EurAsian Journal of BioSciences
Eurasia J Biosci 13, 1433-1445 (2019)

Assessment of the hydro-geochemical situation in Alga region (Aktobe, Kazakhstan) based on component analysis

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Abstract

The article attempts to realize the informational capabilities of the multidimensional component analysis model, one of the purposes of which is to form hypotheses to test numerous hypotheses put forward to identify the sources and pathways of boron element entering into the underground and surface water of the Ilek River valley. Nowadays, the relevance of this problem is being stimulated by the development of the pollution process - a manifestation of the impact on the river of those sources that were not previously recorded in the state monitoring of the quality of the surface waters of this river. As a result of processing the monitoring data for different periods of time, the processes of formation of the chemical composition of groundwater of the Ilek River valley were revealed, which confirmed the presence of various sources of contamination with their boron, in addition, temporal and spatial aspects of the intensity of these processes were established.

Keywords: surface water, groundwater, boron pollution, quality monitoring of water, multidimensional component analysis

Pavlichenko L, Rysmagambetova A, Tanybayeva A (2019) Assessment of the hydro-geochemical situation in Alga region (Aktobe, Kazakhstan) based on component analysis. Eurasia J Biosci 13: 1433-1445.

INTRODUCTION

The Ilek River pollution is associated with the activities of the former Aktobe Chemical Factory named after S.M. Kirov, located in the Alga region (Aktobe, Kazakhstan) on the left bank of the Ilek river. The boron acid production of the factory was commissioned in 1941 and was built without environmental requirements. As a result, all the wastewater of the factory were dumped into the floodplain without purification. Downstream approximately 40 km is a major settlement – Aktobe (Kazakhstan).

Aquifer of mid-Quaternary modern alluvial sediments (aQII-IV) is the source of the city's water supply. The horizon is confined to the alluvial deposits of the floodplain, the first and second terraces of the Ilek River and its tributaries the Tabantal, Eset, Kargaly, Tamdy, Sazdy, Zhenishke rivers (Murtazin et al. 2010).

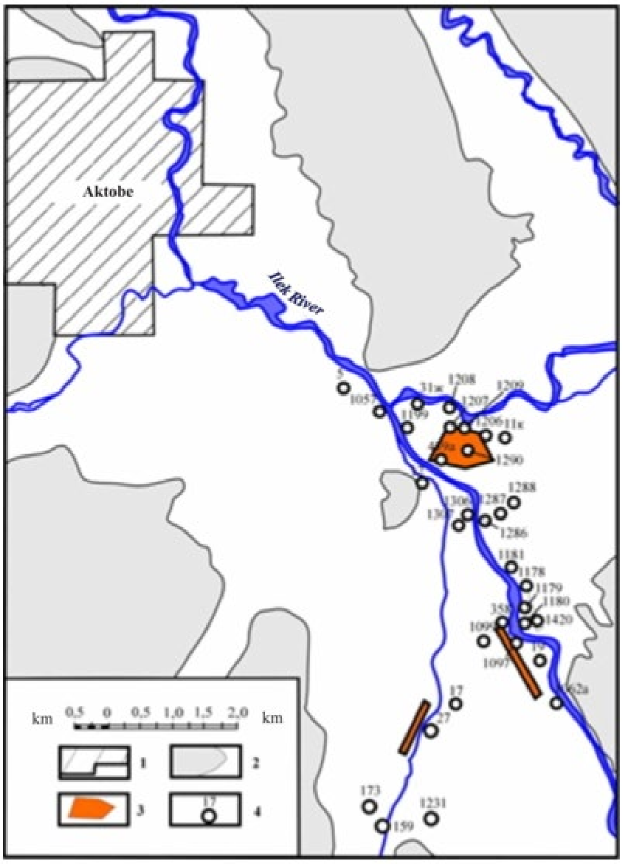
The lithological composition of water-containing alluvial deposits is represented by quartz and quartz-felds path sands, mainly of different grains, sandy loams, loams and pebbles. The thickness of aquifer sediments varies from 0.5 to 14.0 m. The depth of the roof of the aquifer varies from 0.6 to 27.0 m, and the soles from 4.0 to 60.0 m. The clay differences in the underlying sediments of the upper Pliocene serve as a fossil. In some areas, there are no water-resistant formations in the base of the described sediments, and here the interrelation of the underground waters of the mid-Quaternary-modern alluvial sediments with the underlying aquifers takes place. The aeration zone is composed of sandy loam, loam, sand. Its thickness varies from 0.6 to 27.0 m. The filtration coefficient of sandy loam in the aeration zone according to loading data in the holes is 0.3-19.2 m per day.

Alluvial groundwater occurs at a depth of 0.6 to 27.0 m. Absolute level elevations depend on the hypsometric position of the valley within the region and vary within 208.0 and 242.0 m.

Well flow rates vary from 0.08 to 39.9 l/s when the dynamic level decreases by 50.0 m. Average flow rates are 3.5-4.0 l/s. The productivity of wells does not exceed 1.0 l/s when the dynamic level decreases by 3-5 m. The filtration coefficient of aquifer sands, calculated from the results of experimental pumping, varies from 16.2 m/day for medium sands to 53.2 m/day for coarse grained. The most common values of the filtration coefficient are 27.0-28.0 m/day. According to laboratory data, water loss of sand is 19-20% (Bochkarevaet al. 1973).

The magnitude of water mineralization is predominantly fresh (0.2-0.7 g/l) calcium-sodium

Received: February 2019
Accepted: July 2019
Printed: October 2019



(1 - the territory of Aktobe; 2 - bedrock outcrops; 3 - boundaries of water intakes; 4 - regime well and its number)

Fig. 1. The situation plan of the Aktobe water intakes

hydrocarbonate, hydrocarbonate, sulfate, sodium and calcium bicarbonate-sodium-calcium chloride, and slightly salty (1.1-2.6 g/l) sulphate calcium and sodium chloride, sodium chloride sulphate and sulphate magnesium-sodium water. In the area of the Alga locality, groundwater with a salinity of up to 5.5 g/l are noted due to the technogenic metamorphization of groundwater by industrial wastes from the Alga Chemical Factory.

The main source of nutrition of the aquifer are flood water and precipitation. The groundwater of alluvial sediments is used by the local population for drinking and household needs. Ground water intakes, including a number of infiltration waters, are explored and operated for water supply Aktobe city, Alga region and others localities (**Fig. 1**).

The wastewater of the Alga Chemical Factory's boron-acid production discharged into the Ilek river valley. The first storage ponds without an impervious screen of this factory were built in 1956. In 1963, the storage ponds were conserved and their sewage was discontinued. In this time about 20 thousand tons of boron had accumulated in them. The impact intensity of this pollution source can be represented with the hydrogeological map for 2005 y (Korchevskyet al. 2009). In there was the first storage ponds are fixed with an isoline of 50 mg / dm3 boron concentrations, emitting groundwater with concentrations of 50-100 mg/dm3 on the background of concentrations of 10-50 mg/dm3.

In 1963, industrial effluents began to be discharged into the sludge storage, which is now called "old" in all works on the Ilek River and Aktobe reservoir pollution problem. It was also built without an impervious screen, and it is indicated as the main source of groundwater pollution. It was exploited till 1981, when the "new" sludge storage began to operate. This sludge storage was built on the original bank of the Ilek river and was presented as a perfect hydraulic structure, taking into account the hydrogeological conditions and requirements for technological solutions. Unfortunately, the low quality of construction work was manifested by leaks of the liquid phase in its south-western part.

The groundwater pollution with boron was discovered in 1972; and in 1975 a pilot production polygon was set up to study the groundwater pollution by boron-containing industrial discharges. Observations have shown that the change in the natural regime of groundwater is due to the filtration of industrial effluents discharged into ponds. Filtration of alluvial sediments into the aquifer led to an increase in the level of groundwater. The formation of the chemical composition of groundwater alluvial deposits at the site of storage ponds also occurs under the influence of filtration of industrial wastes, which contain chlorides in the amount of 815-2520 mg / l, sulfates 3800-3900, fluorine 7-275, boron - up to 959 mg / l, dry residue varies from 8.6 to 10.9 g / l (Burakov and Pavlichenko 2011).

In order to study the processes of boron accumulation and dynamics in the alluvial aquifer, an observational network was drilled (Davidovich and Frolov 1992). Testing of water points was carried out quarterly. In the wells located above the chemical plant along the river, the boron content did not exceed the Maximum Acceptable Concentration (MAC). With the approach to storage ponds, the boron concentration increased, a halo of pollution formed. The halo of pollution of the alluvial aquifer spread 11.5 km downstream, its area was 14.4 km2 at the initial stage of research. Boron-containing groundwater, wedging into the mainstream, are polluted the Ilek River, and in the area of the "old" sludge storage the boron content in surface water was very high. Consequently, in the area under consideration, groundwater was the source of river water pollution.

Along the Ilek River valley up to the border of the republic, at a distance of 90 km, several profiles of monitoring observation wells were laid. For boron observation the samples were taken from production and regime wells. A spatial study of the boron distribution showed a rather unusual picture. From the pollution source to the Aktobe city, over 40 km, the boron content is lower than the MAC. In the former urban water

(a) View in 2008

(b) View in 2018

Fig. 2. The traces of emergency spills of the pulp during the period of its operation

intakes, boron is present in water in an amount of 2□3 MAC. Then downstream its concentration is also lower than the MAC.

In this situation, the appearance of boron in significant quantities in the operated water intakes required additional studies. For this purpose, in the period 1975-1992 yy. at the pilot production polygon, the dynamics of the boron transition to an aqueous solution were researched. It should be noted, that boron ion (B3+) can be transferred by dissolving free acid and potassium and sodium salts, whose solubility in water is characterized by rather high values. The degree of transition into natural water of soluble and mobile forms of boron, which enclosed in the sludge storage, soil and ground sediments accumulated in the reach was experimentally investigated.

For 2005, three secondary sources of boron contamination of groundwater were recorded outside the sludge storage, in which its concentration exceeds the standards for industrial groundwater of 200-250 mg/dm3. These include the location of the wells №1585 and 1587, located between the southern part of the “old” sludge storage and the Ilek river (a stream flowing around the southern part of the unfinished “wall in the soil”, the area of the wells №1353 and 1598, located north of the north-western edge of the old of the sludge storage and the zone of wells №1297 and 1298, adjacent from the southwest to the “new” sludge storage (the location of the wells is shown in **Fig. 2**).

The causes of the second focus (wells №1353 and 1598) have not been established. The possibilities boron migration was assumed: from the “new” sludge storage along the Suaksu stream surface water or underground water in its valley; from the “new” sludge storage over rocks with very low filtration properties. In this area a sharp decrease of the filtration characters could lead to the appearance of a geochemical barrier. Thus, one of the explanations for high concentrations of boron in wells near the “new” sludge storage (Davidovich 1994) could be seen in the formation of a geochemical barrier due to the low filtration properties of rocks.

After the construction of a reservoir on the Ilek River south of Aktobe city, the pollution of surface and groundwater with boron was significantly reduced in the urbanized area. In the 12 years that have passed since the construction of the “wall in the ground” was completed, and 9 years after the Factory was ended, positive changes were observed in the Alga region, in the center of groundwater polluted with boron and downstream, in particular: a decrease in the total area of boron contaminated groundwater waters from 25.0 km2 in 1993 to 21.1 km2 in 2005 by reducing the area with boron distribution of 0.5–10 mg/dm^3 in the southern and mainly in the northern part of the source of pollution; the boron content in the surface waters of the Ilek River at the release from the Aktobe reservoir decreased, which resulted in a decrease in the boron content in most observation wells at the Ilek infiltration water intake, therefore, in the production wells of this water intake. Another reason explained the positive changes – the dilution of groundwater with clear snow from melt waters during the periods of spring snowmelt and the third, the natural outflow of groundwater downstream.

It is worth noting that the constructed “wall in the ground” section did not play, since it has two large gaps (120 m and 250 m) in its northern part and three local (10–20 m) and one extended (100 m) zones increased water permeability in the south of the site, especially since its total length is less than one third of the design. The influence of the “wall in the ground” affected the internal redistribution of boron-contaminated groundwater: the groundwater “tongue” with a boron content of 50-100 mg/dm^3 flows around the “wall in the ground” from the south and then moves downstream.

By that time, a clear tendency towards clearing underground and surface waters from boron showed that “further work on localizing the source of pollution of groundwater and surface waters of the Ilek River valley should be given to Nature - slowly but surely and at no cost, it will continue the process already started cleansing” (Nedyuzhin and Pogorelov 2005).

However, research of 2007-2009 led to opposite hypotheses, which emphasized the high risk of pollution of groundwater and Aktobe reservoir. The content of the main alternative hypotheses is as follows.

The main ways of boron entry into groundwater are filtration through the bottom of the old sludge storage, infiltration into the aquifer of contamination washed off by snow-melted water and rainwater from the Alga Chemical Factory industrial site, emergency spills and leaks from the zone of new sludge storages, as well as from areas of dust deposition of emissions of former factory, old and new sludge storages.

Wedging contaminated groundwater into the Ilek River, where boron is adsorbed silt, which are deposited in Aktobe reservoir, creates a high risk of conversion Aktobe reservoir into a new pollution source, which disposed lower than its dam infiltration water intake Aktobe. Therefore, the adoption of urgent environmental measures was recommended to prevent the flow of polluted groundwater and surface water into the Aktobe reservoir, “storing” boron in its silts.

As measures that, as soon as possible, reduce boron concentrations in groundwater and surface water above the Aktobe reservoir, solutions were proposed to intercept groundwater polluted by various sources by a number of water wells, clean them and inject into the reservoir through a series of barrage wells providing a hydraulic curtain that delays the flow polluted waters and diluting a regional stream that creeps into the Ilek River and enters the Aktobe reservoir.

However, the project was not implemented, and at present, the impact zones recorded in 2005 as local additional sources have expanded the boundaries and have gone beyond the limits of the design water intake and barrage wells. This is confirmed by the sharp increase in boron concentrations at the Alga 2 post after 2016 violates the trend of their decrease from 1997 to 2016, when the old source of pollution was considered to be the main source of pollution, which operated from 1963-1981 (Information bulletin on the state … n.d., Pavlichenko et al. 2019). This trend does not fit the hypothesis put forward in 2005 about the adequacy of the natural ecological capacity of the Ilek river for complete self-purification from boron, preservation of water quality in the Aktobe reservoir and the resumption of the Aktobe water intakes for drinking water supply in Aktobe.

The purpose of this paper is to assess the dynamics of the hydrological and geochemical situation in the Alga region and test the existing hypotheses about the processes of groundwater pollution in the Ilek River valley by processing the data of hydrochemical monitoring with using the multidimensional statistics method – component analysis involving the interpretation of the migration classical hydrogeochemical patterns and the chemical composition of groundwater metamorphization results.

MATERIALS AND METHODS

The hydrogeochemical testing of the wells of the pilot production site at the Alga region and the wells of the state hydrochemical monitoring at the Aktobe section for the periods of 1982, 1988 and 2003 served as actual material for achieving the goal of the work. These data were obtained in the study of stock hydrogeological materials of “Akpan” LLP, a report on the study of the regime and balance of groundwater in the Aktobe region in 2001-2004 (Open Joint Stock Company “Aktobe Gidro Geologiya”) and experimental investigations of the Center for Health and Environmental Design on the subject of Ministry of Environmental Protection of the Republic of Kazakhstan. In the same sources set out hypotheses of boron in the groundwater Ilek River valley, surface waters of the Ilek river and Aktobe reservoir.

The main research methods were the processing of six samples of initial data on the chemical composition of groundwater for three years (1982, 1988, 2003) and different stages of the hydrological regime (for 1988) with using the multidimensional statistics method - component analysis (Noori et al. 2010) and subject interpretation of the main components as hypotheses about the processes that form the chemical composition of groundwater at different stages of the metamorphization of groundwater through the involvement of classical hydrogeochemical patterns of migration and metamorphization of the chemical composition of the underground water (Gamble and Babbar-Sebens 2012, Guigues et al. 2013).

The main result of the component analysis can be considered the matrix of the eigenvectors of the matrix of paired correlation coefficients of the original features, which in fact represents its internal structure (Parinet et al. 2004). In fact, if the number of eigenvectors turns out to be less than the number of initial parameters, this will be a signal of a linear relationship between a part of the original features. This is expressed, for example, in the fact that one of the columns of the matrix is an algebraic sum with some constant coefficients of two, three, etc. other columns of the same matrix. Thus, the information contained in this column can be obtained by calculation, and the exclusion of this column from the matrix will not prejudice the total information. This is precisely the procedure of space convolution, which is known in matrix algebra.

Since the matrix of component loads is a matrix of eigenvectors multiplied by the diagonal matrix of square roots of eigenvalues, it is quite natural to transfer all the arguments about the contraction of the feature space onto the matrix of component loads. This is precisely the implementation of the component analysis hypothesis about the existence of internal (hidden, not directly measured) parameters or properties that determine the values of the observed parameters. For a geo-ecosystem, such properties are the factors of its formation; therefore, we can rightly say that the component analysis explores, reveals the hidden relationships between the initial features of the geo-ecosystems, and, if properly interpreted, allows us to characterize the processes leading to their formation. The component axes obtained as a result of mathematical transformations can be viewed as a formal record of the processes through one or another association of the parameters that made up the component. These associations are distinguished on the basis of the coincidence of the signs of the parameters, and two associations can be included in one component if they have opposite signs, however, in this case, the component describes one process.

The opposite of the signs of loads on the initial variables, identified by the model in one component, testifies to the multidirectionality of the impact of the geo-ecosystem process under consideration on the associations of features with the same sign. In other words, the combination of parameters in the component in this case gives a coded record of the process, causing a simultaneous increase in the values of the parameters of geo-ecosystems identified with an association with a positive sign of loads while reducing the values of the parameters of geo-ecosystems identified in the same component with an association with a negative sign.

The second important result of the component analysis is the eigenvalues of the matrix of coefficients of pair correlations. This result allows to judge about the degree of hierarchy of the processes allocated by the matrix of component loads. The intensity of the manifestation of the interpreted factor in the territory is investigated by the third result of the model - a matrix of component values. The obtained values of the main components also have positive and negative values, however, here the difference in signs means not a different direction of the process, but different intensity of its manifestation - positive values characterize areas with more intensive manifestation than negative ones (with zero average). It should be noted that a positive value is not an indicator of the goodness of the studied factor and vice versa, but only shows a different intensity of its manifestation in relation to the average value. Negativity or auspiciousness is characterized exclusively by the subject interpretation of the selected components.

Thus, component analysis combines the capabilities of many statistical models and system analysis recommendations on the requirements for the choice of methods for studying complex systems. From the point of view of system analysis, the component analysis model for a given composition of elements makes it possible to comprehensively investigate the geo-ecological system from a systemic point of view. Thus, it provides an opportunity to distinguish system functions and rank them by their contribution to the total system variance (emergence), takes into account the nature of the relationship (the ratio of signs of interrelationships within the component shows synergistic and antagonistic effects of interrelationships) and the system's self-organization (the possibility of closed circuits that the same sign is included in different components). A new result of the model is not only the identification of the function of the system (system-forming factors) based on the interpretation of the system of interrelationships of the original features, but also the zoning of the territory according to the intensity of manifestation of this function.

So, component analysis allows to:

- calculate relationships in the system;
- explore the structure of relationships;
- obtain an emergent result - new information from the previous data set - identification of the processes of formation of geo-ecological systems based on information about its state at a certain point in time;
- rank the processes according to the degree of their influence on the formation of the state of the geo-ecosystem (to build a hierarchy of processes).

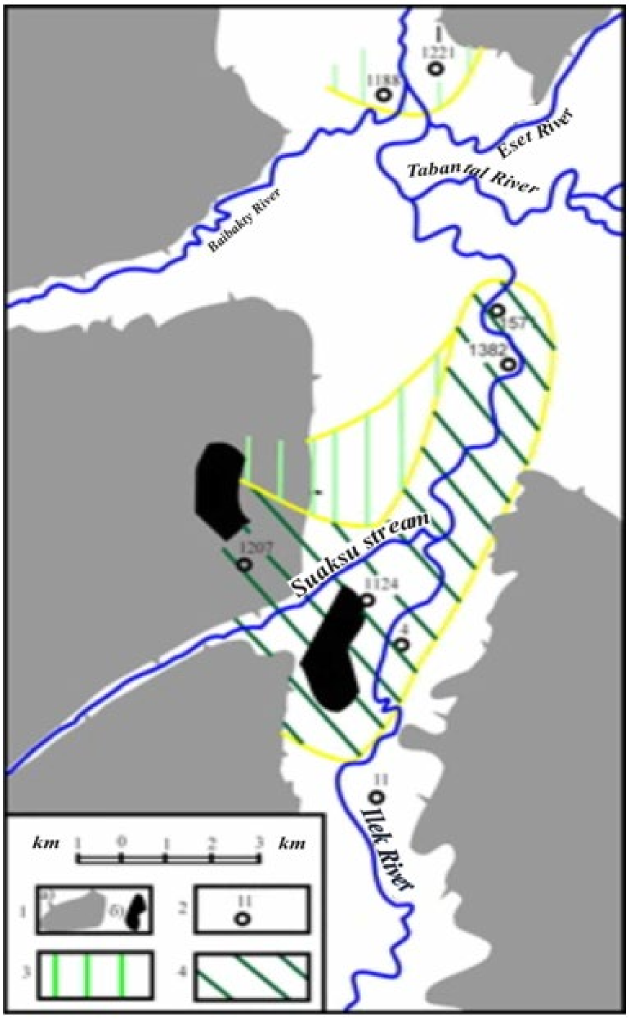
As an additional argument in favor of component analysis, we should add the ability to process diverse data characterizing different subsystems with both quantitative and qualitative characteristics. Another advantage is that cartographically presented signs can be converted to a quantitative level by the coding system of their areas, which will enable more precise than the overlay and coverage operations in the GIS to determine the degree of coincidence of signs, and here the search procedure is not required - the spatially coinciding signs are automatically allocated to the components (Pavlichenko 2007).

RESULTS

To test the previously formed hypotheses about the ways of groundwater pollution and changing the hydro-geochemical situation, six samples of data on the chemical composition of groundwater were processed by component analysis in order to identify the genetic relationships between the original characteristics, i.e. in this case, the ability of component analysis to act as a tool for testing hypotheses was used (Mishra 2010).

The data for the second quarter of 1988 (Task 1) turned out to be, on the one hand, the most representative, and on the other, this quarter is intermediate between the flood and low water, therefore, in this quarter, the maximum number of processes forming the hydrochemical situation manifests itself, therefore the solution this task is considered in detail.

In task 1, the data for July 1988 are presented for 76 wells located in the valley. Ilek and characterized by a set of 13 signs: the depth of the groundwater level



1 - areas - a) bedrock outcrops; b) sludge storages; 2 - well and its number; areas of accumulation of boron - 3 - transit and biogenic; 4 - exchange and biogenic

Fig. 3. The boron pollution schematic map of groundwater of the Alga and Bestamak areas

(DGL), *pH*, $Na^{+}+K^{+}$, Ca^{2+}, Mg^{2+}, *Fe*, Cl^{-}, SO_4^{2-}, HCO_3^{-}, CO_3^{2-}, NO_3^{-}, $NH_4^{+}$and *B*. The distinguished 7 Main Components (MC) describe 95.13% of the total dispersion of the system:

MC1: +[Mg^{2+}, *B*, SO_4^{2-}, $Na^{+}+K^{+}$, Cl^{-}, Ca^{2+}, NH_4^{+}, *Fe*], -[*pH*];

MC2: +[NH_4^{+},CO_3^{2-}, HCO_3^{-}, *Fe*], -[Cl^{-}, *B*];

MC3: +[*pH*, CO_3^{2-}, Ca^{2+}], -[*Fe*, *DGL*];

MC4: +[*Fe*], -[NO_3^{-}, HCO_3^{-}, Ca^{2+}];

MC5: +[*DGL*, HCO_3^{-}, $Na^{+}+K^{+}$, Cl^{-}], -[*Fe*, SO_4^{2-}, NO_3^{-}, Ca^{2+}];

MC6: +[NO_3^{-}, *Fe*, *DGL*, *pH*], -[HCO_3^{-}];

MC7: +[Ca^{2+}, *DGL*, SO_4^{2-}], -[$Na^{+}+K^{+}$, Cl^{-}].

As is known, in arid conditions with significant evaporation intensity from the surface of groundwater, the evaporative stage of formation of the chemical composition of groundwater prevails, during which groundwater salinity increases and their chemical composition changes - from calcium carbonate and sodium bicarbonate to sodium chloride with all transitional subtypes (Shvartsevet al. 1982).

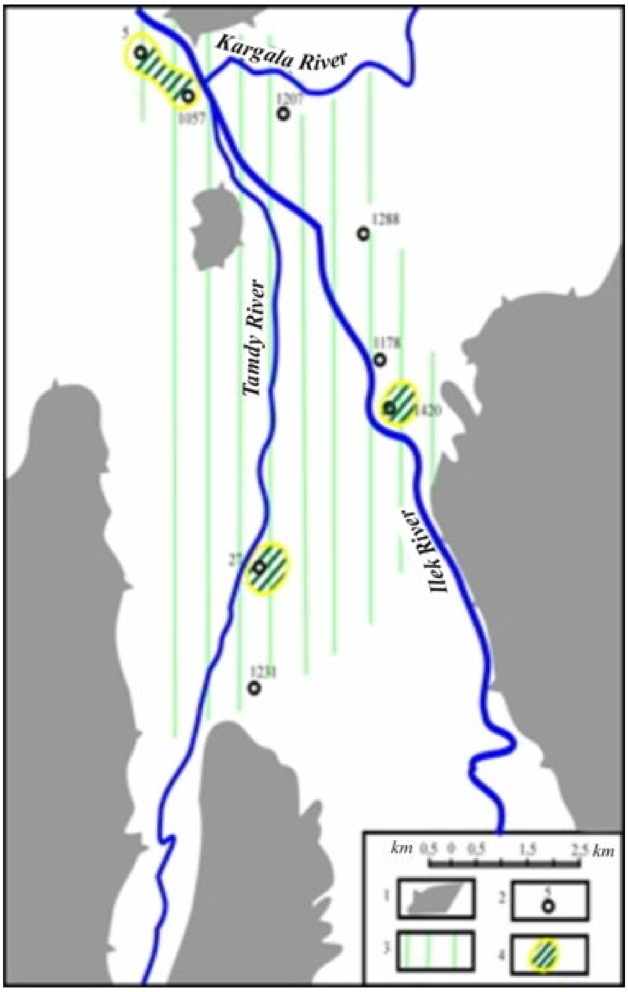
Type MC1 characterizes the transition subtype (Mg^{2+} and SO_4^{2-}had loads greater thanCa^{2+}, Cl^{-}, $Na^{+}+K^{+}$) metamorphization of the chemical composition of groundwater with the participation of the biogenic stage (presence ofNH_4^{+} ions and *Fe*). The presence ofNH_4^{+} indicates a similar source of pollution, a negative load on the *pH* indicates “acidic” water, which is typical for industrial waters, so a large positive load on *B* should be considered more man-made than lithogenic. So, we can assume that in our case MC1 characterizes the transit of acidic industrial waters from the initial stage of the biogenic stage.

The distribution of the values of this component over the sampling points (the second main result, it is often called the solution of the inverse problem of component analysis) confirms this interpretation - large positive loads are confined to the old sludge storage (MC1 values greater than 1in the wells № 1124, 1126, 1191, 1349, 1350). The largest positive value (+6.757) is in well № 1297, characterizing the new sludge storage, i.e. in 1988 (the stage of its filling) the intensity of anthropogenic transfer (removal) of acidic industrial waters from it is more than 5 times higher than the intensity of this process in the old sludge storage (in **Figs. 3** and **4** the generalized distribution of tasks 1-4 is presented).

If additional materials are involved in the MC1 interpretation process, we obtain a more detailed and evidence-based interpretation of both the process reflected by the MC1 and the distribution over the area of intensity of manifestation of this process. Thus, the drawing of the surface contour lines on a topographic map clearly fixes the direction of flow from the well №1297 in the south-east direction, that is, towards the Suaksu stream and the Ilek River. Consequently, both the creek and Ilek are drains, and therefore, the wedging out of groundwater into the creek can only lead to an accelerated flow of pollution by surface runoff to the Ilek river, but in no way to wells №1353 and 1598, whose location zone in 2005 belongs to a separate source of pollution with not established causes of occurrence.

Additional visual analysis of the materials of the field route along the slurry pipeline to the new sludge storage (photos of 2008 and 2017 of traces of emergency spills of the pulp during the period of its operation) gives grounds to consider filtering out small “lakes” of industrial effluents formed at sites of slurry pipeline accidents to form storage device (**Fig. 2**). The “additive” to this source is the soil contaminated by Alga Chemical Factory emissions during their washing with heavy rainfall and snow-melted waters.

Thus, it can be noted that the results of task 1 only on the basis of partial interpretation of GK1 with the



1 - areas - a) bedrock outcrops; b) sludge storages; 2 - well and its number; areas of accumulation of boron - 3 - transit and biogenic; 4 - exchange and biogenic

Fig. 4. The boron pollution schematic map of groundwater in Aktobe area

involvement of additional materials confirmed the hypothesis of the presence of a stream directed towards the stream.

Along the regional groundwater flow, the values of the components also decrease, remaining positive to about well. № 1573 between wells № 1382 and 1381.

This suggests that the influence of technogenic waters in the Alga area practically ends before the right and left tributaries flow into the Ilek river, confirming both the boundary of the halo of pollution in 1988 and the main reason for the decrease in the concentration of polluting elements is soil absorption, it is gradually washed away by snow-melted waters.

All other sites are characterized by negative values of the components, emphasizing a significant reduction in the process of transit of acidic industrial waters by changing its direction in areas of increasing *pH*. But now, against the background of negative values, the components in the wells № 27 and 1420 are abnormal components (water intakes of Aktobe).

Consequently, the substantive interpretation of MC1 also showed that the component analysis confirmed not only the hypotheses about the ways of boron entry into groundwater and the assessment of reservoirs as long-term permanent sources of boron pollution in the hydrosphere of the region, but also allowed to identify the boundary of aloe of boron contamination of groundwater formed by filtering acidic industrial wastewater, and violation of migration processes in the area of water wells.

MC2 is also boron-containing, and it is combined with a negative load with Cl^{-}- a purely transit element, and the biogenic traits combined with positive loads in this component.

The largest negative value of MC2 falls on well № 1297 (-2.322) near the new sludge storage. At the same time, in the wells located near the old sludge storage, the values of this component are positive, i.e. there is active microbiological precipitation of boron. Consequently, a significant negative value of MC2 in well №1297 showed that near the new sludge storage in 1988 there was practically no corresponding microbiological environment. The largest positive value of MC 2 falls on well №1378, where some additional source of pollution is noted.

So, MC2 is actually an addition to MC1, noting the role of the biogenic stage of boron deposition, which is weakly manifested in MC1.

The remaining components do not contain a sign of boron; they characterize different shades of the processes that form the conditions for the migration of elements of the chemical composition of groundwater; therefore, we will not consider them.

We only note that MC3 with positive loads combined signs of *pH*, CO_3^{2-} and Ca^{2+}, with negative loads, *Fe*, *DGL*, i.e. component characterizes the usual for migration processes change in their chemical composition, expressed in the binding of calcium through the formation of insoluble carbonates in areas of shallow groundwater level (negative load on *DGL*) with the presence of biogenic processes (*Fe*).

As noted in Merchant (2010), iron refers to the trace elements involved in the process of photosynthesis. Its deficiency or excess in soil and groundwater adversely affects the conditions of growth and development of plants. It is established that in the ground water, located close to the surface of the earth, ferrous iron is greater than in the water of the lower horizons, due to the large amount of organic matter in the upper soil layers, increasing the solubility of iron compounds and low acidity.

Positive values of the components existed throughout the study area, with the exception of the wells of the Aktobe area, where among the small negative values are wells № 5, 1057 and 1420, where metamorphization processes — precipitation of insoluble calcium compounds — are more active. The presence of microbiological processes (negative MC3 values) for water wells is possible only if these wells pull up river water passing through the layer of activated silt.

From the standpoint of hypothesis testing, MC3 gave indirect confirmation of the hypothesis about the cause of boron occurrence in the working water wells.

The task 2 was solved to study the effect of flood on the pollution of groundwater with boron. It presents data on 71 wells, characterized, as before, by the 13th signs. As a result of data processing, eight main components were obtained describing 96.2% of the total variance of the system:

MC1: +[Mg^{2+}, *B*, SO_4^{2-}, Cl^-, $Na^+ + K^+$, *Fe*, Ca^{2+}], -[*pH*];

MC2: +[*pH*,CO_3^{2-}], -[HCO_3^-, NH_4^+];

MC3: +[*DGL*, NH_4^+, CO_3^{2-}, *Fe*, Cl^-], -[Ca^{2+}, *pH*, NO_3^-];

MC4: +[NO_3^-, *УВ*];

MC5: +[CO_3^{2-}, HCO_3^-, *pH*, NH_4^+, $Na^+ + K^+$], -[*DGL*, *Fe*];

MC6: +[*DGL*, *pH*, Cl^-, $Na^+ + K^+$, HCO_3^-], -[*Fe*, CO_3^{2-}, NO_3^-];

MC7: +[$Na^+ + K^+$, Cl^-, *Fe*], -[*DGL*, Ca^{2+}, SO_4^{2-}, CO_3^{2-}, Mg^{2+}];

MC8: +[*B*, *pH*, *Fe*], -[Ca^{2+}, Cl^-, $Na^+ + K^+$].

The first main component differs from the similar one in the July task only by reducing the load on Ca^{2+} and the absenceNH_4^+, i.e. the flood reduces the influence of the activity of “fresh” nutrient pollution; otherwise, the order and interpretation of the components are the same.

As in July, positive values mainly fall on the Alga area, and the maximum value falls on the well № 1297 (+6.636), which characterizes the new sludge storage, followed by the wells № 1350 (1.067), 1126 (2.138) and 1124 (1.624) showing the spread of contamination from an old sludge storage. Positive values in wells № 17, 1301, located above the old sludge storage, reflect the influence of spills from it. The contamination was traced to well №1382, then the component values downstream change sign. And again, positive values were noted only for operating wells of the Aktobe water intake.

Another boron-containing component is the eighth, characterizing boron, which entered the groundwater mainly through microbiological processes (Fe). There is such a boron on the Alga, Bestamak (wells №1187, 1189, 1220, 1221) and Aktobe areas, and on water intake wells. This component characterizes the biogenic deposition of boron in shallow groundwater, like MC2 in the task for July, but the role of this process is noticeably weaker than in task 1.

Thus, the impact of the flood has affected the further weakening of the biogenic stage of the metamorphization of the transit of acidic industrial waters, as well as a significant decrease in the role of biogenic boron deposition with increasing *pH*.

Task 3 presents data for the low-flow period (September, 1988) for 75 wells with the same set of features. The distinguished 7 main components describe 95.64% of the total dispersion of the system:

MC1: +[*B*, Mg^{2+}, SO_4^{2-},Ca^{2+}, $Na^+ + K^+$, Cl^-, HCO_3^-];

MC2: +[*Fe*, NH_4^+,CO_3^{2-}], -[*pH*];

MC3: +[*DGL*, Cl^-, HCO_3^-], -[CO_3^{2-}, Ca^{2+}, *pH*];

MC4: +[CO_3^{2-}, $Na^+ + K^+$, *DGL*, *pH*], -[NO_3^-, SO_4^{2-}];

MC5: +[NO_3^-, *DGL*, CO_3^{2-}, *pH*];

MC6: +[Cl^-, $Na^+ + K^+$], -[*DGL*, Mg^{2+}, *pH*, SO_4^{2-}, Ca^{2+}];

MC7: +[HCO_3^-, *pH*, NH_4^+, *B*, *Fe*], -[*DGL*, Mg^{2+}, $Na^+ + K^+$, Cl^-, Ca^{2+}].

In the task 3, MC1 characterizes the transition subtype (Mg^{2+} and SO_4^{2-} have loads more than Ca^{2+},$Na^+ + K^+$, Cl^-, HCO_3^-) of metamorphization in the process of migration of polluted groundwater metamorphization (the boron *B* has the greatest load). The biogenic stage is separated into a separate second component. And although the acidity (pH) is not included in the first main component, it is present in II and III with a minus sign, and in all other main components - with a plus sign. Boron-containing components are MC1 and MC7 (*B* in all components with a positive load). As in the previous tasks, the highest MC1 values fall on the Alga area with the maximum value (+7,000) of the new sludge storage, and the increased values mark the area of influence of the old sludge storage. Industrial boron is absorbed within the Alga area, then the MC1 values become negative, and positive anomalies appear in wells characterized by increased salinity of groundwater. The MC7 characterizes “biogenic” boron *B*, which is in “antiphase” with $Na^+ + K^+$ and Cl^-, i.e. this component describes the processes in shallow groundwater.

So, low water increases the pollution of groundwater with industrial effluents and weakens the effect of biogenic sedimentation compared with the July task.

In task 4, data were processed from 38 wells of background monitoring with the same set of features, and the feature $CO_3^{2-}$was automatically excluded from the initial analysis of the data as a feature having zero dispersion. As a result of processing, eight main components were distinguished describing 95.38% of the total dispersion of a system of 38 wells, characterized by 12 signs:

MC1: +[Mg^{2+}, Cl^-, Ca^{2+}, $Na^+ + K^+$, *Fe*, NO_3^-, SO_4^{2-}, B];

MC2: +[$SO_4^{2-}NO_3^-Ca^{2+}$, *pH*, *B*], -[Fe, $Na^+ + K^+$, *УВ*];

MC3: +[HCO_3^-, Ca^{2+}], -[*pH*, NH_4^+, *B*, *DGL*];

MC4: +[NH_4^+, *B*], -[*DGL*, NO_3^-, SO_4^{2-}];

MC5: +[*B*], -[NH_4^+, NO_3^-];

MC6: +[*B*, NH_4^+, SO_4^{2-}, NO_3^-] -[*pH*, Ca^{2+}];

MC7: +[NO_3^-], -[SO_4^{2-}, *УВ*];

MC8: +[Ca^{2+}, *DGL*, *B*], -[SO_4^{2-}, *pH*, Mg^{2+}, HCO_3^-, *Fe*].

As can be seen from the records of the type of MC, *B* is found with small loads in almost all components.

The maximum load (0.779) is accounted for by MC5, which gives a contribution of only 5.5% to the total dispersion. Then, the contribution to the dispersion of boron is followed by MC3 with a negative load (-0.271), MC6 has a positive load of 0.363, and the load in the first component (0.254) is significantly less than the loads for other signs.

Consequently, when characterizing the territory in which boron has concentrations below the MAC, the component view clearly records the change in its role in the formation of the hydro-geochemical environment of the background area — it moved from the first places in the "transit" component to the latter, and the main process in which boron participates - its biogenic sedimentation. In general, the interpretation of all components has undergone small changes, reflecting the absence of man-made water inflows, the increasing role of microbiological processes - their various shades characterize literally all MCs, and the role of NO_3^- has increased significantly, i.e. organic oxidation processes are actively going on at this site.

As for *B*, here it is divided into *B* migration (transit) - MC1 - and *B*, associated with biological (MC3, MC4, MC5, MC6) and exchange processes (MC8). Analysis of the results of the inverse component task again showed that *B* comes into the water wells associated with microbiological processes, which is possible only by pulling in river water through a layer of activated sludge, which is undergoing active organic processing).

Summarizing the results of the tasks 1-4 interpretation, we can see that almost the entire industrial boron is absorbed by the soil grounds within the Alga area, the remaining quantities migrate with the underground stream, and this migration is accompanied by microbiological precipitation (**Figs. 2** and **3**).

For wells in the Aktobe area (**Fig. 3**), within which all water intakes are located, small values of nutrient and exchange boron are noted, and the values of the boron-containing components indicate a tendency to increase negative processes. On the part of the wells of the Bestamak and Ilek areas, there is boron associated with the filtration of groundwater backed by the reservoir.

Task 5 was solved to study the dynamics of changes in the hydro-geochemical state of the Ilek River valley on the basis of component analysis processing of data for the winter period of 1982. By this time, the regime network was still very rare, so task 5 processed data from 21 wells, each of which had groundwater characterized by a set of 11 features (there are no signs of depth groundwater level (DGL) and . As a result of the treatment, seven MC were emerged, which describing 97.47% of the total dispersion of the system:

MC1: +[SO_4^{2-}, Mg^{2+}, Ca^{2+}, *B*, Cl^-, $Na^+ + K^+$, HCO_3^-, NH_4^+], -[*pH*];

MC2: +[NH_4^+, *Fe*, Ca^{2+}], -[*pH*, HCO_3^- B, Mg^{2+}];

MC3: +[NO_3^-, NH_4^+, $Na^+ + K^+$], -[*Fe*, *B*];

MC4: +[*Fe*, Cl^-, $Na^+ + K^+$, *pH*, NO_3^-], -[HCO_3^-, NH_4^+];

MC5: +[NO_3^-, *Fe*, *B*, SO_4^{2-}, Ca^{2+}, Mg^{2+}], -[$Na^+ + K^+$, Cl^-, *pH*];

MC6: +[HCO_3^-, *Fe*, NO_3^-, Cl^-], -[*pH*, Mg^{2+}, *B*, SO_4^{2-}];

MC7: +[NH_4^+, *pH*, HCO_3^-, *Fe*].

Comparison with components in tasks 1-4 through 1988 is made difficult by the different representativeness of wells, however, the general picture is similar. Although the boron element (*B)* sign has got into a large number of components, it is described by the same processes of migration, exchange with soil grounds (MC1, MC2, MC6) and microbiological sedimentation (MC3 and MC5).

MC values showed that the old sludge storage is emitted by large positive loads of MC1 and negative values of MC2 and MC6, that is, here in 1982, absorption processes of B into soil-grounds prevailed. The uneven testing network does not allow one to clearly trace the boundary of the influence of these processes, so the change of signs for the values of boron-containing components had to be assessed by linear interpolation between wells with different signs in the components: wells №1351 and 1187, 1350 and 1189.

This interpolation gave a distance corresponding approximately to well № 1574, i.e. a halo of pollution was formed by 1982 within the same boundaries as in 1988. The intensity of microbiological processes increased in the near-well wells and again in 1982 in the wells The Aktobe region showed weak anomalies in wells №1306 and 1307, and these anomalies were noted in both exchange and microbiological processes. The remaining wells (№ 5, 27, 1420) were simply not observed in 1982, therefore they were not noted in the task, although, as we see, the influence of depression craters formed during pumping by water intakes was also noted for a small number of wells.

Thus, the component analysis showed high sensitivity in the study of the hydro-geochemical situation of the territory, confirmed the hypotheses put forward earlier by boron contamination of water wells, helped to clarify the nature of boron migration from sludge storages.

In tasks 6, a similar data processing was performed in order to assess the dynamics of the identified boron migration processes after the termination of activity Alga Chemical Factory in 1997. Unfortunately, due to problems with the availability of factual material, this assessment was carried out only according to 2003 data.

These data are taken from the report of the state monitoring of groundwater of the Aktobe region, carried out with different goals for different sites, so the set of the studied biogenic parameters for the Alga territory turned out to be (without signs of a nitrate series). In addition, the sampling frequency varies over a wide range; therefore, from the available data set, a matrix of

Table 1. Component load matrix for task 6 for the warm period of 2003

	MC1	MC2	MC3	MC4	MC5	MC6	MC7
$Na^{+}+K^{+}$	0,8222	-0,0466	-0,4947	-0,2637	-0,0153	-0,0262	0,02315
Ca^{2+}	0,728	0,3219	0,3993	0,04729	-0,3225	-0,1244	0,2872
Mg^{2+}	0,864	0,4017	0,159	-0,0057	-0,0342	0,09213	-0,1844
Fe^{3+}	0,3028	-0,7246	-0,0704	0,5365	0,2042	0,03757	0,1907
Fe^{2+}	0,1943	-0,6033	0,438	-0,433	0,4413	0,1451	0,04201
Cl^{-}	0,8619	-0,2238	-0,3771	-0,2213	0,02802	-0,054	0,0654
$SO^{2-}{}_{4}$	0,9103	0,2175	0,306	-0,0039	-0,0506	0,122	-0,0486
$(HCO_3)^{-}$	0,2052	0,7244	0,02976	0,1144	0,5651	-0,3158	0,00425
pH	-0,2359	0,8228	-0,219	0,04727	0,1814	0,3916	0,1746
Мин	0,9824	-0,0418	-0,0881	-0,1069	0,02959	0,00203	0,0374
B	0,8264	-0,1516	-0,012	0,4792	0,05941	0,1013	-0,1734

Table 2. A sample of observation wells with elevated values of MC1 and MC4, characterizing the transit and biogenic migration routes of boron element

Territorial binding	Observation well	Elevated principal components (green color)			
		MC1	MC2	MC3	MC4
Ilek left-bank water intake	1062a	-0,442	-1,009	-0,225	2,488
New sludge storage	1298	5,578	1,414	-2,757	-1,888
Old sludge storage	1353	2,510	-4,639	-2,210	5,866
Ilek right-bank water intake	1420	1,374	-1,460	-4,110	-3,026
Old sludge storage	1585	1,803	1,372	1,199	1,164
	1586	2,094	2,08	1,097	1,240
	1587	2,084	2,084	1,170	1,288
	1588	1,165	-0,322	1,526	0,410
	1589	1,223	-0,525	1,557	0,381
	1593	1,163	0,932	1,744	0,057
	1594	1,128	0,903	1,618	0,051
	1598	1,567	-5,244	3,654	-3,792
	1601	1,526	0,313	1,979	-0,315

initial data has been formed that are very conditionally allocated for a warm period.

For a set of wells, approximately corresponding to the task for 1988, 77 wells were selected, characterized by 11 features: $Na^{+}+K^{+}$; Ca^{2+}; Mg^{2+}: Fe^{3+}; Fe^{2+}; Cl^{-}; $SO^{2-}{}_{4}$; $HCO^{-}{}_{3}$; *pH; Mineralization; B*. In the result of data processing, the following matrix of loads on the main components was obtained (**Table 1**), in which the color indicates statistically insignificant loads in accordance with the percentage points of the sample correlation coefficient (Bolshev and Smirnov 1983, Bewick et al. 2003).

From **Table 1**, the next record kind of principal components was received:

MC1 (49%): +[*Min*, $SO^{2-}{}_{4}$, Mg^{2+}, Cl^{-}, *B*, $(Na^{+}+K^{+})$, Ca^{2+}, Fe^{3+}]

MC2 (23%): +[*pH*, $(HCO_3)^{-}$, Mg^{2+}, Ca^{2+}], - [Fe^{3+}, Fe^{2+}]

MC3 (8%): +[Fe^{2+}, Ca^{2+}, SO_4], - [$(Na^{+}+K^{+})$, Cl^{-}]

MC4 (8%): + [Fe^{3+}, *B*], - [Fe^{2+}, $(Na^{+}+K^{+})$]

MC5 (6%): + [$HCO^{-}{}_{3}$, Fe^{2+}], - [Ca^{2+}]

MC6 (3%) + [*pH*], - [$(HCO_3)^{-}$]

MC7 (2%) + [Ca^{2+}].

As in the 1988 data problem, MC1 characterizes the transition subtype (Mg^{2+} and $SO^{2-}{}_{4}$ have loads greater than Ca^{2+}, Cl^{-}, $Na^{+}+K^{+}$) with the participation of the biogenic stage (presence of Fe^{3+} ions). The presence in the first place of the sign *Min* (mineralization) indicates the predominance of boron in more saline waters. And since in the valley of the river. Ilek in areas without noticeable anthropogenic impact is dominated by fresh water with a salinity of 0.4-0.7 g/dm^3, such an arrangement of parameters in MC1 indicates the presence of industrial water, therefore a large positive load on *B* should still be considered more man-made than lithogenic.

So, we can assume that in 2003, MC1 characterizes the transit of industrial waters. But in contrast to the tasks of 1988, the absence of the *pH* attribute in this component reflects a general change in the hydro-geochemical environment — a decrease in the role of acidity.

The increased values of this component are confined mainly to the old sludge storage, although again its maximum value (5.578), as in the tasks for 1988, falls on the area near the new sludge storage (well №1298), that is, more high boron concentrations.

MC2, in addition to the first, also reflects some increase in alkalinity of groundwater (parallel change in *pH*, $(HCO_3)^{-}$, Mg^{2+} and Ca^{2+}). This and MC3 do not contain boron, they characterize the territorial distribution of waters of varying degrees of salinity. Acidic water characterizes MC6, which reflects only 3% of the total dispersion of traits, which also emphasizes the decreasing role of traditionally acidic industrial waters.

Biogenic boron (MC4 - boron in parallel with Fe^{3+}) is distributed in more fresh waters - here $(Na^{+}+K^{+})$ with a minus sign. The maximum amount accumulated in well №1353 (5.866) is the zone of the source of pollution near the old sludge storage, in which groundwater flows from the territory of the new sludge storage and emergency leakage of the pipeline to the new sludge storage are encountered (**Table 2**).

In contrast to 1988, the conditions for the biogenic migration of boron formed next to the sludge storage (well №1298). Large (by module) negative MC4 value in well №1420 (Ilek right-bank water intake) demonstrates the effect of reducing the concentration of boron on the right bank, where there are no visible sources of groundwater pollution. The distribution of boron to the right bank can be explained by the influence of the “wall in the ground”, when the increase in the backwater formed the conditions for pushing polluted groundwater to the right bank and continued until the beginning of the bypass filtration.

An increase in biogenic boron in the Ilek left-bank water intake demonstrates the effect of forced washing of the boron as a result of the formation of a depression funnel during the operation of the water intake. This effect has already been noted in the 1988 problem.

Thus, a comparison of the results of the processing of monitoring data for 1988 and 2003. A multidimensional statistical model of component composition showed that although the processes of boron migration in groundwater, identified according to 1988 data, continue to operate, the hydro-geochemical situation in the Alga region has noticeably changed towards a decrease in boron migration from acidic industrial water. The redistribution of high concentrations of boron transported in different ways reflects the fact that the soil washing ground and sludge accumulators with snow melt water are far from being completed on the territory of the pollution front.

DISCUSSION

To achieve the goal of the work, assess the dynamics of the hydro-geochemical situation in the Alga region (Aktobe, Kazakhstan) and test the existing hypotheses about groundwater pollution processes in the Ilek River valley, by processing the data of hydrochemical monitoring by the multidimensional statistics method - component analysis - solved 6 problems. The main results of their solution are reduced to the following conclusions.

Results of task 1: only on the basis of partial interpretation of MC1 with the use of additional materials, were confirmed the hypothesis of the presence of a stream directed towards the Suaksu stream, refuted the hypothesis on the formation of a geochemical barrier due to the low filtration properties of rocks and gave a real explanation of the reasons for the formation of the second source of pollution.

In addition, the component analysis confirmed not only the hypotheses about the ways of boron entry into groundwater and the assessment of reservoirs as long-term permanent sources of boron pollution in the hydrosphere of the region, but also made it possible to identify the boundary of a halo of boron pollution caused by filtration of acidic industrial effluents and a violation of migration processes water well zone.

The MC2 is actually an addition to MC1, noting the role of the biogenic stage of boron deposition, which is weakly manifested in MC1. From the standpoint of hypothesis testing, MC2 gave a direct, and MC3 indirect (boron in this component does not have a statistically significant load) confirming the hypothesis of the occurrence of boron in the working water wells as a result of pulling the river water into the depression funnel of the river water leaching boron deposited by silts.

The task 2 was solved to assess the impact of the flood on the nature of the hydro-geochemical environment. This effect affected the weakening of the biogenic stage of the metamorphization of the transit of acidic industrial waters and a significant reduction in the role of biogenic boron precipitation with increasing pH.

Task 3 showed that low-flow water increases pollution of groundwater with industrial effluents and weakens the effect of nutrient deposition compared with the July task.

Task 4 was solved to analyze hydro-geochemical processes in the background area and showed that the component view clearly records the change in the role of boron in the formation of the hydro-geochemical environment of the background area – it moved from the first places in the “transit” component to the last, and the main process in which boron participates - its biogenic sedimentation. In general, the interpretation of all components has undergone small changes, reflecting the absence of man-made water inflows, the increasing role of microbiological processes - their various shades characterize literally all MCs, and the role of has increased significantly, i.e. organic oxidation processes are actively going on at this site.

As for boron element B, here it is divided into B migration (transit) - MC1 - and B, associated with biological (MC3, MC4, MC5, MC6) and exchange processes (MC8). Analysis of the results of the inverse component task again showed that B comes into the water wells associated with microbiological processes, which is possible only by pulling in river water through a layer of activated sludge, which is undergoing active organic processing).

Summarizing the results of the interpretation of tasks 1-4, we see that almost the entire industrial boron is absorbed by the soil grounds within the Alga area, the remaining quantities migrate with the underground flow, and this migration is accompanied by microbiological precipitation. The most active filtering of pollution is observed in the area of influence of the new sludge storage, however, the boundary of its influence has spread to a much smaller distance than from the old one, although at the last new sludge inflows were stopped.

The results of the interpretation of the MC from task 5 (winter, 1982) showed that the overall picture of the processes forming the hydro-geochemical situation is similar to the picture in tasks 1-4 through 1988. Although feature B in the MC of task 5 fell into a large number of components, it is described by those the same processes of migration, exchange with soil (MC1, MC2, MC6) and microbiological precipitation (MC3 and MC5). The area distribution of MC values showed that the old sludge storage is emitted with large positive loads of MC1 and negative values of MC2 and MC6, i.e. here in 1982, absorption processes of B dominated by soil grounds. A boundaries estimate of the pollution halo gave a distance corresponding to approximately well №1574, i.e. a halo of pollution was formed by 1982 within the same boundaries as in 1988. The intensity of microbiological processes increased in the near-well wells and again, as early as 1982, weak anomalies were observed in the Aktobe territory in wells №1306 and 1307, and these anomalies were noted in both exchange and microbiological processes. The remaining wells (№ 5, 27, 1420) were simply not observed in 1982, therefore they were not noted in the task, although, as we see, the influence of depression craters formed during pumping by water intakes was also noted for a small number of wells.

Thus, the component analysis showed high sensitivity in the study of the hydro-geochemical situation of the territory, confirmed the hypotheses put forward earlier by boron contamination of water wells, helped to clarify the nature of boron migration from sludge storage.

Task 6. The interpretation of MC1 according to 2003 data still characterizes the transit of industrial water. But difference from tasks of 1988, the absence of the pH attribute in this component reflects the general change in the hydrogeochemical environment – reducing the role of acidity, while the elevated values of this component are confined mainly to the old sludge storage, although again its maximum value (5.578), as in the tasks in 1988, falls on the area near the new sludge storage (well №1298), i.e. higher boron concentrations are still being filtered from the new sludge storage.

Biogenic boron (MC4) is still confined to shallow groundwater. The maximum amount is noted in well №1353 (5.866) is the zone of the source of pollution near the old sludge storage, in which groundwater flows from the territory of the new sludge storage and emergency leakage of the pipeline to the new sludge storage. In contrast to 1988, the conditions for the biogenic migration of boron formed near the sludge storage (well №1298).

Large (by module) negative GK4 value in the well №1420 (Ilek right-bank water intake) demonstrates the effect of reducing the concentration of boron on the right bank, where there are no visible sources of groundwater pollution. Boron propagation to the right bank is explained by the influence of the “wall in the ground”, when the increase in the backwater formed the conditions for pushing polluted groundwater to the right bank and continued until the beginning of the bypass filtration. The effect of forced washing of boron as a result of the formation of a depression funnel during the operation of the Ilek left-bank water intake remains.

CONCLUSION

Thus, the goal of the work is fully realized – all the previously formed hypotheses on the ways of boron entry into groundwater were confirmed about the formation of a geochemical barrier. Component analysis demonstrated high sensitivity to changes in the hydro-geochemical environment both in the intra-annual and long-term context: in 2003, boron migration processes in groundwater, detected according to 1988 data, continue to operate, but the hydro-geochemical situation in the Alga area has significantly changed manifestations of boron migration with acidic industrial water. The redistribution of high concentrations of boron transported in different ways reflects the fact that the soil washing ground and sludge storage with snow melt water are far from being completed on the territory of the pollution front.

REFERENCES

Berdenov ZhG, Dzhanaliyeva GM (2015) Landscape and geochemical features of man-made Pollution zones of Aktobe Agglomerations. Communications, 38(2): 852-860. https://doi.org/10.26577/JGEM.2015.2.251

Bewick V, Cheek L, Ball J (2003) Statistics review 7: Correlation and regression. Critical care, 7(6): 451-459. https://doi.org/10.1186/cc2401

Bochkareva VA, Sydykov ZS, Dzhangiryants DA (1973) Underground subs of the Caspian Basin and its eastern frames. Alma-Ata.

Bolshev LN, Smirnov NV (1983) Tables of mathematical statistics. Moscow: Science.

Burakov MM, Pavlichenko LM (2011) The scope of the project for the purification of groundwater of the Ilek river valley from boron. Proceedings of the All-Russian Scientific Conference “Problems of hydrogeology, engineering geology and hydroecology.”, pp. 614-622.

Davidovich GT (1994) Report on the results of work on the compilation of a geoecological map of the Aktobe region (stages 1 and 2), RPEC “Kazekologia”.

Davidovich GT, Frolov VV (1992) Report on the results of work for the preparatory period on geological and environmental studies and mapping of the territory of Western Kazakhstan, scale 1: 1000000 for 1991-1992.

Gamble A, Babbar-Sebens M (2012) On the use of multivariate statistical methods for combining in-stream monitoring data and spatial analysis to characterize water quality conditions in the White River Basin, Indiana, USA. Environmental Monitoring and Assessment, 184 (2): 845–75. https://doi.org/10.1007/s10661-011-2005-y

Guigues N, Desenfant M, Hance E (2013) Combining multivariate statistics and analysis of variance to redesign a water quality monitoring network. Environmental Science: Processes and Impacts, 15: 1692–705. https://doi.org/10.1039/c3em00168g

Information bulletin on the state of the environment. Ministry of Energy of the Republic of Kazakhstan. RGP “KAZHYDROMET”. Available at: https://kazhydromet.kz/ru/bulleten/

Korchevsky AA, Pavlichenko LM, Sklyarova GL (2009) Conducting exploration and research to determine the technology for the protection of the waters of the Ilek River in the Aktobe region from contamination with hexavalent chromium and boron. Research Report. Program 003 “Scientific research in the field of environmental protection”. Center for Health and Environmental Design, pp. 367.

Merchant SS (2010) The elements of plant micronutrients. Plant physiology, 154(2): 512-515. https://doi.org/10.1104/pp.110.161810

Mishra A (2010) Assessment of water quality using principal component analysis: A case study of the river Ganges. Journal of Water Chemistry and Technology, 32(4): 227–234. https://doi.org/10.3103/S1063455X10040077

Murtazin Ezh, Burlibaev MZh, Svetlakov VR (2010) Design of water protection zones and strips of the Ilek river within the boundaries of large populated areas (Aktobe, Alga, Kandyagash, Martuk). Kazakhstani Applied Ecology Agency, 1: 30-50.

Nedyuzhin VV, Pogorelov YuS (2005) Report on the results of hydrogeological studies on the verification of the constructed section” walls in the soil “along the northeastern edge of the old sludge storages of the former Aktobe chemical factory of the Alga region on the reliability of isolation of the source of contamination of groundwater with boron. Department of natural resources and environmental management of the Aktobe region. “Aktobegidrogeologiya” LLP, Aktobe.

Noori R, Sabahi MS, Karbassi AR, Baghvand A, Taati Zadeh H. 2010. Multivariate statistical analysis of surface water quality based on correlations and variations in the data set. Desalination, 260(1): 129–136. https://doi.org/10.1016/j.desal.2010.04.053

Parinet B, Lhote A, Legube B (2004) Principal component analysis: an appropriate tool for water quality evaluation and management—application to a tropical lake system. Ecological Modelling, 178: 295–311. https://doi.org/10.1016/j.ecolmodel.2004.03.007

Pavlichenko LM (2007) Multidimensional statistical models in geoecology. Almaty: “ProService LTD”,

Pavlichenko LM, Rysmagambetova AA, Rodrigo Ilarri J (2019) The ecological capacity assessment of the Ilek River with boron pollution. KazNU Bulletin.

Shvartsev SL, Pinneker EV, Perelman AI (1982) Fundamentals of hydrogeology: Hydrogeochemistry - Novosibirsk: Nauka.