Asian Journal of Water, Environment and Pollution, Vol. 7, No. 1, pp. 63-69.

Aral Sea Crisis: Large Scale Irrigation and Its Impact on Drinking Water Quality and Human Health

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Received August 18, 2009; revised and accepted October 1, 2009

Abstract: The Central Asia, home of 40 million people, is located in the land locked region with extreme continental climate. The agriculture feeds almost all population. The decisions during Soviet times on making Central Asia cotton basket of Soviet Union had on-going impacts even today. Millions of people left their home places due to environmental crisis. Every year millions are suffering without drinking water and water for irrigation. The human environment of the basin has also been totally changed. The Aral Sea region now is a completely artificial territory, governed by unnatural processes. The extent of these changes is so great that natural rehabilitation is impossible. More than 2.5 million people live in this disaster zone. The purpose of this paper is to reflect on (i) socio-economic, ecological and institutional changes that contributed to the Aral Sea crisis, and (ii) present status of water resources use and possible developments in the region. The research is based on author's extensive field trips and research during 2001-2006 to the Aral Sea area, and extensive literature review on impacts of large-scale irrigation, e.g. soil salinity and high groundwater levels on human health. The research has indicated that in Central Asia, the irrigation systems are unsustainable, tend to create still huge risks to the human health and the large scale systems, created during the Soviet era became both economically and socially unfitting into the new systems of economy.

Key words: Irrigation, Aral Sea, water management, health, drinking water.

Introduction

The Aral Sea problem has now become world's most well-known, man-made ecological disaster. The world's fourth largest inland sea has dramatically shrunk, very few water now flows into the sea, and the salinity of the seawater increased tenfold during the last decades. Although attempts of reducing water use and reduced application of chemicals in agriculture have had positive consequences for the environment of the Aral Sea, the political and social problems resulted by the problem generally called as "Aral problem" is still serious (Spoor, 1998; Glantz et al., 1993).

The excessive withdrawals of water for irrigation from two main tributaries of the Aral Sea – Amu Darya and Syr Darya – to extend irrigated areas have resulted on disastrous changes in the environment, noticeable ones are drying up of the Aral Sea, increasing salinity of the both land and water resources and contamination of the air, soil and water with different chemicals used in agriculture (Micklin, 1992; Glantz et al., 1993; Spoor, 1998). The most damaged part of the environment is the region's water resources. Approximately 95 percent of Amu Darya, and 100 percent Syr Darya rivers, the main water sources for Aral Sea Basin, are regulated by more than 60 different water reservoirs, canals and dams. From a total 160-170 km^3/year of water resources, the five countries of basin use more than 150 km^3. The quality of surface and ground water has changed dramatically. The Amu Darya was the drinking water source for lower part of basin until 1970. Currently, both ground and surface water contain numerous chemicals, which are very hazardous for human health. The growing population pressure, the absence of appropriate sewerage system and withdrawal of government support from the social sector leading to more deterioration of the water quality (Spoor, 1998). This paper is an attempt to present the impact of the large scale irrigation on drinking water and human health in the Aral Sea basin.

Study Area

The Aral Sea basin, covering the territories of Tajikistan, Uzbekistan, Turkmenistan, and some parts of Afghanistan, Kyrgyzstan and Kazakhstan, is located in the heart of the Euro-Asian continent. Its territory is located between longitudes 56° and 78° east and latitudes 33° and 52° north, and covers about 1.55 million km^2 of the Central Asia and 0.24 million km^2 of the Afghanistan territory.

Diverse terrain and altitudes ranging from 0 to 7500 m above the mean sea level are responsible for the diversity of the microclimate. The average temperatures range from 0-4° C in January to 28-32° C in July. However, summers in some parts of the area can be as hot as 52° C and winters can be as cold as -16° C, making the overall climate of the basin a sharp continental, with hot summers and cold winters. The two main rivers, the Amu Darya and the Syr Darya, together with some thirty primary tributaries, feed the basin. However, many of the tributaries flow now only seasonally, thus drying up before reaching the main rivers. The main rivers originate in mountainous regions that have surplus moisture (precipitation 800 to 1600 mm and potential evapo-transpiration of 100 to 500 mm) resulting in permanent snowfields and glaciers – the Pamir and Tien Shan ranges. Annual precipitation in the basin lowland deserts ranges from 100 mm in the southwest to 200 mm in the foothills of southeastern mountains, and to 30 mm in the Hungry Steppe, southwest of Tashkent. Moisture coefficient in the basin ranges from 0.1 to 0.6 (Micklin, 1992). Thermal conditions in the basin are favourable for crops such as cotton and cereals.

Large Scale Irrigation Development and Its Consequences

At the beginning of the 1960s, the Former Soviet Union (FSU) launched efforts to divert almost all water from the two rivers. The diversion of millions of cubic metres of water to irrigate cotton fields and rice paddies through the massive infrastructure development helped increase the command area from five million ha in 1950s to eight million ha at present. The water development system of the region is described as “one of the most complicated human water development system in the world” (Raskin et al., 1997) as human interventions have gradually modified the natural water flow and resource system. The Aral Sea Basin system now has highly regulated rivers with 20 medium and large size reservoirs and around 60 diversion canals of different sizes. In all, the two rivers have some 50 dams of varying sizes. The diversions of water for agriculture from the Syr Darya are almost equal to its total annual inflow and the annual diversions from the Amu Darya are around 45 cubic kilometres out of its annual inflow of 70-80 cubic kilometres. However, all of the available surface water is virtually diverted for irrigation which eliminates the scope of further expansion of command areas. Thus, improved water management to increase productivity remains the only option to guarantee food security of the region.

The conveyance system of the two rivers comprises a complex web of canals, impoundment, tributaries, irrigation fields, distribution system, and municipal and industrial facilities (Micklin, 1992). The drainage infrastructure is designed in such a way that it discharges most of its effluent back into the two rivers, thus aggravating the downstream water quality gradually. As a result, soil salinity in the downstream areas is emerging as one of the important problems. While cotton was the main crop in the region during FSU, a new trend of diversifying crops is coming up.

The diversion of most of the water of the Aral Sea Basin has led to a gradual deterioration of the environment. In 1965, the Aral Sea received about 50 cubic kilometres of fresh water per year – a number that fell to zero by the early 1980s. Consequently, concentrations of salts and minerals began to rise in the shrinking body of water causing severe soil salinity problems, especially in the downstream areas of the region. The water salinity increases up to two grams/litre in the delta of the Amu Darya and the Syr Darya (Razzakov, 2003). Presently, 31 per cent of the irrigated area has a water table within two metres of the surface and 28% of the irrigated area suffers from moderate to high salinity levels. Crop yields in those areas have declined by 20-30%. An estimated 137 million tons of salt is the average discharge from the irrigated lands (Razzakov, 2003).

That change in rivers’ water chemistry has led to alterations in the Aral Sea’s ecology, causing reduction in the fish population and therefore unforeseen problems for previously thriving commercial fishing industry, which employed roughly 60,000 people in the early 1960s. By 1977 the fish harvest was reduced by 75 percent and then led to essentially elimination of the industry by the early 1980s (Razzakov, 2003). The shrinking Aral Sea has also had a noticeable effect on the region’s climate. The growing season there is now shorter, causing many farmers to switch from cotton to rice, demanding even more diverted water. Salinization even affects the cultural heritage of Central Asia: high groundwater levels and salinity threaten the historic monuments in famous towns of Bukhara and Khiva.

A secondary effect of the reduction in the Aral Sea's overall size is the rapid drying-up and exposure of the bed of the lake. Strong winds that blow across this part of Asia routinely pick up and deposit thousand tens of tons all over of now exposed soil every year. This process has not only contributed to deterioration of breathable air quality for nearby residents, but has also reduced crop yields due to those heavily salt-laden particles falling on arable land.

The main causes of Aral Sea Crisis are the increase in irrigated lands, the low-efficiency use of water resources, inappropriate agricultural practices, especially the dominance of cotton monoculture. During 15 years, 1965-1980, irrigated lands increased by more than three times. Most of the new lands were in the dry zone, an area with low soil fertility. In the past, these lands had once been irrigated, but had become a desert. There was no economic policy governing the effective use of water or land. The government owned the water and land; water was free, it is still free today. The water use efficiency was only 0.35-0.45. This means, if you are taking 100 litres of water from a river, only 35 litres are used to grow crops, and the other 65 litres are lost (Spoor, 1998; Glantz et al., 1993; Micklin, 1992).

The Aral Sea has lost more than 60% of its water-covered area and divided into two parts (Big Sea and Small Sea). The wetlands in the tail of the Syr Darya and Amu Darya mostly dried out. Only few km^3 of water from two feeding rivers are reaching the Aral Sea. It is not enough to save leaved part of the wetlands. These wetlands play an important role not only from biodiversity point; they arrest the progression of salt-sand from Aral Sea into irrigated lands.

The consequences of the above presented changes in Aral Sea and the river systems in the basin result on high vulnerability and reduced resilience of the ecosystems (Molden et al., 2007). Therefore, the population of the Aral Sea basin is more vulnerable under the changing environmental conditions.

Impact on Water Quality – Case of Tail Part of Amu Darya River

The main sources of drinking water in the tail of Amy Darya river are ground water, irrigation canals and piped tap water. All three sources are hydraulically linked into the irrigation water in the large canal systems. Therefore, the quality of the drinking water in this region depends on quality of Amy Darya water.

According to the Uzbek statistics, almost 60% of the population living in the Aral Sea zone (Khorezm and Karakalpakstan regions) have access to safe and piped drinking water (Uzstat, 2006). The Uzbek government has launched ambitious project of providing high quality drinking water for the pre Aral zone as part of its strategy of overcoming the impacts of Aral Sea disaster. The major cities, Urgench, Khiva, Nukus and few district centres have received piped water from Tuyamuyun water reservoir, located 200-250 km above Nukus city. The quality of the reservoir water though better than ground or tap water in locality, still contains high dose of salts and other chemicals. Study, conducted in 2000 at Koshkopir district of the Khorazm province, reveals 29% of population had access to the tap water, 34% had private wells and rest of the people were drinking water from irrigation canals or private wells (Abdullaev and Najimova, 1999). If one considers the fact that the survey was conducted at the centre of the district than the number of people depending for their drinking water from irrigation canals will be much higher in rural settlements.

The Amu Darya river, the larger of the two main feeder rivers to the Aral Sea, provides drinking water to over 2.5 million people in the lower Amu Darya region. Extensive water withdrawals from the Amu Darya began in the 1960s as irrigated agriculture in the region was expanded for cotton production. The sodium content of the river is naturally high and is adversely affected by both excessive diversions for irrigation and return drainage flows from irrigated areas.

Drinking water in the study region originates from the Amu Darya and is delivered via ground water, irrigation canals and piped tap water. The Tuyamuyun Hydroengineering Complex, a complex of artificial water reservoirs located in the lower Amu Darya river, provides the study region with drinking water (piped) and irrigation water. The overall contamination of the water from this reservoir, including sodium levels, has increased since 1990. According to Froebrich et al. (2007) it is noted that under dry year conditions, the Uzbek standard for drinking water (1.0 g L^{-1} for piped water) could be exceeded by as much as 30% – presenting significant concerns for water safety.

According to official Uzbek statistics, approximately 60% of the population in the study region have access to improved drinking water (Uzstat, 2006). Data collected at the field level, however, has found that fewer households are connected to a safe water supply system than officially reported (Abdullaev et al., 1999). In some areas of the study region less than 30% of the population had access to tap water, while 34% had private wells. The remaining share obtained drinking water from irrigation canals. The estimations made by Suvchi (2000), however, are conservative when one considers that the survey was conducted in the centre of the Khorezm province – a predominately urban area. A much higher share of the rural population, therefore, is assumed to be securing their drinking water from irrigation canals than officially reported.

A study, conducted as part of the ZEF/Unesco Khorezm project, found that shallow ground water from tube wells and dug wells was utilized for drinking water in rural areas of the study region. While access differed substantially across the surveyed area, on an average roughly one half of all surveyed households obtained drinking water from piped sources, while 37% from tube wells and 14% from dug wells (Herbst, 2006).

The salt content in water from these various sources differs substantially. Water from irrigation canals fluctuates from 1 g L^{-1} at the head and up to 2 g L^{-1} at the tail end of the irrigation system in the study region (Hamidov, 2006; Razzakov, 2003). Similarly, piped water in the study region has been reported to contain between 1.3 and 1.7 g L^{-1}, while dug wells range from 1.9 to 3.4 g L^{-1}. While the median salt concentration of tube well water was similar to that in dug wells, the variance among the sampling points was much greater (1.9 and 4.6 g L^{-1}). Assuming that water salinity is due to sodium only and an average water consumption of two litres per person/day, a significant share of the population is expected to ingest the maximum recommended daily sodium intake of 2.3 g (100 mmol) which corresponds to 5.8 g salt (sodium chloride) per day, via drinking water alone (Herbst, 2006).

The WHO reported that in 2004, approximately 25% of the rural population in Uzbekistan was without sustainable access to improved drinking water (WHO, 2005). This figure does not account for those households receiving water that is of below international standards in terms of chemical content.

Post Independent Changes in Water Sector

With the collapse of the Soviet Union, following important changes occurred in water sector of the Aral Sea basin: (i) formerly inter-republican water management became an interstate issue, (ii) the water distribution, formerly pure technical issue, became more of contested, social activity (Abdullaev et al., 2008), (iii) formation of user groups at the former collective farm level (Zavgordnyaya, 2006) and (iv) de-collectivization of the agriculture which resulted more plurality in the agricultural production.

Immediately after the collapse of the Soviet Union, previously internal water resources of the basin became an interstate issue and transboundary water management is frequently becoming an issue of irritation between regional countries. The upstream countries Kyrgyzstan and Tajikistan are trying to use water for the electricity generation and therefore higher discharges from the upstream reservoirs are released in the winter, which is leading the frequent conflicts between the riparian countries. The outstanding impact of this change is the higher water release now being in winter and water shortages in summer; the water quality in the summer months will be deteriorating. Although there is no evidence on changes on water quality there is clear indication of growing water scarcity in summer months, especially at the tail end of the Amu Darya and Syr Darya for the last three years.

Water management at the main canal and basin levels did not change until the late 1990s. The basin principles of water management (hydrographic) were introduced in all countries, except Turkmenistan. The territorial water management units at different levels were replaced by hydrographic units, such as basin irrigation system management organizations (BISMO) and canal management organizations (CMO). The irrigation service fees were introduced in three countries out of five, except for Uzbekistan and Turkmenistan. Following are most important socio-political changes which had an impact on water management: (i) collective farms were abolished and accurate cropping records are no more available, and (ii) water allocation process became more politicized due to the transboundary status of major rivers.

In all countries of Central Asia, the efforts to reform the irrigation sector were mainly concentrated on transferring management responsibility to water users at secondary canal levels. Planning, distribution and management of on-farm water became the business of Water Users Associations (WUAs), wherever they existed. Immediately after the independence in 1991, the governments of the Central Asia introduced land reforms, transforming collective farms (locally known as *kolkhozes*) into individual farms. The aim of this transformation was two-fold: first to abolish the Soviet legacy and the second to revive the productivity of the then bankrupt collective farms (Spoor, 2004). During the reforms, the social and organizational structures of collective farming, including one regulating the water management, has been abolished alongside with collective farms. On-farm irrigation and drainage infrastructure, formerly managed and maintained by collective farms were left abandoned. The water distribution became an issue of social interaction, a place of contestation and competition (Wegerich, 2000; Abdullaev et al., 2006).

The impact of land distribution on water management on farm level was initially ignored. In the former collective set up, the number of secondary water users ranged between 10 and 15 units (*brigades*) and water management was linked to the agronomic operations and readiness of the land to be irrigated. Trained and experienced staff, agronomists and hydro-technicians had been employed in every collective farm and were mandated to overlook the irrigation water management. Former members of the collective farms as well as citizens with no agricultural experience became individual farmers.

The land reforms have led to a big increase in the number of individual farm units along secondary and tertiary canals. Given the new setting, the former methods for water distribution, as applied under the former large-scale collective farming system, have become irrelevant, leading to much chaos, inequity and unreliability in water supply to farmers. The formerly, during the collective farming times, the tillers or members of the collective farm had no interest on influencing the water distribution. The state has been ensuring the supply of all inputs into the collective farm because the state was receiving larger share of the outputs. However, after the de-collectivization, situation has been changing; now individual farmers and land owners have much more share on outputs and they have an interest on influencing water management so that they get water on time and enough amounts. Thus, many farmers and water managers have had to resort, with variable success, to some alternative water distribution methods to meet these new challenges. Nevertheless, transparency and equity in local water use still remains an issue.

The competition and contestation on water distribution further exacerbated due to the increasing plurality of agricultural operation and production systems, resulting more of human-made water scarcity and deterioration of the environment (Figure 1). The poor state of the irrigation and drainage (I&D) networks have further exacerbated the water management situation at the on-farm level. The situation, if not changed, will further exacerbate the competition for already precious water resources, especially drinking water provision will be affected badly.

Potential Health Impacts

Health aspects of the large scale irrigation are important and two-fold in Aral Sea basin. First and foremost impact of large scale irrigation is contamination of the both surface and groundwater sources with agricultural chemicals or non-point pollution. The second impact relates with changes in water regime of water bodies, such as rivers, lakes, water reservoirs and canals. The regulated water bodies often have less water for some periods of time (e.g., in winter or summer) when many infectious bacterias are active. The changes in water regimes are mainly influence on chemical and bacteriological regime of the water resources. Most of

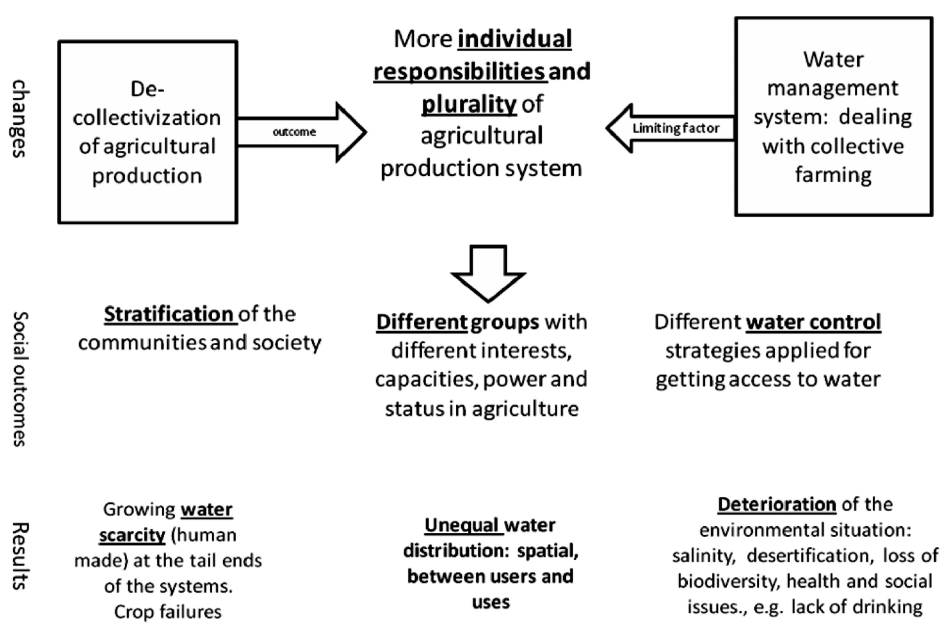

Figure 1: Impacts of the recent changes in agricultural production on water management (Abdullaev et al., 2008).

the health impacts of large scale irrigation are related to deterioration of the water resources quality which is used not only for agriculture but also for livelihood purposes. The contaminated water resources, both ground and surface water has been major source for health problems in rural Uzbekistan (Herbst, 2006; Kudyakov, Fayzieva, van der Meer, 2000; Razzakov and Konukhov, 1996). Throughout the Aral Sea region, 70% of the drinking water does not meet chemical standards. River water contains up to 5500 mg/litre of salts, the ground water at some locations reaches average salt levels of 3300-4500 mg/litre (Razzakov and Konukhov, 1996; Kudyakov, Fayzieva, van der Meer, 2000). High salt concentrations in ground and surface water have a direct effect on the drinking water quality and as shown in a recent study, well water frequently reaches concentrations of salts of up to 2800-3500 mg/litre (Herbst, 2006). High concentrations of the salts and other chemicals in water sources result high level of diseases such as kidney diseases, cardiovascular pathology, stomach diseases, etc. (Razzakov and Konukhov, 1996; Kudyakov, Fayzieva, van der Meer, 2000). According to Ministry of Public Health (2008), number of diseases linked with water contamination and environmental situation has been in rise for last 5 to 6 years.

Conclusions

The concept of "Aral problem" is although very well presented, the ongoing changes in water sector are making the situation further complicated. The growing incidents of water-borne diseases (Spoor, 1998), declining water quality in the rivers and frequent water scarcity in the tail ends of the rivers and irrigation systems are threatening livelihoods of the rural inhabitants (Abdullaev et al., 2008). The changing water management situation both on transboundary and at the national level has put more burdens on environmental sustainability. It is important that both local policy makers and international donors who fund almost all humanitarian and research in the Aral Sea zone recognize new realities of the post Soviet period in the Aral Sea. Although water management paradigms in the region has been progressing from hydraulic mission to more economic one the ownership of the processes towards integrated water management is still not owned by local stakeholders (Abdullaev et al., 2009b). The recent changes in agriculture result in more competition and contestation on water. The poor state of the irrigation and drainage (I&D) networks have further exacerbated the water management situation at the on-farm level. The situation, if not changed, will further exacerbate the competition for already precious water resources, hard hitting water uses for social purposes such as for drinking and household uses. Health aspects of the large scale irrigation are important and manifold in Aral Sea basin. The growing numbers of water-borne diseases coupled with deteriorated social infrastructure after the collapse of former Soviet Union is threatening social and economical sustainability of the region.

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