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Research article

HYGIENIC ASSESSMENT OF CARCINOGENIC HEALTH RISKS ASSOCIATED WITH CONTAMINATION OF DEPOSITING MEDIA WITH HEAVY METALS

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In nature there are depositing media which are relatively stable macrosystems. Their contamination that occurs due to long-term exposure to contaminants influences population health and this is especially vital for urbanized territories with large city-forming enterprises.

Our research goal was to perform hygienic assessment of carcinogenic risks for population health under exposure to heavy metals contained in depositing media.

We analyzed long-term data on contents of heavy metals in such accumulating media as soils and foods collected in 2005–2018. The data were taken from the reports on social and hygienic monitoring and statistical reports provided by the Orenburg Regional Office of the Federal State Statistics Service. Carcinogenic risks were assessed in accordance with the Guide R 2.1.10.1920-04. We used data provided by the territorial section of the National Cancer Registry to analyze prevalence of oncologic diseases of the digestive organs. We performed correlation analysis to examine correlations between the analyzed factors.

The total carcinogenic risk under multi-route introduction of heavy metals from such depositing media as soils and foods has turned out to be unacceptable and amounts to 1.5E-04. The total population carcinogenic risk caused by exposure to heavy metals can reach 85 additional cases of malignant neoplasms over an averaged exposure period which is equal to 70 years.

Heavy metals were detected in soils, nickel, cadmium, and chromium VI included, that produced statistically authentic effects on occurrence of malignant neoplasms in the digestive organs.

We established an authentic correlation between developing malignant neoplasms in the digestive organs and concentrations of arsenic in foods.

We didn't detect any heavy metals with carcinogenic properties in such accumulating media as soils and foods in concentrations deviating from hygienic standards. But still, it doesn't mean there is no negative influence on population health, notably long-term effects and developing malignant neoplasms

Key words: *soil contamination, foods, heavy metals, carcinogens, morbidity, carcinogenic risk assessment, malignant neoplasms of the digestive organs.*

There are two principally different media existing as ecosystems: a transitory one (the dynamically changing atmosphere and hydrosphere being the right example) and a depositing one that gives a clear picture of processes that are extended over time and space (soils, rocks, vegetative and animal biological substrates etc.) [1–4]. Contamination of soils as

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well as vegetable and animal foods with heavy metals results from long-term accumulation of xenobiotics on environmentally unfavorable territories. Ecological condition of accumulating media deteriorates in large cities due to intensive population growth, developing ore mining and oil and gas extraction, unsanctioned deposition of solid wastes and discharge of liquid ones, uncontrollable use of agrochemicals, and ambient air pollution with industrial emissions and exhaust gases [5–10].

Soil is an open system in urban landscapes; it has tight connections with ambient air and the hydrosphere and reflects anthropogenic loads on transitory media as it accumulates and transforms technogenic contaminants [11–14].

According to data provided by the Rospotrebnadzor Regional Office in Orenburg region, a share of soils samples that deviates from hygienic standards as per sanitary-chemical parameters amounts to 1–3 %. The most unfavorable ecological situation in the country is currently in Arkhangelsk and Amur regions. Heavy metals that contaminate soils exert their influence on population both by direct contacts with soil and by toxicants being introduced through media combined with it, including ambient air, water in water sources, and foods. Therefore, it seems necessary to take into account multiple possible routes of xenobiotics introduction into the body [15–17].

Environmental contamination with heavy metals makes for their migration along food chains and accumulation in foods thus making a substantial contribution to chemical loads on population health. As it was shown in previous research performed in Arkhangelsk region and Buryatia, foods, as a rule, conformed to hygienic requirements but still there was no guarantee that health risks were completely absent even if standards as per heavy metal contents were not violated [9, 18–21].

Together with chemization of soils and foods, there is a persistent trend for growing incidence of diseases of barrier systems in the body including malignant neoplasms in the digestive organs [22–24]. Stomach, colon, and rectum tumors occupy a significant place in the structure of oncologic morbidity and their prevalence tends to grow [25, 26].

Therefore, it seems vital to assess contamination of depositing media with heavy metals which have carcinogenic properties and produce negative effects on health, especially given the fact that there is no threshold level of exposure for these chemicals and long-term effects can't be excluded.

Our research goal was to perform hygienic assessment of carcinogenic risks for population health under exposure to heavy metals contained in depositing media.

Materials and methods. We performed hygienic assessment aimed at determining heavy metals contents in soils (nickel, cadmium, chromium, cobalt, and lead) and foods (lead, arsenic, and cadmium). We took data collected over a long-term period of social and hygienic monitoring in Orenburg, data from statistical reports issued by the Orenburg Regional Office of the Federal State Statistics Service and from state reports "On sanitary-epidemiological welfare of the population in Orenburg region" issued in 2005–2018[1].

According to the Sanitary Rules and Norms SanPiN 2.1.3684-21[2] contents of chemicals that

[1] O sostoyanii sanitarno-epidemiologicheskogo blagopoluchiya naseleniya v Orenburgskoi oblasti: Gosudarstvennye doklady (za 2005–2018 gg.) [On sanitary-epidemiological welfare of the population in Orenburg region: State reports (issued in 2005–2018)]. *Orenburg Regional office of the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing*. Available at: http://56.rospotrebnadzor.ru/gosdoklady (July 11, 2021) (in Russian).

[2] SanPiN 2.1.3684-21. Sanitarno-epidemiologicheskie trebovaniya k soderzhaniyu territorii gorodskikh i sel'skikh poselenii, k vodnym ob"ektam, pit'evoi vode i pit'evomu vodosnabzheniyu, atmosfernomu vozdukhu, pochvam, zhilym pomeshcheniyam, ekspluatatsii proizvodstvennykh, obshchestvennykh pomeshchenii, organizatsii i provedeniyu sanitarno-protivoepidemicheskikh (profilakticheskikh) meropriyatii: utv. postanovleniem Glavnogo gosudarstvennogo sanitarnogo vracha RF ot 28 yanvarya 2021 g. № 3 [SanPiN 2.1.3684-21. Sanitary-epidemiologic requirements to maintenance of territories in urban and rural settlements, to water objects, drinking water and public water supply, ambient air, soils, living spaces, exploitation of industrial and public premises, organization and c implementation of sanitary and anti-epidemic (prevention) activities: approved by the RF Chief Sanitary Inspector on January 28, 2021, Order No.3]. *KODEKS: an electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/573536177 (September 14, 2021) (in Russian).

are potentially hazardous for people should not exceed hygienic standards established for soils. Therefore, we analyzed chemical contamination of soils as per contents of heavy metals in their mobile and gross forms (more than 3780 samples) according to SanPiN 1.2.3685-21[3] in four administrative districts in Orenburg (Tsentralniy, Leniskiy, Dzerzhinskiy, and Promyshlenniy).

Total soil contamination (Zc) was determined according to the Methodical guidelines MU 2.1.7.730-999[4].

Quality of foods, both produced locally and brought from other regions, was analyzed according to the Customs Union Technical Regulations (TR CU) 021/2011[5] (more than 1728 samples).

Carcinogenic health risks were assessed as per the Guide R 2.1.10.1920-04[6] and the Methodical guidelines MU 2.3.7.2519-09[7]. Retrospective epidemiological analysis focused on cancer incidence of the digestive organs and was performed using data provided by the territorial section of the National Cancer Register. We took data on cancer incidence collected in 2005–2018 and distributed as per aforementioned administrative districts in Orenburg.

We used Spearman's rank correlation to determine cause-effect relations between the analyzed indicators. Correlation coefficient within $0.1 < R < 0.3$ meant a correlation was weak; within $0.3 < R < 0.5$, moderate; within $0.5 < R < 0.7$, average.

The data were statistically analyzed using Statistica 10 and MS Excel for Windows.

Results and discussion. Soil is a primary accumulating medium in any route toxicants migrate along. Given that, we performed hygienic assessment of heavy metals contents in soils in residential areas with the focus being on metals assigned into Group 1 carcinogens by the International Agency for Research on Cancer (nickel, cadmium and chromium (VI)) and Group 2A carcinogens (cobalt and lead). The assessment was performed in four administrative districts in Orenburg. We didn't detect any soil samples with carcinogens contents deviating from hygienic standards. We

[3] SanPiN 1.2.3685-21. Gigienicheskie normativy i trebovaniya k obespecheniyu bezopasnosti i (ili) bezvrednosti dlya cheloveka faktorov sredy obitaniya: utv. postanovleniem Glavnogo gosudarstvennogo sanitarnogo vracha RF ot 28 yanvarya 2021 g. № 2 [SanPiN 1.2.3685-21. Hygienic standards and requirements to providing safety and (or) harmlessness of the environmental factors for the population: approved by the Order of the RF Chief Sanitary Inspector on January 28, 2021 No. 2]. *KODEKS: an electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/573500115 (September 14, 2021) (in Russian).

[4] MU 2.1.7.730-999. 2.1.7. Pochva, ochistka naselennykh mest, bytovye i promyshlennye otkhody, sanitarnaya okhrana pochvy: utv. i vved. v deistvie Glavnym gosudarstvennym sanitarnym vrachom RF 5 fevralya 1999 g. [MU 2.1.7.730-999. 2.1.7. Soils, purification in settlements, communal and industrial wastes, sanitary protection of soils: approved by the Order of the RF Chief Sanitary Inspector on February 5, 1999]. *KODEKS: an electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200003852 (September 16, 2021) (in Russian).

[5] TR TS 021/2011. O bezopasnosti pishchevoi produktsii (s izmen. na 14 iyulya 2021 g.): utv. resheniem Komissii Tamozhennogo soyuza ot 9 dekabrya 2011 g. № 880 [TR CU 021/2011. On food safety (last amended on July 14, 2021): approved by the decisions of the Customs Union Commission on December 9, 2011 No. 880]. *GARANT: information and legal portal*. Available at: http://docs.cntd.ru/document/902320560 (July 13, 2021) (in Russian).

[6] R 2.1.10.1920-04. 2.1.9. Sostoyanie zdorov'ya naseleniya v svyazi s sostoyaniem okruzhayushchei prirodnoi sredy i usloviyami prozhivaniya naseleniya. Rukovodstvo po otsenke riska dlya zdorov'ya naseleniya pri vozdeistvii khimicheskikh veshchestv, zagryaznyayushchikh okruzhayushchuyu sredu: utv. i vved. v deistvie Pervym zamestitelem Ministra zdravookhraneniya RF, Glavnym gosudarstvennym sanitarnym vrachom RF G.G. Onishchenko 5 marta 2004 g. [R 2.1.10.1920-04. 2.1.9. Population health with respect to the environment and living conditions. Human health risk assessment form environmental chemicals: approved on by G.G. Onishchenko, the First Deputy to the RF Public Healthcare Minister and the RF Chief Sanitary Inspector, on March 5, 2004]. *KODEKS: an electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200037399 (June 20, 2021) (in Russian).

[7] MU 2.3.7.2519-09. 2.3.7. Sostoyanie zdorov'ya naseleniya v svyazi s sostoyaniem pitaniya. Opredelenie ekspozitsii i otsenka riska vozdeistviya khimicheskikh kontaminantov pishchevykh produktov na naselenie: utv. Rukovoditelem Federal'noi sluzhby po nadzoru v sfere zashchity prav potrebitelei i blagopoluchiya cheloveka, Glavnym gosudarstvennym sanitarnym vrachom RF G.G. Onishchenko 5 iyunya 2009 g. [MU 2.3.7.2519-09. 2.3.7. Population health with respect to food quality. Determination of exposure and assessment of risks caused by population exposure to chemical contaminants in foods: approved by G.G. Onishchenko, the head of the Federal Service for Surveillance over Consumer Rights protection and Human Wellbeing and the RF Chief Sanitary Inspector, on June 5, 2009]. *KODEKS: an electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200080418 (July 23, 2021) (in Russian).

also established there were no statistically authentic differences between the districts regarding contents of heavy metals in their mobile and gross forms (Table 1).

The total soil contamination (Zc) turned out to be "permissible" in all four districts and in the city as a whole (Zc < 16).

Carcinogenic health risks caused by exposure to chemical contamination in soils were calculated taking into account inhalation, oral, and skin introduction for mobile forms of heavy metals which take active part in the biological turnover (Table 2).

We comparatively assessed the total carcinogenic risks (SUM CRs) taking into account all ways of introduction and established that the indicator was the highest for people living in Dzerzhniskiy district (3.01E-08); the second place was taken by Leninskiy district (2.84E-08); the third, Promyshlenniy (2.45E-08); and the fourth, Tsentralniy (2.30E-08). The total carcinogenic risks caused by exposure to heavy metals in soils didn't differ authentically in all four districts and were assessed as negligible.

We detected some differences between different territories in share contributions made by different heavy metals to the total carcinogenic risk. This is due to industrial enterprises being located in different parts of the city (Figure 1). Chromium (VI) makes the highest contribution to the total carcinogenic risk in all four districts, but primarily in Dzerzhinskiy with 76 % and Promyshlenniy with 71 %. The highest contribution made by lead was established in Leninskiy and Tsentralniy districts, 34 % and 28 % respectively. Cadmium, cobalt and nickel make similar contributions to SUM CRs in all four districts.

Oral exposure to toxicants is among priority ones; given that it is seems vital to estimate the chemical structure of another accumulating medium, notably foods, and to specifically identify carcinogens in them.

Table 1

Contents of heavy metals in soils (mg/kg) and their shares of MPC (maximum permissible concentrations) in four administrative districts and the city as a whole

Metals	Administrative districts				
	Tsentralniy	Leninskiy	Dzrzhinskiy	Promyshlenniy	City
Mobile forms					
Ni $M \pm m$	2.29 ± 0.28	2.43 ± 0.46	1.97 ± 0.19	2.19 ± 0.22	2.22 ± 0.29
Ni MPC share	0.57	0.61	0.49	0.55	0.56
Pb $M \pm m$	1.48 ± 0.27	2.07 ± 0.84	1.01 ± 0.33	1.07 ± 0.26	1.41 ± 0.42
Pb MPC share	0.25	0.34	0.17	0.18	0.23
Cd $M \pm m$	0.06 ± 0.02	0.06 ± 0.03	0.06 ± 0.01	0.04 ± 0.01	0.05 ± 0.01
Cd MPC share	-*	-	-	-	-
Co $M \pm m$	0.49 ± 0.19	0.27 ± 0.14	0.30 ± 0.13	0.28 ± 0.09	0.34 ± 0.10
Co MPC share	0.1	0.05	0.06	0.06	0.07
Cr $M \pm m$	0.26 ± 0.12	0.36 ± 0.13	0.51 ± 0.13	0.39 ± 0.14	0.31 ± 0.09
Cr MPC share	0.04	0.06	0.08	0.06	0.05
Gross forms					
Ni $M \pm m$	63.39 ± 8.66	54.40 ± 6.38	54.57 ± 9.90	61.8 ± 6.26	59.25 ± 7.80
Ni MPC share	0.79	0.68	0.68	0.77	0.74
Pb $M \pm m$	20.53 ± 8.33	14.38 ± 4.28	14.97 ± 2.45	11.7 ± 2.89	15.79 ± 4.49
Pb MPC share	0.16	0.11	0.12	0.09	0.12
Cd $M \pm m$	0.11 ± 0.03	0.08 ± 0.04	0.05 ± 0.02	0.08 ± 0.04	0.07 ± 0.03
Cd MPC share	0.05	0.04	0.02	0.04	0.04
Co $M \pm m$	4.26 ± 1.5	4.43 ± 0.87	6.12 ± 1.23	3.32 ± 0.88	4.43 ± 1.12
Co MPC share	0.17	0.18	0.24	0.13	0.18
Cr $M \pm m$	72.85 ± 12.53	88.60 ± 10.33	77.20 ± 9.97	76.94 ± 4.18	76.97 ± 9.25
Cr MPC share	0.73	0.89	0.77	0.077	0.77

N o t e : * means MPC hasn't been established for a mobile form.

Table 2

Individual and total carcinogenic risks caused by exposure to chemical contamination of soils in four administrative districts and the city as a whole

Carcinogenic risks*	Administrative districts				
	Tsentralniy	Leninskiy	Dzrzhinskiy	Promyshlenniy	City
Ni CRsi	1.66E-10	1.82E-10	1.48E-10	1.64E-10	1.65E-10
Ni CRso	0	0	0	0	0
Ni CRsd	0	0	0	0	0
Ni CRs	1.66E-10	1.82E-10	1.48E-10	1.64E-10	1.65E-10
Pb CRsi	5.26E-12	7.731E-12	3.78E-12	4.00E-12	5.19E-12
Pb CRso	4.32E-09	6.34E-09	3.10E-09	3.28E-09	4.26E-09
Pb CRsd	2.21E-09	3.26E-09	1.59E-09	1.68E-09	2.19E-09
Pb CRs	6.53E-09	9.61E-09	4.70E-09	4.97E-09	6.45E-09
Cd CRsi	3.06E-11	3.11E-11	3.13E-11	2.42E-11	2.93E-11
Cd CRso	1.35E-09	1.38E-09	1.38E-09	1.07E-09	1.30E-09
Cd CRsd	6.95E-10	7.06E-10	7.10E-10	5.50E-10	6.65E-10
Cd CRs	2.08E-09	2.11E-09	2.13E-09	1.65E-09	1.99E-09
Co CRsi	2.98E-10	2.35E-10	2.63E-10	2.46E-10	2.60E-10
Co CRso	0	0	0	0	0
Co CRsd	0	0	0	0	0
Co CRs	2.98E-10	2.35E-10	2.63E-10	2.46E-10	2.60E-10
Cr CRsi	1.15E-09	1.35E-09	1.89E-09	1.44E-09	1.46E-09
Cr CRso	8.47E-09	9.87E-09	1.38E-08	1.06E-08	1.07E-08
Cr CRsd	4.34E-09	5.06E-09	7.10E-09	5.43E-09	5.49E-09
Cr CRs	1.40E-08	1.63E-08	2.28E-08	1.75E-08	1.76E-08
SUM CRs	2.30E-08	2.84E-08	3.01E-08	2.45E-08	2.65E-08
Rank	4	2	1	3	-

N o t e : * CR means an individual additional carcinogenic risk; indexes: *si* is inhalation exposure to contaminants in soils; *so* is oral exposure; *sd* is skin exposure; SUM CRs is the total carcinogenic risks caused by exposure to chemicals in soils.

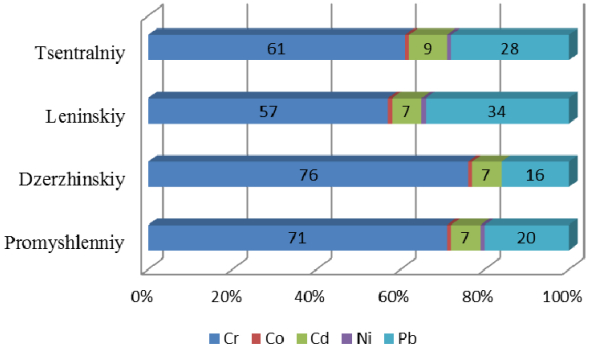

Figure 1. Contributions by priority carcinogens in soils into the total individual carcinogenic risk in all four districts (%)

Average annual contents of heavy metals in foods determined both as a median value and 90-th percentile conform to the requirements fixed in the TR CU 021/2011[5] regarding all the analyzed indicators (Table 3).

We ranked basic foods as per contributions made by specific carcinogens to the overall exposure and established that the leading rank places belonged to the following metals: cadmium in milk and milk products (34.8 %), flour-and-cereals, bakery (30.9 %), fruits and vegetables (25.9 %); lead in milk and milk products (35.3 %), fruits and vegetables (27.4 %); arsenic in fish (37.4 %).

To estimate contributions made by carcinogens in foods to risks of developing oncologic diseases, we calculated individual carcinogenic risks (Table 4).

The total carcinogenic risk caused by exposure to heavy metals in foods, calculated as per a median, conformed to the maximum permissible level; it turned out to be unacceptable for the population when calculated as per 90-th percentile. The greatest specific weight in the total carcinogenic risk belonged to arsenic (Figure 2).

The total individual carcinogenic risk caused by chemicals in soils and in foods is

Table 3

Contents of carcinogenic metals in foods (mg/kg)

Foods	Indicators	Cadmium	Lead	Arsenic
Flour-and-cereals, bakery	$M \pm m$	0.01189 ± 0.0021	0.00612 ± 0.00032	0.00577 ± 0.00042
	median	0.01	0.01	0.01
	90 %	0.014	0.01	0.01
Fruits and vegetables	$M \pm m$	0.00597 ± 0.00081	0.00649 ± 0.00084	0.00746 ± 0.0026
	median	0.01	0.01	0
	90 %	0.01	0.01	0.01
Oils and fats	$M \pm m$	0.00065 ± 0.00028	0.00313 ± 0.00134	0.00103 ± 0.00055
	median	0	0	0
	90 %	0	0.0082	0
Meat and meat products	$M \pm m$	0.00282 ± 0.00032	0.00456 ± 0.00125	0.00282 ± 0.00031
	median	0	0	0
	90 %	0.01	0.01	0.01
Milk and milk products	$M \pm m$	0.00528 ± 0.00034	0.0055 ± 0.00041	0.00524 ± 0.00034
	median	0.01	0.01	0.01
	90 %	0.01	0.01	0.01
Fish	$M \pm m$	0.0084 ± 0.00177	0.02858 ± 0.00675	0.09766 ± 0.01823
	median	0	0.01	0.024
	90 %	0.022	0.07	0.256

Table 4

Individual carcinogenic risks caused by heavy metals introduced with foods

Metal	SF_O*	ICRf** med	ICRf 90 %
Cadmium	0.38	1.6E-05	2.0E-05
Lead	0.047	2.0E-06	2.7E-06
Arsenic	1.5	4.8E-05	1.3E-04
SUM CRf***	–	6.5E-05	1.5E-04
PCR****	–	36	85

Note: * means a slope factor for oral introduction; ** means individual carcinogenic risks caused by exposure to chemicals in foods; *** means the total carcinogenic risk caused by exposure to chemicals in foods; **** means the population carcinogenic risk.

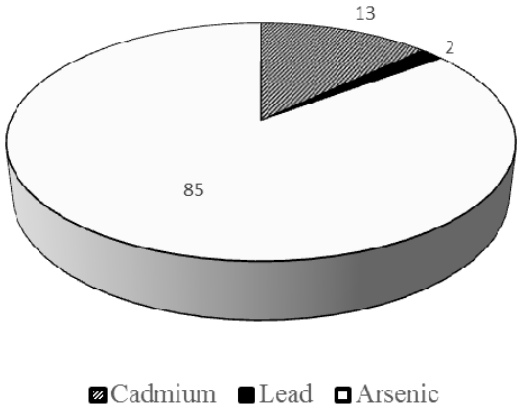

Figure 2. The structure of the total carcinogenic risk caused by exposure to carcinogens in foods taken as per 90-th percentile (%)

equal to 1.5E-04 (90-th percentile) in the city as a whole and this level is unacceptable. The total population carcinogenic risk taken as per the 90-th percentile amounted to 85 additional cancer cases among people living in Orenburg in addition to the background oncologic morbidity under 70-year exposure.

The gastrointestinal tract is the primary barrier between the body and effects produced by heavy metals in depositing media, such as soils and foods. We established that malignant neoplasms (MNs) of the digestive organs had a substantial specific weight in oncologic morbidity in Orenburg, from 24 % to 28 % depending on a district. Retrospective analysis showed a statistically significant growth in the incidence of MNs of the digestive organs over the examined period from 2008 to 2018 ($p \leq 0.05$) (Figure 3).

We ranked the incidence of MNs of the digestive organs as per four districts and established that the first rank place belonged to Leninskiy district; the second, Dzerzhinkiy; the third, Promyshlenniy; and the fourth, Tsentralniy. The incidence was authentically higher in Leninskiy and Dzerzhinskiy than on average in Orenburg ($p \leq 0.05$).

Calculated Spearman's rank correlation coefficients (R) allowed differentiating car-

cinogenic metals in soils and foods influencing MNs of the digestive organs. The incidence of MNs of the digestive organs has a direct statistically significant correlation with nickel concentration in soil (mobile form) ($R = 0.33$ for the MN of the esophagus; $R = 0.35$ for stomach cancer); cadmium (gross form) ($R = 0.5$ for the MN of the colon); chromium ($R = 0.55$ for the MN of the rectum; $R = 0.53$ for the MN of the gall bladder and extrahepatic bile ducts; $R = 0.5$ for the MN of the pancreas). We established a statistically authentic correlation between malignant neoplasms of the liver and intrahepatic bile ducts, gall bladder and extrahepatic bile ducts, and the pancreas and concentrations of arsenic in foods ($R = 0.71$, $R = 0.63$ and $R = 0.45$ respectively).

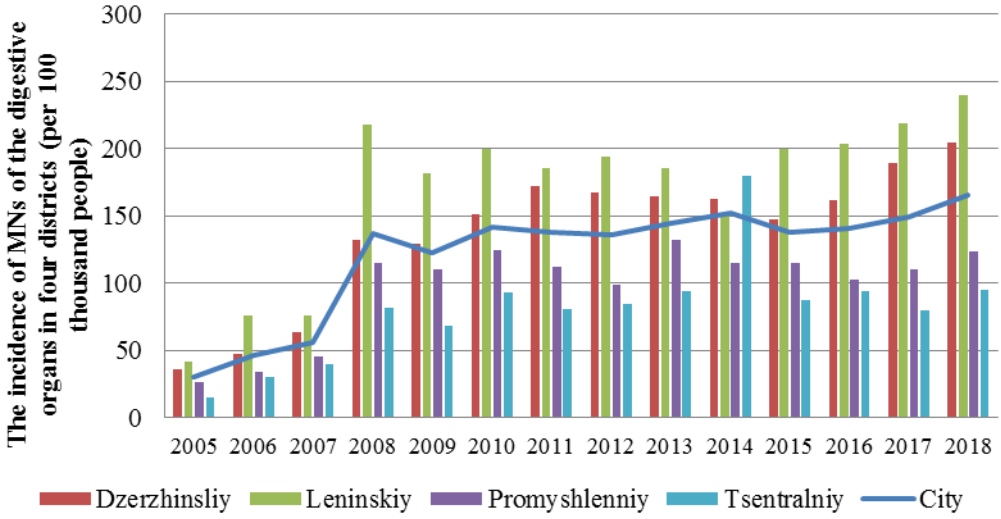

Figure 3. The incidence of malignant neoplasms of digestive organs taken in dynamics (per 100 thousand people) in different districts in Orenburg from 2008 to 2018

Table 5

Correlation coefficients for correlations between the incidence of the MNs of the digestive organs and carcinogenic chemicals in soils and foods

Localization	Carcinogens	Spearman's correlation coefficient *R*
Soil		
MNs of the esophagus	Nickel (mobile)	**0.33***
MNs of the stomach	Nickel (mobile)	**0.35***
MNs of the stomach	Cobalt (gross)	0.51
MNs of the stomach	Chromium (gross)	0.8
MNs of the colon	Cadmium (gross)	**0.5***
MNs of the rectum	Chromium (gross)	**0.55***
MNs of the liver and intrahepatic bile ducts	Chromium (gross)	0.41
MNs of the gall bladder and extrahepatic bile ducts	Chromium (mobile)	**0.53***
MNs of the pancreas	Chromium (mobile)	**0.5***
Foods		
MNs of the colon	Cadmium	0.31
MNs of the stomach	Lead	0.32
MNs of the liver and intrahepatic bile ducts	Arsenic	**0.71***
MNs of the gall bladder and extrahepatic bile ducts	Arsenic	**0.63***
MNs of the pancreas	Arsenic	**0.45***

N o t e : * means the statistical significance is taken at $p < 0.05$.

Conclusions. The total carcinogenic risk under multi-route exposure to heavy metals in such depositing media as soils and foods is unacceptable and amounts to 1.5E-04. The total population carcinogenic risk caused by exposure to heavy metals can reach 85 additional cancer cases over an average exposure period of 70 years.

We have detected carcinogenic heavy metals in soils that produce statistically authentic effects on developing MNs of the digestive organs: nickel (mobile form), MNs of the esophagus and stomach; cadmium (gross form), MNs of the colon; chromium VI (both mobile and gross form) MNs of the gall bladder, extrahepatic bile ducts, and the pancreas.

We established a statistically authentic correlation between arsenic concentrations in foods and malignant neoplasms of the liver and intrahepatic bile ducts, gall bladder and extrahepatic bile ducts, and the pancreas (R = 0.71, R = 0.63 and R = 0.45 respectively).

Therefore, even if contents of carcinogenic heavy metals do not violate hygienic standards in such accumulating media as soils and foods, it doesn't completely eliminate probable negative influence on health including long-term effects and developing malignant neoplasms.

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