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RESEARCH ARTICLE
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Assessment of Groundwater and Surface Water Quality within Agricultural Lands: A Case Study from the Novoanninsky District, Volgograd Region, Russia

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ABSTRACT

The article evaluates the impact of mineralized groundwater on reservoirs and agricultural soils in the Novoanninsky district of the Volgograd region. The article presents the results of a chemical analysis of groundwater, surface water and soil samples. A solution to the identified problem is proposed by creating a biogeochemical barrier in combination with agroforestry techniques. The research was conducted in the spring of 2024 within the Amovsky rural settlement of the Novoanninsky district, Volgograd region. To assess their quality, groundwater, surface water, and soil samples were collected from the upper and lower soil layers. The quantification of water-soluble cations and anions in surface water and soil samples was performed using capillary electrophoresis on a Drops-105 M instrument, following the protocols outlined in HDPE F 16.1:2:2.3:2.2.69-10 and HDPE F 16.1:2:2.2:2.3.74. Based on the results of chemical analysis, groundwater in the studied area has a high mineralization (13-16.9g/L) and significantly affects the soil quality and accordingly, the yield of cultivated crops. The maximum concentration of calcium, chlorine, sulfates, sodium, and magnesium ions in the upper and lower soil layers has been exceeded. Creating a biogeochemical barrier, combined with the use of agroforestry techniques, will reduce mineralization, change the quality and type of groundwater and surface waters, and increase the ecological (species) diversity of the landscape and its stability. Based on the data obtained, it is possible to select materials, calculate their quantity and volume, application methods, design features of the barrier, etc. In the future, it is necessary to conduct pilot field tests to correct the technology and develop a barrier design.

Keywords: Water resources, Land reclamation, Water availability, Agroforestry, Groundwater, Soil degradation, Biogeochemical barrier

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INTRODUCTION

Groundwater refers to water found in the first aquifer beneath the Earth's surface. It plays a crucial role in the formation of surface water bodies and significantly influences the ecological balance of the environment (Berhe, 2020). Groundwater can flow directly into surface reservoirs and watercourses, particularly when the groundwater level rises above the surface or when the impermeable layer separating groundwater from surface water becomes permeable (Yakovlev et al., 2022). Groundwater runoff can be a significant source of replenishment of surface reservoirs and watercourses, especially during periods of drought or in the absence of other sources of nutrition (He et al., 2020). Groundwater can also affect surface waters through the infiltration process. In this context, surface water can recharge groundwater reserves, potentially raising the groundwater level. Groundwater also influences surface water through evaporation. When the groundwater table is near the surface, evaporation may occur at a higher rate. This evaporated water contributes to atmospheric moisture, which can, in turn, affect precipitation patterns and subsequently influence surface runoff (Elsayed et al., 2020).

Vsevolozhskii & Grinevskii (2006) reported the processes of formation and movement of groundwater in

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various climatic and geological conditions. He developed methods for predicting changes in the groundwater level under the influence of natural and anthropogenic factors. Furthermore, in a related study (Vsevolozhskii & Kochetkova, 2005), they explored strategies for safeguarding groundwater from contamination by industrial and domestic wastewater.

Kraynov et al. (2004) studied the chemical composition of groundwater and the processes of migration of chemical elements in the earth's crust. His research explored the formation of groundwater's chemical composition under different factors, such as rock weathering, interaction with organic matter, and microbial activity. Groundwater plays a crucial role in shaping surface water bodies and influencing their quality. This impact occurs through various processes, including groundwater discharge, infiltration, and evaporation (Leybourne et al., 2007). A comprehensive understanding of these mechanisms is essential for developing effective strategies for water resource management and environmental conservation (Silva et al., 2021).

The influence of groundwater on cultivated crops is governed by multiple factors, which can exert both positive and negative effects. Mineralized groundwater located at depths shallower than 1 meter poses a risk to crops, as elevated salt concentrations can accumulate in the root zone, leading to waterlogging and subsequent oxygen deficiency (Kryukova, 2009; Zafar et al., 2023). Rising from the lower layers, groundwater immediately cools the soil, which in itself is bad for any roots. There is practically no oxygen in stagnant groundwater, which leads to the fact that the roots of plants suffocate and the processes of root death begin. In saturated soils, the root system does not merely die; it begins to rot. The decomposition processes in waterlogged soil can rapidly spread throughout the soil horizon and may persist even after excess water has drained. This prolonged presence of rotting material can have lasting detrimental effects on soil health and plant growth. Groundwater is removed from the lower layers of the soil during ascent, through which all toxic substances pass, which went there earlier and were inaccessible to plants due to their deep occurrence (Cheng et al., 2022).

Such a groundwater level, at which soil degradation and plant death begin, is critical. In areas flooded by mineralized groundwater, plant species diversity and abundance decrease (Shcheglov, 2011). The study's novelty lies in determining the influence of groundwater and surface waters on cultivated crops and suggesting ways to increase the fertility of lands affected by highly mineralized groundwater.

Therefore, this study aims to evaluate groundwater quality and assess its impact on surrounding water bodies. The specific objectives include collecting samples of surface water, groundwater, and soil from agricultural fields for subsequent chemical analysis to determine their quality and measuring groundwater levels using the N.F. Kulik drilling rig (patent No. 137613).

MATERIALS & METHODS

Field studies were conducted in the Novoanninsky territory from March 19 to 22, 2024, at the end of the snowmelt period. Coordinates of the points of investigation and sampling: 50°24'58.3"N 42°56'34.2"E; 50°24'55.4"N 42°56'45.0"E; 50°24'56.5"N 42°56'47.2"E; 50°24'54.8"N 42°56'45.4"E. Volgograd region for the purpose of sampling surface, groundwater and soil for chemical analysis. To assess the water quality, sampling was carried out in accordance with GOST R 59024-2020 "Water. General requirements for sampling" and GOST 17.1.5.04-81 81 ("Nature protection. The hydrosphere devices and instrument for sampling, primary processing and storage of natural water samples"). To assess the quality of the soil, sampling was carried out in accordance with GOST 17.4.4.02-2017 ("Nature protection. Soils. Methods of sampling and preparation of samples for chemical, bacteriological, helminthological analysis"). Groundwater sampling was carried out in accordance with GOST 59539-2021 ("Soils. Methods of groundwater extraction"). The analysis of the content of water-soluble cations and anions in surface waters and soil was carried out by capillary electrophoresis using Drops-105M according to the methods of HDPE F 16.1:2:2.3:2.2.69-10 and HDPE F 16.1:2:2.2:2.3.74.

Novoanninsky district is located in the northwestern part of the Volgograd region (Ovcharova, 2020). The condition and quality of water bodies in the studied area can be characterized as intellectual (Brylev, 2007). Reservoirs often suffer from wastewater discharged with insufficient treatment or without pre-treatment at all. The main sources of pollution are housing and communal services, industrial and agricultural enterprises.

RESULTS AND DISCUSSION

During the research of the water bodies of the Amovsky rural settlement of the Novoanninsky district, pollution of the cascade of ponds was discovered. These ponds were established in the early 20th century to regulate runoff and are integral components of both natural and anthropogenic geographical systems, evolving under the influence of various natural factors (Dedova, 2023).

The chemical analysis of the water samples revealed elevated levels of chlorine, sodium, sulfate, bicarbonate, and magnesium ions (Table 1). This indicates an increase in the proportion of groundwater in the reservoir with the end of the spring flood. The mineralization in the ponds varied from 2.4 to 6g/L. To determine the quality of groundwater, 4 wells were drilled in increments of 20m. During the drilling process, groundwater and soil samples were taken from each well from the upper (An) and lower layer (Bn) (n is the well number) to determine groundwater effect on the quality of the soil layer (Table 2).

Based on the results of chemical analysis, it can be concluded that the maximum concentration of calcium, chlorine, sulfate, sodium and magnesium ions in both the upper and lower soil layers has been exceeded. Well 4 was drilled in an agricultural field where sunflower is grown. Compared to the first three wells, the quality of the upper layer is better, but still does not meet the MPC standards. The rise of groundwater leads to a change in the pH of the soil, which negatively affects plant growth and subsequently

Table 1: Results of chemical analysis of pond water samples in Burnatsky farm (Amovskoye rural settlement of Novoanninsky district)

Object	Mineralization (g/l)	Ca^{2+} (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	$HCO3^-$(mg/L)	Mg^{2+} (mg/L)
Pond in Burnatsky farm (Amovskoye rural settlement)	2.4	208	1060	1720	1120	< 0.5	667	226
MPC	1	180	350	500	200	50	60	40

Table 2: Results of chemical analysis of selected water and soil samples

Object		Mineralization (water)/ pH (soil)	Ca^{2+} (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	$HCO3^-$(mg/L)	Mg^{2+} (mg/L)	Depth (cm)
Water	Well No. 1	13.1	100	7500	3900	>5000	<0.5	786	1100	80
	Well No. 2	13.8	106	7654	3940	>5000	<0.5	798	1134	90
	Well No. 3	15.1	910	9200	5300	>5000	<0.5	1050	1490	100
	Well No. 4	16.9	1080	9260	5350	>5000	<0.5	>1200	1510	120
MPC		1	180	350	500	200	50	60	40	
Soil	A_1	8.2	134	27.8	48.9	47.1	9.3	-	23	80
	B_1	8.6	660	633	5520	1740	<2	-	239	
	A_2	8.3	160	649	1890	1160	<2	-	57.8	90
	B_2	8.4	650	3710	5250	3260	<2	-	354	
	A_3	8.6	228	2530	1840	2070	<2	-	128	100
	B_3	8.2	1890	2250	11900	2790	<2	-	630	
	A_4	8.7	57.9	30.6	78	246	<2	-	15.2	120
	B_4	8.5	287	2940	3530	2680	<2	-	212	
MPC		5.5-7	300	10	160	15	300	130	48	

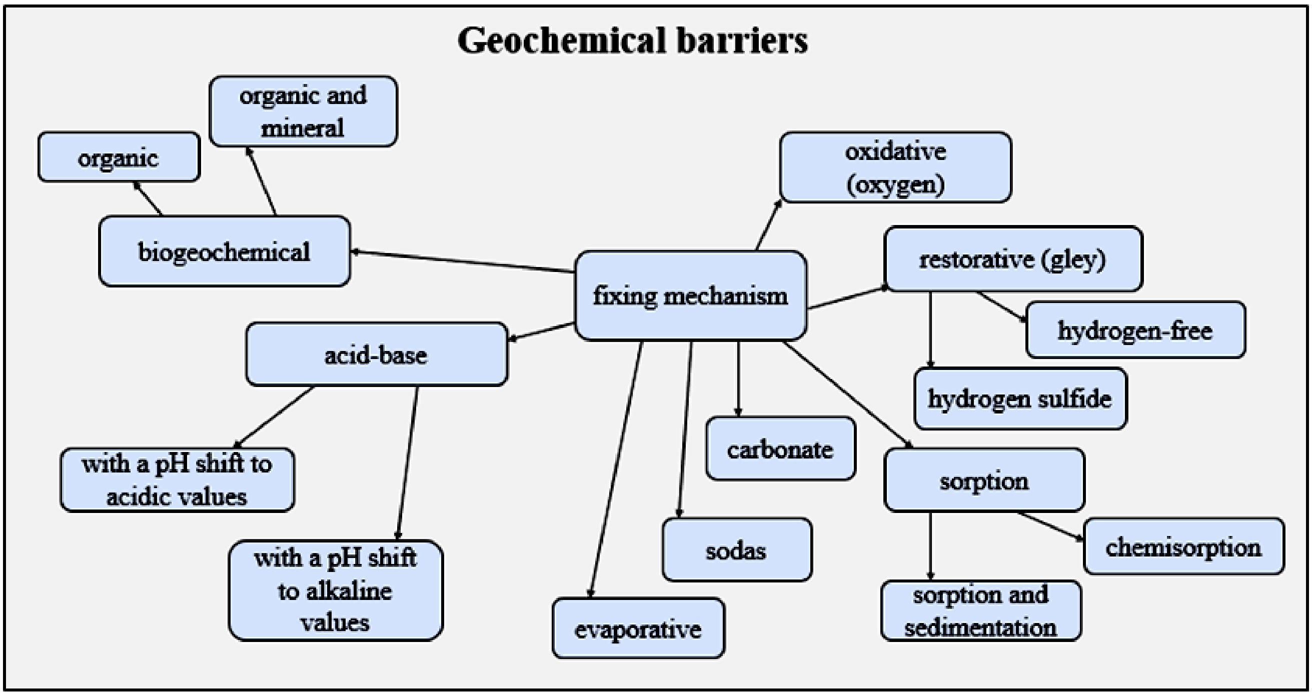

Fig. 1: Types of geochemical barriers.

yields. In the flooding zone (the depth of groundwater is 0.5-2.5m) there are sites located in the flood plain of the Buzuluk river and in the low places of the first floodplain terrace. The depth of groundwater is very important for the normal growth and development of plants. Everyone knows that when groundwater is close, waterlogging occurs, and it is difficult to grow any valuable crops on such a site. But sometimes it turns out that due to prolonged rains or some other natural processes, groundwater that was relatively deep rises. Thus, the groundwater in the studied area has a high mineralization (13-16.9 g/l) and significantly affects the quality of the soil and, accordingly, the yield of cultivated crops. The yield of sunflower in the Novoanninsky district in 2023 is 20.6 quintals per hectare. In the Amovsky rural settlement, the yield of this crop ranges from 13 to 25 quintals per hectare.

One of the ways to solve this problem is to create a biogeochemical barrier (Tong et al., 2021; Antoninova, 2024). Biogeochemical barriers are components or parts of components of geosystems (Fig. 1) in which, at a relatively short distance, as a result of a specific combination of mechanical, physico–chemical, biological processes, selective accumulation of some chemical elements and removal of others occurs (Moskovchenko et al., 2020).

Knowledge of geochemical barriers makes it possible to control physico-chemical processes in groundwater, and in natural conditions – to assess the possibilities of self-purification of groundwater from pollution (Buryak et al., 2022; Lisetskii & Buryak 2023). Complex barriers are common in natural conditions: mechanical and biogeochemical technogenic barriers associated with the overgrowth of the floodplain of the river with macrophytes and its waterlogging, as well as with the creation of ponds as a result of the expansion and deepening of the riverbed, where the flow rate drops sharply. Artificial geochemical barriers can be specially created to solve various tasks, such as environmental protection. Special technologies are being developed to create artificial barriers (Semyachkov, 2013). Various materials and substances are used as materials used to create barriers, depending on the specifics of the barriers and economic feasibility. Natural materials are widely used to create sorption materials (clays, loams, peat, etc.). The advantage of using natural substances is their widespread distribution, which reduces transportation costs and relatively low cost. A promising area is the use of industrial waste. The complexity of this study will be expressed in combination with agro-reclamation techniques of biosorption of polluted lands based on the cultivation of woody plants. For example, a bird cherry or birch is able to absorb up to 200 liters of water per day, in addition, water-absorbing trees have sorption properties (Smedley 1991).

The model of the biogeochemical barrier and the technological scheme of its creation depend on the nature and degree of contamination (Shadrin et al., 2021). Based on the data obtained, it is possible to select materials, calculate their quantity and volume, methods of their application, design features of the barrier, etc. In the future, it is necessary to conduct pilot field tests to correct the technology and develop a barrier design. The essence of the use of phytomeliorant plants lies in the enzymatic transformations associated with them for the degradation of organic pollutants in the soil (Worden & de Beurs, 2020). When using the method for land reclamation, emissions of substances polluting atmospheric air are not generated, a significant amount of energy resources is not required, and the landscape of the area does not significantly change during restoration work. The disadvantage is the time duration of the process of cleaning contaminated soil from organic pollutants. It is planned to conduct laboratory experiments on the selection of meliorant plants and the development of a biogeochemical barrier model.

Conclusion

The findings of this study provide various important insights. The artificially created ponds in the Amovsky rural settlement are currently impacted by natural factors, lacking technical maintenance, and undergoing eutrophication. Consequently, their ability to act as productive accumulators is significantly diminished. Increased levels of key ions, including chloride, sodium, sulfate, bicarbonate, and magnesium, have been detected in the water. This mineralization is contributing to an increase in highly mineralized groundwater levels, altering soil pH and adversely affecting agricultural yields. A promising solution to alleviate these issues require establishment of a biogeochemical barrier. When integrated with agroforestry practices, this approach has the potential to decrease mineralization, ameliorate the quality and composition of groundwater and surface waters, and enhance both the ecological diversity and stability of the landscape. In the future, it is necessary to conduct pilot field tests to correct the technology and develop a barrier design. It is planned to conduct laboratory experiments on the selection of meliorant plants and the development of a biogeochemical barrier model.

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