*Breckle, S.-W. & W. Wucherer (2007): What will be the future of the Aral Sea? In: Lozán, J. L., H. Grassl, P. Hupfer, L.Menzel & C.-D. Schönwiese. Global Change: Enough water for all? Wissenschaftliche Auswertungen, Hamburg. 384 S. Online: www.klima-warnsignale.uni-hamburg.de*

# 2.12 What will be the future of the Aral Sea?

SIEGMAR-W. BRECKLE & WALTER WUCHERER

***SUMMARY:*** *The changing distribution of the water resources and the establishment of huge irrigation systems in Central Asia by the former Soviet Union are the main reasons that the Aral Sea is running dry. Once it was the fourth largest inland lake on the globe, but since 1960 almost 90% of the water body and more than 70% of the surface area have disappeared. Today, the Aral Sea exists only in the form of remnants: the Small Aral Sea in the north (Kazakhstan) and a salt lake (the rest of the Large Aral Sea) in the south-west. The huge, but very flat south-eastern basin will continuously run dry. The Small Aral Sea in the north has a good perspective. Its future surface area will be about 4,000 km² and the salinity about 1.5–2.5% after the planned dam east of Kokaral was erected. On the dry sea floor (new Aralkum desert) salt and sand deserts have developed, being the source of salt- and sand-dust-storms. The situation of the environment, the threatened land-use in the whole area and the worsening health-situation is alarming. Necessary counter-measures to prevent further environmental degradation (in terms of the UNCCD-Convention) in the region of the whole Aral Sea basin are urgently needed (BRECKLE & WUCHERER 2005).*

The water resources in the whole area of western Central Asia (Middle Asia) are consisting of three large inland basins: the Aral Sea, the Balkhash Sea and the Caspi Sea. The area of the Aral basin extends over 1.6 million km². The Aral Sea itself took up an area of about 68,000 km² until 1960. Then, huge canals and irrigation systems were established which diverted the water of the two tributaries Syrdarya and Amudarya. The catastrophic desiccation of the Aral Sea begun. The Aral Sea, located in the basin of Turan, doesn't exist anymore. Its remnants consist of three water bodies, the Small Aral Sea in the North, and the Large Aral Sea in the South, which is divided into a deep western basin and a shallow eastern basin. To date, about 50,000 km² of sea floor ran dry. On the desiccated sea floor sand- and salt deserts have developed: the so-called new desert Aralkum. Its area is now vaster than the whole Netherlands, and it is still increasing. The desiccation of the Aral Sea has been called the biggest environmental disaster which has been caused by human activities through diversion of regional water resources (AGACHANJANZ 1988, WALTER & BRECKLE 1994, BRECKLE et. al. 1998, 2001a, 2001b, 2003, BRECKLE & WUCHERER 2005, GIESE et. al. 1998, KLÖTZLI 1997, LETOLLE & MAINGUET 1996, MICKLIN 1996)

The negative changes over the whole environment of this region, which have been termed the Aral Sea syndrome, are considerably affecting the economic potential as well as the living conditions. The Aral Sea is now an international water body and the two tributary rivers are of great interest for the five neighbouring states which became independent after 1990, including Afghanistan. The northern part (now the Small Aral Sea) lies in Kazakhstan, the southern parts, the Large Aral Sea, belongs partly to Kazakhstan, its southern part to Uzbekistan. Turkmenistan's economy completely depends on the Karakum-Canal, which diverts water from the Amudarya to Turkmenistan. Both rivers, the Amudarya and the Syrdarya are draining a huge mountainous area in Kirgisia, Tadzhikistan, and Afghanistan. The population growth and the overconsumption of water have led to an increasing gap between the available water resources for natural ecosystems and their replenishing and the water use for agriculture and other purposes.

## Hydrological budget of the Aral Basin and the Aral Sea

The first half of the 20th century has been a stable phase for the Aral Sea, with a rather constant water level of 53 m asl (above sea level). The two tributaries, Syrdarya and Amudarya, are draining an area which includes the mountains of the Pamiro-Alai, the Hindu Kush and the Inner Tian Shan in Tadzhikistan, Afghanistan and Kirgisia. The total discharge per year was estimated to be ca.120–130 km³ on average (KIRSTA 1991). The mean discharge to the Aral Sea before the desiccation started has been in the range of 50–60 km³/year. In the last decades, however, it dropped to about (0; absolute minimum) 3–10 (20; temporary maximum) km³/year. PENEVA et al. (2004) showed however that even though the river runoff almost ceased, the shrinkage of the Aral Sea is not as rapid as expected mainly caused by the compensating discharge of groundwater.

The length of the Syrdarya is 2,137 km, the mean annual discharge has been 38 km³ at the Aral Sea, including water from Kirgisia, Tadzhikistan, Uzbekistan and Kazakhstan. At the beginning of the 1960s the irrigated area in the basin of the Syrdarya was about 1.9 million ha, 30 years later it approached about 3.4 million ha (IVANOV & ISMAILOV 1992). During that time, six huge reservoirs were constructed with a total volume of 37.6 km³. This all caused a declining discharge of the Syrdarya to the Aral Sea which currently amounts only about 4–5 km³/year.

The length of the Amudarya is 2,450 km, the mean annual discharge has been 77 km³, with water from Afgha-

*sbreckle@uni-bielefeld.de*

nistan, Tadzhikistan, Turkmenistan and Uzbekistan. Nowadays the annual discharge to the Aral Sea has been reduced to only 5–15 km$^3$/year.

Since 1960 almost 90% of the water volume and more than 70% of the lake area have been lost (*Table 1.12-1*). The desiccation of the Aral Sea has reached a critical phase insofar, that now only remnant water bodies are left and will even become smaller in future, except for the Small Aral Sea. The Aral Sea syndrome and the new Aralkum desert are the new reality.

The desiccation of the Aral Sea is caused by the enormous expansion of the irrigated agriculture in the whole region, with an intensive production of cotton, rice, wheat and vegetables. Since the climate of the region is arid, with mean annual precipitation in the range of 100–150 mm and dominating winter rains, the agriculture of Central Asia totally depends on irrigation. Agriculture is using 87% of the whole water consumption in the area. More than 40% of the people of Uzbekistan and Turkmenistan are involved in agriculture (KLÖTZLI 1996). The same is true for the southern districts of Kazakhstan (Tschimkent, Ksyl-Orda). Restructuring of the economy will not be possible in the near future. Therefore, irrigation will remain the most important resource for agriculture in Central Asia, even more when regarding population growth.

## Large Aral Sea

### *Present situation*

The Aral Sea doesn't exist anymore and will not be restored in the near or distant future. The subdivision into smaller water basins already started in 1988, when the island Kokaral became a peninsula, after the Berg-Bay fell dry. All three main islands, Kokaral, Barsa Kelmes and Vozroshdenye are now connected with the main-land. The future development of the Large Aral Sea and the Small Aral Sea will be very different. The hydrological water budget of the Large Aral Sea is still negative, the desiccation will continue and within a few years the eastern shallow basin will be a local salt lake (STANEV et al. 2004, BENDUHN & RENARD 2004, MIRABDULLAYEV et al. 2004, FRIEDRICH & OBERHÄNSLI 2004) or a system of shallow salt lakes and swamps between the former island Vozrozhdenie and the eastern coast, with an estimated area of about 4,000–6,000 km². Nowadays, the designation »Great or Large Aral Sea« is misleading, since today two almost separate basins exist, the very shallow eastern part and a deep western basin, which will probably remain nearly unchanged during the next few years.

### *Effects of the desiccation of the large Aral Sea*

The desiccation causes negative impacts on the environment of the area, as e.g.:

- Higher climatic continentality, the annual thermal amplitude (monthly means) has increased from 24 K to 27 K (GINZBURG et al. 2003);
- Threat of the nature reserve area of the former island Barsa Kelmes;
- Easier access to the military experimental site on the former island Vozroshdenye (biological and chemical weapons);
- Formation of a huge open salt desert with salt dust and crusts between Vozrozhdenie and the east coast.

Barsa Kelmes is the only nature reserve in the whole area. It was founded in 1939, and occupies an area of 16,795 ha. Barsa Kelmes was an island in the middle of the Aral Sea and was therefore perfectly protected. Between 1996–1998 the area between Barsa Kelmes and the East Coast fell dry, the island became a peninsula easily accessible from the main-land. Since that time, hunting on boars and antilopes started on the former island. Antilopes, wild pigs as well as the famous herd of the kulans (*Equus hemionus kulan*) moved towards the east coast, where close to Kaskakulan are warm springs and all year round good green plant growth. In December 2005 the Parliament of the Republic of Kazakhstan ratified the enlargement of the area of the strict nature reserve Barsa-Kelmes to 173,000 ha, including parts of the area of the dry sea floor.

Between the eastern former coastline and the former islands Barsa Kelmes and Vozrozhdenye the desiccated sea floor turned to an enormous salt desert area, including some flats north of Barsa Kelmes. This salt desert is an open substrate surface with salts, crusted and powdery, with a mixture of NaCl, Sulphates, alkaline Carbonates and other more toxic components. This formation of a salt desert can be compared in size with the Great Iranian desert (Kavir area), or the Great Salt Desert in Utah (USA). The main

| *Year* | *Water level m NN* | *Water surface ( km²)* | *Volume of water (km³)* | *Salinity (% NaCl)* |
|---|---|---|---|---|
| *1960* | *53.4* | *68,000* | *1,150* | *0.9* |
| *1970* | *51.5* | *61,000* | *950* | *1.2* |
| *1980* | *46.0* | *52,000* | *620* | *1.7* |
| *1990* | *38.5* | *38,800* | *350* | *3.2* |
| *2000* | *ca. 32/39*** | *26,000* | *150* | *6-8 / 2.0** |
| *2005* | *ca. 28/39*** | *19,000* | *110* | *7;15** / 1.8** |

***Table 2.12-1:*** Dynamics of the water surface and water volume of the Aral Sea (Aralkum-desert)

* 2000, 2005 the water levels and data of the Small and Large Aral Sea were different

** In 2005, the shrinking Aral Sea has been subdivided into two lakes, the Western and the Eastern basin, with almost no water exchange between them

difference, however, is the temporal sale. The formation of the Iranian or the American salt desert and the changes in environmental conditions followed a geological time-scale. The speed of the dynamics at the Aral Sea is only within a few decades, thus, by magnitudes faster.

The salt desert flats are now also the source for strong impacts by salt dust storms in the whole region. The amount of salts derived from the salt deserts and blown into the atmosphere through storms can only be estimated by a rough guess, ranging between 15 and 150 million tons/year. Strong deflation processes at the open solonchaks (often puffy crusty type) can be observed, reaching 3–7 cm/year of blow-out. Satellite images reveal that the salt dust aerosol clouds often move from the eastern salt flats to south-western direction and are deposited in Karakalpakstan and the densely populated areas at the Amudarya and its delta.

The salt dust deposition cause increased salinity and alkalinity of the agricultural fields, thus changing the balance of natural ecosystems and their potentials. They also play a strong role regarding adverse health impacts in the population of the region (eye and bronchial diseases, etc.).

The ongoing desiccation has lead to the decoupling of the Western and the Eastern basin of the former Aral Sea . The Western basin will probably have a much longer lifetime, its slopes are about 5 times larger than in the Eastern basin. It is expected that it will not disappear but that it will transform into a basin of the type of the Dead Sea (STANEV et al. 2004, BENDUHN & RENARD 2004).

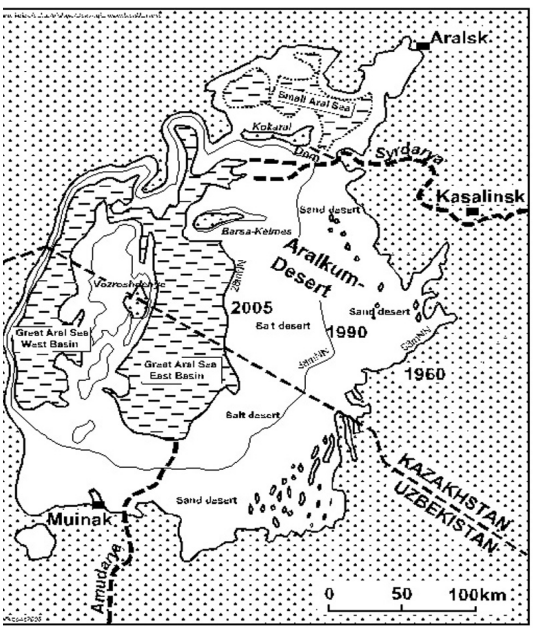


*Fig.2.12-1:* The disappearance of the Aral Sea 1960–2005 and formation of a new desert, the Aralkum (Orig.).

However, it is expected by SHERMATOV et al. (2004), that through natural fluctuations within the watersheds the run-off of the Amudarya may slightly increase again. Calculations by SALOKHIDDINNOV & KHAKIMOV (2004) show that at least 7.6 km$^3$ additional discharge per year would be necessary to preserve the present water levels of the two basins of Large Aral Sea. Consequently, the preservation of the Eastern basin will not be possible, but the current water flux is sufficient to preserve the West Sea, including the preservation of its circulation. In this case the Eastern basin would act as a salt sink and this is perhaps the best role it can play in the future.

The desiccation of the Eastern basin will also lead to an even greater impact by salt dust within the next 5–7 years, when most of the shallow remnant water basins will have disappeared and additional salt plains will have developed. This might cause an even stronger impact on the agricultural regions along the South coast and the Amudarya. It is therefore urgently needed to take countermeasures to decline the salt dust export from the desiccated sea floor. Phytomelioration seems the only reasonable and economic action against salt desertification. Artificial plantings on the saline soils need special techniques, but it was shown by experimental plots that this can be realised (WUCHERER et al. 2005). The older desiccated sea floor, mainly sand desert, was spontaneously covered by natural vegetation. Here, phytomelioration is of secondary importance. The moving sand dunes in that area do not need to be fixed by artificial plantings. It would even be better to allow the sand masses to move towards the salt desert areas to cover the solonchak soils. The salt rich soils of the younger sea floor are a mosaic of shallow deflation basins within an absolutely vegetation free salt desert. Here, plantings are urgently needed. The area is, however, too large, to be planted in a reasonable time. Thus, many smaller areas should be chosen to initiate core areas of vegetation from which it may spread and which, from the beginning, may start to act as wind shelters, thus preventing salt dust cloud formation.

## The small Aral Sea

### *Present situation*

Until 1960 the area of the Small Aral Sea was about 6,000 km² (at a level of 53 m asl). A critical phase of desiccation started at the beginning of the 1990ies, when the water level reached less than 38–39 m asl and the lake area shrinked to 2,600–3,100 km² (BORTNIK 1996). A further decrease of the water level below 38 m asl would have led to a additional subdivision and would consequently have caused a rapid desiccation of the remnant remote western basins. The construction of a dam at the Berg Bay (between peninsula Kokaral and the east coast south of the Syrdarya mouth)

was to stop this deleterious dynamic. The dam was constructed as a »natural dam« from sand, loam and gravel without a concrete foundation or cover. It forced the Syrdarya to discharge its water only to the Small Aral Sea. Thereupon, the hydrological budget turned positive, which led to an increase in water level to about 42 m asl and in a lake area to 3,700 km². The mean annual discharge from the Syrdarya was about 4–5 km³ during that time, being distinctly higher than the years before. This higher discharge can partly be related to the declining area in irrigated paddy fields in the whole Kzyl Orda region (from 100,000 ha to 60,000 ha), partly due to rainy years with precipitation above average. This development led to an unexpected high level of the Small Aral Sea. Consequently, in April 1999, after a strong storm, the dam broke and the water level of the Small Aral Sea sank by about 4 m.

A new program for the whole region, sponsored by World Bank, is now on the way. Several new canal-systems are constructed to improve the efficiency of the water-budget, the management of the irrigated areas and to construct a new and improved dam. This dam (constructed by a Turkish-English-Russian Consortium) is finished by the end of 2005. As a result, it is expected that this program will keep the water level of the Small Aral Sea stable at a constant height of about 42 m asl, so that it will be possible to install a power plant for electricity production. It is also hoped that the whole district from Kzyl Orda down to the delta of the Syrdarya will have a new basis for an efficient and sound reliable water use and distribution for the agricultural systems as well as for fish ponds. This gives hope for an improved standard of living for the people of the whole region, and a new hope for the villages around the northern Aral Sea area.

### *Effects of the recovery of the small Aral Sea*

The economy of the fishing villages around the Small Aral Sea declined steadily. Fishing activities completely stopped during the 1980s. The people from the small fishing villages like Akpasty, Akespe, Birlik, Bugun and others along the coast had to search for other incomes like hunting or grazing. One third of the population left the villages and went to nearby villages or towns or even farther to remote city centers. Hunting is not sufficient for supplying families and grazing was unproductive except in the close vicinity of the delta region. Especially severe have been the consequences of the desiccation of the Aral Sea for the large town of Aralsk at the north coast. In former times it was the centre of the fish industry. The rapid loss of fish as an important and cheap food, the rapid increase in the loss of jobs, the emigration, the increasing poverty of the people and the destruction of the whole natural potential (sea shore, inland tourism) drastically indicate the negative impacts of the Aral Sea syndrome.

The new canal system and the dam shall alter the situation. The increase in water level and water volume by the dam, the initiation of a desalinisation process, and the stabilisation of the hydrobiological situation of the Small Aral Sea will hopefully improve the situation.

At the end of the 1980s the plaice (*Pleuronectes platessa*) (fish from the North Sea) was introduced to the remnant Small Aral Sea. In the second half of the 1990s fishermen could start again to carry out fishing on a low level. According to their information, the catch of fish during spring 1998 amounted to about 1–1.5 t/day. Therefore, this can be considered as some revitalisation of fishing. Some villages started to establish fishing co-operatives. The income of the new fishermen people started to increase. Development aid from Denmark for the constitution of a co-operative supported the new initiative, as well as the use of new fishpond systems around some villages. The increase in water level led also to an increase in available soil moisture and to a higher groundwater level and thus to an increase in shrubby vegetation along the former coast. The stabilisation of soil surface and the improvement of pasture grounds could also be observed.

The local people even think of a complete revitalisation of the Aral Sea in its original size. This will however not be possible. It would mean a huge dam also west of Kokaral. But the positive aspects from new projects has enabled the returning of several families to their old villages at the former coast. Their faith on the Aral Sea came back. Others, who wanted to move, will now stay. The positive psychological effects of the ongoing projects are amazing. We hope that our positive impressions during various stays in the region will be substantiated and will not be reversed in the future.

## Final remarks

The hydrological water budget of the whole Aral Sea basin has not or only very slightly changed within the last centuries. However, the water resources, which are not sufficient any more to achieve the hydrological equilibrium of the Aral Sea, have been diverted. New dams were erected, huge new irrigation projects (areas) were developed, new fishponds and large new water bodies were created and filled (e.g. Sary Kamish). The loss of water by evapotranspiration (evaporation and transpiration) occurs to a great extent nowadays from other surfaces instead as from the Aral Sea surface itself.

All scenarios which have been developed over the last 2 or 3 decades to save the Aral Sea were not successful. The reality is that the Aral Sea does not exist anymore. In future times, only three smaller remnant water bodies will exist, with an area of about 8,000–12,000 km².

The first milestone was the subdivision of the Aral Sea into two independent water bodies at the end of the 1980s.

***Fig. 2.12–2:*** Successful plantings with saplings of saxaul (*Haloxylon aphyllum*) on the desiccated sea floor of the Aral Sea (45°N15'; 61°E08', 39m asl) on superficially sand covered solonchak (phot: SWBreckle, 24.06.2004).

The second decisive point was the formation of a large peninsula from the former small island Vozrozhdenye, thus creating two parts of the Large Aral Sea. The next milestone will probably be around the year 2010: the disappearance of the eastern shallow basin of the Large Aral Sea. The discharge of the Amudarya is relatively low and very variable from year to year. The western basin is rather deep and has rather steep coasts, therefore it will not change its characteristics too much, except in a further increase in salinity. Theoretically this could be used for *Artemia salina* (brine shrimp) breeding and culture as a protein source, depending on the overall economical situation.

Along the south-east to south-west coast few settlements remained and like the town Muinak they are in a desolate situation. The Small Aral Sea in the north with a future surface area of about 4,000 km² and a salinity of about 1.5–2.5% will have a good future perspective. The new developments in fishery, the improvements of the economic basis of the coastal villages, the enhancement of grazing and pastures in parts of the coastal region, and the improved economic infrastructure of the Syrdarya delta region for irrigation will lead to less poverty, and to an improvement of the living conditions of the people.

German scientist have done and are still doing a considerable task in research concerning ecology and the environmental factors of the region in order to establish a better and more sustainable economic system, as e.g. in the Urgench area (Uzbekistan, middle part of Amudarya) as well as in pioneer plantations on the desiccated saline sea floor in order to check the most appropriate species and planting techniques.

Some examples of necessary tasks (Breckle et al 2001a) have been:

- phytomelioration with salinity tolerant shrubs of the area (e.g. *Haloxylon, Halocnemum, Halostachys, Tamarix* etc.) (Wucherer et al. 2005). Truly salinity tolerant tree species are not available.
- windshelter belts around villages
- more efficient water use and energy supply
- management systems for controlled grazing
- participation of village people and capacity building to adopt new planting projects and other environmental initiatives
- normative nature conservation through:

1. enhancing biodiversity
2. developing a plausible strategy for nature conservation
3. securing and enlarging the conservation area around the nature reserve Barsa Kelmes
4. inclusion of the eastern former coastal parts like Kaskakulan with their hot springs,
5. inclusion of the Syrdarya delta with remnants of tugai forests
6. inclusion of the fossil-rich steep slopes (chinks) at the north coasts of the Small Aral Sea
7. establishment of a national park or a biosphere reserve

The actual situation of the environment, the threatened land-use as a consequence of salinisation, the bad health conditions and the poverty are still very alarming. Necessary counter-measures to prevent further degradation and to combat desertification in all its aspects (acc. to the UNCCD: United Nations Convention on Combating desertification) are urgently needed. But also the other UN-Conventions are of importance (UNCCB: United Nations Convention on Conservation of Biodiversity; UNFCCC: United Nations Framework Convention on Climate Change).

Solving these problems is of vital importance for the people in the Aral Sea region ♦