LAKE ARAL - PLANETARY SCALE ECOLOGICAL DISASTER

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Abstract. Aral Sea, is known as one of the great lakes on Earth, which has become desert due to brutal anthropic interference. The paper presents issues like the evolution of morphometric characteristics (area, volume and depth), biodiversity, salinity and the negative impacts on economy and population in the Aral Sea region.
Keywords: Aral Sea, North Aral Sea South Aral Sea, Syr Darya, local and regional changes

Geographical position. Aral Sea is one of the examples of ecological disaster of our time, caused by uncontrolled human activities. Aral Tenghiz or "The Sea of Islands", with the 66 548 km^2, ranked among the three largest lakes on Earth, after the Caspian Sea (371 000 km^2) and Lake Superior (82,100 km^2). Currently, as a direct consequence of human intervention in the supplying basin, the lake surface shrinked to only 16.46 km^2, occupying the 40th position in world ranking (Gâştescu, 2006).

Lake Aral is located in a desert area of Central Asia, on the territory of Kazakhstan and Uzbekistan, at the intersection of Parallel of Latitude 45 degrees north with the Meridian of Longitude 60 degrees east. It lies in an endorheic depression between the Turan Plain, east and Ustyurt Plateau, west, surrounded by deserts: Prearal to the north-east, Little Barsuki to the north, Greater Barsuki to the north-west, Ustyurt to the west, Barsa-Kelmes to the east, Karakum to the south, Kyzyl Kum to the south-east (Petrov, 1986). Altitudes range generally between 90-160 meters (Zonn et al, 2009).

Genesis of lacustrine depression. It is consider that the Aral Sea was part of the Sarmatic Sea which occupied during the middle Tertiary age the area between Vienna Basin and Tian Shan Mountains, being currently a remainder of this sea, together with the Caspian and Black Sea (Gâştescu, 2008). During the Holocene, water volume, surface and sea level showed significant variations (transgression, regression) due to climatic conditions, highlighted by the terraces of the surrounding area. Sea level variations ranged between 53-57 m during transgression phases and between 35-44 m during the regression phases, compared with the current sea level (Ferronskii et al, 2003).

Aspects of Aral Sea recent development. In natural conditions, prior to development of anthropogenic facilities (during 1900-1915), the North Aral Sea waters were rising because of the water supply coming from glaciers and permanent snows in Tian Shan and Pamir Mountains (Gâştescu, 2006).

During 1911-1960, the three parameters-surfaces, depth, volume- reflected on sea level. The sea level variation remained at 81 cm (53.4 m in 1960 and 52.54 m in 1918), the average sea level being of 52.95 m (maximum 69 m), corresponding to an area of 64,600 km2, and a volume of 1057.06 km3. After 1960 the evolution of these parameters showed a continuous and steady decrease (Fig. 2). The average values of sea level decrease on year intervals were: 20 cm / year during 1961-1970; 60.4 cm during 1970-1990 / year; 40.2 cm/ year during 1990-1995 (Kravtsova, 2001). In 1989, as a result of level decrease, according to the morphobatimetric configuration, the aquatic basin was separated into two distinct lakes, North Aral Sea (Small Aral) and South Aral Sea (Large Aral Sea). This separation occurred on the line of Berg isthmus and former Kokaral island (maximum altitude 163 m). Kokaral Island gradually increased its surface, becoming a peninsula during 1968-1978. After 1990, the land surface separating the two lakes widened; in 2006, North Aral Sea had a surface 3000 km^2 and South Aral Sea. of 13140 km^2. In April 2008, the maximum level was only 29.2 m (http://www.cawater-info.net/aral/index_e.htm , Zonn, 2009) (Fig. 1).

The main reason that caused this decline has been the construction of irrigation canals in the hydrographic basins of Syr Darya and Amu Darya starting with 1961, which gradually took up to 10 km^3 of water annually, for irrigating about 7 895 600 ha. Having an arid climate, with average annual rainfall of only 103 mm, in the area of Aral Sea has installed a negative hydrological balance. Hydrological balance during 1911-1960 was relatively balanced, available water resources in the basin being estimated at 115 km^3/year. During 1930 - 1960 water inflow in Aral Sea was of 54 km^3/year, while in 1990 was only 5 km^3/year (http://www.cawater-info.net/aral/index_e.htm , Zonn et al, 2009).

North Aral Sea is located entirely within the territory of Kazakhstan, state which decided to rehabilitate the North Aral Sea situation. Thus, in 1992 and 1997 two dams were built (rebuilt in 2005, Fig. 6) one that separates the North Aral Sea from the South Aral Sea, east of Kokaral Peninsula and another on Syr Darya river. Also, the irrigation canals in the Syr Darya basin were rehabilitated in order to reduce water loss. These actions had a positive effect, because after 1993, the water level began to rise (with about 12 m) and the water surface increased from 2.550 km^2 in 2003 to 3300 km^2 in 2008 (Zonn et al, 2009).

South Aral Sea has the largest area within the administrative territory of Uzbekistan. This country holds one of the worldwide leading places in the culture of cotton and therefore Uzbekistan has no interest in reducing the volume of irrigation, and to increase the water input to Aral. Also, on the bottom of South Aral were found significant hydrocarbon resources, which can be more easily exploited by land than by water.

South Aral Sea situation is even more dramatic. A number of islands in the central-western part (Vozrozhdeniya, Komsomolsky, Konstantin) and Barsa Kelmes Island, located in the northeast (natural reserve declared in 1949, became a peninsula in 1997), have gradually increased their surface separating three lobes: one in the east, with a larger surface, second to the west, where the greatest depths can be found, and another in the north, with a smaller surface. Currently, a small isolated lake remained in north-western part, between Kulandy and Karatup peninsulas (Fig. 3, 4, 7) and another lake in the west, approximately longitudinal, having the greatest depth (30.4 m in 2005), representing the only area that remained relatively unitary from the former lake (Zonn et al, 2009).

Consequences of the sea evolution are reflected in the landscape, both in the former lacustrine basin, and in the surrounding areas. In 1960, the shoreline had a total length of 3238 km.The shoreline was high, almost linearly in the west, with bays and peninsulas in the north-west and north (Kulandy, Karatup, Kokalar, Shubartarauz, Tastubek), with upland alluvial deltas formed by the two rivers Syr Darya, in the northeast and Amu Darya in the south, with lowlands in the east, dotted with numerous islands (Archipelago Akpetkinsky with over 230 islands). The decrease of sea level positioned the former shore cliffs at tens of kilometers from the sea and revealed the former sea bottom. The sub aerial areas are affected by current processes of surface erosion, flow, collapse and deflation, weathering. Neighboring localities, once ports at Aral Sea, are covered by mobile dunes which are buring the buildings. Even the cemetery of Aqbasti village, located on the former perimeter of Kokaral island, is partially "fossilized" (Fig. 5). On the former sea bottom remained mud layers, salt crust and sandy soils, which may have thicknesses up to 10 m. On the former lakebed, Aralkum, the youngest desert has formed (similar with Karakum and Kyzyl Kum deserts). In 2000, its surface was of almost 20,000 km^2 (Zonn et al, 2009).

Water salinity also suffered important changes. If until 1960 the NaCl concentration in water was 10.13 g / l in 2000 increased to 58.6 g / l and now exceeded 100 g / l in the west and 150 g/l in the east (Zonn et al, 2009). Meanwhile, the volume of evaporated water due to the reduction of water table, decreased from 71.13 km^3 in 1960 to 42.52 km^3 in 1985 (Jarsjö et al, 2008).

The decrease of freshwater input, the increase of salts concentration and water pollution (especially by pesticides) led to radical changes in the structure of aquatic ecosystems (or even loss or replacement), and to modification of habitats in adjacent areas.

Consequences on local and regional climate. The decrease of aquatic surface, the occurrence of recent surfaces of dry land, the expansion of irrigation had direct consequences on climatic parameters. The summers became more arid and winters harsher, being influenced by the cold Siberian air. Thus, if during 1901-1950 the annual average temperature of the adjacent area was of 6.8 ° C, during 1983-2002 an increase of up to 2 ° C was registered. The average annual temperature over the water table is 3-5 ° C lower than over the land surface. It is noteworthy that the Aral Sea basin as whole recorded changes in annual average temperature. The average annual temperature had a greater increase in winter (1.85 ° C), compared to only 0.69 ° C in summer. Increases in spring and autumn were 1.07 ° C, 0.81 ° C respectively. Overall, average annual temperature is presently higher with approximately 1.1 ° C. Average annual precipitation were of 103 mm during 1901 -1950. Now, they are in decline due to shrinkage of water surface. Aral Sea basin, from 1983-2002, registered an increase in the amount of precipitation of about 15 mm, distributed unequaly on different seasons: 3.8 mm in spring (5%), 3.0 mm in summer (4%), 2.2 mm in autumn (5%) and 6 mm in winter(% 9). The increase in temperature and precipitation in the Aral Sea Basin is due to irrigation (Petrov, 1986, Zavialov, 2005, Jarsjö et al, 2008, Zonn et al, 2009).

The wind has an important role, its predominant direction being from the east and northeast (especially in winter when the Siberian anticyclone is present), and in the summer also from the northwest, pushing water bodies to the west. This aspect determines differences in water salinity between western (8-10 g / l) and eastern waters (14 g / l) (Zavialov, 2005, Gâştescu, 2008). Currently, the deflation processes are expanding, both over new emerged land and over neighboring deserts. Wind-blown dusts join the alluvium carried by the two rivers and runoff, in the sedimentation process on the lake bottom or accelerate the formation of dunes.

Effects on flora and fauna. Because its isolation and particularities, Aral Sea had a relatively small number of animals and plants, but the high oxygen saturation of the lower strata has created favorable conditions for development of bottom vegetation. There were still over 500 bird species (white herons, flamingos), 200 species of mammals (Turanian Tiger, Saiga antelope), 100 species of fish (of commercial importance, introduced during 1940-1950, such as sturgeon , barbell, pike, roach, bream, salmon, carp, perch). Regional flora was impressive and included 1,200 plants, of which 29 were endemic to Central Asia. Changes in water balance led to loss of valuable species of plants and animals. The level of biogenic substances, especially phosphates, decreased (main source of biogenic material being Amu Darya and Syr Darya, which were fed by mountain snow and glaciers). The increasing in salinity led to almost complete disappearance of fish. Currently, the conversion of thousands of square kilometers of alluvial soils in dry land and salt crust left behind a lifeless sea. Also, water withdrawal has led to the disappearance of shore vegetation, which has affected also the forage for sheep, horses, camels and goats (Zonn et al, 2009).

Socio-economic consequences and implications. Irrational use of land and water resources has led to degradation of arable land, increasing salinity and soil contamination, caused by excessive use of fertilizer and herbicide. From a total of 7.8 million hectares irrigated in Aral Sea basin, over 50% have high levels of salinity. Also, the decrease in water input in Amu Darya and Syr Darya deltas and Aral Sea water withdrawal have led to desertification of deltaic plain and the conversion of approximately 732,000 hectares of fertile alluvial soils in wetlands and solontchaks. The changes in composition of spontaneous vegetation have led to decrease of pastures' productivity, associated with the amplification of desertification phenomenon. (Bakhiev et al 1987, cited by Severskiy et al 2005).

The major ecological changes from the region have contributed to the disappearance or reduction of faunal populations, some with high economic value. It is the case of muskrat populations from the wetlands of Syr Darya and Amu Darya Deltas. In the 50s, 70,000 -230,000 muskrat furs were sold each year. In 1968 their number has reduced to 9000, for reaching only 72 in 1972. Currently muskrat fur trade has disappeared (Kuksa, 1991, Kaspersons et al, 1995).

Water pollution is another major problem throughout the region. Approximately 150,000 tons of toxic chemicals have contaminated water during recent decades and continues to pollute soil and water (Ataniyazova, 2003). Lack or poor quality of freshwater represents a barrier for the development of water-consuming industries in the region.

Also, the increasing of soil salinity and pollution has contributed to the increase of air and water aggressiveness from soil. Chemical agents and microorganisms from air attack high-voltage transmission lines and salinity of soil contribute to the degradation of buildings foundations (Abdulkasimov et al. 2003 Severskiy et al, 2005).

Fishing industry, once thriving, has been virtually destroyed. The increase of water salinity, the shrinking of water surface, and the pollution, have gradually led to the extinction of most fish species that were used by fishing industry in the region. Fish production decreased from 46,000 tones / year in the '60s to 10,000 tones / year in the '70s, for reaching only 1000 tons / year in the '80s. Only in Kazakhstan there were 2 fishery bases, 1 fish enterprise, 8 fish plants, and 19 collective fish farms. A similar situation existed in Uzbekistan. The 61,000 workers involved in fishing and fish processing have lost jobs and the source of a secure income. Currently, there are several fish processing factories (in Aralsk, Muynak) using mainly imported saltwater fish (Fig. 8), which offer employment only to a limited number of about 2000 people (Severskiy et al, 2005).

Ppopulation migration was a natural response to the worsening of life conditions, lack of resources and jobs. The number of people relocated is estimated to 100,000. Massive relocation from affected areas occurred in the '80s, when environmental problems have amplified. (Seiko, 2001).

On the former bottom of the sea remained a lacustrine deposit with toxic chemicals (from pesticides, fertilizer, defoliants) and natural salts that are carried away by wind, affecting the health of population. It is estimated that dust storms, whose frequency is increasing, are carrying 100,000 tones of salts and contaminated sand annually. Another factor leading to high values of morbidity rate is the strong mineralization and high concentrations of chemicals (DDT, methyl mercaptophos, ostametyl, hexacloran, lenacil, etc.) from water consumed by the population. Pollutants in water, soil and air contaminate also the food from affected areas.

Health problems associated with the ecological crisis in the Aral region include the spreading of anemia, tuberculosis, decreased thyroid function, kidney, respiratory, and liver disease. Cancer incidence has increased, exceeding the values of other ex-Soviet countries, including Russia (Glants et al, 1993). Anemia, the most common health problem in the region has grown significantly in the last 30 years. If in the 80's only 17-20% of pregnant women showed anemia, currently the percentage increased to 70% (Ataniyazova, 2003, Ataniyazova et al, 2001)

Infant mortality and morbidity recorded significantly higher values, in Kyzylorda and Karakalpakstan regions, than in other regions of Kazakhstan and Uzbekistan (24 ‰). In 1989, in certain areas of Karakalpakstan region, infant mortality reached 110 ‰ (Kaspersons et al, 1995). In Kyzylorda region, life expectancy at birth has fallen from 64 to 51 years (Ataniyazova, 2003).

Conclusions

Aral Sea represents one of the saddest examples of environmental degradation caused by irrational exploitation of its tributaries waters. The examples and effects presented in this paper show the changes occurred in the surface, volume and salinity of water, the changes in landscape, the influence on local and regional climate, what happened to plants and animals that inhabited the area and surroundings, and which are the socio-economic consequences and implications affecting the entire region's population and economy. Unfortunately, the Aral Sea isn't a unique situation, other endorheic water bodies like Chad Lake, suffering similar consequences.

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Figure1- Aral Sea in August 2009 (http://en.wikipedia.org/wiki/Aral_Sea)
The black line represents the shoreline prior to 1960.

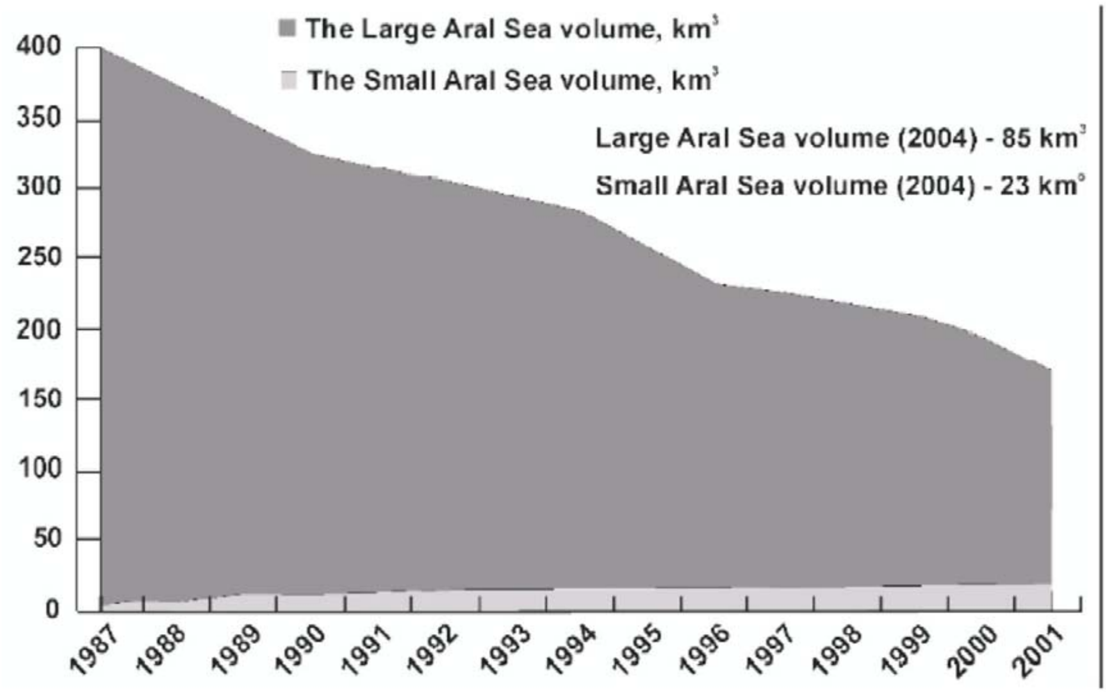

Figure 2 -The decreasing of Aral Sea water volume (by Aladin et al, 2008)

Figure3 - Ships transformed into scrap in the area of former Karatup peninsula. In the background one can see the remaining waters of the South Aral Sea (Photo by Anca Munteanu)

Figure 4 - A former dock on the former Karatup peninsula (Photo by Anca Munteanu)

Figure 5 - Aqbasti village cemetery, located on the perimeter of the former Kokaral Island, buried by mobile dunes (Photo by Anca Munteanu)

Figure 6 - The dam separating North Aral Sea from South Aral Sea (in the area of former Kokaral island), which allowed the rehabilitation of North Aral Sea (Photo by Vadim Bondar)

Figure 7- Former cliff and the bottom of Aral Sea, transformed into desert (Photo by Vadim Bondar)

Figure 8 - Former Aralsk port, with a boat dock and a ship transformed into a tourist information center. In the background one can see the cranes serving the former port and the dry sea bed (Photo by Vadim Bondar)