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Seasonal Changes in Water Quality of Rivers and Ground Water in Karakalpakstan, Uzbekistan

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Abstract: The study investigates the seasonal changes in the chemical characteristics of river water and ground water in Karakalpakstan, Uzbekistan from August 2008 to September 2010. The results indicate that major ion concentrations of ground water were higher than Amu-Darya river water, and NO_3^{2-} concentration in winter were higher than other seasons.

However river water and ground water showed different trends. Particularly, NO_3^{2-} concentrations of ground water in the winter season of 2009 were higher than 2010. In summer 2008, water volumes of Amu-Darya were extra lower than other years, which possibly resulted in higher concentrations for this particular summer.

Key Words: Central asia, Seasonal change, Uzbekistan, Water quality

1. Introduction

Access to safe drinking water is essential to the health of the human beings. It is a component of the effective health protection policy, and it is also a development issue at national, regional and local levels.

Aral Sea Problems is one of the big environmental problems in the world. The Aral Sea is an inland lake and has 2 inflow rivers, Amu-Darya and Syr-Darya. The decrease in Aral Sea area was caused by the large scale irrigated agriculture which started in the 1950's, especially in the Aral Sea basin. As a result, many villages were built in the area and people started producing rice, cotton, wheat, and vegetables.

However, after the Soviet era, Amu-Darya and Syr-Darya became international rivers and water problems had occurred in upstream countries and downstream countries. Karakalpakstan is located in the most downstream along Amu-Darya and experiences drought once every several years.

Ground water or river water is their main source of drinking water in this area. The gradual climate change over the centuries was accelerated by the Aral Sea ecological disaster of the late 20th century in Aral Sea basin, especially Karakalpakstan. By determining EC values, Papa *et. al.* (2004) conducted research on the effect of salinization caused by large-scale irrigation. Crosa *et. al.* (2006a) analyzed pesticides in the Amu-Darya basin and reported about identifying compounds with a high risk of contamination. We investigated about the uranium concentration of drinking water in the villages of the central parts of Uzbekistan and Kazakhstan (2006) and found that the results exceeded the guideline level for drinking water prescribed by WHO (2008).

However no work has been carried out on the seasonal changes in water quality. Therefore, we investigated the seasonal changes in chemical characteristics of river water and ground water and compared between drought years and normal years in Karakalpakstan. However, our study did not include the seasonal change of water quality. Therefore, we investigated the seasonal changes in chemical characteristics of river water and ground water in Karakalpakstan, and compared with streamflow and precipitation.

2. Materials and Methods

Water samples were collected from river water and ground water from 2008 to 2010. At G-staiton and A-station, water samples were collected every month from 2008 August to September 2010. In Karakalpakstan, ground water samples and river water samples were every month from August 2008 to 2010.

The sampling sites are shown in **Figure 1**. The position of each sampling spot was determined by using an eTrex Legend portable Global Positioning System (GARMIN Ltd., Japan).

Water samples were filtered through a 0.45 μm Membrane filter (DISMIC 25AS020AS, ADVANTEC Corporation) and collected in polypropylene bottles. PO_4^{3-}, Cl^-, NO_3^{2-}, SO_4^{2-}, Na^+, NH_4^+, K^+, Mg^{2+} and Ca^{2+}, and concentrations were determined using an LCA-10A ion chromatographic analyzer (Shimadzu Corporation, Japan). Finally, accuracy and

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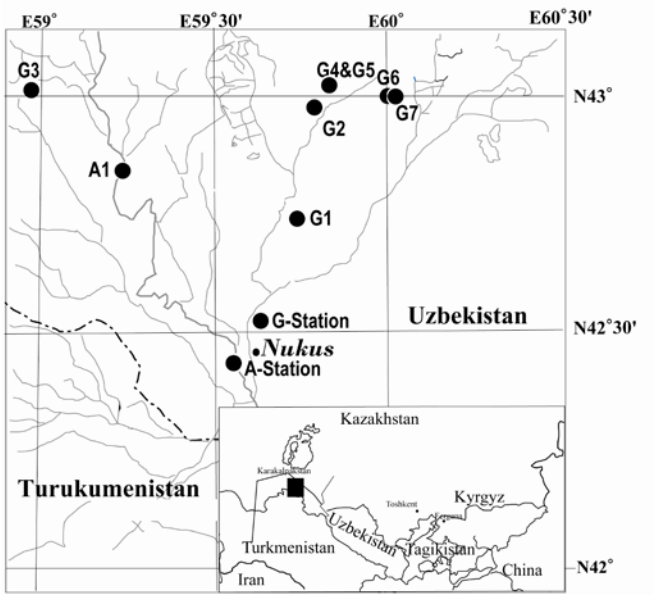

Fig. 1. Sampling sites in Karakalpakstan, Uzbekistan.

Table 1. Major ion and nutrient concentrations in Karakalpakstan. Notes: n.d.: not detected

	Collected year	PO_4^{3-} mg/L	Cl^- mg/L	NO_3^{2-} mg/L	SO_4^{2-} mg/L	Na^+ mg/L	NH_4^+ mg/L	K^+ mg/L	Mg^{2+} mg/L	Ca^{2+} mg/L	Typ of water
G1	2008	n.d.	878.72	n.d.	1591.16	597.40	7.90	17.65	290.56	241.04	Grand water
G2	2008	4.93	238.41	6.14	405.27	201.52	2.70	40.81	37.65	89.11	Grand water
G3	2008	12.87	227.58	n.d.	486.86	229.91	n.d.	5.54	66.95	84.87	Grand water
G4	2008	7.5	350.41	5.28	754.11	299.14	0.85	n.d.	89.53	191.91	Grand water
G5	2008	6.51	397.27	n.d.	1089.30	279.45	2.56	4.41	139.36	314.69	Grand water
G6	2008	5.93	309.16	n.d.	759.94	261.20	n.d.	5.97	96.50	174.64	Grand water
G7	2008	5.84	176.78	n.d.	352.32	138.28	1.11	4.28	42.42	96.63	Grand water
A1	2010	n.d.	4.24	n.d.	6.83	6.18	2.44	2.73	3.28	7.08	River water

precision of the analytical methods used here were tested using Anion Mixed Standard Solution IV and Cation Mixed Standard II for ion chromatography (Kanto Chemical Co., Japan) and shown to be satisfactory with 2-5% error.

3. Results and Discussion

3.1. Major ion and nutrient concentrations

Major ion and nutrient concentrations (PO_4^{3-}, Cl^-, NO_3^{2-}, SO_4^{2-}, Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}) are shown in **Table 1**.

Major ion concentrations and nutrient of Amu-Darya followed the same trend in this area. However, the results were different for ground waters. With the exception of G3, NH_4^{2-} was identified in the other ground water supplies. This result indicates that ground waters were contaminated by sewage.

Table 2. Seasonal change of Amu-Darya. Notes: n.d.: not detected

	PO_4^{3-} mg/L	Cl^- mg/L	NO_3^{2-} mg/L	SO_4^{2-} mg/L	Na^+ mg/L	NH_4^+ mg/L	K^+ mg/L	Mg^{2+} mg/L	Ca^{2+} mg/L
Aug-08	4.16	88.23	1.05	159.74	69.38	0.405	1.98	10.76	63.89
Sep-08	3.38	125.75	n.d.	256.45	96.09	0.718	4.56	29.96	80.55
Oct-08	5.63	206.16	n.d.	410.76	172.23	0.122	5.32	48.96	103.81
Nov-08	4.53	237.40	n.d.	495.78	202.89	0.095	5.37	61.05	126.69
Dec-08	4.45	159.78	1.70	321.54	133.31	n.d.	4.47	40.51	101.81
Jan-09	5.76	228.02	1.88	434.24	185.34	n.d.	5.09	53.44	121.40
Feb-09	4.53	187.51	2.50	346.14	151.92	0.095	4.09	44.63	106.09
Mar-09	4.38	271.30	2.48	526.11	231.16	n.d.	5.99	68.04	129.60
Apr-09	5.46	348.22	2.07	645.24	295.91	n.d.	7.48	83.94	150.74
May-09	5.35	238.53	2.39	438.49	202.50	0.114	3.46	54.90	121.63
Jun-09	4.44	129.73	2.58	254.43	107.52	0.092	4.92	26.57	87.73
Aug-09	3.16	94.33	n.d.	196.12	79.14	n.d.	3.73	22.19	72.18
Sep-09	n.d.	55.93	n.d.	12.52	423.96	130.150	2.65	6.69	67.83
Oct-09	n.d.	143.5	6.50	282.63	104.12	0.451	5.37	30.52	88.20
Nov-09	n.d.	184.24	7.60	346.62	134.26	0.668	4.93	40.18	107.46
Dec-09	n.d.	201.16	7.87	362.77	143.18	0.782	5.35	41.25	103.99
Jan-10	n.d.	201.14	7.25	311.02	135.71	0.664	4.12	34.84	100.20
Feb-10	n.d.	227.91	6.29	377.91	156.54	0.323	3.97	40.76	106.13
Mar-10	n.d.	247.48	4.38	427.19	169.87	0.390	5.22	47.89	121.57
Apr-10	n.d.	234.81	6.46	343.66	154.80	0.534	4.68	36.80	108.02
May-10	n.d.	221.56	5.47	339.05	144.05	0.487	5.98	33.36	108.83
Jun-10	n.d.	107.01	3.31	199.82	82.97	0.641	5.15	23.80	87.05
Jul-10	n.d.	98.28	2.04	160.08	71.76	1.039	4.62	20.37	80.35
Aug-10	n.d.	69.13	n.d.	143.61	59.18	1.270	3.55	20.00	67.79
Avarage	4.60	184.83	4.1	338.24	142.78	0.49	4.76	39.77	101.99
Max.	5.76	348.22	7.87	645.24	295.91	1.27	7.48	83.94	150.74
Mim.	3.16	69.13	1.05	143.61	59.18	0.09	1.98	10.76	63.89

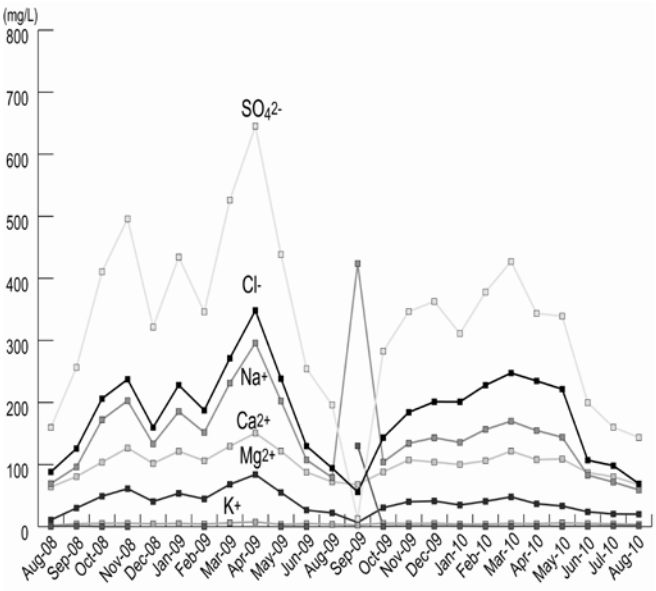

Fig. 2. Seasonal change of ion concentration of Amu-Darya water.

3.2. Seasonal changes in water quality of river and ground water

We collected Amu-Darya river water from A-station and ground water from B-station. Seasonal changes of river

water are shown in **Table 2** and **Figure 2**. Maximum concentrations of major ions were detected in April. This increase in the ion concentrations can be attributed to the melting of snow during this period, which is a common phenomenon.

However, nutrient concentrations showed a different trend. Seasonal changes in these concentrations were not as significant as the major ions, although concentrations of NO_3^{2-} from November to June were higher than other seasons. This was not the agricultural season in Karakalpakstan, so nutrients could not have emanated from agriculture areas.

In summer 2008, water volumes of Amu-Darya were extra lower than other years. Therefore, it was compared with seasonal change of river water and precipitation amount (**Fig. 3**). In Karakalpakstan area, many agriculture fields were not able to produce crops in 2008. In particular, rice fields in these areas were unproductive. However, rice cultivation was possible in 2009 due to the abundance of water in Karakalpakstan. Precipitations in Karakalpakstan were constantly low during the period 2008-2010. Karakalpakstan is an arid area, therefore, precipitation was not a big factor for agriculture. Crosa *et. al.* (2006b) suggested the great irrigation and drainage infrastructure inherited from the times of the Soviet Union had proven difficult to maintain, resulting in shortage of water with a chemical composition suitable for human use. They also reported that salinity at the upstream site (Termez) is reduced during the period from May to September. This same trend was also revealed in our study.

Two main driving forces act in shaping the seasonal variation of the salinity of the Amu Darya River: low natural drainage density of the catchment, which limits the salt loads induced by the natural runoff processes, and the snow and glacier melting in the upper catchment area which promote dissolved salt dilution during the high-flow period (Spring and Summer). Upper stream countries, Kyrgyz and Tajikistan are planning to construct hydroelectric generating plants. If these plans are carried out, more serious problems may appear in Karakalpakstan areas.

In this region, an important factor for agriculture is the volume of the river water other than precipitation. Thus, we tried to compare river water quantity and quality (**Fig. 4**).

Seasonal changes in river water quantity were almost low. Especially, river water was used for irrigation in agriculture seasons (from April to September). As Karakalpakstan areas are located in the downstream of Amu-Darya, they depend mostly on river water for irrigation, and river water was less considered in agriculture season. However, river water volumes in 2010 were abundant so agricultural yield in 2010 was very high. However, a lot of people in karakalpakstan must go away to work. Getting a stable income from agricultural is considered to be difficult as a result of frequent drought occurrences in the region once every few years. Therefore, there is the need for reforms to set up irrigation systems that will ensure a shift towards sustainable irrigation agriculture.

Seasonal changes of ground water were shown in **Table 3** and **Figure 5**. Maximum volumes of major ions and nutrients depended on each ion. The ground waters were much affected from soil than river water. Seasonal changes were not high than Amu-Darya river water and were relatively constant. SO_4^{2-} concentrations of ground water samples and river water samples were higher than other ions. These results were caused by soil components. However, concentrations of ions in summer were higher than winter. This result was different from Amu-Darya river water.

As for salinity, for which an exhaustive analysis will be proposed subsequently, more than 50% of the observations exceeded the value of 1000 mg/l, which is considered as the

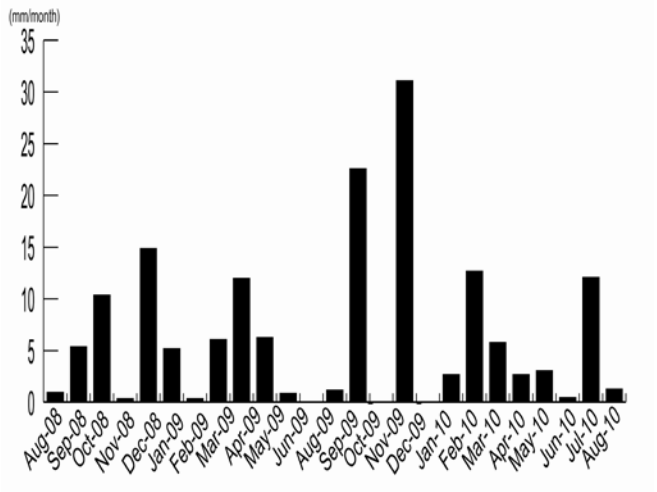

Fig. 3. Seasonal changes in precipitation amount at Nukus

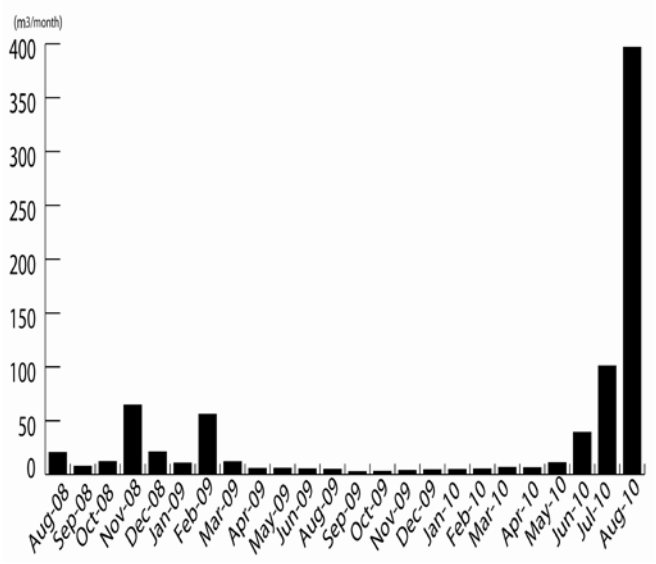

Fig. 4. Seasonal change of streamflow amount of Amu-Darya river.

Table 3. Seasonal change of ground water. Notes: n.d.: not detected

	PO_4^{3-} mg/L	Cl^- mg/L	NO_3^{2-} mg/L	SO_4^{2-} mg/L	Na^+ mg/L	NH_4^+ mg/L	K^+ mg/L	Mg^{2+} mg/L	Ca^{2+} mg/L
Aug-08	11.9	479.15	10.00	672.55	340.17	n.d.	7.12	103.47	224.61
Sep-08	4.94	433.65	5.59	651.95	315.48	0.567	7.09	97.67	159.26
Oct-08	4.33	378.48	9.39	630.88	304.26	n.d.	6.98	93.36	137.32
Nov-08	6.09	320.26	7.11	571.60	281.15	0.130	6.16	81.05	105.37
Dec-08	6.97	311.58	6.82	562.94	273.09	0.083	6.40	77.74	113.67
Jan-09	8.56	335.62	13.37	613.87	292.77	n.d.	6.55	98.74	130.55
Feb-09	7.89	338.85	25.18	591.12	285.63	0.343	6.83	97.10	128.14
Mar-09	7.59	325.80	31.05	562.65	269.04	0.423	6.00	92.57	130.12
Apr-09	6.7	419.40	19.76	679.97	315.08	n.d.	7.48	100.94	178.18
May-09	7.62	449.16	15.73	681.16	329.81	n.d.	7.01	87.49	178.35
Jun-09	6.93	467.32	10.87	695.42	336.80	1.113	7.58	104.63	195.16
Aug-09	n.d.	495.60	8.87	714.64	361.43	n.d.	7.51	111.22	260.52
Oct-09	n.d.	344.99	10.86	641.46	328.41	n.d.	7.56	112.06	151.90
Nov-09	n.d.	350.17	7.31	615.00	277.14	n.d.	7.39	114.14	152.55
Dec-09	n.d.	343.5	13.16	629.78	280.53	n.d.	7.50	110.36	146.76
Jan-10	n.d.	286.79	8.73	530.14	231.85	n.d.	5.78	101.27	138.37
Feb-10	n.d.	310.20	5.79	601.38	290.91	n.d.	6.47	115.96	143.73
Mar-10	n.d.	360.4	9.34	663.16	345.62	n.d.	7.67	115.48	160.24
Apr-10	n.d.	372.79	4.98	668.73	349.02	n.d.	8.55	113.24	172.05
May-10	n.d.	387.12	5.20	684.95	356.60	n.d.	8.51	115.8	185.07
Jun-10	n.d.	390.05	10.92	688.90	268.04	n.d.	9.27	118.94	200.85
Jul-10	n.d.	550.86	13.42	744.96	334.88	n.d.	7.83	102.26	243.54
Aug-10	n.d.	69.13	n.d.	143.61	59.18	1.270	3.55	20.00	67.79
Avarage	7.23	383.66	11.44	641.93	309.43	0.561	7.31	103.21	164.85
Max.	11.9	550.86	31.05	744.96	361.43	1.270	9.27	118.94	260.52
Mim.	4.33	286.79	4.98	530.14	231.85	0.083	5.78	77.74	105.37

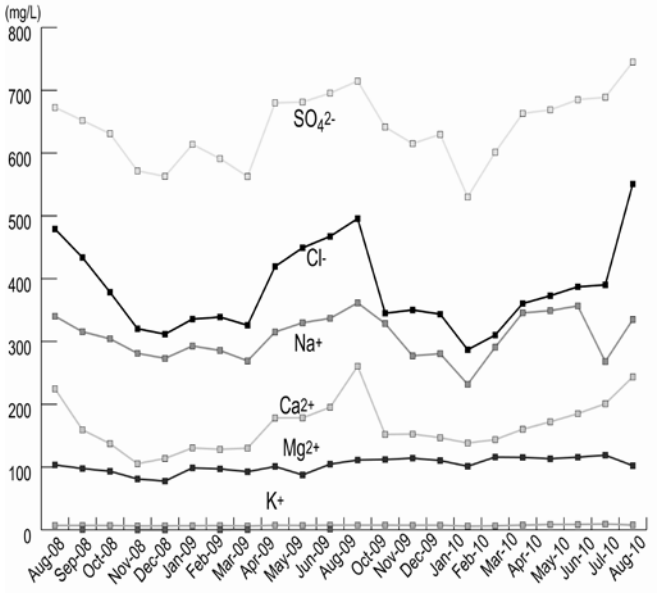

Fig. 5. Seasonal change of ion concentration of ground water in Nukus.

limit of palatability (WHO, 2008). The results were shown same trend with former study, and more serious.

4. Conclusion

The results indicate that major ion concentrations of ground water were higher than Amu-Darya river water, and NO_3^{2-} concentration in winter were higher than other seasons. However river water and ground water showed different trends. Particularly, NO_3^{2-} concentrations of ground water in the winter season of 2009 were higher than 2010. In summer 2008, water volumes of Amu-Darya were extra lower than other years, which possibly resulted in higher concentrations for this particular summer. Agricultural yield in 2010 was very good. However, a lot of people in karakalpakstan must go away to work. Getting a stable income from agricultural is considered to be difficult as a result of frequent drought occurrences in the region once every few years. Therefore, there is the need for reforms to set up irrigation systems that will ensure a shift towards sustainable irrigation agriculture.

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