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Analysis and assessment of surface water quality in the Ilek river basin

Abstract. *The article is devoted to the study of hydrochemical indicators of surface waters of the Ilek River and large tributaries. The study was conducted based on the results of expeditionary observations in 2020-2021. Surface water samples were taken at key sites for chemical analysis of constituents. The scientific article describes natural and technogenic factors influencing the geosystems of the Ilek river basin. The paper reveals the dependence of surface water pollution on the impact of external technogenic factors. The study showed a direct dependence of surface water on the industry. In the upper part of the Ilek River basin, high concentrations of copper and zinc are observed in surface waters. In the middle reaches of the river Ilek exceeding the MPC by a factor of ten for chromium, iron, and boron is obviously associated with intense pollution of the production of the Aktuinsk chromium plant and the Aktobe ferroalloy plant. The work also describes the pollution of the tributaries of the Ilek River of the first and second order, associated with the mining industry in the regions.*

Keywords: *technogenesis, Ilek river basin, hydrochemical indicators, water pollution index.*

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Introduction

Technogenesis is an internally natural process that changes under the influence of external factors to a certain extent [1]. At present, technogenesis is a practically uncontrollable process in a global aspect. In general, it is not subject to the mind and will of people at a modern geological moment. The process takes place at different hierarchical levels, which conditionally can be distinguished by local, regional, and global levels. Local processes, in the course of which human often deliberately intervenes and changes their direction, are more studied. Mostly, technogenesis occurs in a spontaneous way at the regional and global levels. Artificial improvements to the biosphere at the local level can often contribute to regional and global destruction of the environment and human degradation against the human original intention. The study of the relationship between technogenic processes at different hierarchical levels is still poor [2].

The development of technology and the modern technical capabilities of society became one of the main reasons for modern forms of technogenesis. Human engineering activity has a great influence on exogenous processes, first of all, on the river network and erosion [3]. Artificial feeding of rivers is used due to the transfer of water from one river to another and the redistribution of the river flow over time. Dams, sluices, and canals lead to the regulation of both flow rates and erosional activities of rivers. The idea of the so-called equilibrium curve, widespread in modern geomorphology, for the most part, loses its meaning for regulated rivers. An important factor is the geoecological state of surface waters. Surface waters are one of the most important components of the environment and their condition often has a decisive impact on the ecological situation in the region [4].

The state of surface water and river streams serves as an important characteristic of the geoecological situation of the catchment basins. The knowledge of the chemical composition of waters and its changes is a prerequisite for identifying the mechanisms and scales of interaction between the components of the natural environment and for an objective geoecological assessment of the region's territories [5].

Study area

The study area belongs to the Zhaiyk-Caspian water basin. The Ilek river with tributaries of the first order, which flows into the river Zhaiyk (Ural) and further into the Caspian Sea form the hydrographic network [6]. The Ilek river is a left tributary of the Zhaiyk river (Ural), formed by the confluence of the Karaganda (left component) and Zhaiyk (right component) rivers, 8 km north of the Kandagash railway station. It flows into the river Zhaiyk from the left, 1085 km from its mouth which is located in the Orenburg region. The total length of the river is 623 km (from the source of the Zharyk river, 699 km), and the catchment area is about 42 000 km^2 (Figure 1). The river has a two-sided floodplain; the width in the middle course varies from 0.4 to 1 km. The tortuosity coefficient along the length of the river varies insignificantly and averages 1.5. The banks are steep in places, composed of loam and sandy loam. The bottom is sandy loam, in some areas, it is sandy-pebble and loamy, and in some places it is slightly silted [7].

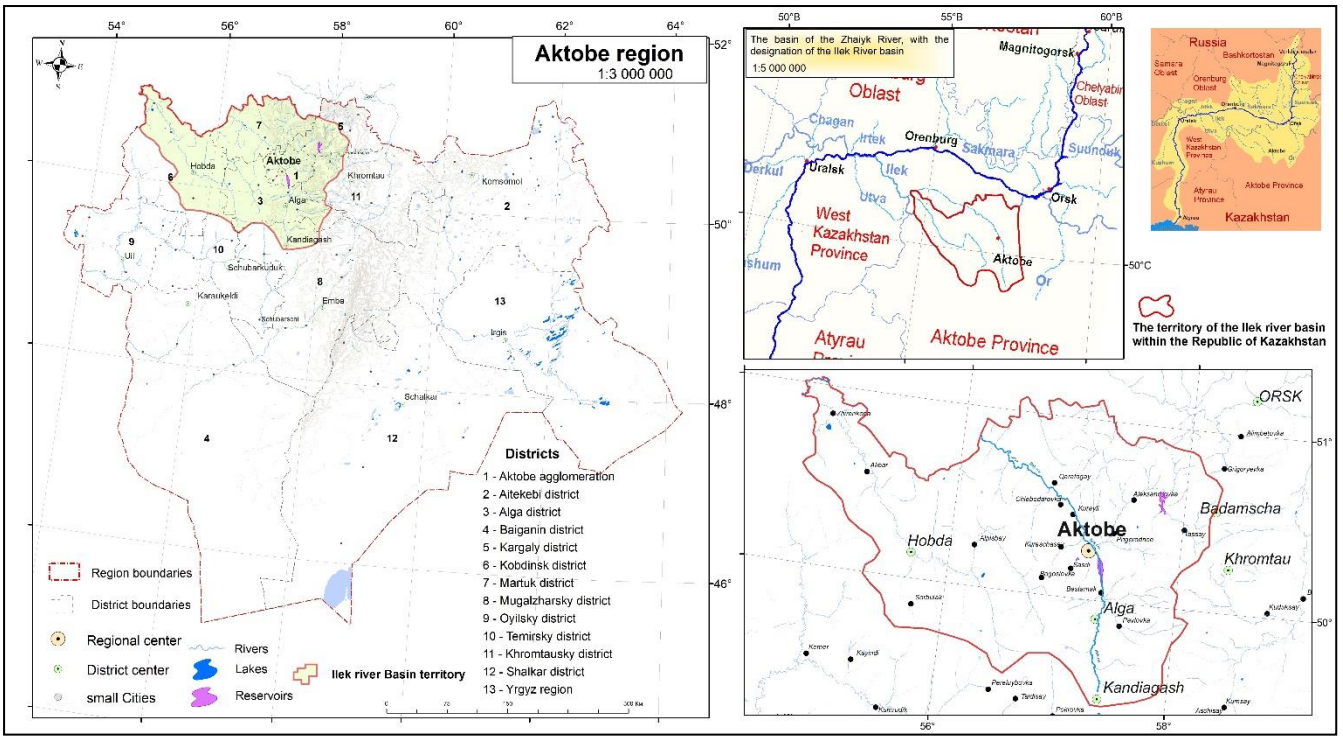

Figure 1. Hydrographic network of the Ilek river basin [created by the author on the ArcGIS program]

The length of the river in the studied Aktobe region is 257 km. The main tributaries include the right side – Koktyube river (length of 38 km), Tabantal river (length of 56 km), Kargala river (length of 114 km), and the left side – Sazdy river (length of 40 km), Tanybergen river (length of 58 km), Aksu river (length of 42 km). In addition to the above, the river receives a number of other tributaries, 20 to 30 km long, and many small dry gullies in summer. The catchment is located on the western spurs of the Mugodzhar mountains and the Dzharyk-tau mountains, and it is characterized by a highly dissected relief. The tributaries form a rather dense hydrographic network. The hydrotechnical structures on the Ilek river include the Aktobe, Kargalinskoye, and Sazdinskoye reservoirs, which are artificial reservoirs of long-term filling with seasonal drawdowns of the water level [5].

One of the main natural factors that ensure the removal of the products of technogenesis from geosystems is the hydrological and hydrogeological factor that appears during the period of intensification of the activity of water flows since their chemical composition has a direct effect on living organisms [8].

Materials and research methods

Traditional methods of geographical research were used during the collecting and analyzing of materials (observation, mapping, and geochemical analysis of surface water samples) [9]. In course of the studies, there was measured the temperature regime of the river, which is one of the important environmental indicators. Surface water temperature is the result of several simultaneously occurring processes, such as solar radiation, evaporation, heat exchange with the atmosphere, heat transfer by currents, turbulent mixing of water, etc. Water temperature is the most crucial factor affecting physical, chemical, biochemical, and biological processes. The oxygen regime and the intensity of self-purification processes largely depend on the water temperature [10].

An important indicator of the ecological state of a reservoir under anthropogenic impact is the concentration of biogenic elements in the water. This primarily refers to mineral compounds of nitrogen and phosphorus, as the most easily assimilated form by phytoplankton. The biogenic elements are characterized by seasonal variability; their content in water is closely related to the vegetation of phytoplankton. In this connection, with a decrease in the biomass of phytoplankton, the concentration of phosphorus increases in winter, and on the contrary, the content of phosphorus consumed by phytoplankton decreases in summer.

A sampling of surface water was carried out in accordance with SS RK 51592 - 2003 “Water. General requirements for sampling” [11]. The sampling was conducted at 10 key areas: from the source to the mouth of the Ilek river samples were taken in large tributaries of the Ilek river to identify the concentration of dilution by the waters of the tributaries. Water analyzes were carried out in the laboratories of the RSE "Kazhydromet" (Aktobe, Kazakhstan), as well as in the laboratory of LLP "IST-ECO". Based on the results of the chemical analysis, there was calculated the water pollution index (WPI) of the surface waters of the tributaries and the main channel of the Ilek river.

Results and discussion

The Ilek river basin is located in mining areas. The specificity and intensity of the flow of chemical elements into watercourses change sharply in the mining and processing areas. In the immediate vicinity of the enterprises, surface and underground waters change their chemical composition under the influence of technogenic load. They accumulate sulfates, heavy metals, and other components, and acidity changes. Acidic waters have an increased content of mobile forms of metals and promote their migration into a conjugated environment [12].

In the Ilek river basin, an association of natural and technogenic elements that function as a single system form a special natural and technogenic geosystem. The technogenic component of the subgeosystems of the studied areas of the basin has a long history of formation, therefore, understanding the conditions for the integration of the environment and the elements of the technosphere is very important [12].

Natural-historical processes of territory pollution have been studied in detail in historical documents and summaries [13].

Aktobe as a business and cultural center was founded in 1869 on the banks of the Ilek river. The main large settlements are located mainly near water bodies, which leads to water pollution with household waste, waste from animal husbandry, and industrial production. Currently, sources of water pollution are industrial enterprises and public utility facilities. The main polluting enterprises are the Aktobe Plant of Chromium Compounds (APCC), the Aktobe Ferroalloy Plant of Kazchrome Corporation JSC (AFP), Alga Chemical Plant named after Kirov (in Alga) shutdown large chemical production, "Aktobe CHP", "Akbulak", "Aktyubrentgen" JSC, "Aktobe Oil Equipment Plant" JSC, alcoholic beverages production "Geom" LLP, "Omirbek" LLP, "Bakhtiyar" LLP, mining enterprises the northwestern part of the large tributaries of the Ilek river: "Aktobe Temir VS", "Kyzyl-Kain Mamyt".

The general scope of anthropogenic factors affecting the Ilek river basin is wide enough. There are presented the main types of technogenic impact determining the current ecological state of the Ilek basin.

Influence of traffic intensity of vehicles.

According to the results of the analysis of a water sample at the 4th key site (Table 1), the close proximity to the location of the large junction station Kandagash near the source of the Ilek river, as well as the location of deposits of building materials (sand, clay), determined the excess of the MPC for such elements as Pb, Zn, Fe. Additionally, the Sazdy river, the left bank tributary of the Ilek river, and the Sazdy reservoir contain Pb more than 7 times exceeding MPC (Table 2). Obviously, this is due to the close location of the airport of the city of Aktobe. The close proximity of the Sazdy reservoir increases the area catching the deposited micropollutants.

Table 1

Average concentrations of pollutants in the Ilek river (based on samples from key sites studied in 2020)

Sampling location	Probable sources of technogenesis	Chemical elements (exceeding maximum permissible concentration / times)								
		B	Cr	Cu	Pb	Fe	Ni	BOD5	PO_4^{3-}	**WPI**
Upper source of the Ilek river, (Kandagash village, Alga city) key 4	Transport hub, deposits of building materials	-	-	13	0,9	0,4	-	1,75	1,1	**2,5**
Ilek river, key 3, near Alga city	Chemical industry, agriculture	20,0	-	13	0,4	0,3	-	1,97	1,0	**8**
Ilek river, key 2, in Aktobe, after the confluence with the Zhenishke river	Metallurgical industry: APCC, AFP, KazChrome, KazZink	13,8	3,85	8	1,1	1,0	2,5	0,65	1,0	**11**
Ilek river, key 1, Aktobe, after the Aktobe reservoir	Melons and gourds, air transport	10,1	-	11	1,1	0,3	-	0,5	0,3	**7**
Ilek river, key 5, near the village of Martuk	Agriculture	10	2,2	6	0,4	-	1,2	1,70	0,5	**5,5**
Note: "-" - values within normal limits										

The activity of the mining enterprises

The mining industry in the eastern part of the basin, confined to the Kargaly river, the right-bank tributary of the Ilek river, plays a special role in the pollution of the basin. The long-term development (since 1921) of primary ore and placer nickel, iron ore and copper deposits had a significant impact on the formation of the modern landscape of the region. Exploration surveys of raw materials covered about two-thirds of the territory of the Kargaly district of the Aktobe region, where most of the left-bank tributaries of the Ilek river are located (77%). Such as the Zhaman Kargaly river, the Zhaksy Kargaly river, the Kosistek river, the Kuagash river, the Tabantal river, the Kokpekty, the Tarangul river, etc. The territory of the Kargalinsky district of the Aktobe region is characterized by a half-century period of

the removal of ore and their accompanying elements to the day surface, which lead to a violation of the natural, biological, hydrogeological, and geochemical equilibrium. Violation of biological balance is manifested in the destruction of aquatic and near-aquatic landscapes. The floodplain terraces of the rivers Kosistek, Karabutak, Kuagash, Kokpekty are practically heaped up with overburden dumps of the Kyzyl-Kain-Mamyt mine. The result of chemical analyzes on the left-bank tributaries of the Ilek river showed a significant excess of MPC for such elements as Cu, Pb, Fe, and Zn, as well as exceeding MPC for BOD5, nitrite, and ammonium ions (Table 2).

Obviously, this is related to the mining industry. Overburdened rocks from geological exploration works are located near the Kuagash river (Badamsha village, Nikeltau village). The Velikhovskoe South and Velikhovskoe North iron deposits with large dump areas are located near the Kosestek river. A large excess of carbonate ions and copper is observed in the Zhaman-Kargaly river. Apparently, this is associated with the Novorossiysk limestone deposit, as well as large copper deposits near the village of Akzhar (formerly Novorossiysk village), Priorskoe deposit (pyrite ores, 1967), deposit "50 years of October", Avangard deposit. Exceeding MPC for nitrogen, nitrite, and ammonium ions is observed in the Zhaksy-Kargaly river (Table 2). This is due to economic activities in the Kargalinsky district, near the village of Shamshi Kaldayakov (formerly Aleksandrovka), the village of Petropavlovka (irrigated agriculture: Tore Agro LLP, Kargala Agro Product LLP, Patsaeva LLP, Tabigat + LLP).

Table 2

Results of chemical analysis of surface waters of the tributaries of the Ilek river, 2021 (mg/dm³)

Index	Sazdy river, near Aktobe city	Kuagash river, near the Badamsha village	Kosistek river, near the Kosistek village	Zhaksy Kargaly river, near the Petropavlovka village	Zhaman Kargaly river, near the Akzhar village	Aksu river, near the Martuk village, before the confluence with the Ilek river
Turbidity	1,3	2,8	1,03	0,88	1,4	0,1
Oxidizability	3,5	2,1	1,9	1,1	1,8	0,9
pH	7,7	8,1	8,4	7,1	8,0	7,0
Total hardness	6	5,8	5,9	5,4	5,5	2,5
Ammonia	0,14	not detected	0,2	0,4	0,3	-
Nitrite	0,004	0,002	not detected	not detected	-	-
Nitrates	38	30	46	49	30	32
Fe	not detected	0,02	0,3	0,08	0,05	not detected
Cu	0,34	0,54	0,24	0,18	0,5	-
Cl^-	35	72	58,2	45,5	52	40,4
F^-	0,5	0,2	0,12	0,1	1,0	not detected

Industry impact

During the second half of the last century, the waters of the Ilek river were heavily polluted by heavy metals, phenols, boron, organic matter, phosphates, sulfates, and other components. The main

sources of pollution were the largest enterprises: Aktobe Chemical Plant named after S.M. Kirov (Alga), which ceased its activities in 1996; Aktobe Plant of Chromium Compounds (APCC), Aktobe Plant of Ferroalloys of TNK Kazchrome JSC (APF), which accounted for about 85% of all pollutants coming from wastewater discharges. In the area of large industrial hubs, the maximum permissible concentration for the main polluting components was exceeded many times resulting in the WPI of the Ilek river after the city of Aktobe varying from 7 to 10. The waters belong to "class 6", which is considered very dirty. Table 1 shows the increase of the WPI from the source to the city of Aktobe depending on the location of the source of technogenesis near the Ilek river This is also associated with the confluence of tributaries with their own water concentration. The maximum WPI is observed in the city of Aktobe, after the confluence of the Zhenishke river into the main channel of the Ilek river. This is mainly due to the location of the industrial zone (Aktobe plant of chrome compounds (APCC), Aktobe ferroalloy plant of TNK Kazchrome JSC (AFP), etc). Due to the dilution of surface waters by the tributaries of the Tanybergen, Zhamansu, Aksu rivers, WPI decreases along the mouth near the Martuk village (closer to the border of the Russian Federation).

Table 2 shows the differences in water pollution indicators in samples from different tributaries. These differences correlate with the economic activities of settlements near rivers.

Water migration of elements mainly occurs during periods of snow melting and after rare heavy rains, when numerous dry channels are filled with water. In addition to the above external factors, the hydrochemical indicators of the river are significantly influenced by the processes occurring directly in the river waters (sedimentation, complexation, oxidation, or reduction of elements, etc.).

Conclusion

The study of the surface waters of the Ilek river and its large tributaries showed the relations between the development of industry and a technogenic load of the basin's geosystem. Sludge collectors of industrial enterprises pose a high danger. In the upper part of the Ilek basin, there is a high content of copper and zinc in surface waters. Pollution in this area belongs to the second hazard class. The exceeding of MPC in some places reaches 40-45 times since the territory of the basin is located in close proximity to the large junction railway station Kandagash, created in 1928 as part of the Aktobe district.

In the middle reaches, the Aktobe plant of chrome compounds (APCC), Aktobe ferroalloy plant of TNK Kazchrome JSC (AFP) are also threatening for the waters of the basin, which intensively pollute river waters with hexavalent chromium compounds from accumulations, chrome-containing sludge of APCC and slags of the ferroalloy production of AFP.

The third, no less significant problem is the mining industry on the right bank of the Ilek river basin. Mining enterprises have rather large mining allotments in use; therefore, the load from them on the environment and on surface waters is also commensurately great. The analysis of the consequences of the development of technogenic processes is very difficult for the reason that a chain of subsequent natural events can accompany the technogenic beginning itself. Withdrawing huge masses of rocks with minerals, they are being introduced into the geological environment that has been forming for millions of years. This leads to a weakening of rock pressure inside the stressed massif; the formation of cavities for the oxidation of natural agents; the formation of ground sinkholes on the day surface; intensification of soil erosion; violation of the primary natural conditions of the environment. The data of hydrochemical monitoring of water bodies in the basin are not only the basis for assessing the quality of surface waters, but also serve as an objective indicator of the geoecological state of the geosystems of the entire basin.

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Елек өзені алабындағы жер үсті суларының сапасын талдау және бағалау

Аңдатпа. Мақала Елек өзені мен оның ірі салалары жер үсті суларының гидрохимиялық көрсеткіштерін зерттеуге арналған. Зерттеу 2020-2021 жылдардағы экспедициялық бақылаулардың нәтижелері бойынша жүргізілді. Құрамдас бөліктерге химиялық талдау жүргізу үшін негізгі учаскелерден жер үсті суларының үлгілері алынды. Ғылыми мақалада Елек өзені бассейнінің геожүйелеріне әсер ететін табиғи және техногендік факторлар сипатталған. Жұмыста жер үсті суларының ластануының сыртқы техногендік факторлардың әсеріне тәуелділігі ашылған. Зерттеу жер үсті суларының өнеркәсіпке тікелей тәуелділігін көрсетті. Елек өзені бассейнінің

жоғарғы бөлігінде жер үсті суларында мыс пен мырыштың жоғары концентрациясы байқалады. Елек өзенінің ортаңғы ағысында хром, темір және бор бойынша ШРК-ның ондаған есе артық болуы АҚХЗ және АФЗ өндірісінің қарқынды ластануымен байланысты екені анықталды. Сондай-ақ, мақалада өңір бойынша тау-кен өнеркәсібіне байланысты бірінші және екінші ретті Елек өзенінің салаларының ластануы сипатталған.

Түйін сөздер: техногенез, Елек өзені алабы, гидрохимиялық көрсеткіштер, судың ластану көрсеткіші.

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Анализ и оценка качества поверхностных вод бассейна реки Илек

Аннотация. Статья посвящена изучению гидрохимических показателей поверхностных вод реки Илек и крупных притоков. Исследование проводилось по результатам экспедиционных наблюдений в 2020-2021 гг. На ключевых участках были отобраны образцы поверхностных вод для химического анализа составляющих компонентов. В работе описаны природные и техногенные факторы, влияющие на геосистемы бассейна реки Илек, раскрыта зависимость загрязнения поверхностных вод от воздействия внешних техногенных факторов. Исследование показало прямую зависимость поверхностных вод от промышленности. В верхней части бассейна реки Илек в поверхностных водах наблюдается высокое содержание меди и цинка. В среднем течении реки Илек наблюдается превышение ПДК в десятки раз по хрому, железу и бору, очевидно, связанное с интенсивным загрязнением производства АЗХС и АЗФ. Также в работе описано загрязнение притоков реки Илек первого и второго порядка, связанное с горнодобывающей промышленностью в регионах.

Ключевые слова: техногенез, бассейн реки Илек, гидрохимические показатели, индекс загрязнения воды.

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