Assessment of the Ecological Status of Springs in Western Kazakhstan on the Basis of Their Hydrochemical and Microbiological Parameters

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Abstract—The results of ecological monitoring of the status of springs in Western Kazakhstan are presented: three of these springs are located in the Atyrau region and twelve are located in the Western Kazakhstan Region. The following properties of spring water samples were determined in accordance with water quality hygiene standards of the Republic of Kazakhstan (RK) and the Russian Federation (RF): temperature, pH, debit, turbidity, total hardness, permanganate index, solid residue, total spring mineralization, content of dissolved oxygen, cations (ammonium, calcium, magnesium, sodium, and pot assium), anions (nitrates, nitrites, carbonates, hydrocarbonates, chlorides, sulphates, and polyphosphates), heavy metals (copper, zinc, lead, cadmium, iron, chrome, manganese, cobalt, and nickel), petrochemicals, and phenols. The microbiological indicators of the waters (total microbial number, total coliform bacteria, and thermotolerant coliform bacteria) and spring bacterial contamination factors were determined. All springs were found to have small debits except the Tilepbulak spring in the Atyrau region, which was a semi-debit. The water of almost all springs studied was neutral except the Ainabulak spring in the Western Kazakhstan region, the water of which was weakly acidic and did not meet the standard indicators of the RF and RK. The springs studied differed by their hydrochemical indicators. The water in most of the springs and did not meet the hygienic standards of the RF and RK. In all the springs of the Atyrau region, the contents of iron, chrome, manganese, nickel, and phenol exceeded the hygienic standards. In the water of Ashituzbulak spring, the content of petrochemicals slightly exceeded accepted standards. High iron concentrations were found in two springs of the Western Kazakhstan region (Taskal-5, Serebryakov). The chrome concentration was high in six springs (Taskal-5, Krasnenkoye, Tsiganovo-2 (Yegendibulak), Bol’shaia Itchka, Ainabulak, Serebryakov). The manganese content was high in two springs (Taskal-1, Serebryakov). The nickel content high was in four springs (Taskal-5, Krasnenkoye, Bol’shaia Itchka, Ainabulak, Serebryakov). The phenol content was high in five springs (Taskal-5, Krasnenkoye, Tsiganovo-2 (Yegendibulak), Bol’shaia Itchka, Ainabulak). In the springs of the Atyraus and Western Kazakhstan regions, no deviations from the hygienic standards were found. The instability of microbiological indicators of the water was due to the fact that most of the springs studied were located near human settlements and actively used for domestic purposes and consumption by farm animals. This paper suggests practical recommendations for the rational use of springs in Western Kazakhstan.

Keywords: spring, hydrochemical indicators, microbiological indicators, water quality

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INTRODUCTION

Water supply for the population in the Republic of Kazakhstan is a particular problem due to the influence of the following factors: geographical location, dependence on transboundary rivers, environmental degradation, and global and regional climate change (Akhmedenov and Koshim, 2014; Akhmedenov, 2015a; Akhmedenov, 2015b). The use of surface water by the population is problematic due to the instability of the quality. In this regard, the use of springs is of particular interest. Springs are traditionally not only used as an alternative source of water consumption in the household as well as for medicinal and recreational purposes, but also play a significant role in the nutrition of other water bodies and affect the formation of the flora of the adjacent territory.

Most of the regions of Western Kazakhstan (West Kazakhstan, Atyrau and Mangystau regions, as well as certain districts of the Aktobe region) are arid. About 200 springs, which can be a reliable source of water supply, have been discovered in Western Kazakhstan.
Most of the groundwater sources are located in close proximity to transport routes, residential and industrial estates, and livestock farms and are subject to intense pollution as a result of human activities (Elpiner, 2015; Lee et al., 2010; Lotter et al., 2014). Contaminated water becomes unsuitable for drinking; therefore, the study of the ecological condition of the springs is relevant and of practical importance (Akhmedenov and Kairgalieva, 2016; Kairgalieva et al., 2016; Shailaja and Johnson, 2007; Idrissova et al., 2017).

The goal of this work was a comprehensive assessment of the water quality of the springs of the Atyrau and Western Kazakhstan regions based on hydro-chemical and microbiological indicators.

MATERIALS AND METHODS

Our studies were carried out during the period from June 5 to October 13, 2017, on the territory of the Atyrau and Western Kazakhstan regions of the Republic of Kazakhstan. Atyrau region is located on the Caspian lowland, northeast of the Caspian Sea, between the lower reaches of the Volga River to the northwest and the Ustyurt plateau to the southeast. The surface is flat, and the small Inder mountains are located to the north. The climate is sharply continental and extremely arid, with hot summers and moderately cold winters. In the area adjacent to this region, the Caspian Sea has a depth of less than 50 m. The coastline is indented little, there are small sand spits and coastal islands.

The region of Western Kazakhstan occupies the northwestern part of the Republic of Kazakhstan, which is a zone of dry steppes and semi-deserts. Its territory extends on both sides of the middle course of the Ural River and is located on the southern spurs of Obshchy Syrt, Podural plateau, and the northern part of the Caspian lowland. The maximum length of the region is 350 km from north to south and 555 km from west to east. Its total area exceeds 15 million hectares.

Three springs of Atyrau region (Tilepbulak, Ashchytuzbulak, and Tuzdybulak) and twelve springs of the Western Kazakhstan region (Taskala-1, Taskala-3, Taskala-5, Ainabulak, Aktau, Spring no. 1 in Krutoi, Spring no. 2 in Krutoi, Taskala-1, Taskala-3, Taskala-5, Krasnenkoe, Aktau, Spring no. 2 in Krutoi, Spring no. 1 in Krutoi, Tisganovo-2 (Yegendibulak), Bol’shaya Itchka, Yanvarsvo, Ainabulak, and Serebryakov).

Field studies of the springs included studying the arrangement of the sources; measuring the debit, pH, temperature, and dissolved oxygen content; determining the coordinates of the spring using a 12-channel Garmin eTrex GPS receiver (Garmin, Taiwan); and photo-recording of the object.

Sampling was carried out according to GOST 31861-2012 “Water: General Sampling Requirements.” The design and equipment of the noncentralized water supply structures were evaluated in accordance with SanPiN 2.1.4.1175-02 “Hygienic Requirements for the Quality of Water in Noncentralized Water Supply: Sanitary Protection of Springs.”

The study of the hydrochemical characteristics was carried out according to the following regulatory documents: GOST 18164-72 “Drinking Water: Method for Determination of the Content of Solids”; GOST 31957-2012 “Water: Methods for Determination of Alkalinity and Mass Concentration of Carbonates and Bicarbonates”; GOST 33045-2014 “Drinking Water: Methods for Determination of Mineral Nitrogen-containing Substances”; GOST 4245-72 “Drinking Water: Method for Determination of the Chloride Content”; GOST 23268.4-78 “Mineral Drinking Water: Healing, Healing-Table, and Natural Table. Method for Determination of Sulfate Ions”; GOST 23268.12-78 “Mineral Drinking Water: Healing,
Healing-Table, and Natural Table. Method for Determination of Sulfate Ions.”

The content of heavy metals (Fe, Zn, Cr, Cd, Cu, Mg) was determined using a SPECTRA AA 140 atomic absorption spectrophotometer (Agilent Technologies, Australia) according to the GOST 31870-2012 “Drinking Water: Determination of the Content of Elements by Atomic Spectrometry” and the Standard of KR GOST R 51309-2003 “Drinking Water: Determination of the Content of Elements by Atomic Spectrometry.”

The active reaction of water (pH) was measured using a Seven Easy pH-meter (Shandong, China) by the potentiometric method (PDNF 14.1:2:3:4:121-97). The turbidity and the concentration of nitrogen-containing substances (nitrites, nitrates), boron, and polyphosphates was determined using a CAPY-50 spectrophotometer (Analytik Jena AG, Germany). Boron was determined according to Standard of KR 016-2000 “Water: Method for Determination of the Mass Concentration of Boron”; polyphosphates were determined according to GOST 18309-2014 “Water: Methods for Determination of Phosphorus-containing Substances.” The determination of petrochemicals and phenols was carried out using a Fluorat 02-3M liquid analyzer (Lumex, Russia) according to the methods KZ 07.00.01667-2013 “Quantitative Chemical Analysis of Water: Method of Measuring the Mass Concentration of Petrochemicals in Samples of Natural, Drinking, and Waste Water by the Fluorimetric Method Using the Fluorat 02-3M Liquid Analyzer (Lumex, Russia) (M-01-05-2012)”; KZ 07.00.01340-2011 “Quantitative Chemical Analysis of Water: Method of Measuring the Mass Concentration of Phenols (Total and Volatile) in Samples of Natural, Drinking, and Waste Water by the Fluorimetric Method Using the Fluorat 02-3M Liquid Analyzer (Lumex, Russia) (M-01-05-2012).”

The results of hydrochemical indicators were compared with the standards of the Republic of Kazakhstan and the Russian Federation: SanPiN 2.1.4.1175-02 “Hygienic Requirements for the Quality of Water in Noncentralized Water Supply: Sanitary Protection of Springs,” Sanitary Regulations “Sanitary and Epidemiological Requirements for Water Sources, Water Intake for Household and Drinking Purposes, Drinking Water Supply and Places for Cultural and Domestic Water Use and the Safety of Water Bodies” (Government Decree of RK no. 104 from January 18, 2012), SanPiN of RK no. 209 from March 16, 2015, “Sanitary and Epidemiological Requirements for Water Sources, Water Intakes for Household and Drinking Purposes, Drinking Water Supply, and Places for Cultural and Domestic Water Use and the Safety of Water Bodies” (2015), and the Hygienic standard “TLV of Chemicals in the Water of Water Bodies for Drinking and Cultural and Domestic Water Use. GN 2.1.5.1315-03” of the RF.

The SanPin standards of the Republic of Kazakhstan and the Russian Federation for most indicators coincide with the exception of the TLV of ammonia and ammonium cation (nitrogen), the permanganate index, total mineralization (solid residue), magnesium, zinc, lead, nickel, and oil and petrochemicals (total).

Microbiological studies were carried out in accordance with the regulatory document of the Republic of Kazakhstan: MUK 10.05.045.03 “Methods of Microbiological Control of Drinking Water.” Assessment of spring waters was carried out according to the following microbiological indicators: total microbial number (TMN), total coliform bacteria (TCB), and thermotolerant coliform bacteria (ThCB).

Statistical processing of the research results was carried out according to generally accepted methods (Ashmarin et al., 1975; Dospekhov, 1985; Markina, 2014). Calculations were performed using Microsoft Excel 2007 software (Windows XP).

RESULTS AND DISCUSSION

Analysis of the hydrological and hydrochemical state of the springs of the Atyrau and Western Kazakhstan regions demonstrated that the temperature of the springs of the Atyrau region varied from +11.1°C (Tuzdybulak) to +12.5°C (Tilepbulak), and the temperature of the springs of the Western Kazakhstan region varied from +6.8°C (Aktau) to +15.0°C (Taskala-5). The oxygen content in the water of the springs of Atyrau region was 3.2 (Ashchytuzbulak) to 3.8 mg/L (Tilepbulak), while in the water of the springs of the Western Kazakhstan region, it ranged from 1.7 (Yanvartsevo) to 7.38 mg/L (Serebryakov). The pH values of the water of the springs of Atyrau region was 7.03 (Ashchytuzbulak) to 7.34 (Tuzdybulak), and the pH values in the water of the springs of the Western Kazakhstan region ranged from 5.79 (Ainabulak) to 7.4 (Serebryakov). The water of almost all the springs studied was neutral and corresponded to the standard except for Ainabulak spring in the Western Kazakhstan region, the water of which was weakly acidic and did not meet the standard indicators of the RF and RK. All springs were found to have small debits except the Tilepbulak spring (Atyraus region), which was a semi-debit (1.0 L/s).

Spring waters of Tuzdybulak and Tilepbulak did not contain ammonium, while in Ashchytuzbulak spring the concentration of this substance was 9.4 mg/L, which did not meet the hygienic standards of the RF and RK. In the Western Kazakhstan region, springs Taskala-1, Taskala-3, Krasnenkoe, Aktau, Spring no. 1 in Krutoi, Spring no. 2 in Krutoi, and Tiganovo–2 (Yegendibilak) did not contain this contaminant, while in other springs the ammonium concentration was 0.1 (Ainabulak) to 1.3 mg/L (Serebryakov). Ammonium concentrations in all springs of
Western Kazakhstan did not exceed those recommended by the RF and RK standards.

The nitrite concentration in the water of the springs of Atyrau region varied from 0.01 (Tuzdybulak) to 0.03 mg/L (Ashchytuzbulak). In the Western Kazakhstan region, nitrites were found only in Yanvartsevo spring (0.04 mg/L). Thus, the nitrite content in the springs studied did not exceed that recommended by the RF and RK standards.

The nitrate content in the water of the springs of Atyrau region varied from 0.10 ± 0.02 (Tuzdybulak) to 0.20 ± 0.003 mg/L (Tilepbulak). In the Western Kazakhstan region, nitrites were found only in Yanvartsevo spring (0.20 ± 0.03 mg/L). Thus, nitrate content in the springs studied did not exceed the recommended standards.

In waters of Ashchytuzbulak and Tilepbulak springs of Atyrau region, turbidity was not detected, while in Tuzdybulak spring, the turbidity value was 0.12 mg/L. In the Western Kazakhstan region, turbidity was not observed in the water of the Taskala-1, Taskala-3, Aktau, Spring no. 1 in Krutoi, and Spring no. 2 in Krutoi springs, while turbidity exceeded the hygienic standards in the waters of Taskala-5 (4.46 mg/L) and Serebryakov (5.22 mg/L). Carbonates were not found in the springs of Atyrau and West Kazakhstan regions. The hydrocarbonate content (HCO$_3^-$) in spring waters of Atyrau region varied from 122.0 (Ashchytuzbulak) to 274.5 mg/L (Tilepbulak), while in the Western Kazakhstan region, it ranged from 61.0 (Taskala-3) to 427.0 mg/L (Serebryakov).

In all springs of the Atyrau region, a significant deviation of the water quality from the hygiene standards of the RF and RK (350 mg/L) for chloride ions was detected: Tuzdybulak at 34900.0, Ashchytuzbulak at 18350.0, and Tilepbulak at 22500.0 mg/L. In the water of the springs of the Western Kazakhstan region, their concentration varied from 14.0 (Ainabulak) to 200.0 mg/L (Taskala-1). The magnesium (Mg$^{2+}$) concentration in the groundwaters of Atyrau region varied from 3756.0 (Ashchytuzbulak) to 4080.0 mg/L (Tuzdybulak); while in the Western Kazakhstan region, it varied from 4.8 (Ainabulak) to 126.0 mg/L (Aktau). Concentrations exceeding the hygiene standard of the RF (50 mg/L) were detected in the following springs: Tuzdybulak (4080.0 mg/L), Ashchytuzbulak (3756.0 mg/L), Tilepbulak (3840.0 mg/L), Taskala-1 (60.5 mg/L), Taskala-5 (105.3 mg/L), and Aktau (126.0 mg/L). In the water of the springs of the Atyrau region, the value of the total hardness varied from 3280.0 (Ashchytuzbulak) to 3500.0 (Tuzdybulak) mg-Eq/L, while in the Western Kazakhstan region, it varied from 1.0 (Taskala-3) to 15.0 mg-Eq/L (Aktau).

A significant deviation of water quality from the established hygiene standards of the RF and RK by total hardness was found in the water of the following springs: Tuzdybulak, Ashchytuzbulak, and Tilepbulak (Atyrau region) and Taskala-1, Taskala-5, and Aktau (Western Kazakhstan region).

The permanganate index in the water of most springs was significantly lower than that in the hygiene standards of the RF and RK (5–7 and 5 mg/L, respectively). The following springs were an exception: Tilepbulak (8.2 mg/L) (Atyrau region); Taskala-5 (7.28 mg/L), Krasnenkoe (10.08 mg/L), Bol’shaya Itchka (12.8 mg/L), and Yanvartsevo (14.6 mg/L) (Western Kazakhstan region).

The content of solids in the water of most springs of the Western Kazakhstan region was significantly lower than that in the standards of the RF and RK (1000–1500 and 1000 mg/L, respectively) except for the Tuscal-1 spring (1108.0 mg/L). It should be noted that the water of all springs of Atyrau region did not meet the established standards: Tuzdybulak at 48273.0, Ashchytuzbulak at 24513.0, and Tilepbulak at 29986.0 mg/L.

Boron and polyphosphates were not found in the water of the springs studied. The contents of sodium and potassium in the springs differed significantly. In the groundwaters of the Atyrau region, the ion concentration varied from 2001.0 (Ashchytuzbulak) to 12576.4 mg/L (Tuzdybulak); while in the waters of the springs of the Western Kazakhstan region, it ranged from 30.8 (Bol’shaya Itchka) to 117.3mg/L (Yanvartsevo).

The total mineralization in the water of most springs was significantly lower than that established by the hygiene standard of the RK, but the following springs were an exception: Tuzdybulak at 53685.0, Ashchytuzbulak at 27220.0, and Tuzdybulak at 33684.0 mg/L (Atyrau region).

Analysis of the content of heavy metals, petrochemicals, and phenols in spring waters (Table 1) made it possible to establish that copper was not found in the springs of the Western Kazakhstan region, while in the springs of Atyrau region it was: Tuzdybulak at 0.237, Ashchytuzbulak at 0.184, and Tilepbulak at 0.208 mg/L. The maximum permissible concentrations were not exceeded. The zinc concentration in the springs of the Atyrau region varied from 0.0183 (Ashchytuzbulak) to 0.0255 mg/L (Tuzdybulak); while in the waters of the springs of the Western Kazakhstan region, it ranged from 0.023 (Krasnenkoe) to 0.0460 mg/L (Aktau). The maximum permissible concentrations were not exceeded. No lead was found in spring waters. The exception was the spring of Taskala-3 (West Kazakhstan region), in the water of which the...
lead content was 0.0073 mg/L. Cadmium was found in the water of only one spring of the Western Kazakhstan region, Serebryakov, but the metal concentration did not exceed the permissible value (0.001 mg/L). An analysis of the iron content demonstrated that water of all the springs of the Atyrau region contained an excess of iron: Tuzdybulak at 0.67, Ashchytuzbulak at 0.51, and Tilepbulak at 0.54 mg/L. In the Western Kazakhstan region, the maximum permissible concentration of iron was exceeded in the Taskala-5 (1.22 mg/L) and Serebryakov springs (1.120.0 mg/L). The permissible concentration of chromium was exceeded in the following springs of Atyrau region: Tuzdybulak at 4.244 mg/L, Ashchytuzbulak at 278.1 mg/L, and Tilepbulak at 3.451 mg/L; and in the following springs of the Western Kazakhstan region: Taskala-5 at 5.166 mg/L, Krasnenkoe at 6.434 mg/L, Tsiganovo-2 (Yegendibulak) at 1.822 mg/L, Bol’shaya Itchka at 5.458 mg/L, Ainabulak at 5.899 mg/L, and Serebryakov at 0.477 mg/L. In the spring waters of Atyrau region (Tilepbulak, Ashchytuzbulak, and Tuzdybulak), the following concentrations of manganese were detected: 0.723, 0.503, and 0.670 mg/L, respectively. In the Western Kazakhstan region, manganese was detected in the springs Taskala-1 (0.919 mg/L) and Serebryakov (1.095 mg/L). Manganese concentrations exceeding the hygienic standards of the RF and RK were detected in the Tuzdybulak, Ashchytuzbulak, Tilepbulak, Taskala-1, and Serebryakov springs. Only in some springs of the Western Kazakhstan region was this metal found: Tsiganovo-2 (Yegendibulak) at 0.011, Bol’shaya Itchka at 0.117, and Serebryakov at 0.019 mg/L. The maximum permissible concentrations of cobalt according to the RF and RK standards (0.1 mg/L) were not exceeded. The nickel concentrations in samples of spring water in Atyrau region varied from 0.022 (Ashchytuzbulak) to 0.059 mg/L (Tuzdybulak), while in the springs of the Western Kazakhstan region the concentrations varied from 0.003 (Tsiganovo-2 (Yegendibulak)) to 0.056 mg/L (Krasnenkoe). Nickel concentrations exceeding the hygienic standard of the RF (0.02 mg/L) were detected in the water of the following springs: in the Atyrau region, Tuzdybulak (0.059 mg/L), Ashchytuzbulak (0.022 mg/L), and Tilepbulak (0.033 mg/L); in the Western Kazakhstan region, Taskala-5 (0.038 mg/L), Krasnenkoe (0.056 mg/L), Bol’shaya Itchka (0.041 mg/L), and Ainabulak (0.055 mg/L). Determination of the petrochemical content in spring waters demonstrated that, in samples from the springs of the Atyrau region, their concentration varied from 0.078 (Tuzdybulak) to 0.125 mg/L (Ashchytuzbulak); in the springs of the Western Kazakhstan region, the concentrations varied from 0.0067 (Spring no. 2 in Krutoi) to 0.091 mg/L (Yanvartsevo). A slight excess of the petrochemical concentrations according to the RK was detected in the water of Ashchytuzbulak (0.125 mg/L) in the Atyrau region. Deviation from the hygienic standard of the RF and RK (0.001 mg/L) for the phenol concentration was detected in the springs Tuzdybulak (0.014 mg/L), Ashchytuzbulak (0.012 mg/L), Tilepbulak (0.013 mg/L), Taskala-5 (0.003 mg/L), Krasnenkoe (0.011 mg/L), Tsiganovo-2 (Yegendibulak) (0.004 mg/L), Bol’shaya Itchka (0.007 mg/L), and Ainabulak (0.003 mg/L).

In the period from June 5 to October 13, 2017, as part of a comprehensive assessment of the condition of the springs, a microbiological study of the water was carried out and the degree of its bacterial contamination was determined. The results of microbiological studies of spring waters in summer and autumn are presented in Tables 2 and 3.

In the summer period, TMN, TCB, and ThCB were not detected in the water of the springs of the Atyrau region. When analyzing spring water samples from the Western Kazakhstan region in the summer period, it was found that the TMN of the springs varied from 2 (Spring no. 1 in Krutoi) to 180 CFU/mL (Yanvartsevo). TMN and TCB in the water of Yanvartsevo spring exceeded the hygienic standards. In the water of Tsiganovo-2 (Yegendibulak) spring, TMN and TCB were also detected that did not meet the hygienic standards.

In the autumn period, in analyzing spring water samples from the Western Kazakhstan region, it was found that the TMN of the springs varies significantly from 0 (Spring no. 1 in Krutoi, Spring no. 2 in Krutoi, Krasnenkoe, Bol’shaya Itchka) to 120 CFU/mL (Yanvartsevo) and significant growth of colony forming bacteria (Serebryakov). It should be noted that the water of Yanvartsevo spring did not meet the established hygienic standards for water quality according to indicators such as TMN and TCB. In waters of Yanvartsevo and Tsiganovo-2 (Yegendibulak) springs, TMN was determined, while in Serebryakov springs TCB was 6 CFU/L. Thermotolerant coliform bacteria were detected in water of Tsiganovo-2 (Yegendibulak) spring. The data obtained demonstrated that water samples from Yanvartsevo, Tsiganovo-2 (Yegendibulak), and Serebryakov springs did not meet the established standard for water quality. In the water of the springs of Atyrau region in the autumn, indicators such as TMN, TCB, and ThCB were also not detected.

In the biological contamination of water sources, factors such as their location, proximity to settlements, and the degree of anthropogenic impact are of great importance. The possibility of the influence of the groundwater level, which rises during floodwaters and leads to pollution of the underground water used for decentralized water supply, cannot be ruled out. Most of the springs studied are located in the immediate vicinity of or in villages (usually on the outskirts). The surroundings of the spring are actively used both for recreational purposes and for household needs, including consumption by farm animals, which leads
Table 1. The content of heavy metals, petrochemicals, and phenols in the spring waters of the Atyrau and Western Kazakhstan regions in 2017, mg/L

| Spring             | Cu  | Zn  | Pb  | Cd  | Fe  | Cr  | Mn  | Co  | Ni  | Petrochemicals | Phenols |
|--------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|----------------|---------|
| Tuzdybulak         | 0.237 | 0.0255 | 0 | 0 | 0.67 | 4.244 | 0.723 | 0 | 0.059 | 0.078 | 0.014 |
| Ashchytuzbulak     | 0.184 | 0.0183 | 0 | 0 | 0.51 | 278.1 | 0.503 | 0 | 0.022 | 0.125 | 0.012 |
| Tilepbulak         | 0.208 | 0.0188 | 0 | 0 | 0.54 | 3.451 | 0.670 | 0 | 0.033 | 0.099 | 0.013 |
| Taskala-1          | 0 | 0 | 0 | 0 | 0 | 0.919 | 0 | 0 | 0 | 0.0355 | 0 |
| Taskala-3          | 0 | 0 | 0.0073 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0099 | 0 |
| Taskala-5          | 0 | 0 | 0 | 1.22 | 5.166 | 0 | 0 | 0.038 | 0.0253 | 0.003 |
| Krasnenkoe        | 0 | 0.0024 | 0 | 0 | 0.08 | 6.434 | 0 | 0 | 0.056 | 0.0107 | 0.011 |
| Aktau              | 0 | 0.0460 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0355 | 0 |
| Spring no. 1       | 0 | 0.0239 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0067 | 0 |
| in Krutoi          | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0065 | 0.001 |
| Spring no. 2       | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0065 | 0.001 |
| in Krutoi          | 0 | 0.0314 | 0 | 0 | 0.02 | 1.822 | 0 | 0.017 | 0.003 | 0.0105 | 0.004 |
| Tsiganovo-2 (Yegendibulak) | 0 | 0.0314 | 0 | 0 | 0.02 | 1.822 | 0 | 0.017 | 0.003 | 0.0105 | 0.004 |
| Bol’shaya Itchka   | 0 | 0 | 0 | 0.07 | 5.458 | 0 | 0.013 | 0.041 | 0.0132 | 0.007 |
| Yanvartsevo        | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.091 | 0.001 |
| Ainabulak          | 0 | 0 | 0 | 0.05 | 5.899 | 0 | 0 | 0.055 | 0.0254 | 0.003 |
| Serebryakov        | 0 | 0.0276 | 0 | 0.001 | 1120.0 | 0.477 | 1.095 | 0.019 | 0.006 | 0.026 |
| GN 2.1.5.1315-03   | 1 | 1 | 0.01 | 0.001 | 0.3 | 0.05 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| SanPiN RK*         | 1 | 5 | 0.03 | 0.001 | 0.3 | 0.05 | 0.1—0.5 | 0.1 | 0.1 | 0.1 |

* Order of the Minister of National Economy of the Republic of Kazakhstan from March 16, 2015, no. 209.

Table 2. The results of microbiological studies of spring waters of Western Kazakhstan (June 5–August 11, 2017)

| No. | Spring                  | Date       | Parameter | TMN | TCB | ThCB |
|-----|-------------------------|------------|-----------|-----|-----|------|
| 1   | Tuzdybulak              | 05.06.2017 |           | 0   | Not detected | Not detected |
| 2   | Tilepbulak              | 05.06.2017 |           | 0   | Same | Same |
| 3   | Ashchytuzbulak          | 05.06.2017 |           | "  | "   | "   |
| 4   | Taskala-1               | 15.06.2017 | 4         | Not detected | Not detected |
| 5   | Spring no. 1 in Krutoi  | 15.06.2017 | 2         | Same | Same |
| 6   | Spring no. 2 in Krutoi  | 15.06.2017 | 30        | "   | "   |
| 7   | Aktau                   | 15.06.2017 | 35        | "   | "   |
| 8   | Taskala-3               | 15.06.2017 | 10        | "   | "   |
| 9   | Ainabulak               | 09.08.2017 | 40        | "   | "   |
| 10  | Taskala-5               | 09.08.2017 | 20        | "   | "   |
| 11  | Krasnenkoe             | 09.08.2017 | 15        | "   | "   |
| 12  | Bol’shaya Itchka       | 09.08.2017 | 15        | "   | "   |
| 13  | Serebryakov            | 21.08.2017 | 10        | "   | "   |
| 14  | Yanvartsevo            | 12.06.2017 | 180       | Detected | "   |
| 15  | Tsiganovo-2 (Yegendibulak) | 11.08.2017 | 10        | Same | Detected |
to high pollution of the reservoir. Spring confinement may protect springs from biological pollution.

Based on the data obtained, environmental passports were compiled for the three springs of the Atyrau region. Ecological passports for the Western Kazakhstan region are known and were compiled earlier (Akhmedenov and Zhantasova, 2013; Akhmedenov, 2014).

The environmental passport of each spring included the following:

— name of the object, location, geographical coordinates, map of the location of the spring on a scale of 1 : 25000, the area of the spring tract, water-bearing rocks;

— characteristic of outlet, debit, landscape description;

— organoleptic characteristics, chemical composition of waters in mg/L;

— mg-eq/L, mg/eq % and in the form of the Kurlov formula;

— a description of the surrounding landscape and a photo of the spring.

In the present study, we developed recommendations on the rational use of springs in Western Kazakhstan, which included the following actions:

— seasonal environmental monitoring of springs according to basic sanitary and hygienic indicators and periodic disinfection of containment (1—2 times a year) to ensure the epidemiological well-being of sources;

— arrangement of springs by means of containment and adjacent territories, taking into account their location (on the territory of the forest, near roads, near settlements);

— arrangement of a sanitary protection zone with a radius of at least 50 m (elimination of sources of anthropogenic pollution, planting of thorny bushes).

To assess the effectiveness of the functioning of the system of springs of Western Kazakhstan, the following recommendations have been made.

Determination of water withdrawal volumes by water consumers in order to maintain an environmentally sound debit of springs, as well as possible pollution of aquifers.

Registration of the results of environmental monitoring of spring waters in a database with the aim of further forecasting the environmental situation, as well as the timely identification of pollution sources.

Certification of springs using ecological and functional models.

Attaching a certified spring to local administrative authorities at the legislative level for the purpose of further care and appropriate control.

Hydrochemical regime studies, which may allow mapping of all water occurrences in Western Kazakhstan and visualizing the geoecological situation and
the state of springs for users of various government departments and departments of the republic.

Detailed geoecological, engineering-geological, and design-survey study of the most valuable and unique springs with a view to their subsequent water-landscape design and transfer to the category of specially protected or recreational areas. This requires the development of water protection rules and regulations on the creation of specially protected spring tracts and springs as natural monuments.

Drilling shallow hydrogeological wells with the aim of objectively clarifying the hydrogeological structure and town-planning properties of the rocks of spring tracts.

Analysis of decentralized water supply facilities in order to organize localized water supply based on springs (this aspect is important for solving the tasks of the Committee for Emergency Situations of the Republic of Kazakhstan in case of emergencies).

CONCLUSIONS

According to the results of a comprehensive study of the springs of two regions of Western Kazakhstan, it was found that the waters in them differ in the hydrochemical indicators. The water in most of the springs did not meet the hygienic standards.

In 2017, an iron content exceeding the hygienic standard was detected in the water of the following springs: Tilepbulak, Ashchytuzbulak, and Tuzdybulak (Atyrau region) and Taskala-5 and Serebryakov (Western Kazakhstan region).

The chromium content was exceeded in the following springs of Atyrau region: Tilepbulak, Ashchytuzbulak, and Tuzdybulak; and in the West Kazakhstan region: Taskala-5, Krasnenkoe, Tsiganovo-2 (Yegendibulak), Bol’shaya Itchka, Ainabulak, and Serebryakov.

The manganese content was exceeded in water of Tilepbulak, Ashchytuzbulak, Tuzdybulak, Taskala-1, and Serebryakov springs.

The nickel content exceeding the hygienic standard was recorded in the water of springs: Atyrau region: Tilepbulak, Ashchytuzbulak, and Tuzdybulak; West Kazakhstan region: Taskala-5, Krasnenkoe, Bol’shaya Itchka, and Ainabulak. A slight excess of petrochemicals was detected in the water of Ashchytuzbulak spring of Atyrau region. An excess of phenol was detected in the following springs of Atyrau region: Tilepbulak, Ashchytuzbulak, and Tuzdybulak; and in the Western Kazakhstan region: Taskala-5, Krasnenkoe, Tsiganovo-2 (Yegendibulak), Bol’shaya Itchka, and Ainabulak. Copper, zinc, lead, cadmium, or cobalt contents exceeding the hygiene standards in the springs of the Atyrau and Western Kazakhstan regions have not been detected.

The instability of the microbiological indicators of water was due to the fact that most of the springs studied were located near human settlements and the area surrounding the springs is actively used for domestic purposes and consumption by farm animals.

The proposed practical recommendations may allow the rational use of springs in Western Kazakhstan and minimize the negative impact.

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COMPLIANCE WITH ETHICAL STANDARDS

The authors declare that they have no conflict of interest.

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