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Integral Estimate of Ecological Status of Nalchik

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***Abstract*—The article presents the results of an integral estimate of pollution in Nalchik using the generalized desirability function of Harrington. As a generalized indicator of desirability, the integral indicator of pollution is used. It is based on the pollution estimate of individual components: chemical and physical pollution of atmospheric air, soil pollution, and noise pollution.**

Keywords—integral estimate of pollution, polutants, anthropogenic pollution, urban environment, desirability function of Harrington, ecological status

I. INTRODUCTION

Since the end of the 1980s, many scientists began to pay attention to environmental problems. From this time period the active development of environmental science has begun with the selection in sections of several science areas. A few topical issues and problems of city ecology, which were previously considered only in theoretical aspects, emerged at that time. They served as a catalyst for developing some methodological materials, conducting an integrated approach to studying the environmental problems of cities, while considering the urban environment as one of the most important factors in global, regional environmental monitoring systems.

A complex of environmental problems is characteristic of almost every large city, due to the concentration of industrial enterprises and a large population. From an ecological point of view, cities are hot spots with a high concentration of population, capital, infrastructure and pollution sources, where a special technogenic environment is formed, often unfavorable for life [2, 9].

To assess the ecological condition of urban areas, its safety for people, it is necessary to determine the total (integral) indicator of environmental pollution. The integral indicator of environmental pollution is determined on the basis of data on the pollution of individual components (soil, air, water, etc.). To assess the complex index, various methods of school and ball grades and many other methods are used.

It is necessary to recognize that almost all currently existing approaches to the environmental estimate are highly subjective. They are unlikely to have a great prospect in environmental regulation (due to lack of binding to human health), but they are effective in assessing the results of geoecological studies and monitoring of environmental pollution. Consequently, if the problem is studied across the plane of unification of the ecological and geochemical information obtained by different researchers, then the generalized function of desirability is suitable for this. The issue of information heterogeneity is not so fundamental here, since it is a question of processing geochemical data, the concentration of chemical elements and their compounds involved in a single biogeochemical circulation [3].

The purpose is to assess the ecological status of two areas of Nalchik using the generalized desirability function of Harrington and data of measurements of the soil chemical composition and air pollution and noise pollution calculations.

II. Methods and materials

To calculate the integral indicators, it is necessary to determine the environment pollution of individual components. Among the main factors of anthropogenic impact are: industry, population density, level of development of the territory, transport networks [1].

Considering the classification of Russian cities according to the method of G. M. Lappo (1997), Nalchik is a “big” city with a population over 230 thousand people. If Nalchik is seen as an agglomeration, the number of urban agglomerations of Nalchik exceeds 250 thousand people. The city is in the foothills at an altitude of over 500m above sea level. The area of the city is about 67 km², the so-called "green" area is 991 hectares. The climate is temperate continental. The amount of precipitation is about 600 mm per year. The main environmental polluter of the city is industry, vehicle exhaust, and agriculture [4].

A rather large number of enterprises of various industries are in Nalchik. Several industrial enterprises were studied. The largest of them are: ACS Nal’chikskiy mashinostroitel’nyy zavod (Nalchik Engineering Plant), ACS Nal’chikskiy zavod vysokovol’tnoy apparatury (Nalchik Plant of High Voltage Equipment), ACS Gidrometallurg (Hydro-Metallurgic), ACS Telemekhanika (Telemechanic). The main part of industrial facilities is in the northwestern, northern and northeastern parts of the city.

The study was carried out in two city districts: the northwestern region of Nalchik, where large polluting plants are located, among them: ACS Gidrometallurg (Hydro-Metallurgic), ACS Nal’chikskiy zavod vysokovol’tnoy apparatury (Nalchik Plant of High Voltage Equipment). The southeast region is studied also. It is the resort part with the park zone of the city.

Atmospheric air pollution was determined by data from an inventory of pollutant emission sources and calculations of the dispersion of pollutants in the atmosphere using the software of the environmental specialist [4]. Table 1 summarizes these data.

The study of soil pollution was carried out by sampling the soil according to GOST 17.4.4.02-84. The determination of the elemental composition in selected soil samples was carried out on a spectroscan by X-ray fluorescence method. Spectroscan is designed to determine the content of chemical elements in substances that are in solid, powdered, dissolved states. The principle of spectrometer operation is based on irradiating the sample with the primary radiation of an X-ray tube, measuring the intensity of the secondary fluorescent radiation from the sample at wavelengths corresponding to the elements to be determined, and then calculating the mass fraction of these elements from the previously constructed calibration characteristic, which is the dependence of the content of the element being determined on the measured intensity.

Noise pollution was based on the calculation of noise characteristics by the method [11] and according to the data [4] and by the ECO Center program.

III. Results

To assess the chemical pollution of the air the data were used. They are given in [3].

TABLE I. Emission to Athmosphere on Nalchik (Studied Areas)

Substance	TLV mg/m3	Hazard class	Studied areas			
			№1	*№2*	*№3*	*№4*
			TLV	*TLV*	*TLV*	*TLV*
1) Ammonia	0.2	4	0.9	0.7	0.3	0.3
2) White corundum	6	4	0.9	0.9		
3) Butyl ethanoate	0.1	4	0.7	0.4	0.05	0.05
4) Nitrogen dioxide	0.085	2	0.3	0.2	0.05	0.05
5) Sulfur dioxide	0.5	3	0.1	0.1		
6) Wood dust	6	4	8.2	8.2		
7) Inorganic dust	0.3	3	0.1	0.2		
8) Iron oxide	0.04	3	0.3	0.3	0.05	0.05
9) Oxocarbon	5	4	0.1	0.1		0.1
10) Soot	0.15	3	0.2	0.3		
11) Hydrocarbon	1	4	0.8	0.65	0.6	0.6
12) Formaldehyde	0.035	2	0.05			0.05
13) Group summation of ammonia and hydrogen sulfide			1.37	1.1	0.3	0.3
14) Group summation of nitrogen dioxide, ammonia, nitrogen oxide			1.5	1.1	0.35	0.35
15) Group summation of oxocarbon and inorganic dust with 20-70% of silicon dioxide			2.58	2.5		

It was obtained that of all pollutants entering the atmosphere of Nalchik, the concentration of 4 pollutants in the territories adjacent to two plants (ACS Gidrometallurg (Hydro-Metallurgic) and ACS Nal’chikskiy zavod vysokovol’tnoy apparatury (Nalchik Plant of High Voltage Equipment) exceeds the maximum permissible concentration (MPC). In the resort area, the concentration of pollutants does not exceed the share of MPC.

Studies of soil contamination with heavy metals.

The main polluters of urban soils are heavy metals. They include chemical elements with an atomic mass in excess of 50, which have the properties of metals. Heavy metals usually enter the soil from the atmosphere and the aquatic environment [4].

Soil contamination with heavy metals is a source of inhalation of heavy metals in the human body by secondary pollution of the atmosphere surface layer [13].

Heavy metals in humans cause serious physiological disorders, toxicosis, allergies, cancer, adversely affect the embryo and genetic heredity [15].

Three horizons are usually distinguished. They are designated by the letters A, B, and C, sometimes D. is also added to them. A is the upper layer, B is the intermediate layer, C is the dispensing rock. The horizon A consists of organic humus and small particles of hard rock. On the horizon B, much more inorganic material is deposited, moreover consisting of larger particles. The horizon C is hard rock. A layer of regolith may be located between horizons B and C [4].

According to researcher Berland M., the maximum amount of harmful emissions from industrial enterprises (particles of 10 microns or more in size) is deposited on the surface, at 10-15 heights of a pipe emitting a source of pollution [7]. The maximum concentrations of heavy metals, therefore, will be much further, considering the pipe height, the place of sampling of the analyzed samples [4].

Four samples were taken on the territory of Nalchik: two samples in the area where ACS Gidrometallurg (Hydro-Metallurgic), ACS Nal'chikskiy zavod vysokovol'tnoy apparatury (Nalchik Plant of High Voltage Equipment) and two samples in the resort area of Nalchik are located. The measurement of the heavy metals content was carried out on the Max spectroscan.

Results of measurements presented in Table 2.

TABLE II. HEAVY METAL CONTENT IN SOIL, MG/KG

Elements	Tested samples				
	Background	*Sample №1 Ratio to backround*	*Sample №2 Ratio to backround*	*Sample №3 Ratio to backround*	*Sample №4 Ratio to backround*
Heavy metals I class of hazardous materials					
Arsenic	2.2	7.27	4.1	1.8	2.6
Zinc	43	2.2	1.6	3.3	2.6
Lead	15	5	4.3	3.2	2.2
Heavy metals II class of hazardous materials					
Nickel	20	2.3	2.2	1.1	1.5
Cooper	15	2.3	1.3	1	0.9
Cobalt	10	1.1	0.9	0.6	0.8
Heavy metals III class of hazardous materials					
Manganese	850	1.2	1	0.68	0.61
Vanadium	100	0.89	0.67	0.34	0.43

In the study of soil contamination with heavy metals, along with individual chemical elements, an analysis of the distribution of chemical elements associations is carried out. The association of chemical elements is a group of elements detected in the environment in quantities that differ from the critical content [14, 10]. The quantitative measure of the association is the total indicator of pollution, which is determined by the formula:

$$Z_c = (K_{c1}+\ldots+K_{cn}) - (n-1) \quad (1)$$

where K_c is the concentration ratio of a chemical, n is the number of chemical elements in the association. The calculation results for the selected samples are given in Table 3 [4].

TABLE III. COMPLEX INDICATORS OF POLUTION

Chemical element	**Studied samples**					
	№1	**№2**	**№3**	**№4**	**№5**	**№6**
	ACS Gidrometallurg	**ACS Nal'chikskiy zavod vysokovol'tnoy apparatury**	**Intersection of Golovko and Kalyuzhnogo streets**	**Kalyuzhnogo Street**	**Intersection of Kalyuzhnogo and El'brusskaya streets**	**El'brusskaya street**
1. Arsenic	7.27	4.1	1.77	2.59	2.13	1.9
2. Zinc	2.16	1.58	3.3	2.53	1.74	1.55
3. Lead	5	4.26	3.22	2.18	3.86	3.2
4. Nickel	2.3	2.2	1.05	1.5	1.95	1.55
5. Cooper	2.33	1.43	1	0.86	1.16	1.06
6. Cobalt	1.1	0.9	0.6	0.8	0.7	0.81
7. Manganese	1.15	1.07	0.67	0.60	0.66	0.71
8. Vanadium	0.89	0.67	0.34	0.43	0.5	0.31
Complex indicators of pollution	15.2	9.21	4.95	4.49	5.7	4.09

Note: on the streets of the study area (No. 3, 5), the number of samples taken is *3, and 5 samples on each of the streets (No. 4, 6). The table shows the average values for the listed samples.*

IV. NOISE POLLUTION

The problem of urban noise is a very relevant topic of study in the modern world. There are several causes of physical (noise) pollution adversely affecting the human body. The World Health Organization (WHO) recognizes city noise as one of the important issues affecting a person's condition. The noise load on the urban population is increasing annually in almost all developed and developing countries of the world. The methods of dealing with it require considerable material resources.

The main sources of noise pollution are: means of transport (land, air, water), factories and enterprises of heavy and light industry, energy facilities, etc.

The main source of noise pollution in Nalchik is road transport. The expected equivalent sound level created by the flow of motor vehicles at seven meters from the lane of the movement of vehicles is determined by the method of [14]. The results of these calculations are shown in table 4.

Equivalent sound levels (dBA) created by the traffic flow at the facade of a building can be obtained by measurements or calculated based on the noise characteristics of the traffic flow, determined by the method, based on the motion characteristics and the composition of the traffic flow. The highest levels of traffic noise at the facade of the building are observed at the height of the third - fifth floors. At the height of the first and second floors, noise levels may be lower due to the absorption of sound by the ground and green areas. The initial parameter for calculating the equivalent sound level created at the facade of a building by the flow of motor vehicles (including buses and trolley buses) is the noise characteristic of the flow LAecq. (dBA) determined according to GOST 20444-85 at 7.5 m from the axis of the near lane of transport [12].

TABLE IV. Equivalent sound levels LA_{equ} И LA_{equ}. TEP.2

Name of street	$L_{Aecq,\ dBa}$	$L_{Aecq.ter.2,\ dBa}$	Exceeding the allowed level (in times)
Golovko	53	50	0.9
Shogentsukova	74.1	73.5	1.22
Kalyuzhnogo	63	61.5	1.11

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To assess the calculations' accuracy, the equivalent sound level was measured by the "SVAN" noise analyzer. Thd comparison of the equivalent level determined by the method showed difference indicator from 3.8% to 82%.

The allowable equivalent sound level in residential areas is 55 dBA during the day and 50 dBA at night. As Table 3 shows, the exceeding of permissible sound level at 7 meters occurs on two streets. The maximum was on Shogentsukova Street (in 1.22 times), on Kalyuzhnogo Street (in 1.11 times).

The calculations show that it is necessary to take protective measures to protect the population from noise exposure in Nalchik. Moreover, in recent years there has been a tendency to increase the number of vehicles in the city.

Protection of residential and public buildings from traffic noise can be accomplished with the help of town planning (rational design of the road network, zoning of urban areas), architectural planning (special noise-protective buildings with orientation of living rooms mainly in the direction of intra-quarter territory), organizational (restriction of cargo transport to residential areas, the speed limit of vehicles, the prohibition of transit transport) and constructive measures. Planting of green space could be carried out. Dense planting of green space and screening facilities located along highways have the property to enhance vertical air currents. This leads to a air decrease in the surface layer behind these structures, the concentrations of toxic substances emitted with exhaust gases of cars. In addition, green areas have the properties of deposition and biological processing of toxic compounds, which enhances their protective effect [12].

To optimize the results of various kinds of data, the Harrington desirability function [1, 5, 6, 11] is used. It is given by the equation

$$d = \exp\left[-\exp(-y)\right] \qquad (2)$$

When using the function, the division of the desirability scale into five categories is accepted:

TABLE V. Quality categories by the meaning of general function of desirability [2, 3]

Quality	General Function of Desirability
Very Good	1.0 - 0.80
Good	0.80 - 0.63
Satisfactory	0.63 - 0.37
Bad	0.37 - 0.20
Very Bad	0.20 - 0.00

The definition of the generalized desirability function (D) is obtained by convolving the partial values of the desirability function di. It can be carried out through the geometric average, which reduces the deviations that have occurred. In the absence of weight coefficients, this will be [8, 5]:

$$D_C = \sqrt[q]{\prod_{i=1}^{q} d_i} \qquad (3)$$

To find (y), all measurement indicators (y') must be converted to a scale of desirability.

In [14], the equations of connection (y) with (y '), which have the form:

$$y=-0.617\ \ln(y) + 0.93 \text{ - for atmospheric air;} \qquad (4)$$

$$y=-0.94\ \ln(y) + 1.523 \text{ – for soil} \qquad (5)$$

To put the measured noise values into the desirability scale, the pollution index is divided (the ratio of noise level to an acceptable level) into five categories of noise pollution index: less than 0.6 - there is no noise pollution, from 0.6 to 0.8 is low, from 0.8-1 is average, from 1 to 10 high level, over 10 extremely high level of noise pollution exposure. To find the relationship equation (y) with (y'), a regression analysis was performed. It resulted in the equation (6) being obtained which looks like:

$$y=-0.21 \ln(y) + 0.93 \quad (6)$$

According to the method described above, generalized desirability functions were determined for two areas of Nalchik: the resort area Dolinsk and the area of two plants ACS Gidrometallurg and ACS Nal'chikskiy zavod vysokovol'tnoy apparatury. In the Dolinsk region, the generalized desirability function is 0.8. Therefore, the ecological condition of the territory can be rated as "very good".

In the area of two ACS Gidrometallurg and ACS Nal'chikskiy zavod vysokovol'tnoy apparatury the generalized desirability function is 0.61, the ecological condition of the territory can be rated as satisfactory.

V. Conclusion

As a result of the research, it was obtained that the ecological state of the resort area of Nalchik is "very good", and the territories adjacent to the two plants "ACS Gidrometallurg and ACS Nal'chikskiy zavod vysokovol'tnoy apparatury are satisfactory.

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