Environmental State of North Caucasus Region, Caused by Mining Activities

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***Abstract*—Two areal spots (Vladikavkaz areal spot and Unal spot) where chemical pollution of soils associated with mining reaches an extremely dangerous level were identified on the territory of North Ossetia-Alania. The areas with varying degrees of environmental stress were identified within the RSO-Alania region based on the obtained data. As a result of eco-geochemical soil sampling in the territory of Vladikavkaz, a technogenic halo of heavy metals dispersion (with an area of about 42 km^2) was singled out, the nuclear zone of which, while being characterized by a high concentration of lead, zinc and copper (more than 1%), remains almost unchanged with a significant decrease in the volume of mineral processing in the last decade. Investigations on the influence of negative environmental factors on the morbidity of the population in urbanized areas of Vladikavkaz and Alagir district were conducted. A correlation relationship between the number of neoplasm cases originating from the age group of cancer patients was established. For a more detailed investigation of the distribution of cancer morbidity by age categories, similar data for the Chechen Republic were analyzed. Investigations on the influence of negative environmental factors on the morbidity of the population in urbanized areas of Vladikavkaz and Alagir district were conducted. A correlation relationship between the number of neoplasm cases originating from the age group of cancer patients was established. For a more detailed investigation of the distribution of cancer morbidity by age categories, similar data for the Chechen Republic were analyzed.**

Keywords—ecological state; heavy metals; technogenic pollution; morbidity; regression analysis

I. INTRODUCTION

Since the construction of the metallurgical plant in 1800, the Republic of North Ossetia-Alania, especially the town Vladikavkaz, has undergone increasingly the effects of chemical pollution by toxic heavy metals stored on its territory in the form of enrichment tailings and metallurgy. Health status of the population worsens under the influence of negative processes in the geological environment that accumulates harmful substances [1-2].

One of the aspects of the problem is to establish a correlation between the parameters of technogenic pollution of the geological environment and the health status of citizens in order to develop the scientific bases for eco-geochemical monitoring and rehabilitation measures.

It is necessary to compare the medical and biological data on the health status of the population of the town with the ecological and geochemical data on the territory contamination in order to achieve the goal of the study.

Two ecologically tense areas, which are characterized by a concentration of the facilities of metal extraction and processing, are singled out as the largest elements of the regional ecological zoning of the territory of the Republic of North Ossetia-Alania.

Total indicators of the harmful effects of emissions and discharges are calculated with the help of the map of anthropogenic objects and the automated database of

environmental data for all groups that are spatially adjacent technogenic sources of environmental pollution of the Republic of North Ossetia-Alania, according to the method of Troshchak L.A.

It was established (as a result of the analysis of anthropogenic load on the territory of North Ossetia – Alania) that the main negative anthropogenic factor here is chemical pollution of the environment, and the level of pollution of components of the geological environment can serve as an indicator of geoecological distress.

II. CHEMICAL POLLUTION OF THE TERRITORY

Two areal spots (Vladikavkaz areal spot and Unal spot areal) where chemical pollution of soils associated with mining reaches an extremely dangerous level were identified on the territory of North Ossetia-Alania. We have identified areas with varying degrees of environmental tension on the basis of the data obtained within the RNO-Alania region (Fig. 1): catastrophic, critical, crisis, tense and relatively satisfactory degrees.

The Vladikavkaz technogenic halo of heavy metal pollution was determined by the research of the Institute of Mineralogy, Geochemistry and Crystal Chemistry of Rare Elements in 1982-1988 [3-4]. Regularity between the amount of pollutants and the area of pollution was established at an early stage of the research.

So, in 1985, the area of dangerous and extremely dangerous pollution was 17.3% of the total area of the zone, and the mass of dangerous and extremely dangerous pollutants was 81.4% of the total mass of pollutants. A detailed study of the nature and structure of the Vladikavkaz halo was conducted in order to substantiate rehabilitation activities in subsequent years (2002, 2003, 2011, 2014) within the framework of several thematic projects.

It has been found out with the help of investigation that the main technogenic source of chemicals in the environment is toxic waste from mining and processing industries. Priority series (ranked lists) of enterprises and pollutants were compiled according to the summing values of the indicators of harmful effects.

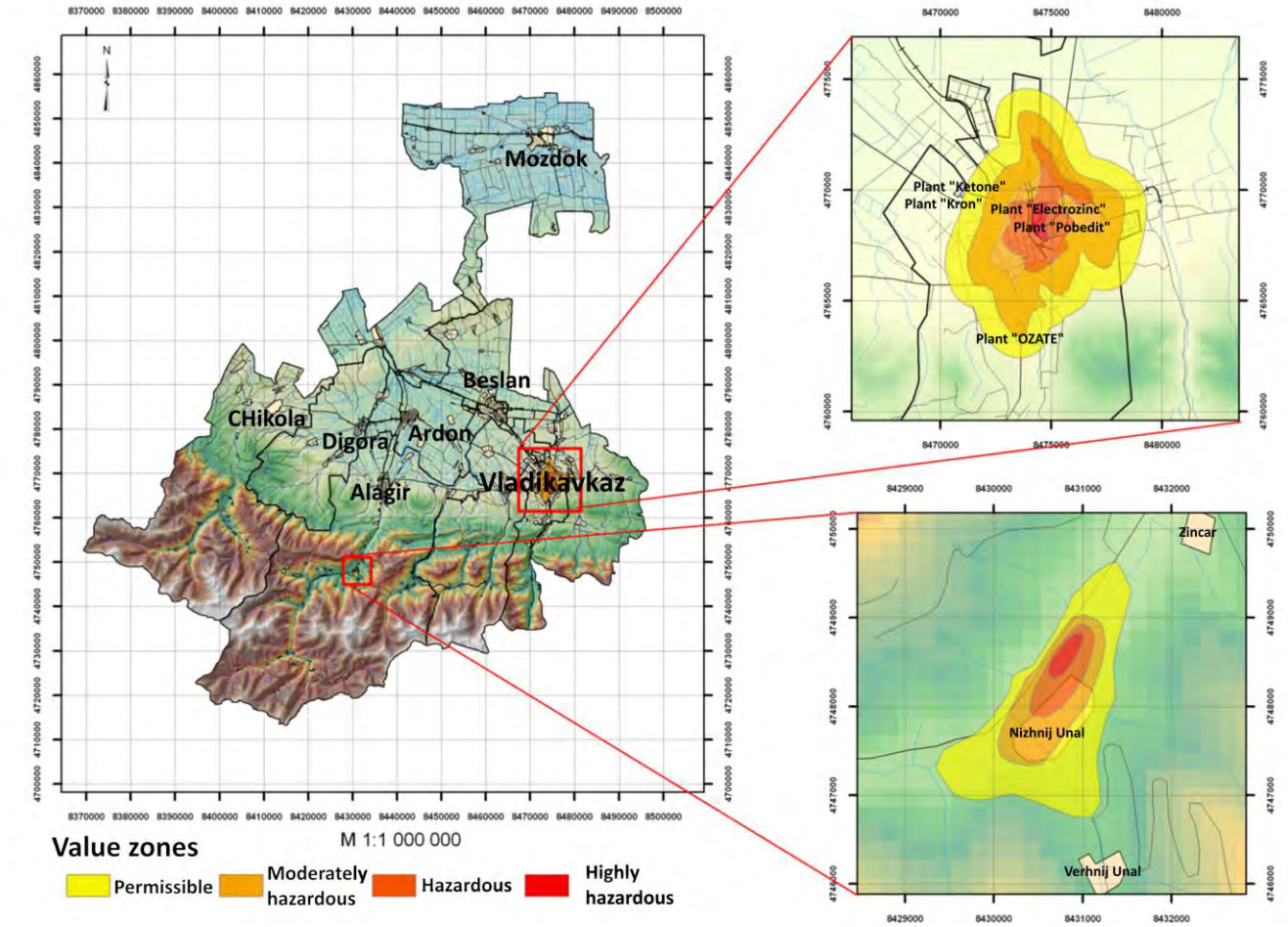

Fig.1. Schematic map of zones of environmental situations in the mining regions of North Ossetia-Alania.

The plants Electrozinc and Pobedit prevail among the polluting facilities of Vladikavkaz, which corresponds to the location of these plants in the cental (nuclear) zone of the Vladikavkaz technogenic halo.

As a result of eco-geochemical soil sampling in the territory of Vladikavkaz, a technogenic halo of heavy metals dispersion with an area of about 42 km2 (which occupies the entire right bank part of the town and a significant part of the left bank) was singled out.

Increased concentrations of elements not only of the first, but also of the second hazard class are observed in the central (nuclear) zone, and the boundary of the zone contours the area where the majority of enterprises with maximum emissions are located.

The center of the technogenic halo central (nuclear) zone, located on the territories of the plants Electrozinc and Pobedit, is characterized by the highest concentrations of the elements mentioned above (content of lead, zinc and copper exceeds 1%); cobalt, manganese, chromium, tungsten, cadmium, indium, bismuth, antimony, lanthanum, phosphorus and niobium are also characterized by anomalous content.

The central part of the halo is contaminated with elements of all three hazard classes. The total pollution index Zc was used in order to obtain an integrated picture of the distribution of chemical elements in the soils of Vladikavkaz (Fig. 2).

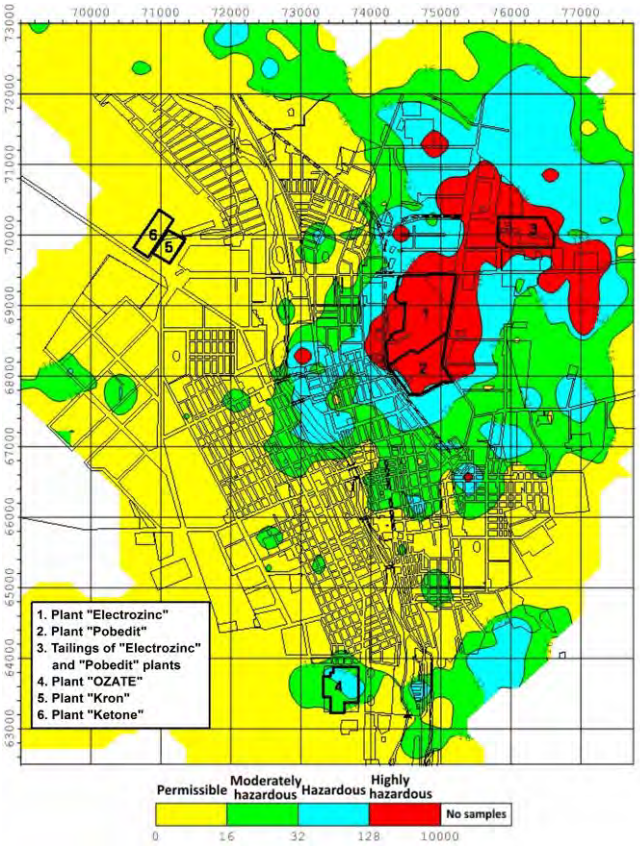

Fig.2. Distribution of pollution index Zc in the soils of Vladikavkaz.

III. Pollution Impact on Health

Anthropogenic pollution of the environment has a clear impact on the health of the population [5-19]. The steady increase in the release of toxic substances into the environment, primarily affects the health of the population [20-28]. In the conditions of mountainous terrain, the problem is even more acute due to the limited and closed space [29-31].

A marker for environmental distress is cancer morbidity of the population [32-34] The carried out investigations on the influence of negative environmental factors on population morbidity in urbanized areas of Vladikavkaz and the Alagir district revealed the interrelation of these factors and the state of health of the population [35].

The data from the polyclinics No. 1, 3, 4, 5, 7 of the city of Vladikavkaz were selected on the morbidity of malignant growth in different parts of the city [36].

For processing and subsequent analysis of the obtained data, a special database was developed [8]. Forming parameters of the base included residence, gender, patient's age, localization of the patient's body lesion (brain, larynx, stomach, female genitals, thyroid, intestines, skin, bones, blood, lungs, lymph nodes, face, mammary gland, male genitals , liver, kidney, prostate gland), a total of 17 designations (full names of patients for ethical reasons are not included in the primary data). Patients were divided into several groups according to age, up to 20, 20–29, 30–39, 40–49, 50–59, 60–69 and 70 years old and older.

To investigate the possible correlation between the number of cases of neoplasms and age group, we compiled a table on the number of cancer cases among the adult population of Vladikavkaz, depending on the age group from 2005 to 2010, along the service borders of polyclinics (Table I) [8]. Using the average value of the number of cases of cancer diseases in polyclinics and making a diagram of dependence of the share of patients on the age group, the shape of the approximating curve was obtained by the least squares technique (Fig. 3). This type of curve has a clearly expressed quadratic form, which was taken into account in its construction. Taking such high level of reliability of the approximation $R^2 = 0.989$, we can conclude that the obtained equation describes the given dependence very accurately.

TABLE I. Dependence of the number of cancer cases on age groups.

Polyclinic No.	The number of cancer cases in different age groups						
	Total number	*18-29*	*30-39*	*40-49*	*50-59*	*60-69*	*70 and over*
1	1843	37	57	217	335	439	758
3	483	8	10	34	102	109	220
4	1661	23	41	121	294	328	851
5	737	11	26	65	120	197	316
7	1045	25	37	113	236	311	323

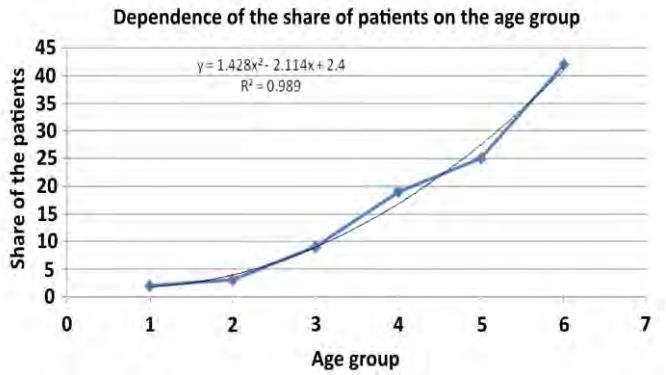

Fig. 3. Dependence of the share of patients on the age group.

According to the above equation, the percentage ratio between different age groups was calculated (Table II).

TABLE II. PERCENT OF DISEASES OUT OF THE TOTAL NUMBER OF CASES

The number of group	Group	% of the total number of diseases
1	18-29	1.7
2	30-39	3.9
3	40-49	8.9
4	50-59	16.8
5	60-69	27.5
6	70 and over	41.1

Using Table II, the prognostic values of the cancer cases distribution depending on the age group were calculated (Table III).

TABLE III. DEPENDENCE OF THE PROGNOSTIC NUMBER OF CANCER CASES ON AGE GROUPS.

Polyclinic No.	Prognostic values of cancer cases						
	Total number	*18-29*	*30-39*	*40-49*	*50-59*	*60-69*	*70 and over*
1	1843	37	55	166	350	461	774
3	483	10	14	43	92	121	203
4	1661	33	50	149	316	415	698
5	737	15	22	66	140	184	310
7	1045	21	31	94	199	261	439

Comparing the data of Tables I and III, we can conclude that the established dependence of the percentage of patients on their age group with a high degree of accuracy allows us to determine the number of manifestations of cancer in different age groups, depending on the total number of cases. In addition, the use of this relationship allows us to prognosticate the number of cancer patients in other age groups and the total number of cases, based on information about the morbidity in only one age group, while the accuracy increases when using values for older age groups.

In order to check the obtained dependence and to determine the distribution of cancer diseases among age groups, the cancer morbidity of the population of the Alagir district was studied. With the help of the determined dependence, the expected number of cancer cases for Alagir was calculated and a comparison with the actual data was made, which shows, that the difference between real and calculated values does not exceed 3% of the total number of oncological patients.

Similar data for the Chechen Republic were analyzed for a more detailed study of the obtained distribution of cancer morbidity by age categories. The dependences of the share of cancer for all age groups from 2007 to 2017 were built (Fig. 4).

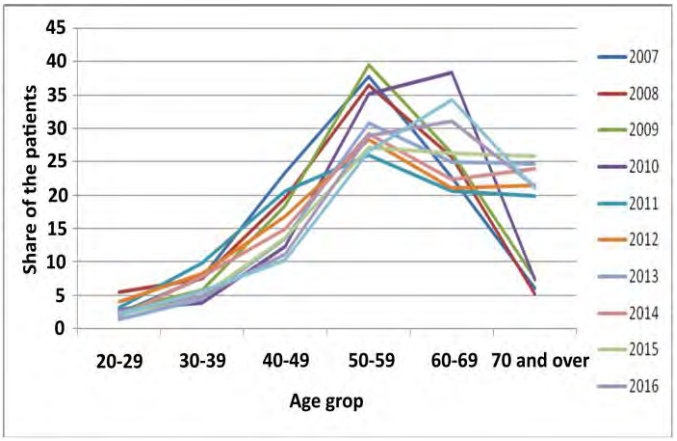

Fig. 4. Dependence of the share of patients on the age group for the Chechen Republic.

In contrast to the dependency obtained for the territory of North Ossetia, on the territory of the Chechen Republic this distribution between age groups was not made.

Three cases were singled out: there was a sharp decrease in the proportion of cases for the two older age groups in the period from 2007 to 2009. From 2011 to 2015 last groups were equalized, with their general level below the age group 50-59; and the period of 2016-2017, when the proportion of cases of the age group of 60-69 became higher than the group of 50-59. The data for 2010 differ from the above-mentioned groups. On the basis of the constructed curves, we can conclude that there is a change in the graphs of the share of patients on age groups to the obtained consistent pattern for the Republic of North Ossetia – Alania. It can be assumed that the population of the older age groups has been significantly reduced in the Chechen Republic. Perhaps the first and the second Chechen companies were the reason for this, which reduced the population of the Chechen Republic who has transferred to the age group over 60 years old in the period from 2007 to 2017. The second possible reason is the refusal of medical care by people of older age groups.

It should be noted that in the age groups of 20-29, 30-39, 40-49 and 50-59, the consistent pattern has the same character as in the Republic of North Ossetia-Alania. Excluding the older age groups, dependencies of the share of patients on the younger age groups were made (Fig. 5).

It can be seen on the graphs that the approximating expressions for the dependence of the share of patients on the group for two republics are almost identical to each other. For clarity, Table IV shows the real and calculated values of the number of people with cancer, obtained from the constructed approximating expressions.

TABLE IV. REAL AND CALCULATED VALUES OF THE NUMBER OF PEOPLE WITH CANCER

Calculation of the diseased people	Age group			
	20-29	*30-39*	*40-49*	*50-59*
Chechen Republic				
Real values	80	177	450	890
According to the formula for Vladikavkaz	58	160	450	928
According to the formula for the Chechen Republic	80	177	448	892
According to the average dependence	69	169	449	910
Vladikavkaz				
Real values	12	29	92	181
According to the formula for Vladikavkaz	11	31	88	182
According to the formula for the Chechen Republic	16	35	88	175
According to the average dependence	14	33	88	179

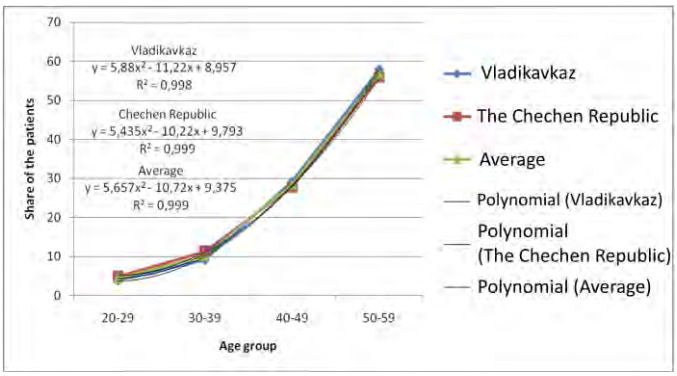

Fig. 5. Dependence of the share of patients on the age group 20-59.

Figure 6 shows the dependence of the number of cancer cases on the age group for the Chechen Republic, calculated with the help of the formula obtained for Vladikavkaz.

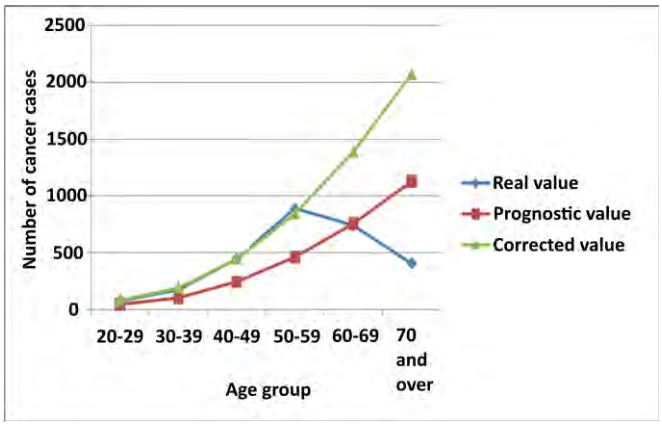

Fig. 6. Dependence of the cancer cases on the age group for the Chechen Republic, calculated with the help of the formula obtained for Vladikavkaz.

It is obvious that the real values do not coincide with the predicted ones. But if we increase the total number of cases from 2747 to 5047, we can see that in the area of the age groups from 20 to 59 years old, there is almost a complete correspondence between theoretical and real values. Therefrom, it can be assumed that there are 2 possible reasons for such values: either the absence of diagnosing diseases of 2300 people of the older age groups, or the absence of a part of the population in these groups.

This fact significantly changes the value of the Chechen Republic population morbidity. If one relies on the average value of 2747 people and the average population of 1,302,547 people, calculated on the basis of data from the site of the Unified Interagency Information and Statistical System (https://www.fedstat.ru/), then the morbidity rate will be 2.11. If one recalculates this index for 5047 people, then the morbidity rate will increase significantly and will be 3.87. It did not take into account the number of residents under the age of 18 years, but even with such calculations, the difference is significant. Nevertheless, this issue requires further in-depth research.

Thus, the morbidity is quite a reliable marker that allows differentiating areas with different levels of contamination with salts of heavy metals. The content of heavy metals in soils, which form a negative impact on the health of the population, is largely determined by the geochemical effects of mining and metallurgical enterprises. Soil and atmospheric air pollution by gases and dust emissions occurs during explosive and mechanical crushing of ore and its redistribution, as well as during dusting of dumps, tailings, etc. Quite high morbidity rate is the consequence of such pollution.

IV. CONCLUSIONS

1. Since the construction of the metallurgical plant in 1800 the Republic of North Ossetia-Alania, especially the town Vladikavkaz, undergoes increasingly the effects of chemical pollution by toxic heavy metals stored on its territory in the form of enrichment tailings and metallurgy.
2. Two areal spots (Vladikavkaz areal spot and Unal spot areal) where chemical pollution of soils associated with mining reaches an extremely dangerous level, were identified on the territory of North Ossetia-Alania. We have identified areas with varying degrees of environmental tension on the basis of the data obtained within the RNO-Alania region: catastrophic, critical, crisis, tense and relatively satisfactory.
3. As a result of eco-geochemical soil sampling in the territory of Vladikavkaz, a technogenic halo of heavy metals dispersion with an area of about 42 km^2 was singled out. Its central (nuclear) zone is characterized by concentrations of lead, zinc and copper of more than 1%, and not decreasing with a decrease in the volume of mineral processing in the last decade.
4. The total pollution index Zc was used in order to obtain an integrated picture of the distribution of chemical elements in the soils of Vladikavkaz.
5. The occurrence of neoplasms among the population of Vladikavkaz and the Alagir district for the period from 2005 to 2010 is studied.
6. The functional dependence of the patients' percentage on the age group with a value of approximation reliability $R^2 = 0.989$ was obtained by the least squares technique.
7. With the help of the determined dependence, the expected number of cancer cases for Alagir was calculated and compared with the actual data.

8. One might assume that in the Chechen Republic the population of the older age groups significantly reduced. Perhaps the first and the second Chechen companies were the reason for this, which reduced the population of the Chechen Republic who transferred to the age group over 60 years old in the period from 2007 to 2017. The second possible reason is the refusal of medical care by people of older age groups. In order to determine the real reasons of the divergence between the theoretical and practical values of the morbidity the further study of the obtained dependences is required.

9. In order to determine the real reasons of the divergence between the theoretical and practical values of the morbidity, further study of the obtained dependences is required.

10. It is determined that the morbidity is quite a reliable marker that allows differentiating areas with different levels of contamination with salts of heavy metals.

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