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# Change in the water quality of the Aral Sea in Uzbekistan, Central Asia

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**Abstract:** The Aral Sea is a large closed lake located in the arid area of Central Asia. The water level of the Aral Sea was heavily depending on the amount of water contributed by two major tributaries, Amu-Darya and Syr-Darya. In the past 60 years, it was the world's fourth largest lake in area. However, its area has decreased rapidly, and its water salinity have become high. They decrease in Aral Sea area was caused by the large scale irrigated agriculture which started in 1950's, especially in the Aral Sea basin. The study investigates the changes in the chemical characteristics of Aral Sea water in Central Asia in 2015 compared with in 1965 and 1994. Results indicated that the current major ion concentrations were higher than in 1965 and 1994. However, $Ca^{2+}$ concentration showed different trends.

**Keywords:** Aral Sea, major ions, large scale irrigation, Uzbekistan

## 1. Introduction

Aral Sea is of a large closed saline lake located in the arid area of Central Asia. The water level of the Aral Sea depends on the amount of water contributed by two major tributaries, Amu-Darya and Syr-Darya.

In the 1960s, the Soviet Union undertook a major water diversion project on the arid plains of Kazakhstan, Uzbekistan, and Turkmenistan. The region's two major rivers, fed by snowmelt and precipitation in faraway mountains, were used to transform the desert into farms for cotton and other crops. Before the project, the Syr Darya and the Amu Darya rivers flowed down from the mountains, cut northwest through the Kyzylkum Desert, and finally pooled together in the lowest part of the basin (NASA).

In the past 60 years, it was the world's fourth largest lake in area but, its area has decreased rapidly and its water salinity level become high since then. The decrease in Aral Sea area was caused by the large scale irrigated agriculture which started in 1950's, in the Aral Sea basin.

Idea of using the river water for irrigation already exited in early 20 century. Economists were compared with income from large scale irrigated agriculture and fisheries and Soviet Union were started large scale irrigation using river water in arid area (Mamedov, 1991).

As a result, many villages were built in the area and people started producing cotton, wheat, rice, and vegetables. The Aral Sea Problems is one of the big environmental Problems in the world (**Figure 1**).

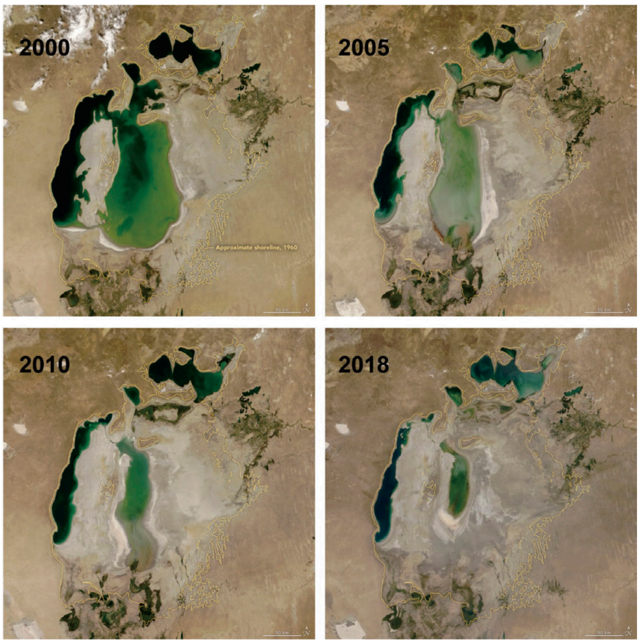


**Fig. 1. Shrinking Aral Sea by NASA**

The wide-scale changes in its water level followed by a rise in salinity and modifications in biodiversity (Aladin and Potts 1992; Micklin 2014a, b; Singh *et al.* 2018). The loss of such an enormous water body has caused climate changes, economic crisis, and health issues over the entire region (Khan *et al.* 2004; Bosch *et al.* 2007; Aladin *et al.* 2009; Lioubimtseva 2014).

After Soviet era, Amu-Darya and Syr-Darya became international rivers and water problems had occurred in upstream countries and downstream countries. The gradual climate change over the centuries was accelerated by

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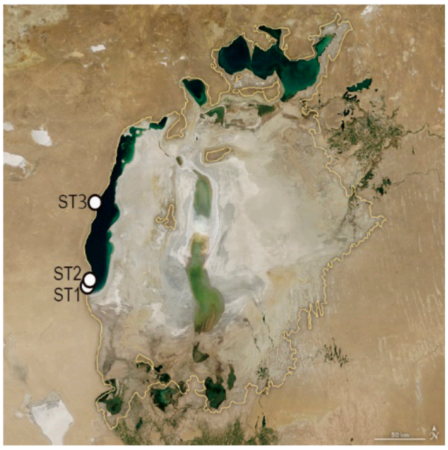


**Fig. 2. Sampling spots in the Aral Sea plotted on the satellite phot of NASA**

the Aral Sea ecological disaster of the late 20th century Kazakhstan constructed the Kok Aral Dam between Small Aral Sea and Large Aral Sea in 2006, thus accumulating the water in the Small Aral Sea from Syr-Darya resulting in rapid shrinking of Large Aral Sea. As a result of the water discharge from the Small Aral through the Kokaral dam to the south, one more water body, the Central Aral (Micklin 2016), has appeared. It is a shallow, very unstable lake. Together with water from the Small Sea, a large number of valuable commercial fish are brought to the Central Aral. However, the salinity (~70‰) in the west of this lake is too high for their survival.

We investigated changes in water quality parameters and ion concentrations and phytoplankton flora of Aral Sea from 1991 to 2015 (Kawabata *et al.*, 1995, Kawabata *et al.*, 1997) and discussed how changes developed over 21 years of investigations.

## 2. Materials and Methods

3 water samples from the west side of the Large Aral Sea were collected on 7 September 2015 (**Figure 2**). We collected the water from shore line using the plastic bottle. The location of each sampling spot was determined using an eTrex Legend portable Global Positioning System (GARMIN Ltd.). Water samples were filtered through 0.45 µm Membrane filter (DISMIC 25AS020AS, ADVANTEC Corporation) and collected in polypropylene bottles.

The main cations ($Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, $K^{+}$, $NH_4^{+}$, $Fe^{3+}$, and $Fe^{2+}$) and anions ($HCO^{3-}$, $Cl^{-}$, and $SO_4^{2-}$) were determined using ICP-MS instrument (Agilent-7500cx). Water mineralization were determined using methods published by Reznikov *et al.* (1970).

## 3. Results and Discussion

### 3.1. Major ion and nutrient concentrations

Physical data, Major ion, nutrient concentrations ($Na^{+}$, $NH_4^{+}$, $K^{+}$, $Mg^{2+}$, $Ca^{2+}$, $HCO^{3-}$, $CO_3^{-}$, $Cl^{-}$, $NO_3^{2-}$, $SO_4^{2-}$), and TDS are shown in **Table 1**. The TDS value of ST3 was lower than ST1 and ST2. This because ST3 has higher latitude than ST1 and ST2 and therefore influenced by the low TDS water coming from Small Aral Sea. However, $Mg^{2+}$ concentrations have opposite trend. And $Ca^{2+}$, $Cl^{-}$ and $HCO_3^{-}$ concentrations of ST2 was higher than ST1 and ST3.

**Table 1. Physical data, Major ion, nutrient concentrations, and TDS in the Aral Sea**

| | ST1 | ST2 | ST3 |
|---|---|---|---|
| **Physical Data** | | | |
| Sampling date | 7-Sep-15 | 7-Sep-15 | 7-Sep-15 |
| Sampling time | 9:50 | 11:05 | 18:00 |
| Latitude | N 44° 27′ 46.1″ | N 44° 31′ 39.8″ | N 45° 05′ 38.1″ |
| Longitude | E 58° 14′ 06.1″ | E 58° 14′ 22.3″ | E 58° 20′ 36.2″ |
| pH | 6.64 | 6.58 | 6.59 |
| EC(µS/cm) | 0.2 | 0.2 | 0.2 |
| Temp. (°C) | 22.2 | 24.3 | 23.2 |
| **Cations(mEq / L)** | | | |
| $Na^{+}$ | $1.54\times10^{3}$ | $1.50\times10^{3}$ | $1.21\times10^{3}$ |
| $K^{+}$ | 44.76 | 47.31 | 44.76 |
| $NH_4^{+}$ | 0.11 | 0.11 | 0.11 |
| $Ca^{2+}$ | 50.00 | 60.00 | 50.00 |
| $Mg^{2+}$ | $8.90\times10^{2}$ | $8.80\times10^{2}$ | $9.15\times10^{2}$ |
| Total | $2.53\times10^{3}$ | $2.49\times10^{3}$ | $2.22\times10^{3}$ |
| **Anions(mEq / L)** | | | |
| $Cl^{-}$ | $1.90\times10^{3}$ | $2.13\times10^{3}$ | $1.88\times10^{3}$ |
| $SO_4^{2-}$ | $6.13\times10^{2}$ | $3.45\times10^{2}$ | $3.28\times10^{2}$ |
| $NO_3^{-}$ | 3.02 | 3.02 | 3.02 |
| $CO_3^{2-}$ | ND | ND | 0.4 |
| $HCO_3^{-}$ | 12.8 | 14.5 | 12.5 |
| Total | $2.53\times10^{3}$ | $2.49\times10^{3}$ | $2.22\times10^{3}$ |
| **TDS(mg/L)** | | | |
| Experimental | $1.48\times10^{5}$ | $1.43\times10^{5}$ | $1.27\times10^{5}$ |
| Calculated | $1.46\times10^{5}$ | $1.40\times10^{5}$ | $1.24\times10^{5}$ |
| **Formula of the salt composition of water** | | | |
| | $TDS148.2\frac{Cl^{75}\ SO_4^{25}}{(Na+K)^{63}\ Mg^{35}}$ | $TDS143.2\frac{Cl^{86}\ SO_4^{14}}{(Na+K)^{62}\ Mg^{36}}$ | $TDS127.3\frac{Cl^{85}\ SO_4^{15}}{(Na+K)^{57}\ Mg^{41}}$ |

**Table 2. The concentrations of major ions of sea water and Aral Sea in 1965, 1994 and 2015**

| | $Na^{+}$ | $K^{+}$ | $Ca^{2+}$ | $Mg^{2+}$ | $Cl^{-}$ | $SO_4^{2-}$ |
|---|---|---|---|---|---|---|
| | (meq./L) | | | | | |
| Sea Water | 459.9 | 9.7 | 20 | 104.6 | 535.3 | 55.2 |
| Aral Sea(1965) | 104.4 | 2.2 | 22.8 | 48.2 | 215.4 | 215.4 |
| Aral Sea(1994) | 246.7 | 7.5 | 135.5 | 122.2 | 256.6 | 162.4 |
| ST1(2015) | $1.54\times10^{3}$ | 44.76 | 50.00 | $8.90\times10^{2}$ | $1.90\times10^{3}$ | $6.13\times10^{2}$ |
| ST2(2015) | $1.50\times10^{3}$ | 47.31 | 60.00 | $8.80\times10^{2}$ | $2.13\times10^{3}$ | $3.45\times10^{2}$ |
| ST3(2015) | $1.21\times10^{3}$ | 44.76 | 50.00 | $9.15\times10^{2}$ | $1.88\times10^{3}$ | $3.28\times10^{2}$ |

Therefore, the concentrations of major ions in 2015 were compared with sea water and Aral Sea in 1965 and 1994 (**Table 2**). Aral Sea data in 1965 was collected from Aladin, 1965. He investigated water quality and fish in the Aral Sea. Aral Sea data in 1994 were selected AR-1 in the north part of the Aral Sea (Kawabata *et al.*, 1995). Major ion concentrations of ST1, ST2, and ST3 were higher than sea water and Aral Sea in 1965 except for $Ca^{2+}$ concentration at ST1, ST2, and ST3 which seemed to decrease relative to results obtained in 1994. We identified many dead shells in the shore line and about 5 cm shell range 5 cm in the core sample of the Aral Sea in 1994. The high concentration of $Ca^{2+}$ of Aral Sea in 1994 was affected by large scale death of shell. After 21 years, demineralization system of Aral Sea in 2015 was changed and $Ca^{2+}$ concentrations in 2015 were decreased. In the sea water, $Ca^{2+}$ ion removed completely as calcium carbonates by the marine biological system (Kitano, 1983). Demineralization system of Aral Sea in 2015 is not

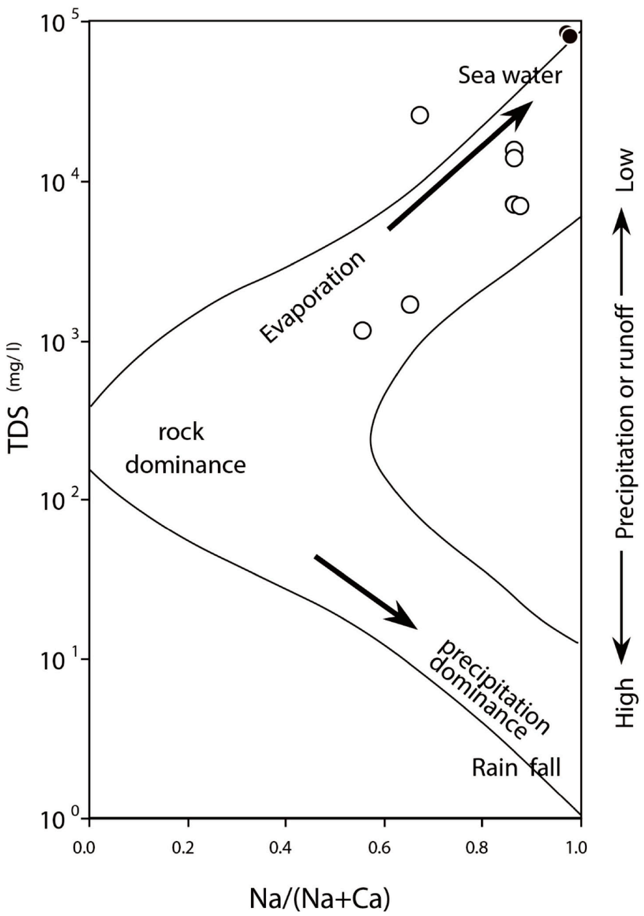


**Fig. 3. The relationship between ionic rations, TDS and the controlling the major composition of natural waters ○Aral Sea in 1994 (Kawabata *et al.*, 1995) ●Aral Sea in 2015**

same with sea water.

Gibbs (1970) studied the relationship between ionic rations, TDS and the major composition of natural waters. We compared Gibbs data and Aral Sea data obtained in 1994, 1996 and 2015 as shown in **Figure 3**. Aral Sea in 1994 was outside the trend of natural water suggested by Gibbs. However, in 2015, materials compositions were near to the om 1994. These results support the recovering demineralization system in the Aral Sea.

Further perspectives for the biodiversity (including zoocenosis) of the residual water bodies of what was once the Aral Sea depend primarily on salinity changes. Its further decrease in the Small Aral may affect the biodiversity of invertebrates, and negatively affect marine species and species from the fauna of saline continental water bodies of the arid zone (Aladin *et al.* 2018). And Uzbekistan Government with international company are collecting natural gas from dry area of the Aral Sea and therefore not recover to the same area of 1960s. However, we should work to minimize the shrinking of Aral Sea, shifting to sustainable agriculture production and minimizing water use.

## 4. Conclusions

The area of the Aral Sea has been shrinking since 1960s caused by large scale irrigation using river water. We measured the major ion concentration of Aral Sea in 2015 and compared it with concentrations reported in 1965 and 1994. TDS increased in 2015 compared to that in 1965 and 1994. However, $Ca^{2+}$ concentration in 2015 was lower than that in 1994. This result indicated that changes in the demineralization system of Aral Sea occurred since 1994 and is becoming similar to other lake.

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