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ASSESSING AIR QUALITY DETERIORATION BY SNOWCOVER REDOX POTENTIAL

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ABSTRACT

This study is an attempt to obtain a qualitative understanding of oxygen concentrations in the winter atmospheric air of a northern city from snowcover redox potential. Snowcover is a natural accumulator of chemicals deposited from the atmosphere and is thus a good indicator of atmospheric pollution. Because the oxygen ratio in the air and snowcover is constant, changes in air oxygen levels during the winter can be qualitatively assessed from redox potentials of snowmelt water.

The redox potential in the urban snowcover was found to be about 200-250 mV lower than background. Lower snowcover Eh values within the city may suggest reduced oxygen levels in the air. The negative redox potential anomalies in the snowcover are associated with the air pollution sources and complex anthropogenic geochemical haloes.

The high level of pollution with added effects of reduced air oxygen levels deteriorates the quality of the urban environment for human health and well-being. Estimation of pollution based on negative redox potential anomalies in snowcover provides an additional means of assessing the winter air quality in urban areas.

Keywords: North, cities, snowcover, redox potential, oxygen deficiency, public health.

Introduction. The urban atmosphere is characterized by a number of factors, such as warmer air temperature compared to the surroundings and higher concentrations of gaseous pollutants (carbon and nitrogen dioxides) and particulate matter, which can cause breathing problems. Atmospheric oxygen level is one of the most important factors affecting the health and well-being of urban residents. The normal atmosphere contains approximately

Table 1

Gas composition in hailstones and snow

Sample	CO_2 / N_2	O_2 / N_2	Ar / N_2	Source
Hailstones, Switzerland	0,0200	0,293	0,0154	[18]
	0,0175	0,297	0,0164	
Snow, Antarctica	-	0,263	0,0118	[19]
Atmospheric air	0,0038	0,268	0,0120	[14]

about 21% oxygen. Animals and humans are very sensitive to atmospheric oxygen concentrations, with their vital functions impaired in response to even a slight decrease in oxygen levels. Long-term exposure to an environment with the reduced partial pressure of oxygen causes a number of adaptive changes in functioning of the respiratory and other systems to compensate for low oxygen levels [10, 11]. A syndrome of "polar stress" [5] or "polar hypoxia" [1] related to the oxygen regime of the polar atmosphere has been reported in northern Siberia and far north-eastern regions of Russia. It is therefore important to know oxygen levels in the atmosphere of northern cities where anthropogenically induced oxygen depletion adds to the health effects of the natural regime. Qualitative knowledge of oxygen concentrations in the winter atmospheric air of residential and industrial zones in the northern regions, and hence of the air quality, can be obtained by estimating the redox potential (Eh) of snow cover.

Being a natural accumulator, snow cover provides actual values of dry and wet deposition during the winter season and therefore can be used as an indicator of atmospheric pollution [9, 2, 7]. Complex geochemical anomalies are formed in the snow cover around the sources of air pollution [3].

It is generally assumed that a negligible amount of air is dissolved in solid precipitation. It is known however that accreted snow crystals may contain relatively high concentrations of gaseous constituents [16].

Matsuo and Miyaki [15] believe that the atmospheric air dissolved in supercooled water droplets, on contact with an ice surface, is enriched with CO_2 and Ar more than other gases and is completely enclosed within ice crystals, since supercooled droplets constitute nuclei of ice crystals [18]. At the same time, the oxygen to nitrogen ratios in snow and atmospheric gas remains fairly similar. This conclusion is confirmed by measurements of snow samples from the East Antarctic sites (Table 1).

Methods. Relative oxygen contents in the urban atmosphere in Yakutsk during winter were estimated by measuring the redox potential of snow cover. The constancy of the ratio of oxygen in atmospheric air and snowcover makes it feasible to estimate the change in O_2 concentration in the atmosphere from the value of snow Eh. Within the city of Yakutsk, negative anomalies of Eh (oxygen deficiency) are well identified with sources of air pollution.

Based on the evidence that the oxygen ratio in the atmospheric air and the gases in snow remain similar [14,18,19], a qualitative assessment of oxygen concentrations in the winter atmosphere of Yakutsk was made in this study by measuring snowcover redox potentials.

Snow samples for the geochemical study were collected from the city area and its vicinity in the second half of March, before the onset of snowmelt. The chemical analysis of melt water was performed in the permafrost geochemistry laboratory of the Melnikov Permafrost Institute (analysts L.Y. Boitsova and O.V. Shepeleva). The redox potential was measured using an ERP-101 electrode on an I-500 ionometric converter (ZAO KRISMAS +). It has a measuring range of -2000… to +2000 mV with a resolution of 0.1 mV and an accuracy of ± 0.7 mV.

Results and discussion. The redox potential of meltwater in the Yakutsk area was found to vary over a wide range (340 to 587 mV) and depend primarily on oxygen concentration in the atmosphere, since concentrations of other oxidants were very low. The atmospheric content of H_2S (below 0.0072 mg/m^3) in Yakutsk was too low to cause the decrease in redox potential. Other oxidants, H_2, Fe, Mn and V, had relatively high concentrations close to those observed at industrial centers, such as Stockton (England) and Pasadena (USA), but were not sufficient to affect the decrease in Eh (Table 2).

Therefore, oxygen is the main potential-controlling component producing oxidizing conditions in the Yakutsk area. Positive redox potential values are known to increase with

Table 2

Concentration of main oxidants in precipitation at industrial centers and Yakutsk

Parameter	Yakutsk	Industrial cities [17]	
		Pasadena, USA	Stockton, England
Population	312,0	135,0	290,0
H2S	< 0.0072	-	-
Fe	1,218	3,2	1,7
Mn	0,050	0,03	0,1
V	0,022	0,01	0,02
Cr	0,009	-	0,008
H+	2,0•10-8	-	-
pH	7,69	-	-

Note: «-» no data.

Table 3

Chemical composition of snowcover in Yakutsk and its vicinity, 2015-2016

Parameter	City of Yakutsk, n=40			Vicinity of Yakutsk (background), n=6		
	min	max	average	min	max	average
pH	5,88	7,86	6,80	5,85	6,12	6,07
Eh	340	508	449	579	587	583
TDR	13,0	193,0	55,0	8,31	9,54	9,0
HCO3-	5,50	48,6	11,49	6,76	7,73	7,15
SO42-	0,20	14,4	3,10	0,33	0,91	0,54
NO3-	0,07	8,60	2,14	0,20	0,80	0,60
Fe3+	0,05	0,3	0,14	<0,05	0,05	<0,05
Mn4+	0,5	538,0	2,5	<0,3	12,0	<0,3
V	0,1	5,0	0,16	<0,1	<0,1	<0,1

Note: n – the number of samples.

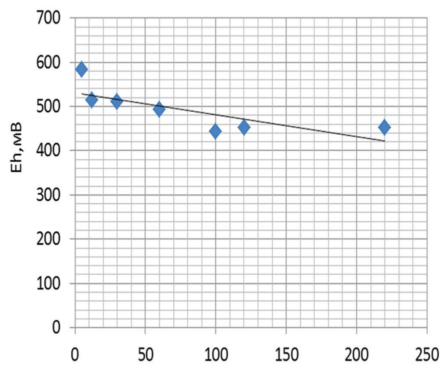

Fig. 1. Correlation between Eh and dust content in the snow cover of Yakutsk.

increasing oxygen content [13].

The measurements showed that the redox potential of the snowcover varied from 340 to 508 mV within the city, averaging 449 mV. The background values of snow Eh from the vicinity of Yakutsk (Tuymaada Valley) were 579 to 587 mV, averaging 583 mV (Table 3).

Factor analysis was used to analyze the large set of measurements in order to obtain a reliable assessment of the relationships between Eh and snow chemistry and to improve data interpretation. Classification of the Eh dependence of the parameters showed

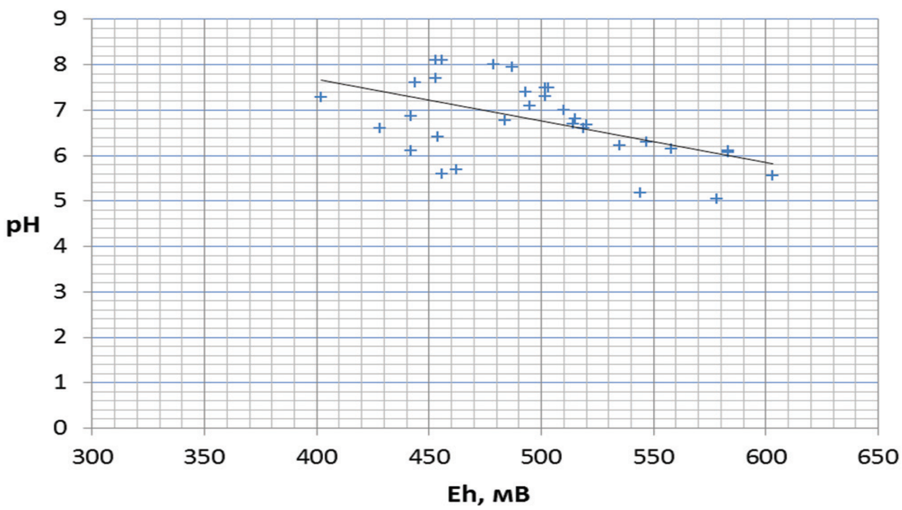

Fig. 2. Correlation between Eh and pH in the snowcover of Yakutsk

the absence of strong positive correlations and the prevalence of significant negative correlations of redox potential with major dissolved constituents of the snow cover and pH values, as well as a strong negative correlation with snow dust content (Fig. 1).

Higher alkalinity of the snowcover is observed in the areas of Yakutsk experiencing high levels of anthropogenic impact related to dust, predominantly carbonate, pollution [6]. It is therefore understandable that there is a negative correlation between Eh and pH values (the decrease in free hydrogen ions, H^+) (Fig. 2.).

It is noteworthy that the lower Eh values (reduced O_2 content in the atmosphere) and the areas of alkaline pH levels coincide with the anomalous concentrations of the main major and minor chemical constituents of the snowcover indicating anthropogenic pollution.

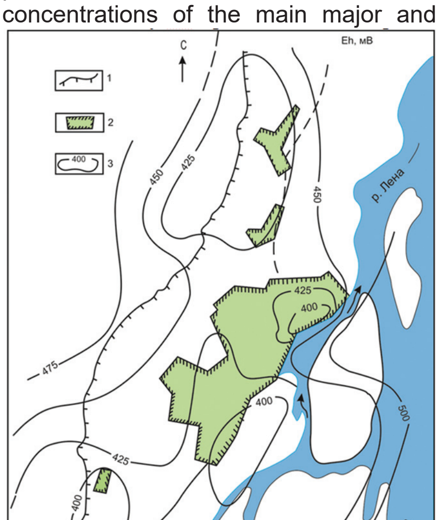

Fig. 3. Negative snow Eh anomalies in Yakutsk, 1997.

1 - Lena River valley side; 2 - urban areas; 3 - Eh isolines, mV.

Correlation analysis showed a significant negative correlation of redox potential with dust emissions (see Fig. 1). It is of interest to examine not only the total impact of dust pollution, but also the effect of minor dust constituents on the decrease in Eh (in O_2 concentration). Among the factors identified, the dust fraction of chalcophile and lithophile elements, mainly heavy metals (Mn, Pb, Zn, Ti, Cu, and Cr), showed strong negative correlations to Eh. Most of these elements are active pollutants of the atmospheric air in Yakutsk. They form strong anthropogenic anomalies in the urban snowcover and soils which are closely associated with the pollution sources [7]. The negative correlations of this group of minor elements to Eh clearly indicate that the decrease in atmospheric O_2 concentration in the areas of intense anthropogenic activity is related not only to pollution with gases and aerosols, but also to dust pollution.

The negative anomalies of Eh occur in the industrial areas of Yakutsk with high air pollution levels, such as Markha, the airport, the Electrical Power Station and the Cogeneration Station in the north, and the Modular Building Combine and the poultry factory and litter storage in the south and south-west (Fig. 3). These areas contain industry-produced geochemical anomalies which are found not only in the air, bust also in the water, soils, and vegetation [8]. The negative Eh anomalies (O_2 deficiency) also extend into the residential areas of Yakutsk. Given the high level of air pollution in the city (Air Quality Index = 5) [3], reduced oxygen concentrations are an additional factor contributing to degradation of the urban environment and related health concerns.

Low atmospheric O_2 levels can have more serious health effects during occasional warmer days in the winter brought by cyclones, when hypoxia may develop and progress in patients with cardiovascular or lung impairments [4, 10].

Conclusions. The atmospheric oxygen regime is one of the important environmental health factors for northern cities. Since the oxygen ratio in the air and snowcover is constant, changes in air oxygen levels during the winter can be qualitatively assessed from redox potentials of snowmelt water.

The negative anomalies of Eh in the snowcover of Yakutsk show clear correlations with the anthropogenic haloes of major and minor constituents in snow, alkaline pH values, dust emission levels, and anomalies of chalcophile elements (Mn, Pb, Zn, Cr, and Cu) in the dust phase of snow.

The average value of snow redox potential is 349 mV within the city and 583 mV in the surrounding area (background). The level of negative redox potential anomalies is 20–25% lower in the urban area compared to the background. Significantly lower values of snow Eh within the city may indicate reduced O_2 contents in the urban atmosphere.

The negative anomalies of snow redox potential are clearly associated with the known industrial sources of air pollution in the city and resulting geochemical anomalies. They are mainly confined to the industrial areas, but partially cover the residential areas as well.

Oxygen deficiency in the air together with the high pollution levels in the city of Yakutsk contributes to deterioration of the environmental quality for human health and well-being.

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ACTUAL TOPIC

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POPULATION DISABILITY AND SOCIO-ECONOMIC FACTORS

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ABSTRACT

The purpose of the research is to study the state of primary disability (PD) in the adult population and determine its relationship with socio-economic indicators.

Materials and methods of research. The PD indicators of the adult population in the Irkutsk region are analyzed for the period of 2000-2017, according to the reporting forms No. 7-sobes The research uses statistical, graphical, and correlation methods (the Pearson coefficients are calculated using 14 socio-economic indicators).

Results and discussion. The PD indicators of the adult population in the Irkutsk region for all the causes, except the malignant tumors, ear diseases and HIV, decreased within the period of 2000-2017. The total PD indicator decreased by 30.4%: from 107.8 per 10 000 people in 2000 to 75.0 per 10 000 people in 2017

The main causes of primary disability of the adult population in the Irkutsk region include: malignant neoplasms, circulatory system diseases, and mental disorders. The PD indicators in the Irkutsk region significantly exceeded the all-Russian indicators (for $p \leq 0.05$) for 9 causes of disability in 2016: HIV (7.0 times), ear diseases (3.3 times), effects of injuries (2.5 times), mental disorders (2.2 times), tuberculosis (1.8 times), etc.

The proportion of adult people with primary disability in the 2nd group decreased both in the Irkutsk region and in the entire Russian Federation, and the proportion of those in the 1st and 3rd groups increased. As compared to the situation in 2000, where more people in the region were in the 2nd group of disability (58.3%), in 2006, the 3rd group (48.3%) started to prevail. The retirement age people continue to predominate in the age structure of the primary disability of the adult population. However, since 2006 the second place has been taken by the middle-aged people, rather than the young.

Conclusion: The research showed that the Irkutsk region is an unfavorable entity due to the primary disability of the adult population caused by HIV, mental disorders, the effects of injuries, eye diseases, etc. Strong correlations were found between 9 individual PD indicators of the adults in the Irkutsk region and socio-economic indicators.

Keywords: primary disability, adult population, socio-economic indicators.

Introduction. According to the WHO estimates, about one billion people live with disability, and this number will increase with the population ageing and the spread of chronic health disorders [3]. Apart from morbidity, the level of disability is affected by a variety of factors [6], including socio-economic ones: the incidence of disability in low-income countries is higher than in high-income countries. As compared to the people who are not disabled, people with disabilities, especially those living in developing countries, have poorer health, suffer from a higher level of poverty, and participate in the education and employment system less [3].

The purpose of the research is to study the state of primary disability (PD) in the adult population of the Irkutsk region and determine its relationship with