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Modeling the Impact of Man-Made Landscapes on the State of the Soil

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Abstract

Currently, the problem of environmental protection from negative impact of geotechnical systems (GTS) are relevant, as industry become GTS, incompatible with the environment. By the end of the 20th century, humanity was facing a sad reality-the presence of numerous actively formed foci with an ecological unfriendly environment. The world community unanimously acknowledges economic activity as the main reason of the growing environmental crisis.

The technogenic activity of humanity was unanimously recognized as the first cause of the ecological crisis. The main role in it is played by the production and use of energy derived from non-renewable natural resources. This category includes transport operating on oil refining products, heat and electric power, petrochemicals, metallurgy, waste processing industries, etc.

Thereby the article is devoted to the research of the impact of the geotechnical system on the environment (soil cover). The article shows the state of the impact of the geotechnical system on the environment (soil cover). In the process of exploitation of deposits, transportation of raw materials there happens pollution of the soil cover and the environment by emissions into the atmosphere, salinization of the lithosphere by mineralized industrial wastewater, contamination of the soil with overburden rocks, small fractions of raw materials, etc.

A methodology for studying the concentration of salts in the process of soil salinization has been developed. The method of simplex-lattice interaction planning in multicomponent systems constructing the full-composition-property diagram by matrix was used. The results of a chemical-analytical study of the content of pollutants, simplex-lattice planning of the effect of salt components on the soil, are presented giving a "composition-property" diagram of the NaCl (X1)-$MgSO_4$ (X2)-$CaSO_4$ (X3) system. It is established that the highest degree of salinity is achieved with the ratio of components X1: X2: X3=10: 60: 30. In the sulfated-enriched area, the degree of salinity is the highest (up to 99.8%): while in the "chloride corner" the degree is lower (to 70%-80%), which is caused by the greater solubility of alkali metal chlorides (in particular, sodium chloride NaCI) and more intensive washout of chlorides in comparison with sulphates. The practical value of the work is development of recommendations for reducing the salinization of the lithosphere by studying the system of natural minerals gallite-NaCI $MgSO_4$ and calcium sulfate $CaSO_4$.

Keywords: ***Environment; Ecosystem; Man-made landscapes; Pollution; Industrial enterprises; Negative impacts; Model***

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Introduction

The soil cover, being the most important component of the biosphere, plays the role of physicochemical and biological depositor and neutralizer of many chemical compounds. Therefore, in recent times, much attention is paid to issues of damage to land in connection with the extraction and processing of minerals in the zones affected by non-ferrous metallurgy and also chemicals introduced into the natural environment [1].

The impact of development of the deposit of polymetallic ores on the environment is characterized by intensity, variety and significant scale. In the process of development and operation of deposits, transportation of raw materials, pollution of the soil cover and the environment by emissions into the atmosphere, salinization by mineralized industrial wastewater, stored on sites by overburden rocks, small fractions of raw materials, etc. takes place [2,3].

The scale and intensity of anthropogenic pressure on the ecosystem in the mining and metallurgical complex adversely affect the ecological balance. In this regard, it is timely to identify and assess foci of soil degradation and desertification, to study geoecological and genetic indicators, to develop scientific bases for the rehabilitation and protection of disturbed lands, to develop environmentally friendly technologies for neutralizing and utilizing waste.

In the improvement of technology to prevent and reduce the negative impact of mining and processing of metallurgical raw materials on the environment, the issues of detailed study of the state of the natural environment in the area of the field and industrial enterprise, identifying negative impact factors are relevant.

A review of the literature on environmental protection in industrial enterprises showed that the first stage of the study of the deposit is an assessment of the state of the components of the biosphere [4]. It has been established that there is insufficient information on the study of soil salinity, detection of lithospheric contamination by modeling pollutant impact on the lithosphere.

On the basis of field and versatile laboratory ecological and analytical studies it is necessary to study the chemical properties of contaminated and disturbed lands, the chemical and ecological indicators of industrial wastes, it is necessary to assess the current ecological state of the territory and to develop conceptual bases for the rehabilitation of anthropogenic disturbance of the natural environment [5].

Object and Method of Investigation

Physical and geographical characteristics of the territory of the geotechnical system (GTS)

Features of the geological and geomorphological structure of the territories determine the continental type of climate. The lack of moisture, a relatively high temperature background, contributes to the formation of semi-desert types of landscapes [6]. The supply of groundwater is due to the infiltration of atmospheric precipitation and partly to the condensation of water vapor. The unloading goes into the depressions and into the underlying aquifer of the Khvalynian sediments.

The presence of a good accumulating medium and uneven barchans relief contribute to the formation of a significant amount of groundwater in sand massifs. They are usually confined to fine, fine-grained, sometimes clayey sands, with interlayers of sandy loam and loam [7].

Due to the presence of a good accumulating medium, natural conditions for groundwater formation are created in Aeolian sands. The absence of waterproof rocks promotes the mixing of fresh waters of sandy sediments with the salt waters of the underlying Khvalynian deposits.

The depth of occurrence of groundwater is within 0.5 m to 4 m. Groundwater is highly mineralized (up to 150 g/l-180 g/l), causing the difference and the nature of the soil and vegetation cover and a variety of landscapes. The highest position of the groundwater table is observed in the eastern part of the sandy massif of Kyzylkum. Here, the levels of groundwater are at 5 m to 10 m. A decrease in the groundwater table is observed to the edge parts of the massif [8].

According to the chemical composition, there are waters of various types: from hydrocarbonate and hydrocarbonate-chloride sodium to sodium-magnesium chloride, up to chloralcium brines in the zone of unloading of deep waters [9]. With increasing mineralization, the hardness of the water increases to 2-15 mg-eq/l. Heavy metals, as a rule, are absent or contained in insignificant quantities. The extremely weak development of vegetation, which is a complex of scattered family of *Halocnemum strobilaceum* on phytogenous hillocks, is characteristic [10,11].

The soil cover is represented by a gray-brown (brown) type of soil in combination with salt marshes and solonetzes. The described area refers to a plain class of landscapes, within which one subclass of relatively lowered plains is distinguished. By the nature of bioclimatic indicators, the region refers to the desert type of landscapes.

The desert type of landscape is on the entire site and is formed on the accumulative sea plane and the Aeolian hilly-ridge plain. Absolute heights range from 13 m to 27 m. This is due primarily to the development of the geological and geomorphologic basement [12,13].

Methods, Results and Discussion

Chemical-analytical studies of soils in the area of the geotechnical system along the mining boundary of the deposit have been carried out. The content of alkaline earth metals (Ca, Mg), alkali metals (Na, K), as well as chlorine and sulfates (SO_4^{2-}) and pH were found in all soil samples. The average concentration of elements from the upper intervals of the well did not differ from the samples of the surface layer of the soil (in the sole of the section of the first meter). The increase in the content of readily soluble salts is explained by the increase in soaking of soils and as a consequence of soil washing [14,15]. The regularities of soil salinity in time are determined: it is established that the most strongly influencing components are calcium ion Ca^{2+}, sulphates [SO42-], chlorine ion [Cl], magnesium ion Mg^{2+}, by simplex-lattice planning the diagram analysis of system NaCl-MgSO4-CaSO4 at t°-25°C was carried out, the highest degree of salinity (up to 99.7%) is in the region of predominance of sulphates [16].

The development of these soils for agriculture is possible only under condition of irrigation. Analytical data establish salinity already in the upper horizon of these soils, where more than 1% of readily soluble salts are observed, the content of salts is increasing with depth, reaching 8% in loamy and clayey interlayers, for a dense residue. According to the type of salinity, these are sulfate-chloride salt marshes. The ratio C1/S04 is greater than one. Of the divalent cations, magnesium predominates over calcium. Soils are carbonate, have an alkaline reaction (pH 7.25) of the soil solution [17].

In the place of exploratory wells, the areas affected by the man-caused impact of marine salt marshes are characterized by the contents of the amount of petroleum products up to 15 mg/kg; arsenic-up to 13.2 mg/kg; lead-up to 145 mg/kg; zinc up to 450 mg/kg. The patterns of changes in the content of salts in the soil for the period 2012-2015 are revealed: priority pollutants are SO_4^{2-}-670 mg/100 g; Ca^{2+}-242.4 mg/100 g; Cl^--127.6 mg/100 g [18,19].

The great variety and diversity of the soil cover, the widespread distribution of saline, alkali soils and salt marshes determine the difficult soil-irrigation conditions, complicated by the aridity of the climate and the weak watering of the territory. All the soils encountered here are characterized by low humus content, low thickness of the humus horizon, low ash content, low absorption capacity [20].

A methodology of systems research including natural minerals (gallite-NaCI, magnesium sulfate Mg_4SO_4 and calcium sulfate $CaSO_4$) has been developed. The study of interaction in such multicomponent systems is aimed at obtaining a complete "composition-property" diagram: the degree of salinity [21,22].

The construction of multicomponent "composition-property" systems is associated with a large amount of experimental work. Such systems can be studied by mathematical modeling: the composition of the q-dimensional system is given by the (q-n)-simplex and the function describing the effect of the composition on the properties of the system can be expressed by a polynomial of some degree on the values of the independent variables X1, X2, ..., Xn and where Xn is the amount of the nth component in the mixture. For the case when the property of the system (for example, the degree of response, the strength of the samples, etc.) depends on the composition of the mixture and not on its quantity, then the experimental points are located, according to the so-called simplex lattices [17].

Simplex-lattice plans are saturated, i.e. contain the minimum possible number of experimental points necessary for estimating the coefficients of polynomials. Therefore, the adequacy of the obtained models is estimated from additional control points, the choice of which is arbitrary: they are usually located on those sections of the diagram, the property in which is of greatest interest to the experimenter, or their choice is based on the possibility of using experimental data for constructing a higher-order model [23,24].

The adequacy of the description of the investigated property of the obtained model at some point of the simplex is estimated by the difference:

$$\Delta У=У_{exp}-У_{calc},$$

Where, Уexp is the experimental value of the property; Уcalc-the value of the property, obtained from the model.

A regulated sum of independent variables ΣXn=1 is adopted. Then, in the systems under consideration the studied property, the degree of salinity, depends on the composition of the mixture, but not on its quantity.

Thus, for the studied 3-component system, we found a fourth-order model in approximation. A fourth-degree model describing the effect of the composition on the degree of salinity of the samples in the NaCl-$MgSO_4$-$CaSO_4$ system has the form:

$$У=ß_1X_1+ß_2X_2+ß_3X_3+ß_{12} X_i X_2+ß_{13} X_i X_3+ß_{23} X_i X_3+y_{12}+X_i X_2 (X_i-X_2)+y_{13}X_i X_3 (X_1 – X_3)+y_{23} X_2 X_3 (X_2 – X_3)+á_{12} X_1 X_2 (X_1 – X_2)^2+á_{13} X_1 X_3 (X_1 – X_3)^2+á_{23} X_2 X_3 (X_2 – X_3)+ß_{1123} X_i^2 X_2 X_3+ß_{1223} X_i X_2^2 X_3+ß_{1233} X_i X_2 X_3^2$$

As a result of the experiments, the values of the degree of salinity of the samples at the temperature studied were obtained. A planning matrix is constructed in which the independent variables X1, X2, X3 are the components of the system (TABLE 1) [17]. We have studied the interaction in the **NaCl-$MgSO_4$-$CaSO_4$** system at 25°C.

TABLE 1. **Matrix planning system NaCl-$MgSO_4$-$CaSO_4$.**

Experiment numbers	Mixture composition						Coefficient index	Degree of salinity, %
	Proportion of units			Mas. %				
	X_1	X_2	X_3	NaCI	$MgSO_4$	$CaSO_4$		
1	1	0	0	100	100	0	$У_1$	69,0
2	0	1	0	0	0	0	$У_2$	89,2
3	0	0	1	0	0	100	$У_3$	93,2
4	½	½	0	50	50	0	$У_{12}$	91,0
5	½	0	½	50	0	50	$У_{13}$	88,0
6	0	½	½	0	50	50	$У_{23}$	93,5
7	¾	¼	0	75	25	0	$У_{1112}$	96,2
8	¼	¾	0	25	75	0	$У_{1223}$	92,0
9	¾	0	¼	75	0	25	$У_{1113}$	90,0

10	¼	0	¾	25	0	75	У_{1333}	97,2
11	0	¾	¼	0	75	25	У_{2223}	98,1
12	0	¼	¾	0	25	75	У_{2333}	99,0
13	½	¼	¼	50	25	25	У_{1123}	98,7
14	¼	½	¼	25	50	25	У_{1223}	99,2
15	¼	¼	½	25	25	50	У_{1233}	98,9

The diagram (TABLE 1) constructed by the simplex lattice method, shows isothermal curves of the degree of salinity with the identification of the areas of formation of the most saline soils. The diagram is based on the computer program "Triangle-Simplex Lattice", which includes reference points. The composition-property diagram constructed by the simplex lattice method shows isothermal curves of the degree of salinity and the areas of formation of the most saline soils are revealed.

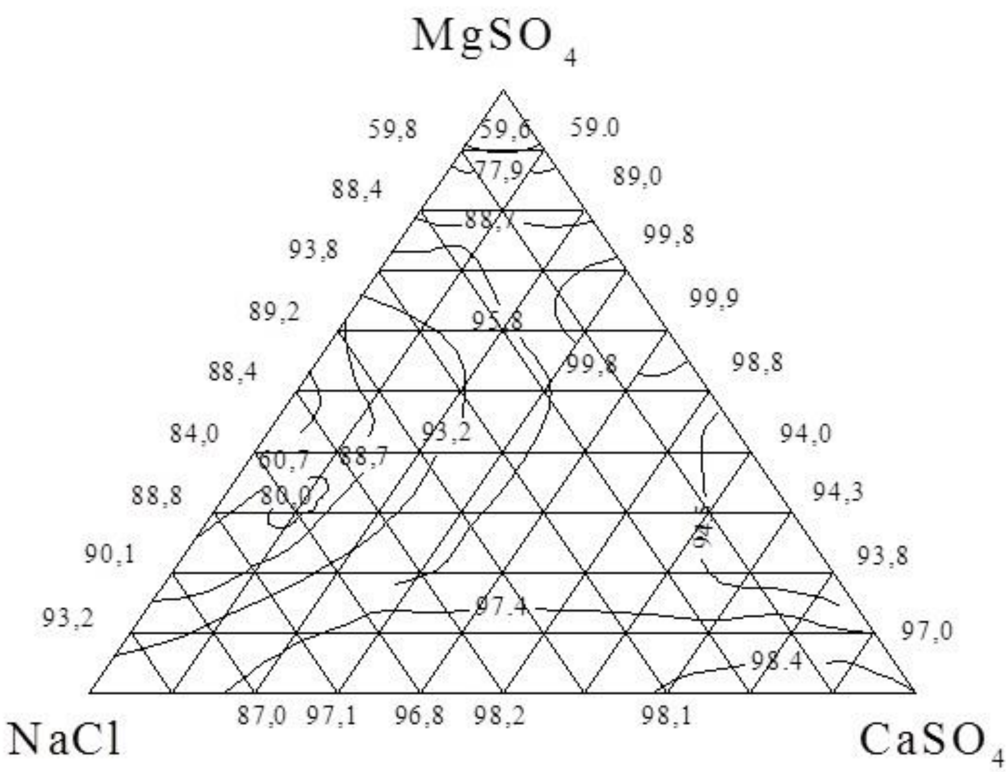

FIG. 1.

Isothermal section of the NaCl-$MgSO_4$-$CaSO_4$ system.

The highest degree of salinity is achieved with the ratio of components $X_1 : X_2 : X_{3=}10: 60: 30$ (FIG. 1). In the region enriched with sulfates $MgSO_4$ and $CaSO_4$, the degree of salinity is the highest (up to 99.8%): while in the "corner" of calcium sulfate the degree is lower (to 70%-80%), which is due to the greater solubility of NaCl by the more intensive sodium chloride solubility in comparison with sulfates of magnesium and calcium.

The investigated area is not suitable for use in agriculture, which is confirmed, among other things, by studies of the Soil Science Institute of the National Academy of Sciences of the Republic of Kazakhstan (NAS RK).

Conclusion

Thus, on the basis of the chemical properties of contaminated and disturbed lands were studied on the basis of field and laboratory ecological and analytical researches. This make it possible allowed us to assess the modern ecological condition of industrial areas.

It was necessary to determine the correspondence between the salinity values of the regularity of the soil condition change in the geotechnical system, including the industrial territory, to reveal the regularities of the salinity change of the soils in time: It was found that the most strongly influencing components are calcium ion Ca^{2+}, sulfates [SO_4^{2-}], chlorine ion [Cl^-], magnesium ion Mg^{2+}. Analytical data revealed salinity already in the upper horizon of the field soils, where more than 1% of readily soluble salts are observed. The Cl/SO_4 ratio is greater than one. Of the divalent cations, magnesium predominates over calcium. The soils are carbonate, have an alkaline reaction (pH 7.25) of the soil solution.

The system research methodology has been developed that includes natural minerals (gallite-NaCI, magnesium sulfate Mg_4SO_4 and calcium sulfate $CaSO_4$). The diagram is constructed using the computer program "Triangle-Simplex Lattice", the program includes reference points. Investigation of the interaction in such multicomponent systems aims to obtain a complete "composition-property" diagram: the degree of salinity.

The impact of the enterprise on soil salinity in the territory of industrial plants was studied by the method of simplex-lattice interaction simulation in the $NaCl-MgSO_4-CaSO_4$ system; also the method of identification of the mineral components of the $NaCl-MgSO_4-CaSO_4$ system, calculations of crystallochemical formulas of minerals was used. The $NaCl-MgSO_4-CaSO_4$ diagram is constructed by the simplex lattice method and shows isothermal curves of the degree of salinity with the identification of the areas of formation of the most saline soils.

The highest degree of salinity is achieved with the ratio of components $X_1 : X_2 : X_3$=10: 60: 30. In the region enriched with sulfates, the degree of salinity is the highest (up to 99.8%), while in the "chloride corner" the degree is lower (up to 70%-80%), which is caused by greater solubility of alkali metal chlorides and more intensive chloride leaching in comparison with sulfates.

Disclosure Statement

There is no potential conflict of interest was reported by the authors.

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