronutrients and fiber, antioxidants in the diet is very high. Moreover, since plants are considered excellent absorbers of metals from the soil, they also contain toxic components in various concentrations. The ability of vegetables to absorb heavy metals varies. If some can accumulate less, then others can accumulate more[2]. Therefore, due to cultivation in polluted regions, this type of food leads to the ingress of toxic pollutants such as heavy metals into the human body. Since there is no strong mechanism for removing heavy metals from the body, even if ingested in small quantities, they are very dangerous[3]. Eating vegetables contaminated with heavy metals poses a great danger to health, causing various serious diseases in humans [4,5,6]. Heavy metal pollution of plants usually occurs when they absorb pollutants from the soil through roots or leaves from polluted air during growth [7,8,9].Currently, studies by many foreign scientists report high levels of heavy metals in the tissues of crops and vegetables grown in polluted urban areas [4,5,10]. In this regard, to date, food contamination with heavy metals and their harmful effects on the health of the local population have become an urgent problem in many countries and it was recommended to constantly monitor heavy metals in vegetables [5,7,8,11].

The purpose of this study is to provide an environmental characterization by determining the concentrations of lead (Pb), cadmium (Cd), copper (Cu)

and zinc (Zn) in garden soils and vegetables located in the sullied region and at a separate of a few kilometers from pollution sources.

Materials and methods

The necessary soil and vegetable samples for research were taken from garden plots near Kazzinc LLP (industrial area) and the village of Akhmer (suburban area), located about 3 km southwest of Ust-Kamenogorsk.

The contribution of the Kazzinc LLP to the pollution of the city's atmospheric air is 47.8% of the total emissions of the city (51 thousand tons), actually for the enterprise – 24.4 thousand tons. The company has received an environmental permit for emissions into the environment for 2023, taking into account a reduction in standards by 4.9%, from 26.1 to 24.8 tons [12].

Sampling of soil and vegetables, their transportation, storage and preparation of samples for analysis were developed on the basis of approved methodological recommendations. Soil samples were completely decomposed with concentrated acids to determine the total content of heavy metals. The overall metal content in the soil was measured using atomic absorption in compliance with the ISO standard [13].

The edible parts of the vegetables were dried at 60 ° C, ground, and converted to ash by heating at 450 ° C for 6 hours in an oven. The resulting ash was dissolved in 5 ml of 6 mol·dm³ HCl and then diluted with distilled water to a constant volume [14]. The prepared plant extracts were analyzed using a Varian Spectra AA2204 FS apparatus to measure the metal content through atomic absorption spectrophotometry (AAS). The total content of heavy metals in beets, carrots, and potatoes was determined by atomic absorption using a spectrophotometer.

To assess the accumulation of heavy metals in soil and garden crops, the following environmental and geochemical indicators were calculated:

- hazard ratio (R_h) – the ratio of the metal content in the soil to the highest safe metal level;

To evaluate the buildup of heavy metals in vegetables, the following metrics are calculated:

- the coefficient of contamination of vegetable crops, which is the ratio of the concentration of an element in a plant to the permissible residual amount;
- the bioaccumulation coefficient (BCF) is defined as the ratio of the concentration of heavy metals in plants to the concentration of heavy metals in soil [15].
- BCF = (concentration of heavy metals in plants) / (concentration of heavy metals in soil).

Results and their discussion

The levels of heavy metals in the examined soil samples are displayed in table 1-2.

Table 1 – The metal content in the soil of gardens situated in close proximity to Kazzinc LLP (mg/kg^{-1}dry weight)

Sample number	Cu	Cd	Pb	Zn
1	93,5	5,58	232,98	819,16
4	116,17	7,3	293,87	1014,21
5	114,17	7,3	280,39	981,62

In general, levels of all studied elements in garden soils within the Kazzinc LLP were **2.6 to 28 times** higher than those found in rural country regions. The mean Cu content in the industrial area was 107.95 mg/kg^{-1} dry weight, while in the soils of the gardens of the village of Akhmer this indicator was determined 2.6 times lower, that is in the amount of 42.06 mg/kg^{-1} dry weight. In the garden soil near Kazzinc LLC, the average Cd content was 6.73 mg/kg^{-1} dry weight, while in a suburban village it was only 0.24 mg/kg^{-1} dry weight, which is 28 times lower. At the same time, the Pb content also showed a fairly high value in the industrial area, 269.08 and 21.92 mg/kg^{-1} dry weight, respectively, that is 12 times higher. The Zn content in urban soil was the highest among the detected heavy metals. Thus, the average zinc content in samples near Kazzinc LLP was 938.33 mg/kg^{-1} dry weight, which is 8.7 times higher than in samples from the village of Akhmer (107.6 mg/kg^{-1} dry weight).

Table 2 – Levels of Cu, Cd, Pb, and Zn in the garden soils of Akhmer village, (mg/kg^{-1} dry weight)

Sample number	Cu	Cd	Pb	Zn
2	42,83	0,30	23,33	95,25
3	38,67	0,23	21,43	87,48
27	44,67	0,20	21,00	140,02

Based on the average concentrations of heavy metals in the soil, the studied elements are arranged in descending order as follows: Zn > Pb > Cu > Cd. Among the analyzed metals, Zn was found in the highest amounts, and Cd showed the lowest level. The obtained values of metals analyzed in garden soils near Kazzinc LLP are 3-10 times higher than the safe levels accepted in Kazakhstan [16,17] (for Cu-33 mg/kg^{-1}, Pb-32 mg/kg^{-1}). The concentration of the studied chemical elements within Kazzinc LLP area, except Cu, was 3 times higher than the safe level established by the Directive [18]. In contrast, the total amount of these metals in soil samples collected from the village of Akhmer did not exceed internationally acceptable safety levels.

Table 3 – Comparative data on the content of heavy metals in the soils (mg/kg^{-1} dry weight)

Sample	Cd	Pb	Zn	Cu	Used literature
Soil	6,73	269,08	938,33	107,95	In this research paper
	4,2	33,48	92,37	23,34	Ashraf et.al.(2021) [5]
	1,40	77,88	246,86	205,04	Moghtaderiet.al.(2018) [19]

The findings of this study indicate that the concentrations of Cd, Pb, Zn, and Cu in the soil of the industrial area are 4 to 10 times higher than the levels reported by foreign researchers [5,19]. However, in contrast to these results, Moghtaderi and colleagues [19] found Cu in the industrial soils at a concentration of 205.04 mg/kg^{-1}, which is nearly twice the amount observed in this study (107.95 mg/kg^{-1}).

The quantitative content of heavy metals is not sufficient to assess the ecological state of soils. Therefore, for a comprehensive study of soil quality, a hazard coefficient was used, which shows the ratio of the amount of metal in the soil to the safe metal level.

Among the heavy metals studied, zinc (Zn) ranked the highest in terms of the hazard coefficient. The metals in the soils near Kazzinc LLP showed the following decreasing order: Zn > Cd > Pb > Cu and soils of the village of Akhmer: Zn > Pb > Cu >Cd.

Table 4 – The hazard coefficient of heavy metals in soils in the immediate vicinity of Kazzinc LLP and the orchards of the village of Akhmer

Area under study	Pb	Cu	Cd	Zn
Soils near Kazzink LLP	1,9	0,36	2,24	3,13
Soil of the orchards of the village of Akhmer	0,16	0,14	0,08	0,36

Therefore, it is evident that zinc and cadmium exhibit the highest hazard ratios in the industrial areas of the city. In general, the hazard coefficients in the suburban area did not differ statistically, and the hazard coefficients in the industrial area showed a significantly higher level.

The concentration of heavy metals in vegetables cultivated in the industrial zones of Ust- Kamenogorsk and throughout the city

Vegetables grown in vegetable gardens near Kazzink LLP and Akhmer village had different heavy metal content. This differentiation is closely related

to the level of soil pollution and the physiological characteristics of plants. For example, despite the high concentration of Pb in the soil of the industrial area, the least amount of this metal was found in vegetables. The evidence that plants accumulate less Pb from the soil relates to the research of Latif A. and others [20].

The largest amount of all the studied heavy metals was recorded in beetroot, which showed a greater tendency to absorb heavy metals. Of all the vegetables studied, the Zn content was the highest, the largest amount of Zn among vegetables was found in beetroot (mg/kg^{-1}), the smallest in potatoes (15.9 mg/kg^{-1}). This is due to the high concentration of this metal in the soil in which vegetables were grown.

The Cu level in vegetables was also significantly higher. Although Cu is an essential element for the human body, its excess can cause serious harm to human health. Beetroot showed the highest Cu concentration (7.45 mg/kg^{-1}), whereas carrots had the lowest (2.99 mg/kg^{-1}). In the works of Pipoyan and others [21], -12.01 mg·kg^{-1} was found in potatoes grown in an industrial zone, and -5.78 mg·kg^{-1} Cu was found in carrots, these values are slightly higher than the results of this study.

Table 5 – Levels of heavy metals in vegetables cultivated in private gardens near Kazzinc LLP and in the village of Akhmer, mg·kg^{-1} dry weight

Area under study	Cu	Zn	Pb	Cd
	beetroot			
Suburb of Kazzinc LLP	7,45	96,5	0,88	0,66
Village of Akhmer	4,52	28,7	0,01	0,23
	carrot			
Suburb of Kazzinc LLP	2,99	26,6	0,28	0,48
Village of Akhmer	3,9	21,9	0,46	0,16
	potato			
Suburb of Kazzinc LLP	3,35	20,2	0,1	0,42
Village of Akhmer	6,72	15,9	0,02	0,29

The Pb level was relatively low, from 0.01 to 0.88 mg/kg. Among the studied elements, the Cd level was the lowest, from 0.16 to 0.66 mg/kg.

Comparing the data obtained with the results of foreign studies, studies by Johann M.R. and others [22] showed that the Pb and Cd content in carrots and potatoes was 4-16 times lower (the amount of Cd in carrots is -0.041 mg/kg^{-1} and in potatoes -0.096 mg/kg^{-1}, the Pb content in carrots is 0.006 mg / kg^{-1}, in potatoes-0.054 mg / kg^{-1}).

The safe limits of heavy metal content in food products as recommended by FAO/WHO are 73.0 mg·kg^{-1} for Cu, 99.0 mg·kg^{-1} for Zn, 0.3 mg·kg^{-1} for Pb, and 0.2 mg·kg^{-1} for Cd [23]. Comparing these limits with the data from this study, it was found that the levels of Cu and Zn in the tested vegetables did not exceed the established standards. However, the Pb content in beetroot grown near Kazzinc LLP was three times higher than the safe limit. Additionally, the study results indicated that the Cd levels exceeded the safe limits in all vegetables grown in the areas from which the samples were taken. In a study by B. Moyo and others [24], Cd -1.08 mg·kg^{-1} was found in beetroot grown in close proximity to the industrial area, which is 1.6 times higher than the results obtained in this study. Cadmium is considered more toxic than lead, and according to the decision of the World Health Organization is classified as one of the most dangerous substances for human health. For example, chronic Cd exposure can lead to lung cancer, bone fractures, impaired kidney function, and hypertension [25]. Therefore, special attention should be paid to the contamination of vegetables grown in the city of Ust-Kamenogorsk with heavy metals, especially cadmium content.

The bioconcentration factor (BCF) is a common metric used to evaluate the toxicity of heavy metals and their transfer from soil to plants [26, 27]. In this study, the heavy metal concentration coefficient values ranged from 0.0003 to 1.2

Table 6 – BCF of heavy metals in vegetable crops grown on various soils of the city

Study area	Cd	Cu	Pb	Zn
	beetroot			
Vicinity of Kazzinc LLP	0,1	0,07	0,003	0,01
Village of Akhmer	0,27	0,11	0,0005	0,95
	carrot			
Suburb of Kazzinc LLP	0,03	0,03	0,001	0,07
Village of Akhmer	0,2	0,09	0,02	0,67
	potato			
Suburb of Kazzinc LLP	0,02	0,03	0,0003	0,06
Village of Akhmer	0,15	0,16	0,0009	1,2

BCF values were less than 1 for all vegetables studied, except potatoes grown in the village of Akhmer. This indicates a poor reaction of plants to the absorption of heavy metals. According to the value of the bioconcentration coefficient, heavy metals can be divided in the following descending order: Cd > Zn > Cu > Pb. The lowest BCF values were determined for Pb, and the highest ones for Cd. As for the analysis of data from the literature, the data obtained coincide with the research of Bifeng H. and others [28]. In addition, studies by B. Moyo and others [24] have also shown that the highest BCF coefficient was specific to Cd, and vegetables have a high ability to absorb Cd. Although there were variations in the minimum and maximum BCF values, they were influenced by the region where the vegetables and plants were cultivated. Among the vegetables, the lowest values were observed in the industrial area, while the highest values were found in the suburban area.

Conclusion

As a result of continuous industrialization and urbanization, heavy metal contamination has emerged as a significant environmental issue in Kazakhstan. The ability of the vegetables studied in this scientific work to absorb heavy metals from the soil was uneven. Nevertheless, it is disturbing that in almost all samples the amount of Cd exceeded the safe limits of heavy metal content in food products recommended by the FAO/WHO, it is obvious that prolonged consumption of food contaminated with cadmium can have a negative impact on the health of city residents. In this regard, heavy metals in vegetables should be monitored in order to reduce potential harm to public health. The data on the control of heavy metal levels in this study are of great importance as useful information for promoting food security in Kazakhstan and for establishing a national standard, which currently does not exist.

References

1. Woszczyk M., Spychalski W., Boluspaeva L. Trace metal (Cd, Cu, Pb, Zn) fractionation in urban-industrial soils of Ust-Kamenogorsk (Oskemen), Kazakhstan-implications for the assessment of environmental quality // Environ Monit Assess. -2018. No190 (6). P.362 (1-16).

2. Shafiq M, Bakht J, Iqbal A, Shaf M. Growth, protein expresion and heavy metal uptak by Tobacco under heavy metals contaminated soil // Pak. J. Bot. -2020. 52(5). P.1569-1576. DOI: http://dx.doi.org/10.30848/PJB2020-5(13)

3. Ghosh AK, Bhatt MA, Agrawal HP. Effect of long-term application of treated sewage water on heavy metal accumulation in vegetables grown in Northern India Environmental Monitoring and Assessment// -2012. 184. P. 1025-1036.

4. Souri M.K., Hatamian M., Tesfamariam T. Plant growth stage infuences heavy metal accumulation in leafy vegetables of garden cress and sweet basil //Chem. Biol. Technol. Agric. -2019. https://doi.org/10.1186/s40538-019-0170-3

5. Ashraf I. ,Ahmad F., Sharif A., Altaf, A.R., Teng H. Heavy Metals Assessment in Water, Soil, Vegetables and Their Associated Health Risks via Consumption of Vegetables, District Kasur, Pakistan// SN Appl. Sci. -2021.3. P. 552.

6. Sandeep G., Vijayalatha K.R., Anitha T. Heavy metals and its impact in vegetable crops //Int. J. Chem. Stud. -2019. 7. P. 1612–1621.

7. Souri MK, Alipanahi N., Hatamian M., Ahmadi M., Tesfamariam T. Elemental profle of heavy metals in garden cress, coriander, lettuce and spinach, commonly cultivated in Kahrizak, South of Tehran-Iran //Open Agric. -2018. 3(1). P. 7–32.

8. Zwolak A., Szpyrka E., Stawarczyk K. Sources of Soil Pollution by Heavy Metals and Their Accumulation in Vegetables. A Review. //Water Air Soil Poll. -2019.230 . P. 164.

9. Gupta, N., Yadav K.K., Kumar V, Kumar S., Chadd R.P., Kumar A. Trace elements in soil-vegetables interface: Translocation, bioaccumulation, toxicity and amelioration-A review. // Sci. Total Environ. -2019. 651. -P. 2927–2942.

10. Boluspayeva L., Jakubus M., Spychalski W., Abzhalelov A., Bitmanov Y. Health Risk of Heavy Metals Related to Consumption of Vegetables in Areas of Industrial Impact in the Republic of Kazakhstan—Case Study for Oskemen. Int. J. Environ. Res. Public Health.- 2023. 20. 275. https://doi.org/ 10.3390/ijerph20010275

11. Vanisree C.R., Sankhla M.S., Singh P., Jadhav E.B., Verma R.K., Awasthi K.K., Awasthi G., Naga V. Heavy metal contamination of food crops: Transportation via food chain, human consumption, toxicity and management strategies. In Environmental Impact and Remediation of Heavy Metals. // IntechOpen. London, UK, -2022.

12. https://zhaikpress.kz/ru/news/kazcink-sokratit-vybrosy-dioksida-sery-na-20-k-2024-godu/(accessed on 30 December 2023).

13. ISO 11466; Soil Quality-Extraction of Trace Elements Soluble in Aqua Regia. International Organization of Standardization: Geneve, Switzerland, 1995.

14. Ostrowska A., Gawlinski S., Szczubialka Z. Methods for Analysis and Evaluation of Soil and Plant Properties, 1st ed.; IOS Warszawa:Warszawa, Poland, 1991; pp. 158–167. (In Polish)

15. Jakubus M., Bakinowska E. The effect of immobilizing agents on Zn and Cu availability for plants in relation to their potential health risk. // Appl. Sci. -2022.12. 6538.

16. Order of the Minister of Health of the Republic of Kazakhstan dated 21 April 2021. On Approval of the Hygienic Standards for the Safety of the Environment. Available online: https://adilet.zan.kz/rus/docs/V2100022595 (accessed on 19 December 2023).

17. Standards for Maximum Permissible Concentrations of Harmful Substances, Harmful Organisms and Other Biological Substances that Pollute the Soil, Approved by the Joint Order of the Ministry of Health of the Republic of Kazakhstan Dated 30 January 2004 № 99 and the Ministry of Environmental Protection of the Republic of Kazakhstan dated January 27, 2004. Available online: https://online.zakon.kz/Document/?doc_id=1046570&pos=32;-47#pos=32;-47 (accessed on 19 December 2023).

18. Directive 86/278/EWG. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A31986L0278 (accessed on 25 January 2023)

19. Moghtaderi T., Mahmoudi S., Shakeri A., Masihabadi H.M. Heavy Metals Contamination and Human Health Risk Assessment in Soils of an Industrial Area, Bandar Abbas—South Central Iran. // Hum. Ecol. Risk Assess. -2018, 24, -P. 1058–1073.

20. Latif A., Bilal M., Asghar W., Azeem M., Ahmad MI, et al. Heavy Metal Accumulation in Vegetables and Assessment of their Potential Health Risk. //J Environ Anal Chem 5. -2018. 234. doi:10.4172/2380-2391.1000234

21. Pipoyan D., Stepanyan S., Stepanyan S., Beglaryan M., Merendino N. Health Risk Assessment of Potentially Toxic Trace and Elements in Vegetables Grown Under the Impact of Kajaran Mining Complex. // Biological Trace Element Research. – 2019. https://doi.org/10.1007/s12011-019-01675-w

22. Johann M.R., Leslie A., Hoo F., Charles N. G.Assessment of the potential health risks associated with the aluminium, arsenic, cadmium and lead content in selected fruits and vegetables grown in Jamaica. //Toxicology Reports.- 2017. 4. –P. 181-187. https://doi.org/10.1016/j.toxrep.2017.03.006

23. ALINORM 01/12A. 24; Food additives and contaminants, Joint Codex Alimentarius Commission, FAO/WHO. Food standards Programme, FAO/WHO: Geneve, Switzerland, 2001.

24. Babra Moyo, Vhahangwele Matodzi, Malebogo A. Determination of Cd, Mn and Ni accumulated in fruits, vegetables and soil in the Thohoyandou town area, South Africa Water. //SA. -2020. No 46(2). – P. 285–290

25. Satarug S., Baker J.R., Urbenjapol S. Haswell-Elkins M., Reilly P.E., Williams D.J., Moore M.R. A global perspective on cadmium pollution and toxicity in non-occupationally exposed population. // Toxicol. Lett. -2003.137. – P. 65–83.

26. Jakubus M., Bakinowska E., Compost utilisation in a heavy metal immobilisation process evaluated by bioconcentration factors. //J. Elem. -2019. 24. – P. 1291–1307.

27. Rai K.P., Lee S.S., Zhan M., Tsang Y.F., Kim, K.H. Heavy metals in food crops: Health, risk, fate, mechanism and management. // Environ. Int. -2019. 125. – P 365–385.

28. Bifeng H., Xiaolin J., Jie H., Dongyun X., Fang X., Yan L. Assessment of Heavy Metal Pollution and Health Risks in the Soil-Plant-Human System in the Yangtze River Delta, China. // Int. J. Environ. Res. Public Health.- 2017. 14. 1042. doi:10.3390/ijerph14091042

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