https://doi.org/10.18321/ectj1478

Preliminary Study and Assessment of Drinking Water from Almaty, Kazakhstan

Y. Sailaukhanuly[1,2,3,4], A. Popova[2], T. Mansur[2], K. Bexeitova[3], S. Azat[1,3]*, K. Toshtay[3], A. Tovassarov[4], A. Tasmagambetova[4]

[1]Satbayev University, 22a Satpaev str., Almaty, Kazakhstan
[2]Shoqan Walikhanov Private School, Samal 3, 37/1, Almaty, Kazakhstan
[3]al-Farabi Kazakh National University, 71 Al-Farabi ave., Almaty, Kazakhstan
[4]Central Asian Institute for Ecological Research, 300/26 Dostyk ave., Almaty, Kazakhstan

Article info

Received:
5 April 2022

Received in revised form:
24 May 2022

Accepted:
2 July 2022

Keywords:
Drinking water
Quality indicators
Chemical analysis

Abstract

Drinking water samples from eight districts of Almaty, Kazakhstan was collected and physical and chemical analysis of the samples was carried out. Quality indicators of drinking water, such as organoleptic characteristics of water (smell, taste, color, and turbidity), general characteristics (pH, total hardness, permanganate demand, and dry residue), inorganic substances (cations and anions) and contaminants (heavy metals and total petroleum hydrocarbons) were determined, except pesticide residues which will be analyzed for further analysis with a wide range of pollutants. According to all indicators obtained for all districts of Almaty, the anthropogenic impact on drinking water in Almaty districts is assessed as low, not exceeding the permissible maximum allowable concentrations (MAC) values, and drinking water in Almaty corresponds to the approved standards and rules for drinking water of Kazakhstan. Despite of the fact that studied pollutants are below their MAC values, they still pose threat to public health due to their accumulative properties. The study of drinking water in the districts of Almaty made it possible to assess the ecological state in the studied districts of Almaty, as well as to propose recommendations for improving the quality of drinking water in areas where water quality indicators are closer to their MAC values.

1. Introduction

Kazakhstan has large reserves of natural resources. However, water resources are limited [1]. The freshwater reserves are estimated at 524 km^3, including 80 km^3 in glaciers, 190 km^3 in lakes, and 101 km^3 in river resources. Groundwater reserves are 7.6 km^3 [2]. On average per capita, there is not an acute shortage of water resources. Despite the absence of a shortage, the irrational use and uneven distribution of water resources in Kazakhstan significantly complicate the solution of the tasks of providing the population of the country with high-quality drinking water in the required volume, which has not yet been fully resolved in many settlements [3]. Kazakhstan took 54th place out of 179 in the ranking of countries in terms of drinking water quality. The drinking water quality index was 55.8 (out of 100). Drinking water was measured using the number of age-standardized disability-adjusted life-years lost per 100.000 persons (DALY rate) due to exposure to unsafe drinking water. A score of 100 indicates a country has among the lowest DALY rates in the world (≤5th percentile), while a score of 0 indicates a country is among the highest (≥95th percentile). Calculate indicator data come from the Institute for Health Metrics & Evaluation's (IHME) Global Burden of Disease (GBD) study [4].

Almaty is the former capital and the largest city of Kazakhstan, with a population of more than 2 million. Drinking water for the city of Almaty comes from several sources of water supply.

*Corresponding author.
E-mail: seytkhan.azat@gmail.com

Surface waters (Mountain Rivers) and underground waters (wells) are used as water sources for household and drinking purposes in Almaty. Currently, 70% of the water supplied to the city is underground water supply sources, which are extracted from wells up to 500 meters deep. There are 386 artesian wells in total. Surface sources include the Bolshaya and Malaya Almatinka, Kim-Asar, Kargaly, and Aksay rivers [5]. The city's water supply system operates tens of kilometers of water networks built from metal pipes. Their gradual wear and corrosion fouling, and poor quality of sanitary fittings lead to frequent accidents, interruptions in water supply, water leaks, as well as secondary pollution in water supply networks on the way to the consumer. As a result, the quality of water intended for household and the drinking needs of the population is deteriorating, which in turn requires constant monitoring and the adoption of measures to prevent pollution. The city of Almaty needs a serious revision and reconstruction of its water supply systems. According to the Almaty Development Center JSC, "the depreciation level of networks in the city is 65.9%, and water supply losses are 25.7%. For example, in the Nauryzbay district of the city, only 15% of the population is provided with water supply; the system was built by the population of the district on their own and does not meet building standards [6]. The quality of the drinking water accessed by the population is clearly of major importance, not only in terms of the actual quality as measured by its chemical, biological, qualities, but also in terms of people's perception of this water's quality. Over 40% of respondents asserted that there is a problem with the quality of drinking water. The main water quality issues highlighted by the population included coloration of the water, dirty water containing sediment, and water leaving stains on the dishes. Nearly a third of the respondents who had problems with water quality highlighted taste as a problem; 14% of the respondents who considered water quality to be an issue cited the main problem as being the fact that the water is salty [7]. The main reason for treating drinking water were poor water quality and health concerns. The fact that the water is opaque was by far the most common argument; a large number of people mentioned that they need to treat their drinking water to eliminate particles. About a quarter of the households that treat their water do so for health reasons, with taste being a secondary consideration [7].

As a result of anthropogenic impact on the environment, the chemical composition of not only surface but also groundwater has noticeably changed. Despite the relatively high protection from groundwater pollution compared to surface waters, they already contain heavy metals (Al, Si, Cr, Mn, Fe, Zn, As, Ba, Pb, Hg, Se, Ni, Cd, Sr, Li, Cs, Co, Cu, and Ti), and petroleum hydrocarbons and potential sources of contamination, includes urban, agricultural activities, electrical and electronic waste disposal, and fuel storage facilities [8–9]. At present, there is a trend towards an increase in cases of detection of nitrates and phosphates in water from wells, which indicates the release of mineral and organic fertilizers into aquifers [10]. Despite the absence of industries that would pollute the reservoirs supplying Almaty with drinking water, the main problems caused by the quality of drinking water in the city are the poor condition of water utilities and the vital activity of buildings located adjacent to water protection zones, which in turn contaminates water sources in Almaty [6].

Requirements for the quality of drinking water are based on the principle of epidemiological safety, harmlessness in chemical composition and favorable organoleptic properties. In accordance with regulatory requirements [11] heavy metals, toxic organic compounds, pesticides, radioactive elements in drinking water should be absent, and chlorides, sulfates, nitrates should not exceed their MAC value. Therefore, the quality of water supplied to the population is constantly monitored [12]. But for this study some toxicants like toxic organic compounds, pesticides and radioactive elements were not analyzed due to the lack of their sources. The study of drinking water and water supply systems, their examination, and practical work on protection is a necessary condition for regulating the accumulated environmental problems of Almaty [11–13]. A comprehensive chemical assessment of the composition of drinking water determines the potential hazard of chemicals present in drinking water samples for public health [14], taking into account the assessment of sanitary conditions and the epidemiological situation in various districts of Almaty.

Based on the results of the analysis, a list of indicators, the number and frequency of drinking water sampling for continuous monitoring are proposed [12]. Our work is devoted to a preliminary study and assessment of the quality of drinking water in the districts of the city of Almaty in order to reveal possible pollution of drinking water due to public concern.

2. Experimental

2.1. Sampling of drinking water from Almaty districts

A total of 16 drinking water samples were collected from 8 districts of Almaty. Samples were collected by sampling two samples from each district in glass containers with a volume of up to 2 L. Prior to water sampling, the containers were rinsed several times with the test water before filling, leaving some volume for the water to expand when heated, sealed tightly, and a label was attached indicating the sample number, place, and date of sampling (Fig. 1).

2.2. Methods

Drinking water samples were prior filtered through the membrane (0.45 μm), and then 1:1 nitric acid was added. After appropriate dilution with nitric acid, an aliquot of each water sample was applied to analytical instruments for each analysis of the characteristics of water. Organoleptic characteristics of drinking water (smell, taste, color, and turbidity) were determined in accordance with Kazakhstan Standard methods GOST 2874-82 and SanPiN 2.1.4.559-96 [11, 12]. General characteristics: pH was determined by pH meter pH150MI (Russia), dry residue by gravimetric method by GOST 18164-72, total hardness and permanganate demand by titrimetric methods GOST 4151-72 and STRK 1498-2006 [11, 12]. Inorganic substances (cations and anions) were determined by capillary electrophoresisKapel-150M (Russia) with methods GOST 31869-2012 and PNDF 14.1:2:4.157-99, and heavy metals by atomic absorption spectrometer AgilentAADuo55B/240Z(USA) with method ST RK GOST R 51309-2003, and total petroleum hydrocarbons by nephelometric method on liquid analyzers "FLUORAT®-02-5M" with method PNDF 14.1:2:4.128-98 (Russia) [11, 12].

3. Results and discussion

3.1. Organoleptic characteristics of drinking water

Quality control of drinking water is associated with the analysis of different parameters, and organoleptic characteristics [2]. The organoleptic quality is defined as the result of evaluating water based on odor, taste, color, and turbidity. If the water has a taste or odor (or it is cloudy or colored), it may be interpreted as a health risk and a problem in the water source, its treatment, or the water network.

3.2. Odor

The odor of drinking water can be natural and artificial origin. Odors of natural origin (aromatic, swampy, putrid, woody, etc.) are due to water chemistry, living organisms, decaying crop residues, algae consumption and emissions. Odors of artificial origin, characteristic of anthropogenic sources, are included in industrial wastewater. They are characterized by the composition of organic compounds, like organic acids, aldehydes, ketones, esters and some other compounds [12]. Quantitatively, the presence of odor is evaluated in points on a five-point scale (Table 1). The intensity of the odor of drinking water at 20 °C should not be more than 2 scores and tested by two people in order to avoid misinterpretation of results. The odor intensity of all drinking water samples taken was 0 scores on a five-point scale, i.e., there is no smell for all samples, and accordingly all water samples meet the requirements for drinking water quality of Kazakhstan sanitary norms [11, 12].

Table 1
Organoleptic properties of drinking water

Properties	Units	Max Permitted Levels, not more
Odor	Score	2 (0 to 5)
Taste	Score	2 (0 to 5)
Color	Degrees	20 (0 to 20)
Turbidity	mg/L	2.6

3.3. Taste

The taste of drinking water is characterized by the presence of natural compounds (compounds secreted by living organisms in the course of their vital activity) or anthropogenic origin, which can enter wastewater [12]. The quantitative intensity of the taste of drinking water is evaluated on a five-point scale. To determine the taste, water samples were taken into the mouth in small portions and kept in the mouth for 3–5 sec without swallowing. The quantitative intensity of taste is evaluated on a five-point scale and tested by two people in order to avoid misinterpretation of results. The intensity of the taste of drinking water should not exceed 2 points according to the Kazakhstan sanitary norms

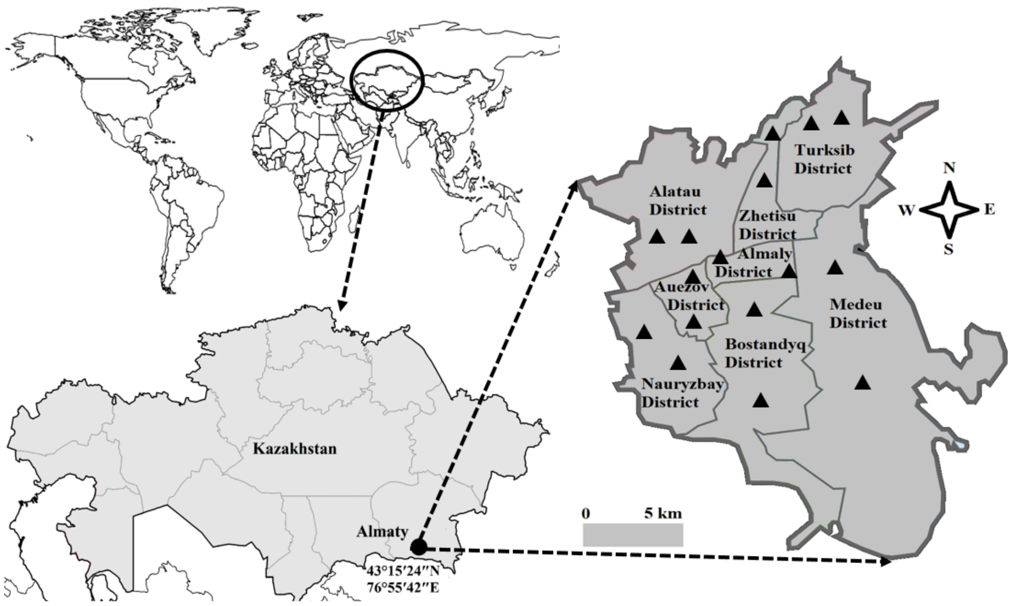

Fig. 1. Sampling points (▲) on the map of Almaty.

[11, 12]. The intensity of the taste of all selected water samples was 0 points and meet the requirements for the quality of drinking water of Kazakhstan sanitary norms [11, 12].

3.4. Color

Dissolved and suspended impurities in water determine its color (colloidal compounds, humic and colored substances). The color of water can vary from colorless to brown, depending on the amount of humic acids and their salts (humates) [12]. A quantitative assessment of the color of drinking water is expressed in degrees of color by photometric comparison of water samples with a scale of color solutions that mimic the color of natural water and is expressed in color degrees of this scale [12]. If there is no color, the water is considered colorless. According to the norms, the color of drinking water should be no more than 20°. The color scale was prepared by mixing color solutions in different ratios. Quantitatively, the color of water samples was determined by the chromate-cobalt scale. The color scale was prepared by mixing solution No. 1 (0.0875 g of potassium bichromate ($K_2Cr_2O_7$)) with solution No. 2 (2.0 g of cobalt sulfate ($CoSO_{4.7}H_2O$)). The color scale was prepared in five cylinders of 50 ml each by mixing solutions No. 1 and No. 2 in various ratios. The optical density or water samples and color solutions of the chromium-cobalt color scale are measured at a wavelength of 380 nm relative to distilled water [11, 12]. The results of water color studies showed that the color of all selected water samples was 0 points and thus met the requirements for drinking water quality of Kazakhstan sanitary norms [11, 12].

3.5. Turbidity

The turbidity of water is due to coarsely dispersed impurities undissolved in water, i.e., suspended solids: particles of sand, silt, clay, plankton, decay products of plant and animal organisms. Quantitative determination of turbidity of drinking water samples was carried out by the nephelometric method on liquid analyzers “FLUORAT®-02-5M” [12]. The turbidity value was measured automatically using the calibration curve stored in the instrument’s memory. The turbidity value of drinking water should be no more than 2.6 FMU (turbidity units according to formazin) according to Kazakhstan sanitary norms [12]. For all drinking water samples, the turbidity index was below a threshold and thus met the requirements for drinking water quality of Kazakhstan sanitary norms [11, 12].

4. General characteristics of drinking water

4.1. Dry residue

Dry residue is the total amount of substances dissolved in a unit volume of water. The dry residue is obtained after evaporation of the filtered water sample and drying to constant weight at 110 °C [15]. The water samples evaporated in a water bath and dried to constant weight in a thermostat at 110 °C. The dry residue of drinking quality water should be no more than 1.5 g/L [12]. For all drinking water samples, the dry residue was below 1.5 g/L thus meeting the requirements for drinking water quality of Kazakhstan sanitary norms [11, 12].

4.2. pH measurement

According to the norms, the pH of drinking water should be in the range from 6.0 to 9.0. The pH was determined using a pH meter pH-150MI. The results of the pH of the water lie in the range from 6.0 to 9.0 and meet the requirements for the quality of drinking water of Kazakhstan sanitary norms [11, 12].

4.3. Water hardness

Water hardness is a combination of properties due to the content of calcium and magnesium cations in water. It can also be caused by salts of barium, strontium, iron and heavy metals dissolved in water, but their content in most sources used for water consumption is negligible, therefore the hardness of natural waters is characterized by the total content of calcium and magnesium cations. The sum of their concentrations, expressed in mmol/L, is called the total hardness [11, 12].

The concentration of Ca^{2+} and Mg^{2+} ions in water, equivalent to the content of the HCO_3^- ion, determines the carbonate hardness of water, and the concentration of Ca^{2+} and Mg^{2+} ions, equivalent to all other anions (SO_4^{2-}, Cl^-, etc.), determines the non-carbonate hardness. The sum of carbonate and non-carbonate hardness determines the total hardness of water. The non-carbonate hardness is caused by the presence of sulfates and chlorides of calcium and magnesium in the water.

According to the magnitude of the total hardness, natural waters are divided into very soft, soft (0–1.5 mmol/L), medium hardness (1.5–3 mmol/L), hard (3–5 mmol/L) and very hard (>7 mmol/L). Regulatory requirements for the hardness of drinking water in water supply systems, according to current Kazakhstan sanitary rules, should not exceed 7 mmol/L [11, 12].

When monitoring the quality of drinking water, the total hardness is determined by complexometric method, using Na-EDTA as a titrant until the pink color of the solution changes to blue in the presence of the eriochrome black indicator T.

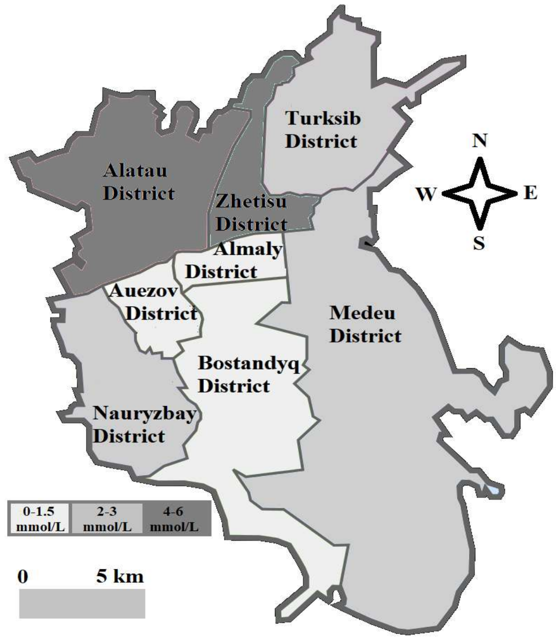

Fig. 2. Water hardness map of Almaty

As a result of the experiment to determine the total hardness of drinking water, it was found that the drinking water of the districts of Almaty, according to the scale of water types in terms of total hardness, varies from soft water (0–1.5 mmol/L) to moderate water hardness (4–6 mmol/L). The results of the experiment showed that soft water corresponds to tap water from the Medeu, Almaly and Bostandyq districts (hardness indicators, respectively, 1.5; 1.7 and 1.4 mmol/L); water of medium hardness in the Nauryzbay and Turksib districts of Almaty (hardness indicators 2.8 and 2.0 mmol/L); the hardest water was found in the Alatau and Zhetysu districts of Almaty (hardness indicators 4.3 and 5 mmol/l). Soft water from Medeu, Almaly and Bostandyk districts, which are located in the southern part of the city, is due to the mountain origin of drinking water. In the districts of Almaty (Nauryzbay and Turksib), where the water has an average hardness, there is a mixture of mountain and underground water. Hard water in the districts of Almaty (Alatau and Zhetisu), which are located in the northern and eastern parts of the city, is caused by underground sources. It is recommended to use drinking water treatment plants based on ion exchange or reverse osmosis methods to soften hard water. The results of determining the total hardness of water are mapped and presented in Fig. 2.

4.4. Permanganate demand

Permanganate demand is a quantity characterized by the content of organic and mineral substances in water, oxidized by a strong chemical oxidizing agents under certain conditions. It is expressed in milligrams of oxygen used for the oxidation of organic substances contained in 1 L of water (mg O/L). Surface waters have a higher permanganate demand (tens of mg O/L) compared to underground waters (tenths and hundredths of a milligram of oxygen per 1 liter), with the exception of groundwater, which is fed by swamps. Standards (maximum allowable concentrations) of permanganate demand for drinking water is 5 mg O/L [11, 12].

The method for determination of permanganate demand is based on the oxidation of organic and inorganic substances present in a water sample with a known amount of potassium permanganate in a sulfuric acidic medium (pH ≤ 1) during boiling. Unreacted potassium permanganate is reduced with oxalic acid or a salt of oxalic acid (for example, potassium oxalate). An excess of oxalic acid (oxalate ion) is titrated with a solution of potassium permanganate.

As a result of the experiment to determine the permanganate oxidizability of drinking water, it was found that the drinking water of Almaty districts does not exceed the maximum allowable concentration of permanganate oxidizability of drinking water, which is 5.0 mgO/l.

4.5. Inorganic substances (cations and anions)

Capillary electrophoresis was used to determine cations and anions in drinking water. The method of capillary electrophoresis is based on the separation of cations and anions due to their different electrophoretic mobility during migration along a quartz capillary in an electrolyte under the action of an electric field, followed by recording the difference in the optical absorption of the electrolyte and cations or anions in the ultraviolet region of the radiation spectrum [11, 12]. Identification and quantification of the analyzed cations and anions was carried out by recording ultraviolet absorption at a certain wavelength, using a mixture of 0.004 M benzimidazole solution, 0.002 M tartaric acid solution and 0.001 M 18-Crown-6 solution (in the case of cations) as the leading electrolyte buffer solution (in the case of anions). Despite of fact

Table 2

Results of determination of cations by capillary electrophoresis

Sample No	Cations, mg/L							
	NH^{4+}	Ca^{2+}	K^+	Na^+	Ba^{2+}	Li^+	Mg^{2+}	Sr^{2+}
1	<0.5	24.2	0.78	4.12	<0.05	<0.015	2.60	<0.25
2	<0.5	24.2	0.64	3.97	<0.05	<0.015	2.53	<0.25
3	<0.5	19.7	1.00	3.23	<0.05	<0.015	1.82	<0.25
4	<0.5	21.5	1.01	3.48	<0.05	<0.015	1.95	<0.25
5	<0.5	21.4	0.86	3.43	<0.05	<0.015	1.93	<0.25
6	<0.5	54.5	1.77	18.0	<0.05	<0.015	13.8	0.49
7	<0.5	53.4	1.95	12.1	<0.05	<0.015	11.8	0.40
8	<0.5	60.3	2.15	11.3	<0.05	<0.015	11.1	0.38
9	<0.5	54.9	2.24	7.20	<0.05	<0.015	9.15	0.29
10	<0.5	135.3	0.98	3.34	<0.05	<0.015	1.85	<0.25
11	<0.5	57.1	1.96	15.7	<0.05	<0.015	14.1	0.43
12	<0.5	43.2	1.10	4.69	<0.05	<0.015	6.50	<0.25
13	<0.5	19.8	1.74	9.51	<0.05	<0.015	3.36	<0.25
14	<0.5	26.2	1.75	14.1	<0.05	<0.015	5.83	<0.25
15	<0.5	27.6	1.58	4.47	<0.05	<0.015	3.70	<0.25
16	<0.5	26.6	1.6	4.5	<0.05	<0.015	3.5	<0.25
MAC, mg/L	2.0	-	-	200	0.7	0.03	-	7.0

that atomic absorption spectrometry more sensitive rather than capillary electrophoresis for metal analysis, capillary electrophoresis detection limits below for some ions (NH^{4+} – 0.5 mg/L, Ba^{2+} – 0.05 mg/L, Li^{+} – 0.015 mg/L) but their MAC values (NH^{4+} – 2 mg/L Ba^{2+} – 0.7 mg/L and Li^{+} – 0.03 mg/L) relatively high enough to determine with capillary electrophoresis.

The results of the determination of cations and anions are presented in Tables 2 and 3.

As a result of determination of cations in drinking water, it was found that the concentration of cations such as ammonium, potassium, calcium, sodium, barium, lithium, magnesium, strontium does not exceed their established MAC values in drinking water. The high content of calcium and magnesium ions in drinking water samples in Alatau and Zhetisu districts of Almaty is associated with water hardness of these areas. In drinking water from centralized water supply, the content of calcium and magnesium is not directly standardized: in tap water, the hardness parameter is standardized. Ca^{2+} ions, along with Mg^{2+} and Sr^{2+}, contribute to the hardness index: if we assume that the hardness of tap water is caused only by Ca^{2+}, its MAC will be 140 mg/l, and if Mg^{2+}, its MAC will be 85 mg/l. Despite this, calcium and magnesium have both negative and positive effects on the human body. In this regard, it is necessary to control the level of Ca^{2+} and Mg^{2+} in drinking water and regulate their content in drinking water in the optimal range, by reducing their content using methods based on reverse osmosis or ion exchange. The standards of physiological usefulness of Ca^{2+} and Mg^{2+} in drinking water are in the range of 25–130 mg/L for Ca^{2+} and 5–65 mg/L for Mg^{2+}.

As can be seen from Table 3, the content of anions in drinking water does not exceed their MAC in water. The current Kazakhstan sanitary rules set the norm for the content of nitrates in drinking water – 45 mg/L. In the districts of Almaty, located in the northern part of the city, the content of nitrate ions reaches half of the MAC in water samples from the Alatau and Zhetisu districts. There are several sources of water pollution by nitrates. Nitrates are naturally formed in the soil and participate in the nitrogen cycle in the environment , and are a very important source of nitrogen for living organisms that consume them. Also, the presence of nitrate ions in drinking water can be associated with the use of nitrogen fertilizers in farmland, which in turn pollute underground sources with nitrates through the soil. The presence of nitrates in water can have a negative effect on the human

Table 3
Results of determination of anions by capillary electrophoresis

Sample No	Anions, mg/L					
	NO_3^-	**NO_2^-**	**SO_4^{2-}**	**Cl^-**	**F^-**	**PO_4^{3-}**
1	3.28	<0.2	7.86	5.37	<0.1	1.09
2	3.25	<0.2	7.82	5.20	<0.1	1.09
3	2.4	<0.2	13.5	4.49	<0.1	0.56
4	2.85	<0.2	8.29	3.59	<0.1	0.88
5	2.88	<0.2	7.92	3.23	<0.1	0.9
6	19.1	<0.2	24.0	6.37	<0.1	1.46
7	18.3	<0.2	17.8	5.41	<0.1	1.32
8	24.4	<0.2	46.7	16.7	<0.1	1.01
9	29.5	<0.2	17.8	10.4	<0.1	1.34
10	2.79	<0.2	11.3	3.42	<0.1	0.93
11	14.7	<1.59	41.6	9.28	<0.1	1.4
12	7.43	<0.2	9.87	1.27	<0.1	0.44
13	2.69	<0.2	6.44	1.94	<0.1	1.25
14	6.04	<0.2	18.8	5.24	<0.1	1.41
15	8.49	<0.2	9.98	4.12	<0.1	1.64
16	7.8	<0.2	11.	5.2	<0.1	1.5
MAC, mg/L	45	3.0	500	350	1.5	-

body, forming methemoglobin in the blood, a dangerous substance that can lead to oxygen starvation. If the level of methemoglobin reaches 15%, fatigue, lethargy and dizziness appear. Its further increase in the level can lead to fatal consequences. Excess levels of nitrates in drinking water can cause poisoning, disruption of the gastrointestinal tract, excretory and endocrine systems, destruction of tooth enamel and the appearance of caries [9]. In connection with the above consequences

Table 4
Heavy metals content in drinking water samples

Sample No	Metals, mg/L								
	Ag	**Al**	**Va**	**Bi**	**As**	**Be**	**Cd**	**Co**	**Cr**
1	<0.0005	0.0124	<0.005	<0.005	<0.005	<0.0001	<0.0001	<0.001	<0.001
2	<0.0005	0.0232	<0.005	<0.005	<0.005	0.0009	<0.0001	<0.001	<0.001
3	<0.0005	0.0494	<0.005	<0.005	<0.005	<0.0001	<0.0001	<0.001	<0.001
4	<0.0005	0.0215	<0.005	<0.005	<0.005	<0.0001	<0.0001	<0.001	<0.001
5	<0.0005	0.0208	<0.005	<0.005	<0.005	0.0001	<0.0001	<0.001	<0.001
6	<0.0005	<0.01	<0.005	<0.005	<0.005	<0.0001	<0.0001	<0.001	<0.001
7	<0.0005	<0.01	<0.005	<0.005	<0.005	0.0008	<0.0001	<0.001	<0.001
8	<0.0005	0.01	<0.005	<0.005	<0.005	<0.0001	<0.0001	<0.001	<0.001
9	<0.0005	<0.01	<0.005	<0.005	<0.005	<0.0001	<0.0001	<0.001	<0.001
10	<0.0005	0.0337	<0.005	<0.005	<0.005	<0.0001	<0.0001	<0.001	<0.001
11	<0.0005	<0.01	<0.005	<0.005	<0.005	<0.0001	<0.0001	<0.001	<0.001
12	<0.0005	<0.01	<0.005	<0.005	<0.005	<0.0001	<0.0001	<0.001	<0.001
13	<0.0005	<0.01	<0.005	<0.005	<0.005	<0.0001	<0.0001	<0.001	<0.001
14	<0.0005	<0.0204	<0.005	<0.005	<0.005	<0.0001	<0.0001	<0.001	<0.001
15	<0.0005	<0.01	<0.005	<0.005	<0.005	<0.0001	<0.0001	<0.001	<0.001
16	<0.0005	<0.01	<0.005	<0.005	<0.005	<0.0001	<0.0001	<0.001	<0.001
MAC, mg/L	0.05	0.5	0.1	0.1	0.05	0.0002	0.001	0.1	0.05
Sample No	**Metals, mg/L**								
	Cu	**Mn**	**Mo**	**Ni**	**Pb**	**Zn**	**Hg**	**Fe**	
1	<0.001	0.0078	<0.001	0.0015	<0.001	<0.001	<0.0001	<0.05	
2	<0.001	0.0015	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.05	
3	0.0031	0.011	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.05	
4	0.0022	0.0018	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.05	
5	0.0015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.05	
6	0.021	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.05	
7	0.0725	0.0015	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.05	
8	<0.001	0.0016	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.05	
9	0.0054	0.0027	<0.001	0.0033	<0.001	<0.001	<0.0001	<0.05	
10	0.0011	0.0011	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.05	
11	0.0030	0.0014	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.05	
12	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.05	
13	0.0022	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.05	
14	0.064	0.0015	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.05	
15	0.0021	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.05	
16	0.0021	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.05	
MAC, mg/L	1.0	0.1	0.25	0.1	0.03	5.0	0.0005	0.3	

of the high content of nitrates in water, it is recommended to use additional purification of drinking water in the districts of Almaty, located in the northern part of the city (Alatau and Zhetysu districts) based on reverse osmosis methods, which allows to reduce the content of unwanted ions during the passage of liquid through a semi-permeable membrane. Some of the carbon materials for these methods are presented in the following researches [15–17].

4.6. Heavy metals

Heavy metals were determined with standard method STRKGOST R 51309–2003 by atomic absorption spectrometry with electrothermal atomization AgilentAADuo55B/240Zby measuring the absorption of resonant wavelength radiation by the atomic vapor of the element being determined, which is formed as a result of flame and electrothermal atomization of the analyzed sample in the graphite furnace of the spectrometer [11, 12].

Before starting the measurements of drinking water samples, the instrument was calibrated by measuring the value of the atomic absorption of a blank sample and each calibration solution of the metal being determined. Calibration solutions were prepared by diluting the necessary standard sample of the composition of an aqueous solution of metal with a 0.3 M solution of nitric acid in a volumetric vessel. Standard samples of the composition of aqueous solutions of metals were used as calibration solutions.

The test water samples were preliminarily prepared by adding and thoroughly mixing 3 ml of concentrated nitric acid and holding for at least 3 h. Having established the optimal measurement modes for a particular metal in accordance with the instrument's instructions, an aliquot of the prepared water sample was introduced into the graphite furnace of the spectrometer with a microdoser. The sample was heated in a flow of an inert gas (argon) according to a program that included drying, ashing, sample atomization, and furnace annealing. In each sample, the atomic absorption of the metal was measured twice. The mass concentration of the metal in the drinking water sample was determined from the values of the atomic absorption of the metal in the tested water sample and in the blank sample using a calibration curve. The results of the determination of metals by atomic absorption spectrometry are presented in Table 4.

As can be seen from Table 4, the concentrations of heavy metals in drinking water do not exceed their MAC value in water (Table 4), established by Kazakhstan sanitary rules, which indicates compliance with the requirements for the quality of drinking water.

4.7. Total petroleum hydrocarbons

Total petroleum hydrocarbons is a several hundred chemical compounds that originally come from crude oil. Petroleum products are made from crude oil, which can contaminate the environment. It is impractical to measure each chemical separately because crude oil and other petroleum products contain a wide variety of them. However, determining the total TPH is more practical.

The determination of total petroleum hydrocarbons (TPH) in drinking water samples was carried out using the fluorimetric method with standard PNDF 14.1:2:4.128-98. The fluorimetric method is based on the extraction of TPH with hexane from a water sample and measuring the fluorescence intensity of the extract on a liquid analyzer Fluorat-02 (Russia) [11, 12].

The device was calibrated by measuring the fluorescence signals of standard solutions of TPH and hexane. The tested water samples were extracted with hexane and the fluorescence intensity of the obtained extract was measured. To do this, a water sample was placed in a separating funnel, and after rinsing the vessel with 10 ml of hexane, in which the water sample was located, it was added as an extractant to the separating funnel. The resulting mixture was vigorously shaken and left until a clear upper layer appeared. The volume of the separated aqueous phase was accurately measured with a graduated cylinder. Next, the hexane extract was placed in the cuvette of the device, and the mass concentration of oil products in the extract was measured on the Fluorat-02 liquid analyzer in the "Measurement" mode. The value of the mass concentration is displayed on the instrument display.

As a result of the experiment, the absence of TPH in the drinking water samples was established, which indicates compliance with the requirements for the quality of drinking water.

5. Conclusions

According to the results of the study reported above of drinking water samples, the following results were obtained.

Comparative analyzes of literary sources describing the general characteristics of drinking water, water supply, sources of drinking water pollution, as well as standards and regulatory requirements for drinking water and the main parameters of drinking water quality for its constant monitoring in Kazakhstan have been studied. Drinking water samples were taken from 8 districts of Almaty. A drinking water sampling map was compiled. A preliminary physical and chemical analysis of selected samples of drinking water was carried out. Drinking water quality indicators were determined, such as organoleptic characteristics of water (smell, taste, color, and turbidity), general characteristics (pH, total hardness, permanganate demand, and dry residue), inorganic substances (cations and anions) and contaminants (heavy metals and total petroleum hydrocarbons). A comparative analysis of the obtained results was carried out. As a result of the experiment to determine the total hardness of drinking water, it was found that the drinking water of Almaty districts, according to the scale of water types in terms of total hardness, varies from soft water (0–1.5 mmol/L to water of moderate hardness (4–6 mmol/L). A map of the hardness of drinking water in Almaty has been compiled. In the districts of Almaty, located in the northern part of the city (Alatau and Zhetisu districts), the concentrations of nitrates reach half of their MAC values, which indicates its contamination, which in turn can cause poisoning, disruption of the gastrointestinal tract, excretory and endocrine systems, destruction of the dental enamel and caries. According to all drinking water quality indicators obtained for all districts of Almaty, the anthropogenic impact on drinking water of Almaty districts is assessed as low, not exceeding the MAC standards and drinking water in Almaty meets the approved norms and rules of Kazakhstan for drinking water. Recommendations are proposed for improving the quality of drinking water in the districts of Almaty, where water quality indicators are closer to their maximum allowable standards, as well as in areas located in the northern part of the city, where water intake is carried out from underground waters (wells).

Acknowledgments

The authors wish to thank Central Asian Institute for Ecology Research for providing analysis and technical assistance throughout the project.

References

[1]. G. Issanova, R. Jilili, J. Abuduwaili, A. Kaldybayev, et al., *Paddy Water Environ.* 16 (2018) 183–191. DOI: 10.1007/s10333-018-0630-6

[2]. Baseline study and target indicators to the Protocol on Water and Health May. Astana, 2017, 52 p. (In Russian)

[3]. Seminar on the role of ecosystems as water suppliers. Kazakhstan national report Geneva. 2004, 32 p. (in Russian)

[4]. Unsafe drinking water. https://epi.yale.edu/epi-results/2020/component/uwd

[5]. Water supplies. https://almatysu.kz/?page_id=661&lang=ru

[6]. Water condition in Almaty: Is it time to worry? https://www.the-village-kz.com/village/city/situation/3897-water-in-almaty

[7]. UNDP Project. National Plan for Integrated Water Resources Management and Water Efficiency in Kazakhstan, http://www.caresd.net/iwrm/new/en/doc/report_eng.pdf

[8]. I. Radelyuk, K. Tussupova, M. Persson, K. Zhapargazinova, et al., *Environ. Geochem. Health* 43 (2021) 1029–1050. DOI: 10.1007/s10653-020-00685-1

[9]. H. de León-Gómez, M.A. Martin del Campo-Delgado, M.V. Esteller-Alberich, F. Velasco-Tapia, et al., *Environ. Earth Sci.* 79 (2020). DOI: 10.1007/s12665-020-09164-3

[10]. E. Abascal, L. Gómez-Coma, I. Ortiz, A. Ortiz, *Sci. Total Environ.* 810 (2022) 152233. DOI: 10.1016/j.scitotenv.2021.152233

[11]. Order of the Minister of National Economy of the Republic of Kazakhstan, March 16, 2015, # 209. https://adilet.zan.kz/rus/docs/V1500010774

[12]. Guidance to ensure compliance with health regulations and SanPiN norms, 2.1.4.559-96, https://online.zakon.kz/Document/?doc_id=1029011

[13]. A. Nazhmetdinova, G. Sarmanbetova, A. Magai, *J. Environ. Health Sci. Engineer.* 16 (2018) 81–88. DOI: 10.1007/s40201-018-0299-1

[14]. Z. Bekturganov, K. Tussupova, R. Berndtsson, N. Sharapatova, et al., *Water* 8 (2016) 219. DOI: 10.3390/w8060219

[15]. S. Azat, R. Busquets, V.V. Pavlenko, A.R. Kerimkulova, et al., *Appl. Mech. Mater*. 467 (2014) 49–51. DOI: 10.4028/www.scientific.net/AMM.467.49

[16]. S. Azat, E. Arkhangelsky, T. Papathanasiou, A.A. Zorpas, et al., *Comptes Rendus Chimie* 23 (2020) 77–92. DOI: 10.5802/crchim.19

[17]. Z.A. Mansurov, J.M. Jandosov, A.R. Kerimkulova, S. Azat, et al., *Eurasian Chem.-Technol. J.* 15 (2013) 209–217. DOI: 10.18321/ectj224