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Pathogen Contamination of Groundwater Affecting Drinking Water Quality with Potential Health Effects in Pavlodar Region, Kazakhstan

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Abstract: Groundwater is becoming increasingly important as surface water is decreasing and becoming more and more polluted. In particular, rural areas in the arid region of Central Asia face problems with both water quantity and quality. In view of this, we investigated the drinking water quality in the Maysky district in the Pavlodar region, Kazakhstan. The organoleptic properties, together with microbiological indicators, as well as organic and inorganic substances of drinking water before and after treatment, and tap water were studied and compared to recommended levels. The bacteriological indicators of the drinking water, especially, showed that the water represents health risks since the presence of bacteria of the genus *Pseudomonas aeruginosa* was confirmed. Water treatment reduced the total microbial count (TMC) indicator by 3.6 times. However, TMC still exceeded permissible levels in the tap water, indicating that the drinking water is sanitary and epidemiologically not acceptable. Pathogenic contamination of drinking water can severely affect weaker individuals and children. It has been estimated that the infant mortality rate in Kazakhstan is six times higher as compared to the EU and less than 30% of Kazakhstan's population have access to safe water. Also, 50% of the population drink water that does not comply with the international standards, e.g., bacteriological levels. Thus, it is important to continuously monitor the groundwater quality to minimize health risks and work towards access to safe drinking water, in line with the UN SDGs.

Keywords: drinking water quality; water treatment; organoleptic pollutants; turbidity; microbiological content

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1. Introduction

Groundwater is becoming increasingly vulnerable and environmentally challenged, especially in arid areas [1]. In many of these areas, salinity [2] or other surface water pollutants are a major hazard [3]. Therefore, it is increasingly important to estimate sustainable use, relations between surface and groundwater [4], and risks in the long-term [5]. It is a general knowledge that surface use and management of surface water [6], has potential implications for groundwater [7]. However, the hypothesis of this paper is that management of clean groundwater [7] can also affect the drinking water quality [8]. This is still a little researched subject [9], especially for Central Asian countries [10–12].

Central Asian countries have limited water resources, although, the per capita available water resources do not yet indicate an acute water deficit. However, irrational and wasteful usage and uneven geographical distribution of water resources significantly complicate possibilities to provide the country's population with safe access to drinking

water [13]. Rural areas experience problems with safe [14] and continuous drinking water supply [15]. One of these regions in the country, where there is an uneven distribution of water resources, is the Pavlodar region. Out of about 1200 small lakes in the Pavlodar region, most of these are saline and only 10% have fresh water [16]. The main water resources are concentrated in the Aktogay, Bayanaul, Maysky, and Irtysh districts. The Irtysh River crosses the territories of seven districts, the cities of Aksu and Pavlodar [17], and it is used for irrigation in the Akkuli, Zhelezin, Irtysh, Maysky, Pavlodar, and Terencolsky districts [18]. There are seven reservoirs in the region to regulate the flow of the Irtysh–Karaganda channel [19].

Deterioration of the Irtysh River water quality [20], as well as the danger of transboundary pollution [21], by various chemical compounds, including mercury, has been highlighted in many studies [22]. One of the topical problems in the region that requires an urgent solution is the provision of good-quality drinking water to rural areas. Unfortunately, much of the water supply infrastructure and water treatment plants have been in deterioration since the downfall of the Soviet Union. Industrial and agricultural development without treatment of wastewater has accelerated the decrease in the quality of surface water. This has accentuated the lack of suitable surface water not only in cities, but also in rural settlements, which is observed in the Pavlodar region.

Natural and anthropogenic factors have characteristic effects on the composition of drinking water in certain settlements of the Pavlodar region. Drinking water in Lebjazhenskij, Maysky, and Ekibastuz districts has a high concentration of silver, associated with the proximity of the gold–barite polymetallic ore deposit Alpys [23], where the average silver content is 50.4 g t^{-1} [24]. It should be noted that 39% of the territory of the Semipalatinsk (Semey) nuclear test site falls within the Maysky district area [25], which aggravates the problem of drinking water quality in the area [26]. Adding to this problem is the lack of access to centralized tap water for some rural residents of the Maysky district located in the southeastern part of the Pavlodar region with a population of more than 12,000 people [27]. Under the Ak Bulak National Program, the reconstruction of the Maysky water infrastructure was planned, which would have improved water supply [28] and provision of water to the rural population of the Pavlodar region [29]. However, the planned improvements in this program were not implemented and the problems of drinking water supply [27] in the rural areas largely remain unsolved [30]. In the Maysky district, only 34% of the population are supplied water via pipeline. Up to 30% of water drinking water samples did not meet minimum requirements for water quality composition, such as bacterial content, and kidney infection rates among the rural population were 2.5 times above the national level [31]. To alleviate the water problems, a new water distribution system was introduced in December 2019, where groundwater is extracted for household and drinking water supply. It is constituted of seven wells, with a design capacity of about 4150 m^3 day^{-1}, that serve 15 settlements [30]. However, the distribution system has not been fully evaluated. It is important to continuously monitor the state of the drinking water system in neglected rural areas without centralized water supply. There are very few studies in this regard that give a representative view of the drinking water quality for rural settlements in Kazakhstan.

In view of the above, this study thoroughly investigated the groundwater quality situation and effects of water treatment for the newly supplied groundwater supply system in the Maysky district, Pavlodar, Kazakhstan. The objective was to analyze this representative case study of a rural water supply system for different drinking water quality indicators [32]. The area is under severe influence from anthropogenic and natural geologic pollution sources but comprehensive effects on the groundwater and drinking water supply system have not been studied previously in the area. It is, thus, important to establish if the applied treatment of the water is effective for the occurring pollutant sources [33]. It has been established that the infant mortality rate in Kazakhstan is six times higher as compared to the EU. As well, less than 30% of Kazakhstan's population have access to safe water. About 50% of the population drink water that does not comply with the

international standards, e.g., bacteriological levels. There are, however, few links between existing problems of the quality of the water supply and health effects. Very few studies have investigated the pathogenic standards of drinking water. Thus, it is important to establish the existing pathogenic levels of groundwater supply especially, since this is a major water supply of Kazakhstan. The present paper is in line with this objective as it assesses pathogenic contamination of groundwater that potentially affects health in the Pavlodar region, Kazakhstan.

2. Materials and Methods

2.1. Sampling

Maysky district (Figure 1) in the Pavlodar region is located in a distinctly continental arid climate south of the West Siberian Plain in the middle reaches of the Irtysh River. The annual precipitation is about 300 mm. Pavlodar has a Köppen Dfb climate with a warm-summer humid continental climate with long, cold winters. The average monthly temperature varies from −15.8 °C in January to 21.5 °C in July, with an absolute maximum of +42 °C and an absolute minimum of −47 °C.

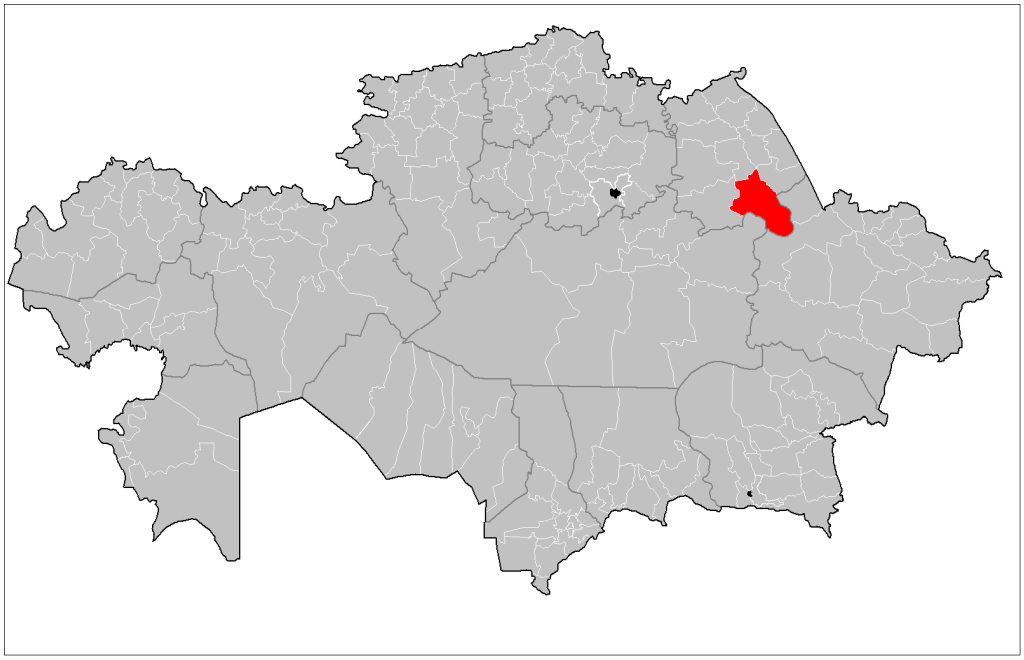

Figure 1. The experimental study region Maysky district (in red) in Pavlodar, northeastern Kazakhstan (latitude 45°02′23.0″ N and longitude 75°04′31.9″ E; from Wikipedia).

The geology of the study area consists of four main geologic layers: contemporary sediments (land cover), upper-quaternary and contemporary aeolian–diluvial deposits (clayey sand), and upper-quaternary alluvial deposits (loam and/or fine-to-medium-grained sand) [34–36]. Groundwater is found in shallow unconfined and confined aquifers with an upper aquifer composed of clay–sand and mixed-size sand. The main part of the aquifer is at 8.0–24.0 m depth below soil surface level. The aquifer is mainly recharged from rainwater infiltration and the Irtysh River. At the location for groundwater extraction to supply households with drinking water, the uppermost soil layer consists of sand and gravel up to a depth of 0.7 m. At a depth of 0.7 to 4.0 m, there is dark gray, plastic clay. From a depth of 4.0 to 11.6 m, the composition includes sand with gravel, and at depths ranging from 11.6 to 15.0 m, clay predominates.

Flow representative water samples (5 L each) were taken in October from the groundwater before (W_1), after (W_2), and tap water 3000 m downstream (W_3) of the raw water treatment plant of the Maysky district. The water sampling followed ISO Standards [37]. The depth of the groundwater wells is about 15 m, consisting of a sump (0.3 m), a filter

(4.5 m), and an above-filter part (7.1 m) (Figure 2). The raw water treatment after the described filtration consists of clarification, de-ironing, and disinfection. The total length of the piped water system is 148.7 km. The water from the wells is chemically characterized as chloride–hydrocarbonate (in terms of anions) and mixed (in terms of cations).

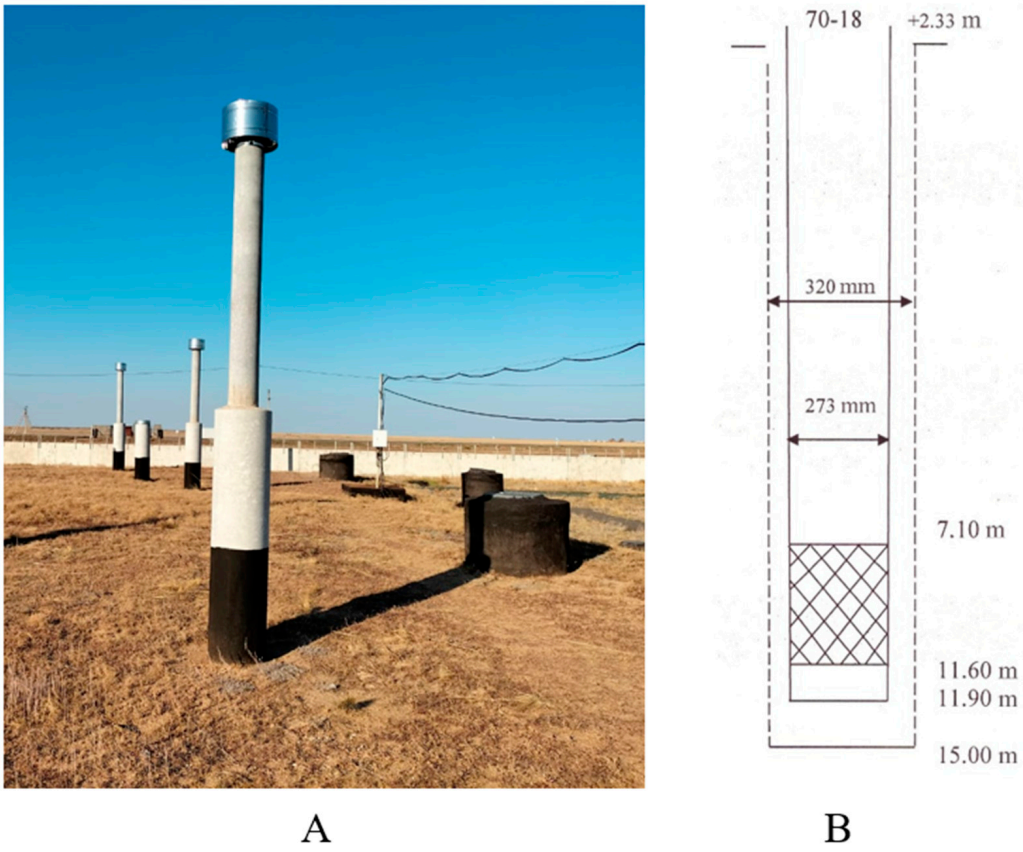

Figure 2. Groundwater wells used in the water supply system (**A**) and description of well (**B**).

2.2. General Drinking Water Indicators

Dry residue, carbonate, and hydrocarbonate were determined by gravimetric method according to State standards [38]. Total hardness and calcium content were analyzed using the complexometric method [39]. Surface-active substances (surfactants), phenolic index, and boron content were determined by fluorometric method according to [40–42] respectively. Organoleptic characteristics were determined according to [43,44].

2.3. Inorganic and Organic Substances

Inorganic substances were analyzed according to [45–48]. Aluminum content was determined by inductively coupled plasma atomic emission spectrometry method according to [45]. Mass concentration of total iron was determined by complexometric method based on the interaction of iron ions in an alkaline medium with sulfosalicylic acid to form a complex compound colored yellow [49]. The contents of ammonia, nitrate, and nitrite ions were determined by photometric method without sample dilution. Potassium concentration was determined by flame photometric method according to [50]. Cobalt, nickel, copper, zinc, cadmium, and lead contents were examined by flame atomic absorption spectrometric method [51]. Copper was determined by extraction-photo colorimetric method according to [52]. Beryllium, boron, cadmium, cobalt, silicon, lithium, manganese, copper, molybdenum, arsenic, sodium, nickel, lead, selenium, silver, strontium, chrome, and zinc contents were determined by atomic-emission spectrometry with inductively coupled plasma [53]. Magnesium ions in the presence of calcium [54] were determined by the complexometric method [51]. The potentiometric method was applied to determine

the total concentration of fluoride using fluoride ion selective electrode [52]. Sulfate ion was analyzed by complexometric method according to GOST 4389-72. The concentration of cyanide from 0.01 to 0.25 mg L^{-1} was determined by photometric method [53]. Chloride content was measured by titrimetric method [54]. To determine gamma isomer of hexachlorocyclohexane and sum of DDT isomers, we used gas–liquid chromatography method using gas chromatograph with electron capture detector [55].

2.4. Microbiological Indicators

Microorganism identification was made according to standard procedure SOP-TS-013 "Handling, storage, monitoring, and preparation of test cultures", and "Bergey's Manual of Systematic Bacteriology". Disinfection of surfaces and equipment was performed using sterilizing agent "Farmdezin-Forte" (NGO MediDez, RK) working concentration 0.5%. For decontamination of smears after Gram staining, sodium dichloroisocyanurate tablets (Achlor Donge Ltd., Liaocheng, China) were used. The nutrient media and reagents used in the study are listed in Table 1.

Table 1. Nutrient media and reagents used for microbiological analyses.

No.	Name and Coding of Nutrient Media and Reagents	Manufacturer	Characteristics
1	Standard TTC-NKS nutrient carton plates	Dr. Moller-Schmelz, Göttingen, Germany	Sterile
2	Endo agar (M029)	HiMedia, Mumbai, India	pH (25 °C) 7.4 ± 0.2
3	Tryptone soy agar (M290)	HiMedia, Mumbai, India	pH (25 °C) 7.4 ± 0.2
4	Water	-	Sterile
5	Ethanol	Talgar Spirit (ethanol), Astana, Kazakhstan	96%
6	NEFERM test	MIKROLATEST, Brno, Czech Cat. No.: MLT00010	-
7	Clostridium agar	HiMedia, Mumbai, India	pH (25 °C) 7.4 ± 0.2
8	Oxidase discs	HiMedia, Mumbai, India	-
9	Hydrogen peroxide-DF 100 mL solution	Dospharm, Almaty, Kazakhstan	3.0%

For the determination of common coliform bacteria (OCB—Gram-negative, oxidase-negative, non-spore-forming bacilli), the cultures were placed in a thermostat at 37 ± 1 °C for 24 h on differential diagnostic media (Endo agar).

The thermotolerant coliform bacteria (TCB) are among the common coliform bacteria, possess all their features, and, in addition, are capable of fermenting lactose to acid, aldehyde, and gas at 44 ± 0.5 °C for 24 h. Plants on differential diagnostic media (Endo agar) were placed at 44 ± 1 °C for 24 h.

To determine the spores of sulfite-reducing bacteria in water, the method of direct seeding into nutrient media was used. This trait is used to identify the bacterium. The essence of the method consists in sowing 20 mL of the test sample into Petri dishes. Then, selective medium was added, and the seeding was poured over the top with a layer of the same medium and then incubated in anaerobic conditions at 37 ± 10 °C for 24 h, after which typical colonies were counted.

The procedure for isolation of microorganisms (TMC) from water samples was performed by membrane filtration through a 0.45 μm filter. A Sartorius vacuum filtration system was used for this purpose.

Membrane filters were removed from the frits with sterile forceps and placed on TCA nutrient medium (tryptone soy agar) with the top grid. The cups were incubated with nutrient media in MB-INC-03 and MB-INC-04 thermostat. In parallel, direct seeding was performed by placing 1 mL of water sample on the surface of tryptone soy agar and distributing it evenly with a spatula. Colonies were counted after 5 days (final results), and the arithmetic mean number of aerobic microorganisms in 100 mL of water was determined. The temperature and incubation time of the samples are given in Table 2.

Table 2. Incubation conditions for microbiology tests.

Media	Temperature	Incubation Time
Standard TTC substrates	37 ± 1 °C	5 days
Endo agar	37 ± 1 °C	18–48 h
Endo agar	43 ± 1 °C	18–48 h
Tryptone soy agar	37 ± 1 °C	18–24 h
Medium for clostridia	37 ± 1 °C	18–24 h

The count of grown colonies was performed on the cups without removing the filters from the cup. The colonies that grew from the sampling points on the media were subjected to identification. Morpho-cultural, tinctorial, and biochemical properties of the grown colonies were determined. Biochemical differential diagnostic tests were performed to establish species identity.

To identify Gram-negative non-fermenting bacteria and representatives of the *Vibrionaceae* family of the genera *Aeromonas* and *Pseudomonas*, a set of non-fermenters was used. Tests were also carried out on glucose oxidation, glucose alkalization, catalase production, the ability to form hemolysis, and the production of yellow pigment.

3. Results and Discussion

3.1. Microcomponent and Macrocomponent Analysis

The results of the organoleptic and general water indicators are shown in Tables 3 and 4. Turbidity of water before purification exceeded the permissible standard by 2.3 times (Table 3). However, after treatment, turbidity was not detected in the water. pH of the water varied between 7.15 and 7.75, i.e., it was neutral (Table 4). The total mineralization showed that the groundwater in Maysky is fresh and has an average hardness. All general water indicators were within the standard and, accordingly, the water is suitable for use for household and drinking purposes.

Table 3. Organoleptic indicators of water samples (W_1 = raw groundwater before treatment, W_2 = after treatment, and W_3 = delivered tap water).

Indicator	Water Sample			Standard * [32]
	W_1	W_2	W_3	
Smell, score	0	0	0	≤2
Chromaticity, degree	0	0	0	≤20 (35)
Turbidity, mg/L (kaolin)	3.5	0	0	≤1.5

Note: * According to the Chief State Sanitary Doctor for a specific water supply system based on an assessment of the sanitary and epidemiological situation in the locality and the water treatment technology used.

Table 4. General indicators of water samples (W_1 = raw groundwater before treatment, W_2 = after treatment, and W_3 = delivered tap water).

Indicator	Water Sample			Standard ** [32]
	W_1	W_2	W_3	
pH	7.15	7.75	7.42	Within 6–9
Total mineralization	429 290	423 278	405 278	≤1000 (1500)
Dry residue, mg/L	4.1	4.03	3.7	≤7.0 (10)
Total hardness, mmol/L	0.004	0.002	0.002	* n.d. (0.1)
Total petroleum products, mg/L	* n.d. (0.05)	* n.d. (0.05)	* n.d. (0.05)	* n.d. (0.5)
Surfactants, mg/L	* n.d. (0.0001)	* n.d. (0.0001)	* n.d. (0.0001)	* n.d. (0.25)

Notes: * n.d. not detected, detection limit is given in brackets; ** According to the Chief State Sanitary Doctor for a specific water supply system based on the assessment of the sanitary and epidemiological situation in the settlement and the applied water treatment technology.

Cation and anion composition indicated hydrocarbonate-type water, where the main constituent is calcium ions (60.1–66.1 mg/L; Table 5). Organic and inorganic substances showed that the content of manganese exceeded the recommended quality standard MES by 16.9 times in water samples before treatment (Table 5). This may be due to impact from the Pavlodar–Ekibastuz territorial industrial complex, which includes the largest Kazakhstan state district power plant based on local coal (thermal power plant), chemical, mining, metallurgical industries, filtration fields, and settling tanks of industrial enterprises. The main pollutants are untreated industrial and domestic sewage discharge and polluted water from utilities. A recent study [33] showed that groundwater in the Maysky district (water intake at Sputnik, Kyzylkuroma, and Kurgol) has very high contents of iron and manganese. Our results confirm manganese pollution in the Maysky district groundwater. After water purification, however, the manganese content was within the normal range (Table 5).

Table 5. Organic and inorganic substances of water samples (W1 = raw groundwater before treatment, W2 = after treatment, and W3 = delivered tap water).

Indicator	Water Sample			Standard ** [32]
	W_1	W_2	W_3	
γ- Hexachlorocyclohexane (lindane)	* n.d. (0.0001)	* n.d. (0.0001)	* n.d. (0.0001)	≤0.002
DDT (sum of isomers)	* n.d. (0.0001)	* n.d. (0.0001)	* n.d. (0.0001)	≤0.002
2,4-D	* n.d. (0.0005)	* n.d. (0.0005)	* n.d. (0.0005)	≤0.03
Aluminum (Al^{3+}), mg/L	* n.d. (0.04)	* n.d. (0.04)	* n.d. (0.04)	≤0.5
Ammonia (by nitrogen), mg/L	* n.d. (0.05)	* n.d. (0.05)	* n.d. (0.05)	≤2.0
Beryllium (Be^{2+}), mg/L	* n.d. (0.0002)	* n.d. (0.0002)	* n.d. (0.0002)	≤0.0002
Boron (B, total), mg/L	* n.d. (0.01)	* n.d. (0.01)	* n.d. (0.01)	≤0.5
Hydrocarbonates (HCO_3), mg/L	256.3	250.2	238.0	Not regulated
Iron (Fe, total), mg/L	* n.d. (0.05)	* n.d. (0.05)	* n.d. (0.05)	≤0.3 (1.0)
Potassium (K^+), mg/L	2.0	1.6	1.9	Not regulated
Carbonate (CO_3^{2-}), mg/L	* n.d. (8.0)	* n.d. (8.0)	* n.d. (8.0)	Not regulated
Calcium (Ca^{2+}), mg/L	66.1	65.1	60.1	Not regulated
Cadmium (Cd, total), mg/L	* n.d. (0.01)	* n.d. (0.01)	* n.d. (0.01)	≤0.001
Cobalt (Co), mg/L	0.0008	0.0006	0.0006	≤0.1
Silicon (Si), mg/L	8.6	8.6	8.4	≤10
Lithium (Li^+), mg/L	* n.d. (0.01)	* n.d. (0.01)	* n.d. (0.01)	≤0.03
Magnesium (Mg^{2+})	9.7	9.4	8.5	Not regulated
Manganese (Mn), mg/L	1.69	0.006	0.017	≤0.1 (0.5)
Copper (Cu), mg/L	0.001	0.004	0.008	≤1.0
Molybdenum (Mo), mg/L	0.002	0.001	0.001	≤0.25
Arsenic (As), mg/L	0.0015	0.0015	0.0019	≤0.05
Sodium (Na^+), mg/L	31.1	31.0	30.3	≤200.0
Nickel (Ni), mg/L	0.003	0.005	0.006	≤0.1
Nitrates (NO_3^-), mg/L	* n.d. (0.2)	* n.d. (0.2)	* n.d. (0.2)	≤45
Nitrite (NO_2^-), mg/L	* n.d. (0.005)	* n.d. (0.005)	* n.d. (0.005)	≤3.0
Mercury (Hg), mg/L	* n.d. (0.0001)	* n.d. (0.0001)	* n.d. (0.0001)	≤0.0005
Lead (Pb), mg/L	0.0002	* n.d. (0.01)	0.0003	≤0.03
Selenium (Se), mg/L	* n.d. (0.0002)	* n.d. (0.0002)	* n.d. (0.0002)	≤0.01
Silver (Ag), mg/L	* n.d. (0.01)	* n.d. (0.01)	0.0001	≤0.05
Strontium (Sr^{2+}), mg/L	0.3	0.3	0.3	≤7.0
Sulfate (SO_4^{2-}), mg/L	40.3	41.2	42.0	≤500
Chloride (Cl^-), mg/L	14.9	15.6	15.6	≤350
Chromium (Cr), mg/L	0.002	0.002	0.002	≤0.5
Cyanide (CN^-), mg/L	* n.d. (0.005)	* n.d. (0.005)	* n.d. (0.005)	≤0.035
Zinc (Zn^{2+}), mg/L	* n.d. (0.01)	* n.d. (0.01)	* n.d. (0.01)	≤5.0

Notes: * n.d.—component not detected, in parentheses the lower limit of determination of the component is given; ** According to the Chief State Sanitary Doctor for the particular water supply system, based on an assessment of the sanitary and epidemiological situation in the settlement and the applied water treatment technology.

3.2. Microbiological Analyses

To detect the content of microorganisms, all water samples were examined by seeding on a nutrient medium. As a result, there was no growth of coliform and thermotolerant coliform bacteria in all tested water samples. There were also no spores of sulfite-reducing clostridia (Table 6). However, in all water samples, the total microbial count (TMC) exceeded the norm, specifically, in water samples before treatment by 23.9 times, after treatment by 6.6 times, and 12.3 times in tap water samples in private homes (Table 6). Thus, the obtained data indicate the influence of pollutants from domestic wastewater.

Table 6. Microbiological parameters of water samples (W_1 = raw groundwater before treatment, W_2 = after treatment, and W_3 = delivered tap water).

Indicator	Water Sample						Regulatory Document [32]
	W_1, M ± StD	W_1, CV, %	W_2, M ± StD	W_2, CV, %	W_3, M ± StD	W_3, CV, %	
Total microbial count, CFU/mL	1198.3 ± 13.5	1.13	331.3 ± 25.5	7.7	616.0 ± 24.0	3.9	≤50
Total coliform bacteria, CFU/100 mL	* n.d.	* n.d.	* n.d.	* n.d.	* n.d.	* n.d.	* n.d.
Coliform thermotolerant bacteria, CFU/100 mL	* n.d.	* n.d.	* n.d.	* n.d.	* n.d.	* n.d.	* n.d.
Sulfite-reducing clostridium spores, number of spores in 20 mL	* n.d.	* n.d.	* n.d.	* n.d.	* n.d.	* n.d.	* n.d.

Note: * n.d.—not detected.

From the seeding of W_1 (water before entering the treatment plant) on the filter and by direct seeding, growth of transparent mucilaginous colonies with uneven edges (Figure 3A) and yellowish rough mucilaginous colonies (Figure 3B) was observed. Dry rough-edged colonies (Figure 3C) and two types of yellowish dry and slimy transparent colonies (Figure 3D) grew in tryptone soy agar (TSA) through a filter and by direct seeding of the W_2 (after treatment plant). For W_3 (tap water), there was a growth of slimy uneven colony edges (Figure 3E), and two types of colonies, a yellowish slimy and a dry with uneven colony edges (Figure 3F).

Microscopic examination of cell morphology and tinctorial properties of the growing bacteria was performed using microscopic smears and Gram staining. Figure 4 shows microphotographs of the isolates, with ×1000 magnification under immersion. In smears of water samples before entering the wastewater treatment plant (W_1 on filters), Gram-positive bacteria arranged in pairs or tetrads in the form of irregular clusters, characteristic of *Sarcina* (Figure 4A), were observed. The direct method of inoculation revealed large Gram-positive bacilli arranged in a chain (Figure 4B). In smears of W_2 samples after treatment, both filters and smears showed large Gram-positive bacilli arranged in parallel to each other, characteristic of bacteria of the genus *Bacillus* spp. (Figure 4C,D). In smears from the colonies of sample W_3 (tap water grown on a filter), large Gram-positive bacilli arranged in chains, typical of the arrangement of bacteria of the genus *Bacillus* spp., were observed (Figure 4E), along with small gram-negative bacilli in the direct method of seeding, the arrangement of which is characteristic of bacteria of the genus *Pseudomonas* spp. (Figure 4F).

The routine identification of Gram-negative non-fermenting bacteria, as well as representatives of the family *Vibrionaceae* (genera *Aeromonas* and *Pseudomonas*) are shown in Table 7. The obtained results confirm that all water samples contained *Pseudomonas aeruginosa* and *Bacillus* spp. Two types of *Pseudomonas* bacteria were present in water samples before treatment: *P. aeruginosa* and *P. monteilii*, as well as bacteria of the genus *Vasillus* spp. and *Sarcina* spp. *Pseudomonas aeruginosa* is an important microorganism in water quality control.

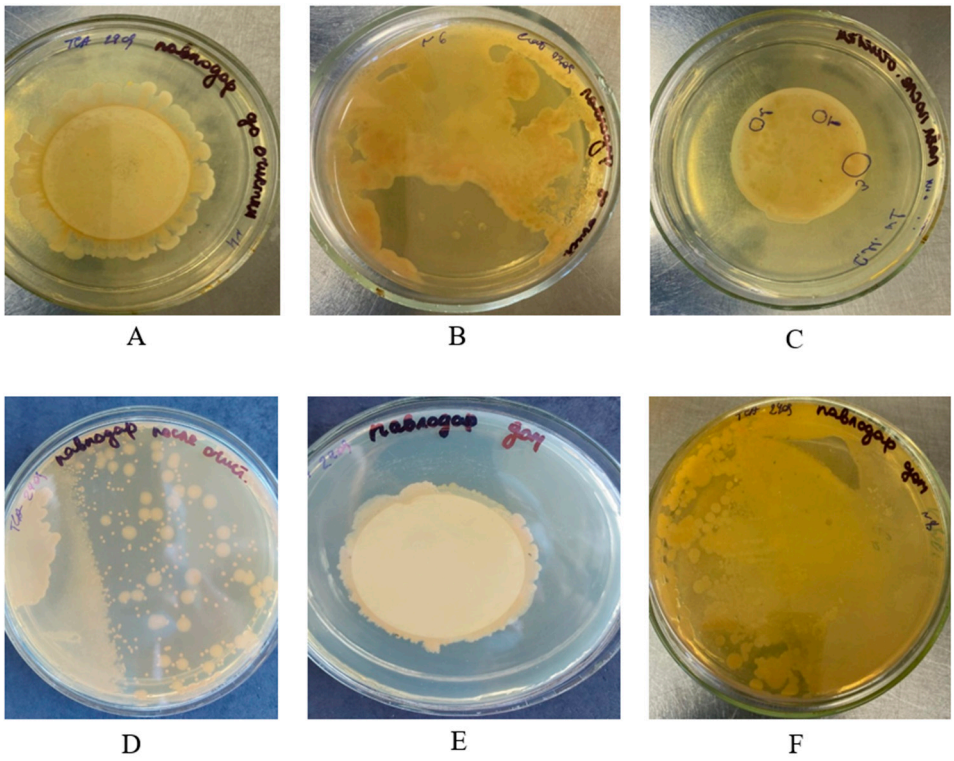

Figure 3. Determination of TMC index in water samples on tryptone soy agar: (**A**,**B**)—water before entering the water treatment plant—W1; (**C**,**D**)—water after treatment—W2; (**E**,**F**)—drinking tap water—W3.

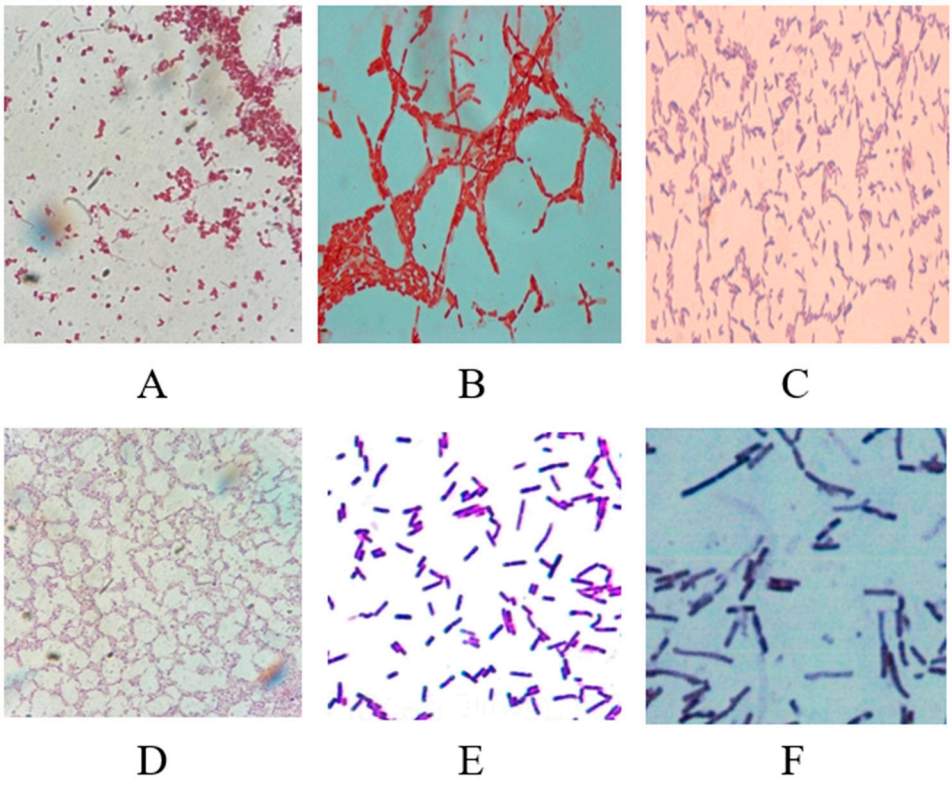

Figure 4. Microscope photographs of isolates, ×1000 magnification under immersion: (**A**,**B**)—water before entering the water treatment plant—W_1; (**C**,**D**)—water after treatment—W_2; (**E**,**F**)—drinking tap water—W_3.

Table 7. Results of microbiological tests of water samples (W1 = raw groundwater before treatment, W2 = after treatment, and W3 = delivered tap water).

Water Sample	Test Method			
	Oxidase Test	***Catalase Activity Test***	**NEFERM Test, %**	**Tinctorial Properties**
W_1	+	+	*Pseudomonas aeruginosa*—99.4	*Bacillus* spp., *Sarcina* spp.
W_2	+	+	*Pseudomonas aeruginosa*—99.4	*Bacillus* spp.
W_3	+	+	*Pseudomonas aeruginosa*—99.4 *Pseudomonas monteilii*—81.0	*Bacillus* spp.

Note: "+"—positive test reaction.

Contact of mucous membranes and skin lesions with water contaminated with *Pseudomonas aeruginosa* can cause urological and pulmonary infections, meningitis, and skin and eye diseases for humans [56]. The release of enzymes such as endotoxin, elastase, and collagenase by this bacterium aggravates the above diseases [57]. The presence of *Pseudomonas aeruginosa* bacteria in the water indicates that the water is affected by domestic wastewater and epidemics [58]. *Bacillus subtilis* is a spore-forming aerobic bacterium, a representative of the *Bacillus* genus, which can cause human food poisoning in large numbers, despite the ability to suppress the growth of pathogenic and conditionally pathogenic microorganisms, including *Salmonella*, *E. coli*, *Pseudomonads*, etc.

After water purification, TMC decreased by 3.6 times relative to water sampled before treatment but did not meet the standards, i.e., exceeded 6.62 MES (Table 6). It was found that in tap water samples, the TBN indicator increased by two times, indicating microbial contamination of the pipes through which water is delivered after treatment (Table 6). This may be due to the leaks in water pipes and transfer of various microorganisms from wastewater that tend to multiply in these conditions. The results consequently indicate a significant impact of industrial and domestic human activities, high wear and tear and low level of efficient operation of water supply networks, and population of certain microbiota in both groundwater and water supply systems, as well as possible presence of nutrients for microorganisms in the groundwater.

Previous studies on bacterial influence on water supply are sparse in Kazakhstan. Nurtazin et al. [40], however, studied the quality of drinking water in the Balkash district of Almaty. Besides high concentrations of chemicals, they found that TMC exceeded standards in some groundwater wells. They emphasized that water treatment systems in rural areas face several practical challenges. These include frequent breakdown of pumps, leakage from supply lines, and lack of funds. Similarly, stakeholders and users are often unaware of the benefits of treatment [59–62].

It should be noted that we used the total content of mesophilic aerobic and facultatively anaerobic microorganisms in 1 mL of the studied water. This indicator provided information about the state of the total microbial contamination of the water body. Therefore, a more complete diagnosis of the state of drinking water in the Maysky region is important for the further studies of dynamics of TMC and effects of water treatment on the tap water.

4. Conclusions

We investigated the groundwater and drinking water quality for the Maysky district in the Pavlodar region and compared the results to recommended levels. It was found that groundwater samples exceeded the standard turbidity index and recommended standard for manganese, which, however, were decreased after water treatment. Microbiological indicators of drinking water samples, however, showed a high level of bacterial contamination. Water treatment reduced the TMC indicator by 3.6 times. However, TMC still exceeded permissible levels in the tap water, indicating that the drinking water is sanitary and epidemiologically not acceptable. The high level of bacterial contamination in the drinking water of Maysky district merits further research, focusing on a broader

system analysis. General quality indicators of drinking water, however, including pH, total mineralization, and hardness, were within the recommended standards.

To the authors' knowledge, this is the first comprehensive study of pathogenic content of groundwater and tap water in the region. It has previously been established that less than 30% of Kazakhstan's population have access to safe water and more than 57.3% use groundwater from wells [63]. Also, it has been estimated that 50% of the population drink water that does not comply with international standards, e.g., bacteriological levels. At the same time, the infant mortality rate is six times higher as compared to the EU [64]. Thus, it is important to continuously monitor the groundwater quality to minimize health risks.

The obtained results can be further used in monitoring water supply systems in the Pavlodar region for comparison and in evaluation of anthropogenic and domestic pollution of drinking water in Central Asia and elsewhere in the world with similar climatic and socioeconomic conditions.

Future studies should examine a larger geographic area to increase the generalizability of the results and to account for seasonal variations in water quality that could affect levels of contaminants, such as metals and bacterial loads, and long-term monitoring will be needed to assess these potential variations.

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Abbreviations

CFU	Colony-forming unit
DDT	Dichlorodiphenyltrichloroethane
EU	European Union
GOST	State standards
MG	Methodological guidelines
MES	Recommended water quality standard of manganese
NGO	Non-governmental organization
OCB	Oxidase coliform bacteria
RK	Republic of Kazakhstan
TCA	Trichloroacetic acid
TCB	Thermotolerant coliform bacteria
TMC	Total microbial count
TSA	Tryptone soy agar
TTC	Triphenyltetrazolium chloride

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