Artículo de investigación

HYGIENIC ASSESSMENT OF SOIL COVER AND VEGETATION PRODUCTS IN AREAS ADJACENT TO OIL REFINERIES AND PETROCHEMICAL COMPLEXES OF THE REPUBLIC OF BASHKORTOSTAN

ГИГИЕНИЧЕСКАЯ ОЦЕНКА СОСТОЯНИЯ ПОЧВЕННОГО ПОКРОВА И РАСТИТЕЛЬНОЙ ПРОДУКЦИИ НА ТЕРРИТОРИЯХ, ПРИЛЕГАЮЩИХ К НЕФТЕПЕРЕРАБАТЫВАЮЩИМ И НЕФТЕХИМИЧЕСКИМ КОМПЛЕКСАМ РЕСПУБЛИКИ БАШКОРТОСТАН

EVALUACIÓN HIGIÉNICA DE LA CUBIERTA DEL SUELO Y DE LOS PRODUCTOS DE VEGETACIÓN EN ÁREAS ADECUADAS A LAS REFINERÍAS DE PETRÓLEO Y COMPLEJOS PETROQUÍMICOS DE LA REPÚBLICA DE BASHKORTOSTÁN

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Abstract

Soil contamination occurs as a result of adsorption of atmospheric emissions, storage and disposal of waste in the extraction, processing of oil and petrochemical industries. The evidence of participation of the petrochemical complex in soil contamination of adjacent territories with oil products and other chemical compounds was obtained. Hygienic assessment of the state of the soil cover is based on the study of polymetallic pollution, some elements of which have reasonable hygienic regulations. The detected concentrations of polymetals and petroleum products at a distance of 1 - 3 km and 3 - 6 km from the petrochemical complex can be attributed to soil contamination, respectively, to the category of "extremely dangerous" and "dangerous". The characteristic of the hygienic condition of the soil cover and agricultural crops (vegetables) grown in these territories is given. The main harmful components of the petrochemical complex are capable of

Аннотация

Загрязнение почвенного покрова происходит в результате адсорбции атмосферных выбросов, складирования и захоронения отходов при добыче, переработке нефти и нефтехимических производств. Получены доказательства участия нефтехимического комплекса в загрязнении почвы прилегающих территорий нефтепродуктами и др. химическими соединениями. Гигиеническая оценка состояния почвенного покрова основана на изучении полиметаллического загрязнения, отдельные элементы которого имеют обоснованные гигиенические регламенты. Обнаруженные концентрации полиметаллов и нефтепродуктов на расстоянии 1 - 3 км и 3 - 6 км от нефтехимического комплекса позволяют отнести загрязнённость почвы, соответственно к категории «чрезвычайно опасных» и «опасных». Дана характеристика гигиенического состояния почвенного

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translocation from contaminated soil to crops and vegetables within a radius of 20-25 km. The most intensive pollution of vegetables is observed at a distance of 6-10 km from the sources of pollution.

Keywords soil condition, plant products, petrochemical complex.

покрова и сельскохозяйственных культур (овощей), выращенных на этих территориях. Основные вредные компоненты нефтехимического комплекса способны к транслокации из загрязненной почвы в сельскохозяйственные культуры и овощи в радиусе до 20-25 км. Наиболее интенсивное загрязнение овощей отмечается на удалении до 6-10 км от источников загрязнения.

Ключевые слова: состояние почвы, продукция растительного происхождения, нефтехимический комплекс.

Resumen

La contaminación de la cubierta del suelo se produce como consecuencia de la adsorción de las emisiones atmosféricas, el almacenamiento y el entierro de los residuos durante las industrias de extracción, refinación y petroquímica. Se ha obtenido evidencia de la participación del complejo petroquímico en la contaminación del suelo de los territorios adyacentes con productos derivados del petróleo y otros compuestos químicos. La evaluación higiénica de la condición del suelo se basa en el estudio de la contaminación polimetálica, algunos de los cuales tienen regulaciones higiénicas razonables. Las concentraciones encontradas de polimetales y productos petrolíferos a una distancia de 1 a 3 km y de 3 a 6 km del complejo petroquímico permiten clasificar la contaminación del suelo como “extremadamente peligrosa” y “peligrosa”, respectivamente. Se presenta la característica del estado higiénico de la cobertura del suelo y los cultivos (hortalizas) cultivados en estos territorios. Los principales componentes dañinos del complejo petroquímico son capaces de translocarse de suelos contaminados a cultivos y vegetales en un radio de hasta 20-25 km. La contaminación más intensa de los vegetales se observa a una distancia de hasta 6-10 km de las fuentes de contaminación.

Palabras clave: condición del suelo, productos de origen vegetal, complejo petroquímico.

Introduction

Currently, the environmental situation in the Russian Federation (RF) is characterized by a high level of anthropogenic impact on the environment and significant environmental consequences of past economic activities. There is a tendency to deterioration of soil and land practically in all regions. The distribution zones of pollutants that can accumulate in the soil cover an area of 18 million hectares directly around industrial complexes (Basics of state policy in the field of environmental development of the Russian Federation for the period, 2012).

Analysis of waste generation in the Republic of Bashkortostan (RB) in the context of types of economic activity shows that the bulk of the generated waste is accounted for by enterprises engaged in the extraction and processing of mineral resources. This number includes enterprises of oil and gas and oil refining complex (hereinafter - petrochemical complex).

In 2018, in order to implement breakthrough scientific, technological and socio-economic development, the President of the Russian Federation signed a decree “On the national goals and strategic objectives of the development of the Russian Federation for the period up to 2024” (Presidential Decree, 2018), which instructed to implement 12 national projects, including environmental and health care.

Soil pollution occurs as a result of adsorption of atmospheric emissions in ecologically unfavorable territories. According to published data of recent years, the zone of active soil pollution by objects of the petrochemical industry is up to two or three kilometers from enterprises. In this case, the general distribution of harmful substances can reach up to 20 km or more. The soil serves as a reservoir in which harmful substances can accumulate in large quantities (Solovyanov, 2015). Thus, studies conducted by authors in Novokuibyshevsk showed that the concentration of oil products in the soil reached 5805.6 mg / kg of dry soil. The content of volatile phenols reaches up to 48.1 mg / kg, benzo (a) pyrene – 0.2 mg / kg, mobile forms of copper –37.9 maximum allowable concentrations (MAC), nickel –3.8 MAC, zinc – 1 , 3 MAC, lead –1.2 MAC, cadmium – up to 2.5 approximate permissible concentrations (APC), arsenic – 2.2 APC (Sazonova et al.., 2017). Soil contamination with oil products and other chemical compounds from emissions from oil refineries leads to a significant change in the structural organization of the main components of the soil, salinity and reduced productivity of soil resources and the penetration of toxicants into plants. Petroleum products and phenol are found not only in the soils of these areas, but also in horticultural products grown on these soils (Seredina et al., 2017; Tsunina, 2002). From the hygienic point of view, the soil is one of the components of a complex environmental complex that is in constant interaction with the human body.

According to expert estimates, more than two million tons of solid and semi-liquid oil waste and sludge have been accumulated in the Republic of Bashkortostan for more than eight decades of work of petrochemical complexes (Safety vector of the Department of Occupational Safety, Industrial Safety and Ecology of JSOC Bashneft, 2014). Currently, there is no scientific evidence-based MAC for oil, and there is no consensus on its background content in the soil. The range of suggested background values, according to different authors, ranges from 0.01 to 1000 mg / kg, which is largely due to regional soil and climatic conditions (Trofimov, Amosov, 2000; Rusakov et al.., 2007). According to the results of our studies of past years, the soil cover in the area of storage of industrial waste (sludge) contained heavy fractions of petroleum products in the amount of –4645 mg / kg, α–methylstyrene – 1.99 mg / kg, toluene – 0.78 mg / kg, benzene – 0.17 mg / kg and gasoline — 0.29 mg / kg.

The purpose of the research is a hygienic assessment of the soil, the determination of the real level and range of the spread of soil contamination by the main components of emissions from the petrochemical complex. The objects of research were soil cover around the petrochemical complexes and agricultural and vegetable crops grown in these territories.

Material and research methods

To study the soil contamination, we used the data of ecological and hygienic studies in the areas where petrochemical complexes are located (the cities of Ufa, Salavat, Sterlitamak, Ishimbay and the surrounding rural areas), the data of social and hygienic monitoring of the Office of Rospotrebnadzor in the Republic of Bashkortostan, the Bashkir Hydrometeorology and Monitoring Department environment, the reporting forms of "2-TP (air)" and maximum allowable emissions. Soil samples were taken at a distance of 1 to 25 km in accordance with the current recommendations (MUK 4.1.1956-05; Methodical recommendations on the geochemical assessment of contamination of urban areas with chemical elements, 1982). Sampling of root crops, tubers, potatoes was carried out directly in the places of their growth in accordance with the known requirements. "Point samples" were taken in 4-5 places using the "envelope method". The combined sample, weighing 1 kg, was packed in plastic bags. An average sample was formed from the combined sample of crop production. The quantitative determination of harmful substances in the soil and in plant products is made in the chemical-analytical department of the institute accredited for technical competence (accreditation certificate No. ROSS RU, 0001.510411 of the testing center of the FBUN Ufa Research Institute of Labor Medicine and Human Ecology). Analysis of the content of micro– and macroelements in environmental objects and food products was performed on imported equipment (a set of two highly sensitive atomic absorption spectrometers Spectr AA 240FS and 240Z with flame and graphite atomization from Varian (Australia)). Statistical processing of the results was performed using the spectrometer software and the Microsoft Excel software package. Quantitative intergroup differences were assessed by Student's criterion (Ayvazyan et al.., 1989).

The results and discussion

The results of hygienic studies and the analysis of data from the above-mentioned regulatory bodies allow us to conclude that the atmospheric air of cities and towns of the republic is polluted with a complex composition of chemicals. The most intense pollution is found in the area where the oil refining and petrochemical complexes are located. The situation is complicated by the fact that atmospheric pollution is accumulated in the depositing environment (snow, soil and surface water) and therefore are sources of additional pollution of environmental objects. Table 1 shows the chemical load on the territory of three cities, due to emissions of petrochemical complexes in the dynamics of five consecutive years. It follows from the presented data that the average annual load on the territory depends on the amount of emissions. In cities with a developed petrochemical complex, the chemical load is 2–3.5 times higher than in a city without such enterprises.

Table 1. Chemical load from emissions of pollutants into the atmosphere (tons / year) per 1 hectare of the territory

Cities	On 1 hectare of territory					Average load
	2008	2009	2010	2011	2012	
Ufa	4,586	3,790	4,929	4,605	5,703	= 4,723
Salavat	5,954	7,881	6,419	4,000	3,902	= 5,637
Sterlitamak	8,626	8,515	8,648	9,556	9,590	= 8,987
City averages	6,389	6,729	6,665	6,054	6,398	= 6,447
For comparison - the control city (mainly transport emissions)						
Belebey	2,070	2,385	1,999	3,442	2,187	= 2,417

The magnitude of the formation of oily waste for individual oil refineries in Ufa are shown in Table 2.

Table 2. Average annual volumes of oil refining enterprises waste

Enterprise	Volumes of oil waste (thousand tons per year)	Volumes of used oil waste (thousand tons per year)
OJSC "Ufa Refinery"	24,348	4,228
OJSC "Novo-Ufa refinery"	38,251	8,879
JSC "Ufaneftekhim"	21,839	14,425
Average:	=28,146	= 9,177

Table 3 presents the averaged results of soil studies in areas where petrochemical enterprises are located. In the list of concentrations, the first place is occupied by petroleum products, the second is sulfates. The remaining substances are in very small quantities. Thus, direct dependences of polluting concentrations on the distance to the source are characteristic only for massive pollution, which is represented by the indicated oil products and sulphates. These data are explained by the fact that the table shows the average research results for 5 years. Meanwhile, in some years of observation, high levels of soil contamination were recorded in the adjacent territories of a number of petrochemical complexes. The spatial distribution of petroleum hydrocarbons in the soil cover depends on the height of emission into the atmosphere. Thus, the petrochemical enterprises of Sterlitamak carry out emissions to a height of up to 50-100 m. The greatest hydrocarbon pollution of the soil is found 1.5-2.0 km from the complex. In the soil, the total iron content exceeds the MAC by 2.4-3.16 times, manganese by 1.0-1.3 times, and chromium by 2.0-2.15 times. Benz (a) pyrene (up to 325 MAC), isopropyl benzene (up to 98 MAC), styrene (up to 270 MAC),-methylstyrene (up to 15 MAC), benzene (up to 4.5 km), toluene and xylene (up to 13 MAC) and gasoline (up to 15 MPC) were found at a distance of 2.5 km from JSC "Ufaneftekhim".

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Table 3. Soil contamination in areas adjacent to petrochemical complexes (average data for 5 years of observations, in mg / kg)

Pollution list	**Distances from objects, km**		
	0 - 3	**6 - 10**	**15 - 20**
Oil products	2325±425	284±63	410±82
Sulfates	156,5±28,3	117,0±25,4	53,8±10,2
Petrol	0,1±0,03	0,1±0,01	0,12±0,02
Benzene	0,1±0,02	0,05±0,01	0,003±0,001
Xylene	0,2±0,04	0,08±0,01	0,25±0,04
Ethylbenzene	0,3±0,08	0,03±0,01	0,004±0,001
Toluene	0,007±0,001	0,03±0,01	0,004±0,001
Styrene	0,03±0,01	0,03±0,01	0,006±0,001
Isopropyl benzene	0,2±0,03	0,1±0,01	0,02±0,003
α-methylstyrene	0,2±0,03	0,03±0,0004	0,003±0,001
Benz(a)pyrene	0,2±0,02	0,3±0,05	0,7±0,04

When assessing soil contamination for the ecological condition of a territory, the content of oil products in the soil cannot be considered as the only indicator of pollution. The impact of petroleum products on biological objects is determined not only by the concentration of hydrocarbons in the soil, but also by the nature of the interaction of these hydrocarbons with the biological content of the soil. This interaction is of an adsorption nature and is in a certain way related to the structure of the soil layers. The formation of toxic oxygen-containing products — aldehydes, ketones, alcohols, esters, and organic acids — was revealed during the transformation of the hydrocarbon component of oil in the soil. These substances are not included in the concept of "petroleum", but are the result of their decomposition. The variety of molecular mass distribution of hydrocarbons in oil leads to the fact that the same mass concentrations of oil products in the soil can lead to different forms of negative effects on biological objects.

Table 4. The content of heavy metals in the soil from the agricultural fields of Sterlitamak district (gross form)

Settlements	**Fe**	**Cu**	**Zn**	**b**	**g**	**Mn**	**Ni**	**d**	**Cr**
	Maximum allowable concentrations, mg / kg								
	10,9	**132**	**220**	**130**	**1,21**	**425**	**80**	**2,0**	**35,6**
	Content, mg / kg (dry soil)								
Oktyabrskoe	26 476	19,6	39,6	9,6	0,05	421,6	48,4	0,19	71,5
Verhnie Usly	32 690	21,6	46,1	10,1	0,05	469,5	59,2	0,19	73,4
Yuzhnoe	34 418	22,3	46,7	10,8	0,05	473,7	59,8	0,21	76,1
Begenyashskoe	28 352	23,2	44,2	9,8	0,05	521,8	63,8	0,22	74,8
Burikazganovo	32 578	23,1	46,1	10,6	0,04	554,6	71,8	0,23	74,9
Pervomajskij	27 719	22,9	44,3	9,7	0,04	493,3	67,6	0,20	76,5

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"Roshchinskij"	31 022	21,7	42,7	11,5	0,04	528,4	58,1	0,30	73,4

Table 5. The content of heavy metals in the soil from the agricultural fields of the Sterlitamak region (mobile form)

Settlements	**Fe**	**Cu**	**Zn**	**Pb**	**Hg**	**Mn**	**Ni**	**Cd**
	Maximum allowable concentrations, mg / kg							
	ground	**3,0**	**23,0**	**6,0**	**500**	**4,0**		**6,0**
	Content, mg / kg (dry soil)							
Oktyabrskoe	3,07	<0,01	0,46	0,61	62,23	0,87	0,084	0,23
Verhnie Usly	1,40	0,04	0,35	0,56	68,72	0,79	0,239	0,12
Yuzhnoe	1,65	0,07	0,25	0,48	65,90	0,82	0,097	0,20
Begenyashskoe	1,45	0,10	0,33	0,50	63,62	0,70	0,085	0,21
Burikazganovo	0,92	0,13	0,28	0,45	84,70	0,89	0,074	0,44
Pervomajskij	1,31	0,11	0,39	0,56	80,31	0,63	0,102	0,12
"Roshchinskij"	11,42	0,14	0,47	0,41	49,51	0,89	0,084	0,66

In agriculture, plant protection products are used. They may also be of interest in a hygienic assessment of the degree of environmental pollution. Therefore, Table 6 compares the levels of pollution of fields with oil products and isomers of hexachlorocyclohexane (HCCH) and dichlorodiphenyl acetic acid (DDA).

Table 6. The content of organic matter in soil from agricultural fields Sterlitamak district (mg / kg)

Place of selection	**Oil products**	**HCCH (sum of isomers)**	**DDA (sum of isomers)**
Village "Oktyabrskoe", a wheat field	348,8	0,003	not found
Village "Verhnie Usly", potato field	1638,0	0,006	not found
Village "Yuzhnoe"	167,3	not found	not found
Village "Begenyashskoe", wheat field	132,0	not found	not found
Village "Burikazganovo"	93,0	not found	not found
Village "Pervomajskij", wheat field	92,3	0,009	not found
State Farm "Roshchinskij", rye field	205,5	not found	not found

The dynamics of aldehyde accumulation in polluted soil can serve as an indicator of the biological degradation of petroleum hydrocarbons. Hydrocarbons, especially aromatics, formed during the processing of oil, are more toxic than natural oil.

We revealed a direct correlation dependence of the average force between the content of atmospheric air and soil: gasoline, xylenes, the sum of hydrocarbons, lead, chromium, soot, and benzo (a) pyrene. The inverse correlation of the same roughly force is established for nitrogen, ammonia and sulfuric acid. No signs of interdependence between the intensity of air pollution and soil contamination were found for phenol, toluene, and manganese. Hydrogen sulfide and sulfur oxides, the main pollutants of petrochemical plants with precipitation fall into the soil cover, are adsorbed by the soil absorbing complex, and then converted to sulfates. Therefore, a high content of sulfates in the soil indicates pollution by petrochemical emissions. An elevated chloride content in soil samples also indicates the adverse effects of emissions from these industries.

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Analysis of waste generation processes shows that their bulk is not disposed of and is located in oil barns, sludge tanks and at special landfills. Considerable land resources are alienated for their storage. All three oil refineries of ANK Bashneft PJSC in Ufa have oil and slag storage sites from 0.5 to 15 hectares. Since it is impossible to isolate waste storage sites from environmental objects, the migration of toxic substances in the soil, into water sources and atmospheric air is constantly observed. Table 7 shows the ratio of household and industrial waste generated per inhabitant of the cities of the republic, where there are petrochemical and oil refining enterprises.

Table 7. Waste generation per inhabitant in a number of cities in the region (on average over five years)

Cities	Population (thousand people)	Amount of waste (thousand tons / year)	Waste amount per resident (thousand tons / year)	Recycled waste (% of total)	Neutralized waste (% of total)
Salavat	157,6	460,764	2,9	41.7	-
Sterlitamak	263,8	1749,689	6,6	52,4	6,6
Ufa	1092,6	2285,896	2,1	29,4	0,15
Belebey	59,4	83,368	1,4	6,5	0,5

The exception in the list of cities in this table is Belebey, where there are no petrochemical enterprises. In this city, an average of 1.4 thousand tons of waste is generated per year. At the same time only a small part of the waste is disposed of and neutralized. Most of the waste is exported for disposal. If the waste does not pose a particular hazard in the city of Belebey, then the majority of the waste in the other cities contains refined products and petrochemicals. The best situation is in the city of Sterlitamak: the largest share of waste per inhabitant, but their utilization amounts to a significant percentage. The waste is not neutralized at all in the city Salavat - it is transported to burial sites.

We conducted a chemical analysis of vegetables and potatoes growing on the territory of collective farms (gardens) and located directly in the sanitary protection zones of the complexes. When determining specific chemical compounds in cultures grown at distances of 1-3, 6-10, 15-20 km from these complexes, the greatest accumulation of chemicals is typical for distances up to 3-6 km.

Table 8. Contamination of crops in areas adjacent to petrochemical complexes (average data for three years)

List of pollutants	Distance from objects, km		
	0 - 3	6 - 10	15 - 20
Radish	0,02±0,005	0,02±0,003	0,007±0,001
Petrol	0,008±0,001	Not found	Not found
Benzene	0,004±0,001	Not found	Not found
Toluene	Not found	0,005±0,001	Not found
Ethylbenzene	0,64± 0,08	0,96±0,15	0,58±0,12
Xylene	0,13±0,04	0,1±0,03	0,01±0,004
Styrene	0,01±0,004	0,02±0,003	0,005±0,001
α- methylstyrene	0,01+0,003	0,02±0,004	0,005±0,001
Bow			
Petrol	0,04± 0,01	0,04± 0,008	0,04± 0,007

Benzene	0,01±0,003	0,01±0,003	
Toluene	0,09±0,01	0,18±0,03	0,09± 0,008
Ethylbenzene	0,24±0,06	0,27± 0,04	0,007±0,001
Xylene	0,71+0,15	1,1±0,32	0,65±0,12
α- methylstyrene	Not found	Not found	0,2±0,040
Potatoes			
Petrol	0,12±0,03	0,4±0,1	Not found
Benzene	0,01+0,002	Not found	Not found
Toluene	0,11±0,02	Not found	Not found
Ethylbenzene	0,003±0,001	0,005±0,001	Not found
Xylene	0,003±0,0008	0,1±0,03	Not found
Styrene	Not found	Not found	0,002±0,0001
α- methylstyrene	0,004±0,001	Not found	Not found
Beet			
Petrol	0,015±0,003	0,031±0,007	0,01±0,003
Benzene	0,006±0,0010	Not found	Not found
Toluene	0,004±0,0010	Not found	Not found
Ethylbenzene	0,0051 ±0,001	Not found	Not found
Xylene	0,0051±0,001	0,041± 0,01	0,0071±0,001
Styrene	0.0061±0,001	Not found	Not found
Carrot			
Petrol	0,041±0,01	0,0340±0,005	0,0131±0,0050
Benzene	0,061±0,01	0,0051±0,001	Not found
Toluene	0,0031±0,001	Not found	Not found
Ethylbenzene	0,311±0,08	Not found	Not found
Cucumber			
Petrol	0,0151±0,004	0,0041± 0,001	Not found
Benzene	0,571±0,08	0,231±0,07	Not found
Toluene	0,0151±0,005	0,081±0,01	Not found
Styrene	0,21±0,04	0,081±0,01	Not found
Tomato			
Petrol	0,091±0,02	0,030±0,008	Not found
Benzene			
Toluene	0,021±0,006	0,00171±0,001	Not found
Ethylbenzene	0,0319±0,008	0,011±0,004	Not found
Xylene			
Styrene	0,061±0,01	0,041±0,008	Not found

Cabbage			
Petrol	0,041±0,01	0,031±0,009	Not found
Ethylbenzene	0,091±0,01	0,061±0,02	Not found
Xylene	0,21±0,05	0,061±0,01	Not found

Thus, our comprehensive research and hygienic assessment of technogenic pollution allowed us to justify the priority criteria for the quality of environmental objects in regions with developed petrochemical complex. Table 9 presents 33 indicators specific to petrochemical pollution in three environments: air, water, and soil. The definition of one or another indicator for the characterization of pollution provides for its optional determination. Taking into account the developed criteria for the priority of individual pollutants in the analysis of environmental and hygienic risks to public health will increase the accuracy of estimates and clarify the hazard ranking in the calculations.

Table 9. The list of priority indicators for the quality control of environmental objects in the regions of petrochemical complexes' influence

N	Indicators	Atmospheric air	Water reservoirs	Soil cover
1	Ammonia nitrogen		+	
2	Nitrogen dioxide	+		
3	α - methylstyrene		+ +	+ +
4	Ammonia	+	+	
5	Sulfurous anhydride	+		
6	Acetaldehyde	+ +		
7	Acetone	+ +	+	
8	Petrol			+
9	Benzene	+	+	+
10	Benz (a) pyrene	+	+	+
11	Biochemical Oxygen Demand BOD20		+	
12	Hexane			
13	Isopropyl benzene		+ +	+ +
14	Dissolved oxygen		+	
15	Xylene	+ +	+ +	+ +
16	Methyl ethyl ketone			
17	Naphthenic acids		+ +	
18	Methanol	+ +	+ +	
19	Oil products		+	+
20	Pentane			
21	Hydrogen sulphide	+		
22	Carbon disulfide	+ +		
23	Styrene	+ +	+ +	+

24	Sulfates		+	+
25	Toluene	+ +		+ +
26	Hydrocarbons	+		
27	Carbon oxide	+		
28	Tetrachloride carbon	+ +		
29	Phenol	+	+	+ +
30	Formaldehyde	+	+	
31	Chemical Oxygen Demand (COD)		+	
32	Cyclohexane	+ +		
33	Ethylbenzene	+		+ +

Note to table 9: the sign "+" means obligatory determination of the substance, two signs "++" - optional research.

In the hygienic assessment of soil contamination, along with the listed chemicals, special attention should be paid to heavy metals. The advantage of their evaluation is that the content of metals in the soil is determined by approved hygienic regulations. Our latest research on the impact of industrial emissions from Ufa enterprises showed that not only the distance and direction from the selection point to the city, but also the chemical composition of the soil on which main vegetables and potatoes are grown affects the elemental composition of food (Daukaev et al., 2018). So, the total soil pollution with heavy metals is higher in the northern part, and water-soluble forms in the southern part of the city. The accumulation of heavy metals in vegetables is multidirectional, for example, more cadmium was detected in the samples in the northeast and southeast zones, lead and nickel predominate in the southern zone. In general, it is necessary to state that vegetable products produced in the zone of influence of city enterprises do not meet the requirements of hygienic standards for high content of nickel, chromium and cadmium. At the same time, an insufficient content of such elements as iron, copper, manganese and zinc was found in potatoes and other vegetables. The level of manganese and iron is largely determined not by the selection point, but by the type of vegetables. So, manganese is most detected in beets (4.5 ± 2.18 mg / kg), and iron is found in potatoes (4.50 ± 1.17 mg / kg). The content of zinc and copper does not differ significantly depending on the type of vegetable products. At the same time, the highest levels of cadmium, chromium and nickel are found in beets and carrots at a distance of up to 25 km or more in different directions from the city of Ufa.

The results of the studies confirm and complement our data, obtained in the 70s-90s (Suleymanov et al., 1996), about the “dangerous” level of contamination of soil and crops within a radius of at least 15-20 km from the existing petrochemical complexes.

Conclusions

1. The soil cover is significantly polluted with oil products, organic compounds, metals, salts and other products of oil refining in the territories adjacent to large petrochemical complexes, at a distance of up to 3 km from the enterprises.
2. The main harmful components of the petrochemical complex are capable of translocation from contaminated soil to crops and vegetables within a radius of up to 20-25 km. The most intensive pollution of vegetables is observed at a distance of up to 6-10 km from pollution sources. The accumulation of heavy metals in vegetables and potatoes in recent years has a multidirectional nature and does not always depend on the distance of harmful emissions from petrochemical complexes. The increased content of heavy metals in soil and agricultural products over the past 10–15 years may be due to a multiple increase in the number of motor vehicles and the accumulation of their harmful emissions.
3. Conducted research and hygienic assessment of anthropogenic pollution allowed to justify the priority criteria for the quality of environmental objects in regions with developed petrochemical industry (Table 9). The introduction of

these criteria in the current socio-hygienic monitoring system will increase its focus in assessing the ecological and hygienic situation in certain regions.

4. As part of the implementation of the regional component of the national program on ecology until 2024, the most important and environmentally sound management decision on the protection of soil cover and other environmental objects in the Republic of Bashkorstarstan is the decision of ANK Bashneft PJSC to complete the design (in 2018), build and introduce operation of a modern installation for processing all previously accumulated oil sludge in the region at the Bashneft-Ufaneftekhim enterprise.

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