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Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

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КАЗАХСТАН
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IMPACT OF TECHNOGENIC FACTORS ON SURFACE WATER OF THE ILEK RIVER BASIN

Abstract. The article presents the general scope of anthropogenic factors that negatively affecting the geosystems of the Ilek river basin. The paper considers the hydrochemical investigations of the Ilek river and large tributaries as a result of expeditionary observations for 2021. Natural and technogenic factors that have been affecting the geosystems of the Ilek river basin for many decades have been identified. Paper reveals its dependence with the elements of the technosphere based on the results of chemical analyzes of surface water samples from key areas. The research showed the relations between development of industry and technogenic load of the basin's geosystem. 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. 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 the hexavalent chromium compounds from accumulations, the chrome-containing sludge of APCC and slags of the AFP. The research established contamination of the tributaries of the Ilek river of the first and second order, in the northeastern part of the basin, with heavy metals as a consequence of the mining industry and geological exploration. The water

pollution index (WPI) of the Ilek river and large tributaries has been calculated. The calculated WPI value is in the range of 2.5-11.

Key words: Ilek river, technogenesis, river basin, hydrochemical indicators, geoecological state.

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ИЛЕК ӨЗЕНІ АЛАБЫНЫҢ ЖЕР ҮСТІ СУЛАРЫНА ТЕХНОГЕНДІК ФАКТОРЛАРДЫҢ ӘСЕРІ

Аннотация. Мақалада Илек өзені алабының геожүйелеріне теріс әсер ететін антропогендік факторлардың жалпы спектрі берілген. Мақалада 2021 жылға арналған экспедициялық бақылаулар нәтижесінде Илек өзені мен ірі салаларының гидрохимиялық зерттеулері қарастырылған. Көптеген ондаған жылдар бойы Илек өзені алабының геожүйелеріне әсер еткен табиғи және техногендік факторлар анықталды. Мақалада негізгі аймақтардан алынған сынамалардың химиялық талдауларының нәтижелері негізінде жер үсті суларының күйі техносфера элементтеріне тәуелділігі көрсетілген. Зерттеу өнеркәсіптің дамуы мен өзен алабы геожүйесінің техногендік жүктемесінің арасындағы байланысты көрсетті. Илек өзені алабының жоғарғы бөлігінде жер үсті суларында мыс пен мырыштың жоғары концентрациясы байқалады. Бұл аймақтың ластануы екінші қауіптілік класына жатады. Өзен алабының аумағы Қандыағаш темір жол станциясының ірі айрығына жақын орналасқандықтан, кейбір жерлерде ШРК-дан асып кету 40-45 есеге жетеді. Орташа мәнде Ақтөбе хром қосындылары зауыты (АХҚЗ), «Қазхром ТҰК» АҚ Ақтөбе ферроқорытпа зауыты (АФЗ) құрамында хром бар АХҚЗ шламын жинақтағыштардан алты валентті хром қосындыларының және АФЗ күл жинағыштарының қарқынды ластануына байланысты бассейн суларына қауіп төндіреді. Зерттеу барысында тау-кен өнеркәсібі мен геологиялық барлау жұмыстарының нәтижесінде бассейннің солтүстік-шығыс бөлігіндегі бірінші және екінші

ретті Илек өзенінің салаларының ауыр металдармен ластануы анықталды. Илек өзені мен негізгі салаларының судың ластану индексі (WPI) есептелді. WPI есептелген мәні 2,5-11 диапазон аралығында орналасқан.

Түйін сөздер: Илек өзені, техногенез, өзен алабы, гидрохимиялық көрсеткіштер, геоэкологиялық жағдай.

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ВЛИЯНИЕ ТЕХНОГЕННЫХ ФАКТОРОВ НА ПОВЕРХНОСТНЫЕ ВОДЫ БАССЕЙНА РЕКИ ИЛЕК

Аннотация. В статье представлен общий спектр антропогенных факторов, негативно влияющих на геосистемы бассейна реки Илек. В статье рассматриваются гидрохимические исследования реки Илек и крупных притоков как результат экспедиционных наблюдений за 2021 год. Были выявлены природные и техногенные факторы, влияющие на геосистемы бассейна реки Илек на протяжении многих десятилетий. В статье раскрывается зависимость состояния поверхностных вод от элементов техносферы, выявленная на основе результатов химических анализов проб, отобранных из ключевых участков. Исследование показало взаимосвязь между развитием промышленности и техногенной нагрузкой на геосистему бассейна. В верхней части бассейна реки Илек в поверхностных водах наблюдается высокое содержание меди и цинка. Загрязнение в этой области относится ко второму классу опасности. Превышение ПДК в некоторых местах достигает 40-45 раз, так как территория бассейна расположена в непосредственной близости от крупной узловой железнодорожной станции Кандагаш. В среднем течении Актюбинский завод хромовых соединений (АЗХС), Актюбинский завод ферросплавов АО «ТНК Казхром» (АЗФ) также представляют угрозу для вод бассейна, в связи с интенсивным загрязнением соединениями шестивалентного хрома из накопителей

хромсодержащего шлама АЗХС и золошламонакопителей АЗФ. В ходе исследования было установлено загрязнение притоков реки Илек первого и второго порядка в северо-восточной части бассейна тяжелыми металлами в результате горнодобывающей промышленности и геологоразведочных работ. Был рассчитан индекс загрязнения воды (WPI) реки Илек и крупных притоков. Рассчитанное значение WPI находится в диапазоне 2,5-11.

Ключевые слова: река Илек, техногенез, речной бассейн, гидрохимические показатели, геоэкологическое состояние.

Introduction. Technogenesis is an internally natural process that changes under the influence of external factors to a certain extent (Berdenov et al., 2015; Dubey et al., 2021). 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. Technogenesis at the regional and global levels occurs mainly spontaneously. 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's original intention (Lavrusevich, 2010). The study of the relationship between technogenic processes at different hierarchical levels is still poor (Dzhanaleyeva et al., 2017).

The development of technology and 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 (Beketova et al., 2019). Artificial feeding of rivers is used due to the transfer of water from one river to another and the redistribution of the river flow in time. Dams, sluices and canals lead to 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 (Krabbenhoft & Kashian, 2020).

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 (Ozgeldinova et al., 2021; Ramazanova et al., 2019).

The choice of the territory is based on more than a century and a half history of anthropogenic influence on the surface waters of the Ilek river basin (Aktobe, Kazakhstan). For 70 years, the surface waters of the Ilek river basin have been polluted with boron, for more than 50 years - with chromium. For more than 150 years in a row, sewage waste not only from industrial enterprises, but also from all settlements of the region has been discharged into the river channel (Berdenov, 2017).

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 (Dzhanaleeva, 2010). 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 that is located in the Orenburg region. The total length of the river is 623 km (from the source of the Zharyk river, 699 km), the catchment area is about 42 000 km^2 (Fig. 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 and sandy loam, in some areas sandy-pebble and loamy, in places slightly silted (Abdullin, 1994).

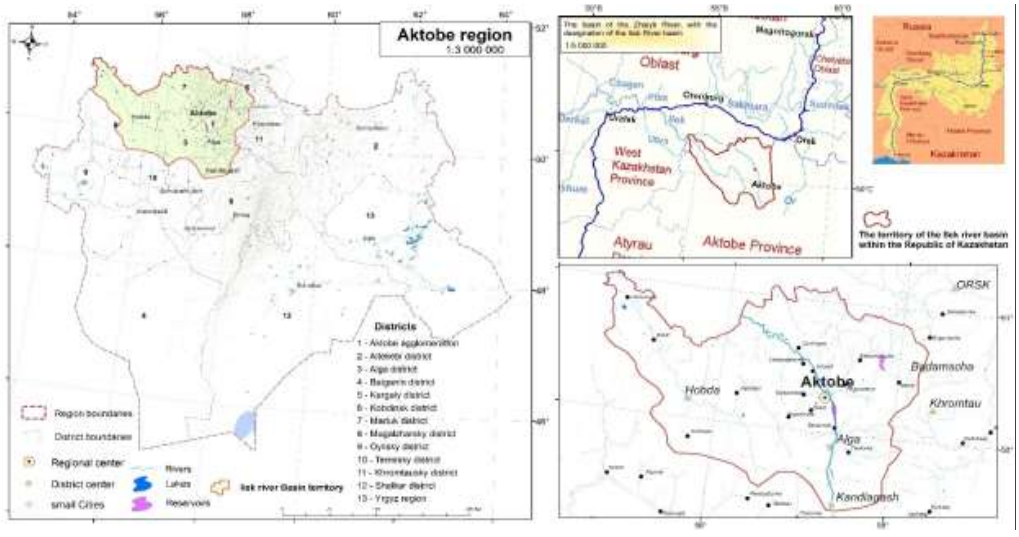

Figure 1. Hydrographic network of the Ilek river basin (created by the author on the ArcGis program)

The length of the river in the studied Aktobe region is 257 km. Main tributaries include: the right side – Koktyube river (length 38 km), Tabantal river (length 56 km), Kargala river (length 114 km), and the left side – Sazdy river (length 40 km), Tanybergen river (length 58 km), Aksu river (length 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 (Berdenov et al., 2016). The catchment is located on the western spurs of the Mugodzhar mountains and the Dzharyk-tau mountains, 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 (The Actual State of Water Resources in the Aktobe Region in 2012: Information and Analytical Report, 2012).

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 (Nizovcev, 1999).

Materials and research methods. Traditional methods of geographical research were used during the collecting and analyzing materials (observation, mapping, and geochemical analysis of surface water samples) (Safarov et al., 2020). In course of the studies, the temperature regime of the river, one of the important environmental indicators, was measured. 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 (Ben-Said, 2021).

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 (Yuan et al., 2020). 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 (Dezsi et al., 2014; Ilies et al., 2018; ST RK GOST R 51592-2003 “Water. General Requirements for Sampling”, 2003).

Sampling of surface water was carried out in accordance with ST RK GOST

R 51592-2003 “Water. General requirements for sampling” (Chibilev, 1992). The sampling was conducted at 10 key areas (Fig. 2 Map of keys with a table by coordinates): 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 chemical analysis, the water pollution index (WPI) of the surface waters of the tributaries and the main channel of the Ilek river was calculated. This index is a typical additive coefficient and represents the average share of exceeding the MPC (maximum permissible concentration) for a strictly limited number of individual ingredients. Calculated according to the formula 1.

$$WPI = \frac{1}{n} * \sum_{i-1}^{n} \frac{C_i}{MPC_i} \qquad (1)$$

Ci – component concentration (in some cases, the value of a physicochemical parameter);

n – number of indicators used to calculate the index, n = 6;

MPC_i – the established value of the standard for the corresponding type of water body.

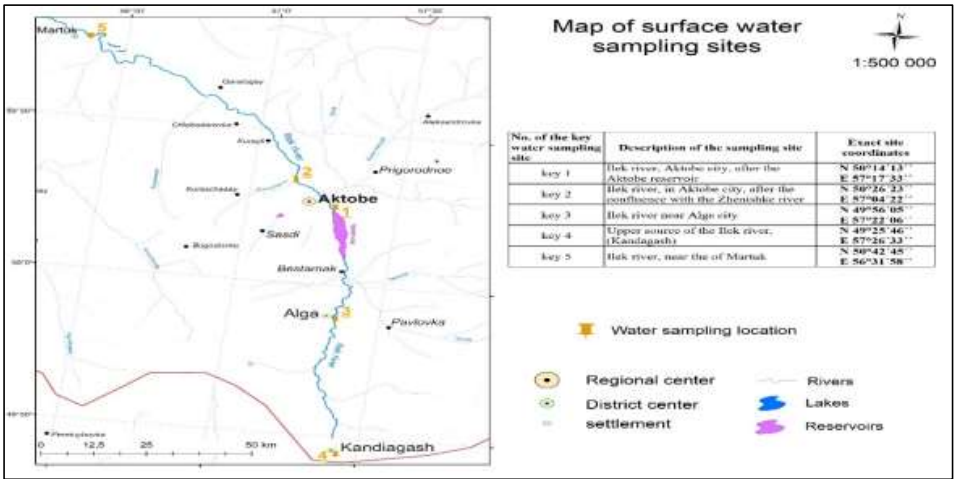

Figure 2. Map of key sites (surface water sampling sites).

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 dramatically 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, acidity changes. Acidic waters have an increased content of mobile forms of metals and promote their migration into conjugated environment (Mendybayev et al., 2015; Stoica et al., 2018).

In the Ilek river basin, 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 (Berdenov, 2017; Berdenov et al., 2016; The Actual State of Water Resources in the Aktobe Region in 2012: Information and Analytical Report, 2012).

Natural-historical processes of territory pollution have been studied in detail in historical documents and summaries (Information and Analytical Report on the Control and Law Enforcement Activities of the Aktobe Environmental Inspectorate for 2010, 2011; Nuryshev & Omarov, 2007).

Aktobe as business and cultural center was founded in 1869 on the banks of the Ilek river (Stoica et al., 2018). 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 (Nuryshev & Omarov, 2007; I. Suleimenov et al., 2022; I. E. Suleimenov et al., 2017). The main polluting enterprises are: Aktobe Plant of Chromium Compounds (APCC), 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» (Information and Analytical Report on the Control and Law Enforcement Activities of the Aktobe Environmental Inspectorate for 2010, 2011).

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

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 micro pollutants.

Table 1 - Average concentrations of pollutants in the Ilek river (based on samples from key sites studied in 2021)

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										

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 results of chemical analysis on the left-bank tributaries of the Ilek river showed a significant excess of MPC for such elements as Cu, Pb, Fe, Zn, as well as exceeding of MPC for BOD5, nitrite and ammonium ions (Table 2).

Obviously, this is related with the mining industry. Overburden 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 of 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/dm^3)

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
Oxidi-zability	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 varies 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 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 large tributaries showed the relations between development of industry and 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 in 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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