Assessment of the hydroecological state of the Syrdarya delta

Dinara Arystambekova¹*, Niels Thevs², Madina Tursumbayeva¹

¹Al-Farabi Kazakh National University, Almaty, Kazakhstan
²International Center for Research of Agroforestry (ICRAF), Bishkek, Kyrgyzstan

*Corresponding author
Email: d_arystambekova@mail.ru

Received: 24 April 2019; Received in revised form: 09 September 2019; Accepted: 22 September 2019; Published online: 01 October 2019.


Abstract
After a catastrophic decline in the water level at the end of the 20th century, the formation of a new delta of the river Syrdarya has begun. The modern delta of the river is located within the Kazalinsk and Aral regions in Kyzylorda oblast. This paper gives an assessment of the hydroecological state of the river’s delta. The hydrological and ecological characteristics of the Syrdarya delta were evaluated using the data from the Karateren and Kazalinsk gauging stations. A number of hydroecological indicators are given, such as: water level, annual flow, delta area, mineralization, content of suspended substances, copper and biochemical oxygen consumption (BOC₃) in the river. All indicators were compared to the maximum permissible concentration (MPC).

Keywords: Syrdarya, delta, pollution, water level, mineralization.

Paper type: Literature Review

1. Introduction

In 1960, the Aral Sea was the world's fourth largest inland water body by in terms of its surface area (Micklin 2014b). The sea supported large-scale fishing industry and functioned as a key regional transport route. The sea supported a major fishery industry (Micklin 2014a; Plotnikov et al. 2014a). In the vast deltas of the Syrdarya and Amudarya rivers there was a variety of flora and fauna, as well as irrigated agriculture, animal husbandry, hunting and trapping, fishing and reed harvesting. The extensive deltas of the Syrdarya and Amudarya rivers sustained a diversity of flora and fauna as well as irrigated agriculture, animal husbandry, hunting and trapping, fishing, and harvesting of reeds. Since 1960, the Aral Sea has undergone the processes of rapid desiccation and salinization. The Syrdarya Basin is one of two major basins belonging to Aral Sea Basin in Central Asia. It has an area of 402,760 km² and it divided between four ex-Soviet states: Kyrgyzstan, Uzbekistan, Tajikistan and Kazakhstan (Oxana et al. 2003).
The high biodiversity of the Amudarya and Syrdarya deltas have suffered considerable harm from reduced river flows, elimination of spring floods, and declining ground water levels leading to spreading desertification (Micklin 2014b; Micklin, 2000). Salts accumulating on the surface have formed pans where practically nothing will grow. Expanses of unique tugay forests along the main and secondary watercourses have drastically shrunk. Desiccation of the deltas has significantly diminished the area of lakes, wetlands, and their associated reed communities (Indoitu 2015). These changes caused the number of species of mammals and birds to drop precipitously. Strong winds blow sand, salt and dust from the dried bottom of the Aral Sea onto surrounding lands causing harm to natural vegetation, crops, and wild and domestic animals (Indoitu 2015). As the sea has dried and more of the bottom has been exposed, dust storms with entrained salts in 7 particulate and aerosol form have become more frequent and intense, covering at times more than 100,000 km² and extending downwind more than 500 kilometers (Micklin 2016).

There are large environmental problems in the region, due to the excessive exploitation of water resources for agriculture. Syrdarya inflow to Aral Sea has been significantly decreasing since the 1960s, contributing to the unprecedented low levels of Aral Sea (Oxana et al. 2003).

In the modern conditions of climate change, non-rational water use and intensive economic activity the problem of preservation of natural ecosystems and a biodiversity in valleys and deltas of the rivers of a desert zone, including the Syrdarya river is very relevant.

Terrestrial ecosystems of arid regions are very vulnerable. Even small changes in the environment can cause an irreversible change in the composition and structure of their components (Baybulov 2009).

The large-scale irrigation development of the Syrdarya valley, the regulation of the flow of the rivers of the Aral Sea basin, exceeding the permissible norms of agricultural production and the lack of balanced water management measures led to a violation of the ecological balance in the lower reaches of the Syrdarya river (Budnikova 2005).

For the rational management of water resources and environmental planning, it is very important to assess the hydroecological state of the Syrdarya river delta. The main purpose of this work was to assess the modern hydroecological state of the delta of Syrdarya river. For this (1) the relevant literature was reviewed on hydrological characteristics such as water level, water flow, area of the delta, and (2) the water quality was assessed on the following parameters (mineralization, suspended substances, copper and biochemical oxygen consumption BOCs).

A review of scientific literature on this topic allowed to summarize scientific materials and assess the current hydrological and environmental status of the Syrdarya River Delta better.
2. Study area

The problems of the Aral region are well known all over the world. They are the consequences of the irrational employment of water resources that was aggravated by the fact that the Aral sea is a drainless water body, cut off from the world system of oceans and seas. The Aral Sea, being recently the forth land-locked sea to the size, currently appeared to be the basin with the water mineralization more than 60 g/l. The lands around the sea experience desertification and became the sources of dust storms for the region where 3 mln people reside. Until the middle of 1960 the Aral Sea and the Aral coastal area of the Syrdarya river were economically rich and ecologically clear regions. The sea and the delta of the Syrdarya river represented the united compensated ecosystem (Kipshakbayev et al. 2010).

The Syrdarya river is one of the main water arteries feeding the Aral Sea. It originates outside the territory of Kazakhstan, in the mountains of the Central Tien Shan in the eastern part of the Fergana Valley. The river is formed from the confluence of the Naryn and Karadarya rivers. The basin area is 250,870 km² (Amirgaliev 2007). The total length of the river from the place of the confluence to the Aral Sea is 2212 km. Its length from the border of Uzbekistan to the Aral Sea is 1390 km (Amirgaliev 2007). In Kazakhstan, the river has three tributaries - the Keles, Kurukkeles and Arys rivers.

The Syrdarya crosses the Kyzylorda region from the south-east to the north-west. There are shallow shoals and spits. Along the river Syrdarya and its tributaries, oxbow lakes, which have now become water supply canals, are the alluvial plains of the ancient delta (Veselova et al. 2017).

![Figure 1. Location of Aral Sea basin in Central Asia (Micklin and Aladin 2008).](image-url)
Climate in the basin is hot and arid. It is determined by the considerable remoteness from water basins, the latitudinal position and mainly flat nature of the surface (Bultekov et al. 2006; Volkov 1983). Its distinctive feature is the extreme hydrothermal mode, due to increased solar radiation.

The average annual temperature of the considered area ranges from +11.1 to +6.8 °C. The average temperature in January is -7 and -13.5 °C, in July +28.2 and 26.3 °C. The amount of precipitation during the year, according to the weather station, decreases from 156 to 91 mm (Bultekov et al. 2006). In many ways, the nature of vegetation depends on the mode of precipitation and its distribution over the seasons.

The flat part of the Syrdarya basin is a vast territory with an area of over 300 000 km², mostly with a desert natural landscape. The territory is characterized with a small amount of precipitation and high evaporation. The river network is very rare. Swamp were developed in the delta of the Syrdarya and in the floodplain zone of its lower and middle currents. In the delta there are more than 20 settlements with population about 40 thousand persons (Kipshakbayev et al. 2010). The plain region of the Syrdarya basin is one of the main areas of irrigated agriculture. Irrigation canals create an extremely dense and branched artificial hydrographic network that interweaves with the natural hydrographic network and changes them by draining natural watercourses and creating new ones in return.

3. Methods

3.1. Hydrological characteristics
The main purposes of this study was to review the research studies to find out the current situation in the study area and to collect hydrological characteristics (runoff, water level, water flow, area of the delta) of the Syrdarya delta. The hydrological data were mainly taken from Shinkarenko and Solodovnikov (2018) for the period of about 25 years starting from 1990s to assess multi-year changes in this hydrological characteristics.

3.2. Characteristics of water quality
To assess the quality of surface waters, the seasonal dynamics of pollution is of particular interest. To see the dynamics of water pollution, several figures were constructed. For this, the concentration data from the Kazakh Agency for Applied Ecology (KAAE) were used to assess the dynamics of mineralization, suspended substances, copper and biochemical oxygen consumption BOC₅ concentrations.

To study the patterns of intra-annual pollution dynamics of the delta Syrdarya were taken averaged monthly concentrations of the above indicators in Kazalinsk gauge station for the period 2001 – 2016. The gauge station of Kazalinsk is located directly in the delta of the Syrdarya river. All the characteristics were compared with maximum permissible
concentrations (MPC) for each pollutant. Data for MPC were taken from (Burlibayev et al 2018).

4. Research results and discussion

4.1. Hydrological characteristics

During the sea level decrease, a significant reorganization of hydrological processes in the estuary region of Syrdarya took place. Reduced water flow turned the old huge Syrdarya delta into a section of transit flow. The main feature of the delta, the flow branching into the sleeves, has disappeared. Currently, this part of the Syrdarya valley can be considered as a relic delta (Shinkarenko & Solodovnikov 2018). Its hydrographic network consists of a main riverbed, numerous irrigation canals and other hydraulic structures. Formation of a new delta (according to the classification of Korotayev (2012) began after the stabilization of the Small Aral Sea level at about 42 m mark. It should be noted that the emerging new delta of the river is unique.

After 1988, the Syrdarya river flow increased. This led to an increase in the sea level and intensification of riverbed processes. As a result, the transport of sediment and their removal to the delta part has increased (Shonbayeva et al. 2015). Despite the increase in the level of the receiving reservoir, accumulating sediment flow caused the delta area enlargement. Also, after construction of the Aklak permanent river-bed hydropower plant, bringing water to the delta and transit water pass into the North Aral Sea (NAS) became possible. A distinctive feature of the Syrdarya delta system is that, unlike the Amudarya delta, which has a central regulator (Mezhdurechensk reservoir), the Syrdarya delta is completed by the NAS, which accumulates the entire river flow after it passes through the delta (Dukhovny 2017).

Figure 2. Changes in the annual runoff of the river Syrdarya on the gauge station Karateren (Shinkarenko & Solodovnikov 2018), the NAS level (Dukhovny 2017) and the delta square (Shinkarenko & Solodovnikov 2018).
The Figure 2 shows that area of the river’s delta is changeable with a general trend aimed at increasing. The time interval of 2009–2011 attracts attention, when after the high water of 2010, the area of the delta in 2011 decreased slightly compared to 2009. A similar situation was observed in 2016–2017. In wet years, the sediment balance in the estuary region of the Syrdarya becomes negative due to the increased flow (including solid runoff) through the Kokaral dike.

The delta area increased from 2025 hectares in 1998 to 3905 hectares in 2017. Changes in the flow of the Syrdarya and the corresponding fluctuations in sea level in 2006–2017 certainly affect the accuracy of determining the area (Figure 3). Nevertheless, the growth of the delta part is obvious (Shinkarenko & Solodovnikov 2018).

![Aral Sea](image)

**Figure 3.** The scheme of changes in the coastline of the Northern Aral Sea in the Syrdarya delta (Shinkarenko & Solodovnikov 2018).

Comparison explication of floodplain land shows the land transformation degree during the stated period (Table I).

<table>
<thead>
<tr>
<th>Land name</th>
<th>Parameters, ths.ha</th>
<th>1960</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area of the delta</td>
<td></td>
<td>750.0</td>
<td>1100.0</td>
</tr>
<tr>
<td>including: Dried bed of the Aral Sea</td>
<td></td>
<td>-</td>
<td>350.0</td>
</tr>
<tr>
<td>Fish-industry lakes</td>
<td></td>
<td>69.1</td>
<td>32.5</td>
</tr>
<tr>
<td>Small (non-fish-industry) lakes</td>
<td></td>
<td>6.7</td>
<td>2.2</td>
</tr>
<tr>
<td>Wetlands</td>
<td></td>
<td>51.9</td>
<td>56.7</td>
</tr>
<tr>
<td>Tugai forests and bushes</td>
<td></td>
<td>21.0</td>
<td>16.5</td>
</tr>
</tbody>
</table>
The flora of the lower reaches of the Syrdarya before the regulation of runoff consisted of about 170 species of higher plants belonging to 46 families. By 1980, the flora of the lower delta was already 97 species belonging to 21 families (Budnikova 2005). According to the work of Budnikova (2005), by 1992, there were only 96 species of higher plants in the delta of the Syrdarya River. As a result of changes in the hydrological regime and excessive mowing, a qualitative restructuring of the communities took place: the area of reed grasslands has decreased 6-7 times since 1960, the yield has decreased to the level of yield of pastures in the watershed plains. Everywhere, the area of the reed grass, licorice, grass - forb grass communities decreased by 70 - 75%. At present, the area of tugai has decreased by almost 20 times. As a result of drying of the delta, the areas of primary pastures decreased by 47%, the areas of hayfields decreased by almost 3 times, the areas of secondary and halophytic communities increased by 4.7 times (Budnikova 2005).

### 4.2. Characteristics of water quality

In Kazakhstan, the largest share in the use of water resources also belongs to irrigation (from 89 to 96 %). Based on data from the Aral-Syrdarya Basin, Water Management Association, Shomantaev (2001) indicates that there are 1,476 water consumers in the Kazakhstan zone of the Syrdarya basin, of which 970 are located in South Kazakhstan oblast and 506 in the Kyzylorda oblast. For various economic needs, about 12,000 million m$^3$ of water is annually taken from the Syrdarya river basin, including 9,600 million m$^3$ for irrigation, i.e. 80%.

In the Kazakhstan part of the Syrdarya river basin there are 6 irrigation arrays with a total area of 772,246 thousand hectares (Amirgaliev 2007). According to the data (Kipshakbayev 2004), the total volume of collector-drainage water formed in the territory of Kazakhstan in 1995 amounted to 1,580 million m$^3$. About 1300 million m$^3$ of collector-drainage water is formed in the South Kazakhstan oblast, the remaining 280 million m$^3$ - in the Kyzylorda oblast. About 900 million m$^3$ from the total amount of collector-drainage water, is discharged into the Syrdarya river basin, and the rest is diverted into natural depressions or partially used for re-irrigation. Returnable from irrigated water masses, as a rule, contain elevated concentrations of mineral salts, residues of nitrogen - phosphorus fertilizers, pesticides and other toxic substances, which significantly pollute river waters (Amirgaliev 2007).

Water mineralization is one of the most important hydrochemical parameters, reflecting both the genetic features of the formation of the natural waters composition, and their drinking, technical and irrigation qualities (Figure 4). The study of its regime is especially important for the river Syrdarya, because its water resources are used comprehensively by all sectors of the
economy and the river is subject to pollution by collector-drainage and other wastewater both in the territory of neighboring countries and Kazakhstan (Burlibayev et al 2018).

![Graph showing intra-annual change in mineralization for the period 2001–2016 Syrdarya river - town Kazalinsk.]

As can be seen from Figure 4, intra-annual change in mineralization is unevenly distributed throughout the year. The average value for the period 2001 - 2016 is 1196 mg/dm³, which exceeds the level of MPC by 1.2. The greatest mineralization is observed in November (1300 mg/dm³) and the least one is observed in March (1090 mg/dm³). This may be due to the influence of collector-drainage water flowing into the river system and irrigation arrays located in the upper part of the river.

The intra-annual course of suspended substances is also analyzed for a selected period of 2001–2016 (Figure 5).
Suspended substances depend on the amount of runoff, as well as on various unknown factors. Organic matter is always present in natural water. Usually, to assess the quality of water, which characterizes the total content of organic substances in water, such an indicator is used as biochemical oxygen consumption BOC$_5$ (Figure 6).
At this target, the BOC₅ value did not exceed the level of maximum permissible concentration (MPC) according to fishery and household criteria (MPC₇ and MPC₇ₕ). In addition to the above indicators of water quality, Kazakhstan Agency for Applied Ecology (KAAE) studies were carried out (Burlibayev et al. 2018) to identify exceeding the permissible standards of heavy metals. However, complete data for this gauge station are available only for copper for the considered period (Figure 7).

![Figure 7. Intra-annual change in copper for the period 2001 – 2016, Syrdarya River - town Kazalinsk.](image)

As it can be seen from Figure 6, the concentration of copper constantly exceeds the permissible norms, on average by 2.96 mg/dm³ (3 MPC). The presence of copper in elevated concentrations in water suggests that the main source of pollution is the anthropogenic factor: collector-drainage drains, metallurgy production, household waste (MetalMininginfo, 2016).

**5. Conclusion**

Based on the data from the gauging station Kazalinsk, there is an excess of concentrations for mineralization, an average of 1.2 MPC. The observed increased level of water salinity in the lower part of the river is the result of (1) the collector-drainage water entering the river network, as well as (2) the river feeding from saline groundwater.

BOC₅ values did not exceed the level of maximum permissible concentration for the considered period. Seasonal changes depend mainly on temperature changes and on the initial concentration of dissolved oxygen.

The average concentration of copper in the water constantly exceeds the permissible norms, on average by 3 MPC. The flow of the Syrdarya River contains copper (heavy metal) above the standard norms, which accumulate and undergo transformation in the Shardara reservoir.
and in the lower part of the river. Thus, copper is one of the main sources of pollution of aquatic ecosystems.

The change in water salinity and suspended matter in rivers are in accordance with changes in the flow of water in the river throughout the year. However, during the flood period and during discharges, the concentrations of natural salts in river waters are diluted. Simultaneously, with surface runoff a certain amount of salts is received from saline soils. Mineralized groundwater entering the river beds from the drainage adjacent areas of river basins and collector-drainage can also serve as the source of salts. Thus, the formation of the hydrochemical regime and quality indicators of water in the lower parts of the river occurs under the influence of return water from irrigated lands and industrial, domestic wastewater entering the river network both on average and in lower parts of the river.

The lack of water resources in the regions poorly supplied by this resource, requires more and more careful study of this issue in order to anticipate possible negative consequences both for humans in particular and for various ecosystems in general. In the near future, a significant change in the hydrological and hydrochemical regimes of water bodies can occur only due to changes in economic activities in the territory of Kazakhstan and neighboring countries. In the event of an increase in the production of industrial and agricultural products in the neighboring countries, the volume of wastewater, collector-drainage and wastewater entering the transboundary water bodies will inevitably increase, which, in turn, will increase the pollution of rivers.

6. References


