

# Evaluation of Water Quality and Its Suitability for Drinking and Agriculture Use in Azerbaijan

M. M. Ahmedov<sup>1</sup>, F. Y. Humbatov<sup>1</sup>, V. S. Balaev<sup>1</sup>, A. Sardarli<sup>2,\*</sup>

<sup>1</sup>Institute of Radiation Problems, National Academy of Sciences of Azerbaijan, Azerbaijan

<sup>2</sup>First Nations University of Canada, Canada

**Abstract** Within the presented project, 29 water samples collected from different rivers of Azerbaijan were analysed to assess water quality and suitability for domestic, livestock, and irrigation usage. The pH of the river water varied from 7.79-9.34. Electrical conductivity (EC) of all collected water samples was within the range of 279-2738  $\mu\text{S}/\text{cm}$ . The cation chemistry indicated that out of 29 water samples, 16 samples showed a dominance sequence of  $\text{Ca} > \text{Na} > \text{Mg} > \text{K}$ , 5 samples showed a dominance sequence of  $\text{Na} > \text{Ca} > \text{Mg} > \text{K}$ , 6 samples showed a dominance sequence of  $\text{Ca} > \text{Na} > \text{K} > \text{Mg}$ , and 2 samples showed a dominance sequence of  $\text{Na} > \text{K} > \text{Ca} > \text{Mg}$ . The quality assessment showed relatively high values of EC, total dissolved solid (TDS),  $\text{HCO}_3^-$ ,  $\text{Cl}^-$ , and  $\text{SO}_4^{2-}$ , in several water samples, which would make them unsafe for drinking, livestock, and irrigation purposes. The uranium concentration lies in the range of 0.0429 -7.0355  $\mu\text{g}\cdot\text{L}^{-1}$  with an average of 0.6162  $\mu\text{g}\cdot\text{L}^{-1}$  in water samples from different rivers in Azerbaijan. The values of thorium on all sampling points was less than 0.01  $\mu\text{g}/\text{L}$ .

**Keywords** Azerbaijan, Inductively Coupled Plasma Mass Spectrometer (ICP-MS), Residual Sodium Carbonate (RSC), Sodium Absorption Ratio (SAR), Soluble Sodium Percent (SSR), Water quality management

## 1. Introduction

Water Quality Management is the surface water and groundwater quality control required to supply water with a required quality and for a specific use at any time. For water quality control, determining the physical, chemical and biological characteristics of a river is necessary. To achieve this objective, it is necessary to have the proper monitoring of water quality; however, even availability of the data is not enough for appropriate water quality management without proper interpretation [1, 2].

The capacity for water resources to meet various needs (domestic, livestock, and irrigation) has led to water sources being over-stressed, leading to the scarcity of quality water. Various reasons can be advanced to account for this water scarcity, including: population increase, climate change, environmental degradation, weak and inadequate institutional capacities, and growing poverty levels in the country [3]. The rapid population increase subjected the limited available water resources to significant pressure in the effort to meet various needs. Climate variability and

change has also significantly altered rainfall patterns and amounts, thereby effecting the replenishment rate of water bodies [3, 4].

Hydro-chemical analysis and subsequent water quality evaluation often reveals quality of water that is suitable for domestic consumption, agriculture, and industrial purposes, as well as aiding in the management of the water resource. Furthermore, it is possible to understand the change in water quality due to either rock water interaction or anthropogenic influence. Water often consists of seven major chemical ions which include cations  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$ ,  $\text{K}^+$  and anions  $\text{Cl}^-$ ,  $\text{HCO}_3^-$ ,  $\text{SO}_4^{2-}$ . Other parameters include pH, Colour, Turbidity, Free Carbon Dioxide and Total Dissolved Solid. These chemical parameters play a significant role in classifying and assessing water quality.

Determination of natural radionuclides such as U and Th in water samples are also important [5]. The natural isotopic composition of uranium consists of three isotopes:  $^{238}\text{U}$ ,  $^{235}\text{U}$  and  $^{234}\text{U}$ ; all of them are radioactive. The groups of uranium isotopes exist in Earth's crust with an abundance of  $4 \times 10^{-4}$  percent and are found in rocks and minerals such as granite, metamorphic rocks lignite, monazite sand, and phosphate deposits as well as in uranium minerals such as uraninite, carnotite, and pitchblende [5-7]. Uranium present in the Earth, is transferred to water, plants, food supplements, and then to human beings. Uranium nuclides emit alpha rays of high ionization power and therefore may be hazardous if inhaled or ingested in higher quantities.

\* Corresponding author:

asardarli@fnuniv.ca (A. Sardarli)

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Adverse health effects from natural uranium can be due to its radioactive and chemical properties. The radioactive effects from natural uranium are not substantial; however, chemically, it can be harmful to the kidneys with significant exposure. Uranium is a very reactive element readily combining with many elements to form a variety of complexes. The need for the estimation of uranium concentration in water is multifaceted; it is an important fuel for nuclear power reactors. Hydro geochemical prospecting for uranium is essential and the assessment of risk of health hazards due to high concentration of uranium in water is of the utmost significance [5-7].

Thorium is a naturally occurring radioactive metal that is found at low levels in soil, rocks, water, plants, and animals. Almost all naturally occurring thorium exists in the form of either radioactive isotope  $^{232}\text{Th}$ ,  $^{230}\text{Th}$ , or  $^{228}\text{Th}$ . There are more than 10 other thorium isotopes that can be artificially produced. Smaller amounts of these isotopes are usually produced as decay products of other radionuclides and as unwanted products of nuclear reactions. Studies have shown that inhaling thorium dust causes an increased risk of developing disease, including lung cancer and pancreatic cancer. Liver disease and some types of cancer have been found in people injected with thorium for the purpose of X-rays. Bone cancer is also a potential health effect due to the storage of thorium in bone [8].

In this article, we present the results of our studies on the water quality in Azerbaijan Republic. The water samples were collected from different rivers of the Azerbaijan Republic, and were analysed/compared with water quality standards for domestic, industrial, livestock, and irrigation usage.

**Geography.** The Azerbaijan Republic is one of three countries in the South Caucasus and has a territory of 86,600 km<sup>2</sup>. Azerbaijan borders Russia in the north for 289 km along the Samur River, 340 km with Georgia in the northwest, 766 km with Armenia in the west, 11 km with Turkey in the southwest, and 618 km with Iran in the south. The length of its Caspian Sea coastline from the Astara River to the Samur River is 825 km. The range of elevation within the Republic varies from 4,480 m. in the Major Caucasus Mountains (Bazarduzu crest) to -26.0 m (Caspian Sea level). The average altitude of the area is 384 m with 18 per cent of the area below sea level, 39.5 per cent between 0 and 500 m, 15.5 per cent between 500 and 1,000 m, and 27 per cent greater than 1,000 m [9]. Sharp changes of altitude due to the orographic structure of the Major and Minor Caucasus Mountains and the location of the Kur-Araz lowlands form the unique climate in the Republic. Climate conditions and relief of the area plays an important role in formation of the water resources of the Republic. As a predominantly mountainous country, Azerbaijan is surrounded by the Major Caucasus, Minor Caucasus, Talysh, and North Iranian Mountains. The Kur-Araz Lowland, between the Greater and Lesser Caucasus, stretches to the Caspian Sea in the eastern part of the country.

**Geology.** Azerbaijan has a unique tectonic environment (the Greater and Lesser Caucasus, Talysh Mts., Kur and Caspian Basins, etc.) that finds a corresponding reflection in the studied geophysical fields. Geological – geophysical data on the geological structure of Azerbaijan can shed light on the basic principles of evolution of the Earth, the distribution of economic minerals and seismic activity. Geodynamically, this region can be considered a consequence of the interaction of several microplates — fragments of the Afro-Arabian and Eurasian lithospheric plates [9].

The geological structure of Azerbaijan includes complex sedimentary, metamorphic and magmatic formations, representing wide stratigraphic expansion from the Cambrian to recent eras. Most deposits are well-characterized faunistically. Simultaneously, the same age deposits undergo serious lithofacial changes in space based on the different circumstances of their formation [10].

The Greater Caucasus, situated in the north of the country and stretching from the northwest to the southeast, protects the country from the direct influences of northern cold air masses. This mountain range leads to the formation of a subtropical climate on most of the foothills and plains of the country. Other mountain ranges surrounding the country also impact air circulation. The complexity of the landscape causes the non-uniform formation of climate zones and creates vertical climate zones.

Physiographic conditions and different atmosphere circulations admit 8 types of air currents including: continental, sea, arctic, and tropical currents of air that formulate the climate of the Republic. The maximum annual precipitation that falls in the Lenkoran is 1,600 to 1,800 mm and the minimum in Absheron is 200 to 350 mm. A maximum daily precipitation of 334 mm was observed at the Bilieser Station in 1955. [10].

Eight out of eleven existing climate types, including semi-desert, arid steppe, and mountain tundra. are present in the country. The annual average air temperature is approximately 14.6°C in the Kur-Araz lowlands and 0°C in the mountains. The absolute minimum temperature observed was -33.0°C (in Julfa and Ordubad) and an absolute maximum temperature of +46.0°C was again observed in Julfa and Ordubad. [10].

## 2. Method

**Sample collection and analysis.** During the sample collection, handling, and preservation, the standard procedures recommended by the EPA were followed to ensure data quality and consistency. In this study, 29 river water samples were collected from April 2014 to August 2014 (Table 1).

The water samples were collected after 30 minutes of pumping to avoid stagnant and contaminated water. The white plastic containers were rinsed out 3-4 times with the sample water. Then the containers were filled up to capacity and were immediately sealed to avoid exposure to air. After

collecting the samples, the containers were labelled for identification and brought to the laboratory.

The water samples were analysed in the laboratory “Physics and chemistry of harmful factors effecting the environment” (Institute of Radiation Problems, Azerbaijan National Academy of Sciences) analysed for pH, TDS, sodium ( $\text{Na}^+$ ), potassium ( $\text{K}^+$ ), calcium ( $\text{Ca}^{2+}$ ), magnesium

( $\text{Mg}^{2+}$ ), sulphate ( $\text{SO}_4^{2-}$ ), chloride ( $\text{Cl}^-$ ), and bicarbonate ( $\text{HCO}_3^-$ ). Among the analysed parameters,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ , and  $\text{Mg}^{2+}$  were determined by using a flame atomic absorption spectrometer. In the present investigations, uranium and thorium concentration in water samples have been measured using inductively coupled plasma mass spectrometry (ICP-MS) [11, 12].

**Table 1.** Water sampling points

№	Water source ID	Administrative Region	Source Coordinates	
			longitude	latitude
1	Kusarchay, Khural village	Kusar	48.10866335	41.29709412
2	Kudyalchay, Khinalik	Kuba	48.1279673	41.16852145
3	Kara chay, Karxun village	Kuba	48.31530395	41.14240538
4	Babachay, Cini cayla birlesme	Kuba	48.46050934	41.13296478
5	Jimichay, Konaqkend	Kuba	48.58331442	41.04327639
7	Valvalachay, Tengealti	Kuba	48.63059818	41.18875151
8	Davachichay, Agzibirjala	Shabran	48.84047442	41.16750301
9	Kızılchay, Juxurezeni village	Shabran	48.87998243	40.99982763
10	Gilgilchay, Yeni village	Siyazan	49.09019046	41.15700063
11	Atachay, Altiagac village	Khizi	48.96787541	40.87271841
12	Pirsaatchay, Konaq village,	Shamakhi	48.7102211	40.68944766
13	Aksu chay	Aksu	48.50326082	40.68127999
14	Girdimanchay, Eyyubeylik village	Ismayilli	48.251809	40.624743
15	Goychay, Cayqovushan village	Ismayilli	48.07362502	40.93569565
16	Vandamchay, Vandam village	Kabala	47.89829927	40.96156759
17	Damiraparanchay, Laza village	Kabala	47.9178228	41.03101183
18	Karachay (follow point of Damiraparan river to Turyanchay river)	Kabala	47.6183257	40.79411485
19	Tikanlichay, Abrikh village	Kabala	47.73820445	41.0336731
20	Turyanchay	Kabala	47.54845183	40.70954613
21	Ayrichay, Cuma village	Shaki	46.94797353	41.21434733
22	Kurmukchay, tag - bridge till to Ilistu village	Khakh	47.02424825	41.46070353
23	Hamamchay	Khakh	46.9957164	41.43154079
24	Akchay, follow point - bridge	Khakh	47.00652599	41.44977758
25	Karachay, Sabunchu and Alasgarli vilages	Zakatala	46.81917813	41.56938504
26	Katehkhchay, Ititala village	Balakan	46.3600146	41.58415095
27	Khram river	Kazakh	45.07474038	41.32833509
28	Kura river	Tovuz	45.79271913	41.07540642
29	Araks river	Saatli	48.344802	39.944839

### 3. Results and Discussion

Results of the geochemical analysis of 29 water samples were taken from rivers situated in the North of Azerbaijan and are present in Tables 2 and 4. Table 3 represents the range of change, the average of measured parameters, and the standards for humans, livestock, and irrigation.

As shown in Table 2, PH changes from 7.79 to 9.34 and has the average of 8.46. For all measured water samples, pH was greater than 7 and were alkaline water samples. Out of

29, 18 samples have  $\text{pH} < 8.5$  and they may be used as drinkable water. For 10 samples, pH was less than 8.4; therefore, they are suitable for irrigation but for all measured samples, pH was higher than 7.5 and these water sources are not suitable for use as livestock drinking water.

Electroconductivity of all measured samples changed from  $279 \mu\text{S}/\text{cm}$  till  $2738 \mu\text{S}/\text{cm}$  and had the average of  $483 \mu\text{S}/\text{cm}$ . As shown in Table 2, only two samples' electroconductivity has a value higher than  $750 \mu\text{S}/\text{cm}$ . Therefore, according to the standards for the

electroconductivity [13], all samples are suitable for drinking purpose, except the samples from points 10 and 29. TDS – which is equal to the sum of all dissolved ions in water, changed in the range of 166mg/L-4047mg/L and has the average of 522mg/L. Comparing the received TDS results with the standards showed that 6 water samples were not suitable for human drinking and livestock drinking purpose, while all samples complied to requested standards and may be used in irrigation. Anions and cations analysis results in samples that demonstrate that,  $\text{HCO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$ , and  $\text{Ca}^{2+}$  ions dominate investigated areas. Comparison of the cation concentrations of investigated water samples showed that 16 water samples have the  $\text{Ca} > \text{Mg} > \text{Na} > \text{K}$  sequence, 5 water samples have the  $\text{Na} > \text{Ca} > \text{Mg} > \text{K}$  sequence, 6 water samples have the  $\text{Ca} > \text{Na} > \text{Mg} > \text{K}$  sequence, and 2 water samples have the  $\text{Na} > \text{K} > \text{Ca} > \text{Mg}$  sequence of cations. This means that Na ions prevail over K ions and Ca ions prevail over Mg ions for all sequences of cations. It is known that, observation of the existence of Ca and Mg in water samples is the result of the weathering of crystalline dolomitic limestones and Ca-Mg silicates (amphiboles, pyroxenes, olivine, biotite and others [4, 12, 14]. The origin of Na and K in water may be atmospheric deposition, evaporate dissolution, and silicate as albite, anorthite, orthoclase and microcline weather [4, 13, 15-17]. As it is noted in [4], if Na concentration in water is less than 50mg/L, it is not dangerous for human drinking and if it is less than 920 mg/L it is not dangerous for irrigation. For investigated water samples, the concentration of sodium changes in the range of 4.56 - 820 mg/L and has the average of 72.84mg/L. As shown in the Table 2, all water samples are suitable for irrigation and 25 samples are suitable for human drinking. 4 samples have sodium concentration higher than 50mg/L and are not suitable for human drinking [18]. K concentration obtained for water samples, changes from 0.979 mg/L to 17.64mg/L and has the average of 4.08mg/L. Comparison of potassium concentration in investigated water samples with standards (Table 3) shows that, for all samples K concentration is less than 100mg/L and these waters are suitable for drinking. 15 water sources are problematic for irrigation. The concentration of Ca for measured samples changes from 23.68 mg/L to 148 mg/L and has the average of 48.74 mg/L. If the concentration of Ca in the water is less than 800 mg/L, it has no danger for irrigation. Therefore, all measured water samples can be implemented for irrigation and using water of this standard for irrigation is not problematic for soil [4]. Considering the opinion of authors [4, 13, 16] we can note that all water samples are suitable for human drinking, except one sample (sample from point 29). The concentration of Mg for investigated samples changes in the range of 3.99 mg/L – 240 mg/L, and has the average of 25.63 mg/L. As shown in Table 3, if the concentration of Mg in water is less than 120 mg/L, this source has no danger for irrigation. Only one of the measured samples is not suitable for irrigation according to the Mg results. For human drinking water, the maximum

acceptable concentration of Mg is 30 mg/L [13]. Therefore, all measured samples, except 4 samples, may be used as human drinking water.  $\text{HCO}_3^-$  anion concentration for investigated river waters changes in the range of 97 mg/L – 720 mg/L and has the average of 173 mg/L. Only 3 samples have more than 200 mg/L  $\text{HCO}_3^-$  anion concentration and cannot be used as human and livestock drinking water. The  $\text{HCO}_3^-$  anion concentration of 26 samples complies to the requested standards [13] and they are suitable for being used use as drinking water. But it has to be noted that, these samples are not suitable for irrigation, according to the  $\text{HCO}_3^-$  anion concentration rate. The concentration of  $\text{Cl}^-$  ions contained in the water samples collected from rivers of Azerbaijan varied from 0.31 to 667 mg/L with the average of 43.2 mg/L (Table 2). From investigated samples, 2 samples are not suitable for human and livestock drinking and one sample is not suitable for irrigation.

The concentration of  $\text{SO}_4^{2-}$  ions in the measured water samples varies from 25 mg/L to 1676 mg/L with the average of 198 mg/L. Water for agriculture usage purposes has a permissible level equal to 20 mg/L for  $\text{SO}_4^{2-}$  ions, according to Tables 2 and 3. Therefore, not all water samples from the investigation areas can be used for irrigation. For human and livestock drinking water, recommended levels are 200 mg/L and <250 mg/L according to [4, 11]. Therefore, all investigated water samples, except for 4 samples are suitable for usage. The suitability of water for irrigation purposes depends on its mineral constituents. Several criteria for judging its suitability have been proposed [19, 20]. Irrigation water containing large amounts of sodium is of special concern due to sodium's effects on the soil and its potential to pose a sodium hazard. The high concentration of sodium in irrigation water may negatively affect the soil structure and decrease the soil hydraulic conductivity in fine-textured soil. The degree to which sodium will be absorbed by soil is a function of the amount of sodium to divalent cations (Ca and Mg) and is regularly stated by the sodium adsorption ratio (SAR) [21].

The Sodium Absorption Ratio (SAR), can be calculated from the ratio of sodium to calcium and magnesium [22].

The equation is expressed as follows:

$$\text{SAR} = \frac{\text{Na}^+}{\sqrt{(\text{Ca}^{2+} + \text{Mg}^{2+})/2}}$$

where, all the ions are expressed in meq/L.

Variation from 0.156 to 10.4 with an average value of 1.53 (Table 4). Sodium Absorption Ratios for all water samples (except the sample from Devehichay river) are less than 10.

The potential for sodium hazard increases in waters with higher sodium adsorption ratios (SAR) values. The sodium absorption ratio (SAR) content in the study area has shown and indicate excellent quality for irrigation; the samples fall in the excellent (S1) category while Sodium Absorption Ratios for water sample from Devehichay river are within the range of 10-18 and indicate good quality for irrigation; the samples fall in the good (S2) category (Table 4).

**Table 2.** Data for investigated water parameters

№	pH	Conductivity	TDS	Chloride (Cl <sup>-</sup> )	Sulphate (SO <sub>4</sub> )	Bicarbonate	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)
		uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	8.39	335.8	215	0.92	77	107	7.215	1.35	44.06	11.248
2	8.38	305	202	0.49	72	100	6.363	1.16	40.08	9.238
3	8.5	350.1	203	0.53	55	126	6.1485	1.65	41.48	12.062
4	8.46	445.1	293	1.2	106	144	15.237	3.26	44.31	19.1905
5	8.53	414.3	271	1.3	86	144	14.376	3.91	39.03	17.22
7	8.47	418	278	1.6	101	134	16.656	3.72	39.39	18.105
8	8.24	374.5	4047	667	1676	720	819.75	14.37	70.4	240.08
9	8.65	663.4	928	20	492	224	197.08	11.63	31.15	38.227
10	8.28	786.6	1104	83	516	185	234.12	10.98	47.6	34.587
11	9.01	490.1	578	25	150	325	89.2	17.64	59.2	26.88
12	8.33	581.5	344	4.7	111	190	55.8	5.13	42.66	12.14
13	8.39	398.4	509	11.3	190	195	71.61	1.91	58.02	18.489
14	8.41	456.5	402	20	180	124	38.682	3.71	46.88	22.676
15	8.53	309.5	166	0.76	31	148	7.347	2.10	35.86	11.214
16	8.55	311	188	0.39	41	112	4.563	1.72	39.03	7.9785
17	8.47	383.5	252	0.38	88	115	6.3165	1.21	51.8	11.128
18	8.29	402.5	295	2.7	61	200	12.428	1.92	56.61	15.384
19	8.54	391.1	255	0.31	92	120	4.763	1.65	54.38	9.672
20	8.26	374.8	289	4.3	76	166	15.168	2.29	49.23	16.215
21	8.9	345.4	270	12	108	98	22.628	4.09	23.68	20.064
22	8.44	334.5	337	0.82	147	133	15.195	2.13	59.4	15.615
23	8.57	294.3	168	0.66	29	134	16.587	1.37	32.52	3.989
24	8.58	340.2	188	0.39	57	132	5.381	1.76	45.525	7.9425
25	8.25	305.6	231	1.5	101	110	8.718	1.35	50.86	9.172
26	8.45	279.1	197	13.8	25	143	13.833	0.98	40.425	6.5475
27	7.83	310.2	212	6.3	44	110	14.664	1.50	30.7	7.69
28	7.79	375	233	10.5	61	124	18.258	1.53	42.18	8.212
29	9.34	2738	1955	319	780	285	301.3	8.16	148.16	86.656
MIN	7.79	279.1	166	0.31	25	98	4.563	0.98	23.68	3.989
MAX	9.34	2738	4047	667	1676	720	819.75	17.64	148.16	240.08
MEAN	8.46	482.64	521.79	43.24	198.32	173.14	72.84	4.08	48.74	25.63

**Table 3.** Geochemical parameters in the water samples compared to desirable standard values for drinking, livestock and irrigation use

Parameters	Range	Mean	Max. desirable value for drinking water	Max. desirable value for livestock drinking water	Max. desirable value for irrigation
pH	7.79-9.34	8.46	7.0-8.5	6.8-7.5	6.0-8.4
EC(μS/cm)	279-2738	483	750	-	-
TDS(mg/L)	166-4047	522	500	<500	-
HCO <sub>3</sub> <sup>-</sup> (mg/L)	97-720	173	200	<400	92
SO <sub>4</sub> <sup>-</sup> (mg/L)	25-1676	198	200	<250	20
Cl <sup>-</sup> (mg/L)	0.31-667	43.2	250	-	142
Ca <sup>2+</sup> (mg/L)	23.68-148	48.74	75	-	800
Mg <sup>2+</sup> (mg/L)	3.99-240	25.63	30	-	120
Na <sup>+</sup> (mg/L)	4.56-820	72.84	50	-	920
K <sup>+</sup> (mg/L)	0.979-17.64	4.08	100	-	2.0

**Table 4.** The results of the geochemical analysis of water samples collected from rivers of Azerbaijan

№	Na, meq/L	K, meq/L	Ca, meq/L	Mg, meq/L	Cl-, meq/L	SO <sub>4</sub> , meq/L	Bicarbonate, meq/L	SAR	% Sodium	RSC	KR
1	0.3137	0.0345	2.203	0.9373	0.0259	1.6042	1.7541	0.2503	9.9809	-1.3862	0.0999
2	0.2767	0.0298	2.004	0.7698	0.0138	1.5000	1.6393	0.2349	9.9486	-1.1345	0.0997
3	0.2673	0.0424	2.074	1.0052	0.0149	1.1458	2.0656	0.2154	9.1398	-1.0136	0.0868
4	0.6625	0.0836	2.216	1.5992	0.0338	2.2083	2.3607	0.4797	16.3581	-1.4541	0.1737
5	0.6250	0.1002	1.952	1.4350	0.0366	1.7917	2.3607	0.4803	17.6389	-1.0258	0.1846
7	0.7242	0.0954	1.970	1.5088	0.0451	2.1042	2.1967	0.5491	19.0699	-1.2815	0.2082
8	35.6413	0.3684	3.520	20.0067	18.7887	34.9167	11.8033	10.3917	60.4835	-11.7234	1.5149
9	8.5687	0.2982	1.558	3.1856	0.5634	10.2500	3.6721	5.5642	65.1501	-1.0710	1.8066
10	10.1791	0.2816	2.380	2.8823	2.3380	10.7500	3.0328	6.2754	66.5314	-2.2295	1.9344
11	3.8783	0.4522	2.960	2.2400	0.7042	3.1250	5.3279	2.4052	45.4382	0.1279	0.7458
12	2.4261	0.1314	2.133	1.0117	0.1324	2.3125	3.1148	1.9348	44.8516	-0.0299	0.7715
13	3.1135	0.0491	2.901	1.5408	0.3183	3.9583	3.1967	2.0892	41.5889	-1.2450	0.7010
14	1.6818	0.0952	2.344	1.8897	0.5634	3.7500	2.0328	1.1559	29.5648	-2.2009	0.3973
15	0.3194	0.0538	1.793	0.9345	0.0214	0.6458	2.4262	0.2735	12.0369	-0.3013	0.1171
16	0.1984	0.0440	1.952	0.6649	0.0110	0.8542	1.8361	0.1735	8.4791	-0.7803	0.0758
17	0.2746	0.0310	2.590	0.9273	0.0107	1.8333	1.8852	0.2071	7.9942	-1.6321	0.0781
18	0.5403	0.0493	2.831	1.2820	0.0761	1.2708	3.2787	0.3768	12.5398	-0.8338	0.1314
19	0.2071	0.0424	2.719	0.8060	0.0087	1.9167	1.9672	0.1560	6.6088	-1.5578	0.0587
20	0.6595	0.0587	2.462	1.3513	0.1211	1.5833	2.7213	0.4776	15.8501	-1.0914	0.1730
21	0.9838	0.1049	1.184	1.6720	0.3380	2.2500	1.6066	0.8233	27.5994	-1.2494	0.3445
22	0.6607	0.0547	2.970	1.3013	0.0231	3.0625	2.1803	0.4521	14.3452	-2.0909	0.1547
23	0.7212	0.0351	1.626	0.3324	0.0186	0.6042	2.1967	0.7288	27.8573	0.2383	0.3682
24	0.2340	0.0451	2.276	0.6619	0.0110	1.1875	2.1639	0.1930	8.6753	-0.7742	0.0796
25	0.3790	0.0345	2.543	0.7643	0.0423	2.1042	1.8033	0.2948	11.1143	-1.5041	0.1146
26	0.6014	0.0251	2.021	0.5456	0.3887	0.5208	2.3443	0.5309	19.6197	-0.2226	0.2343
27	0.6376	0.0384	1.535	0.6408	0.1775	0.9167	1.8033	0.6113	23.7026	-0.3726	0.2930
28	0.7938	0.0393	2.109	0.6843	0.2958	1.2708	2.0328	0.6717	22.9728	-0.7605	0.2842
29	13.1000	0.2094	7.408	7.2213	8.9859	16.2500	4.6721	4.8437	47.6377	-9.9572	0.8955
MIN								0.1560	6.6088	-11.7234	0.0587
MAX								10.3917	66.5314	0.2383	1.9344
MEAN								1.5300	25.0992	-1.7342	0.4331

**Soluble Sodium Percent (SSP)** is also used to evaluate sodium hazard. SSP is defined as the ratio of sodium to the total cations. Water with a SSP greater than 60 [22, 23]:

$$SSP = \frac{\text{Soluble}(Na^+ + K) \cdot 100}{\text{Total cations concentration}}$$

where, all the ionic concentrations are expressed in meq/L.

Soluble Sodium Percent (SSP) values less than 50 or equal to 50 indicate good quality water and those more than 50 indicate water quality unsuitable for irrigation. The values of Soluble Sodium Percent (SSP) range from 6.61 to 66.53 and average 25.1. 96.6% Soluble Sodium Percent (SSP) for water in test areas is less than 50 and indicates good quality water for irrigation purposes while remaining 3.4% more than 50% and may result in sodium accumulations that will cause a breakdown in the soil's physical properties (Table 5).

**KR:** Sodium measured against  $Ca^{2+}$  and  $Mg^{2+}$  is used to

calculate Kelley's ratio. The formula used in the estimation of Kelley's Ratio [19, 24]

$$KR = Na^+ / (Ca^{2+} + Mg^{2+})$$

A Kelley's Ratio (KR) of more than one indicates an excess level of sodium in waters. Hence, waters with a Kelley's Ratio less than one are suitable for irrigation, while those with a ratio of more than one are unsuitable for irrigation. The values of Kelley's Ratio (KR) ranges from 0.059 to 1.93 and averages 0.43. 89.7% of Kelley's Ratio values for the water of the test area are less than 1 and indicate good quality water for irrigation purpose while remaining 10.3% more than 1 and indicate water unsuitable for irrigation (Table 5).

**Residual sodium carbonate (RSC):** The Residual Sodium Carbonate (RSC) was also calculated and used for irrigation water quality assessment. This parameter is used

for the assessment of the effect of carbonate and bicarbonate on the quality of water for agricultural purposes. RSC is calculated as follows:

$$\text{RSC} = (\text{CO}_3^{2-} + \text{HCO}_3^-) - (\text{Ca}^{2+} + \text{Mg}^{2+})$$

where, all the ions are expressed in meq/L.

**Table 5.** Classification of water based on SAR, KR, SSP and RSC

Parameter	Range	Water Class	Samples	% age
SAR	<10	Excellent (S1)	28	96.6
	10-18	Good (S2)		
	18-26	Doubtful (S3)	1	3.4
	>26	Unsuitable (S4)		
SSP	<50/>50	Good/Bad	26/3	89.7/10.3
KR	<1/>1	Good/Unsuitable	26/3	89.7/10.3
RSC	<1.25	Good	29	100
	1.25-2.5	Doubtful		
	>2.5	Unsuitable		

The potential for sodium hazard increases as RSC increases, and much of the calcium and the magnesium are precipitated out of solution when water is applied to the soil. Salts become concentrated when soil dries out, as less soluble ions (as  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ ) tend to precipitate out of solution [25, 26, 27]. The values of RSC ranges from -11.72 to 0.283 meq/L with average value of -1.734 (Table 1). In the test area, the RSC is negative (with the exception of 2 samples) showing that  $\text{Na}^+$  build-up is unlikely, with practically no  $\text{Na}^+$  hazard and therefore classified as suitable for irrigation. Water having less than or equal to 1.25 epm of RSC is safe for irrigation purposes.

The water having a RSC from 1.25 to 2.5 epm is marginally suitable for irrigation purposes, whereas water having more than 2.5 epm of RSC is not suitable for irrigation purposes. Based on RSC values, all the samples of the test area have values less than 1.25 epm and are safe for irrigation (Table 5).

**Table 6.** Uranium and Thorium Determination in Water Samples taken from rivers of Azerbaijan

No	Water source ID	Administrative Region	U238 ug/L	Th232 ug/L
1	Kusarchay, Khural village	Kusar	0.1473	<0.01
2	Kudyalchay, Khinalik	Kuba	0.0429	<0.01
3	Kara chay, Karxun village	Kuba	0.0791	<0.01
4	Babachay, Cini cayla birlesme	Kuba	0.1479	<0.01
5	Jimichay, Konaqkend	Kuba	0.1920	<0.01
7	Valvalachay, Tengealti	Kuba	0.1802	<0.01
8	Davachichay, Agzibirjala	Shabran	0.4187	<0.01
9	Kızılchay, Juxurezeni village	Shabran	0.6097	<0.01
10	Gilgilchay, Yeni village	Siyazan	1.4216	<0.01
11	Atachay, Altiagac village	Khizi	0.8617	<0.01
12	Pirsaatchay, Konaq village,	Shamakhi	1.1589	<0.01
13	Aksu chay	Aksu	1.5192	<0.01
14	Girdimanchay, Eyyubeylik village	Ismayilli	0.4573	<0.01
15	Goychay, Caygovushan village	Ismayilli	0.1230	<0.01
16	Vandamchay, Vandam village	Kabala	0.0814	<0.01
17	Damiraparanchay, Laza village	Kabala	0.0495	<0.01
18	Karachay (Damiraparan to Turyanchay)	Kabala	0.2446	<0.01
19	Tikanlichay, Abrikh village	Kabala	0.0500	<0.01
20	Turyanchay	Kabala	0.2313	<0.01
21	Ayrichay, Cuma village	Shaki	0.3447	<0.01
22	Kurmukchay, tag - bridge till to Ilisu village	Khakh	0.0944	<0.01
23	Hamamchay	Khakh	0.0483	<0.01
24	Akchay, follow point - bridge	Khakh	0.0794	<0.01
25	Karachay, Sabunchu and Alasgarli vilages	Zakatala	0.1060	<0.01
26	Katehkhchay, Ititala village	Balakan	0.1049	<0.01
27	Khran river	Kazakh	0.7085	<0.01
28	Kura river	Tovuz	0.7158	<0.01
29	Araks river	Saathl	7.0355	<0.01
MIN			0.0429	
MAX			7.0355	
MEAN			0.6162	

The values of uranium and thorium in samples are present in Table 6. The values of thorium on all sampling are less than 0.01  $\mu\text{g/L}$ . The values of uranium in samples range from 0.0429  $\mu\text{g/L}$  in Kudyalchay River, Khinalik to 7.0355  $\mu\text{g/L}$  in Araks River, and an average value of 0.6162  $\mu\text{g/L}$  in Saatli River. The EPA and WHO have set a Maximum Contaminant Level for uranium at the level of 30 micrograms per litre, based on the chemical toxicity of uranium. The current Canadian guideline for uranium in drinking water is a MAC (Maximum acceptable concentration) of 20  $\mu\text{g/L}$ . The Indian Atomic Energy Regulatory Board has set a limit for uranium in drinking water of 60  $\mu\text{g/L}$ . The measured uranium content in our water samples has been found to be less than the limit of 30  $\mu\text{g/L}$  recommended by the World Health Organization and US Environmental Protection Agency [24].

#### 4. Conclusions

Rivers' waters were sampled and analysed for their hydrochemical characteristics and an evaluation of the water quality for drinking and irrigation purposes was made. The cation chemistry indicated that out of 29 water samples, 16 samples showed a dominance sequence of  $\text{Ca} > \text{Na} > \text{Mg} > \text{K}$ , 5 samples showed a dominance sequence of  $\text{Na} > \text{Ca} > \text{Mg} > \text{K}$ , 6 samples showed a dominance sequence of  $\text{Ca} > \text{Na} > \text{K} > \text{Mg}$ , and 2 samples showed a dominance sequence of  $\text{Na} > \text{K} > \text{Ca} > \text{Mg}$ . SAR values and the sodium percentage ( $\text{Na} \%$ ) in test locations indicate that the majority of the river water samples are suitable for use in irrigation. Hydrochemical analysis demonstrates that the samples are typical of shallow fresh waters. The EC values in all eleven rivers range from 279-2738  $\mu\text{S/cm}$ . Similarly, the pH value of all the collected samples range from 7.79-9.34, comparative to the recommended WHO guideline range of 6.5-8.5 for drinking water. The anion chemistry of the analysed water samples shows  $\text{HCO}_3^-$ ,  $\text{Cl}^-$ , and  $\text{SO}_4^{2-}$  to be the dominant anions at the test area. With respect to  $\text{HCO}_3^-$  and  $\text{SO}_4^{2-}$  content, all water samples were found suitable for drinking (except for 3 samples) and livestock usage. However, all water samples exceeded the recommended limit for irrigation. With regards to  $\text{Cl}^-$ , all water samples under the investigation area were found suitable for drinking (except for 2 samples from stations 8 and 29) and livestock purpose. The rest of the samples were found unsuitable for irrigation usage.

From the present observations, it can be concluded that the concentration of uranium level varies considerably from natural source to natural source and place to place. The range of uranium in the water samples from different rivers varies from 0.0429 to 7.0355  $\mu\text{g}\cdot\text{L}^{-1}$  with an average value of 0.6162  $\mu\text{g}\cdot\text{L}^{-1}$ . The measured thorium content in all water samples is less than 0.01  $\mu\text{g/L}$ . However, the uranium concentration in all the water samples is well below the recommended limit of 30  $\mu\text{g}\cdot\text{L}^{-1}$ . The daily intake of uranium through drinking water in the region is much less

than the tolerable intake limit. The annual effective dose from drinking water samples of these areas is in the range of 0.02-37.78  $\mu\text{Sv}$ , which is safe from the health hazard point of view.

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