Doubling Freshwater Inflow is Key to Curbing the Aral Sea Crisis

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Introduction: The Global Problem of Growing Demand for Freshwater

There is now a greater understanding of the need to regard freshwater as a finite natural resource. The availability and quality of water are crucial, both for sustainable human development and the survival of environmental systems in different regions of our planet and the Earth as a whole. But, as we approach the new millennium, the quantity and quality of water resources are under threat.

Freshwater withdrawals around the world have increased nearly tenfold this century. Global per capita water supplies have been declining rapidly over the past several decades; they are now a third lower than they were 25 years ago. More than 430 million people live in countries with water stress (less than 1,700 cubic meters of freshwater available per person) or water scarcity (less than 1,000 cubic meters per person), facing chronic and widespread water shortages. Further increases in population and economic activities are expected to boost demand for water. The share of the world's population experiencing water stress could increase more than fivefold by 2050. Environmental degradation resulting from intensive use of water has become a great concern for both developing and industrialized countries, however they have different capacities for dealing with this problem. More than one billion people lack access to safe water: some 270 million in urban areas and close to 900 million in rural areas. Almost all of them live in developing countries [10, pp. 118-119].

The amount of water used by a country is clearly dependent on its level of economic development. In low-and-middle income economies, most water is used for agriculture. In high-income economies, industry has the main water user. The share of domestic water use increases with the level of income. (Table 1)

Table 1. Global Water Withdrawal by Sector in Low-, Middle-, and High-income Economies

	% for agriculture	% for industry	% for domestic
Low income	91	5	4
Middle income	74	17	9
High income	40	45	15

Source: *World Development Indicators, 1999*, World Bank, Washington D.C., 1999, p. 119.

Throughout the world, growing industrialization and urbanization have resulted in an increased reliance on lakes and water reservoirs as opposed to rivers. Lakes and reservoirs have increasingly become the most reliable sources of large quantities of water, especially in big cities and industrial centers. At the same time, however, the environment around lakes and reservoirs, as well as their volume and water quality, has deteriorated rapidly. In a sense, they are a vivid sign of accumulated environmental decline and serve as litmus tests to demonstrate the discord between economic activity and nature.

Literature on lakes and water reservoirs [2, pp. 13-20] has identif ied six major types of environmental disruptions:

1) decline in water levels (as a result of the overuse of water from the lake itself or from inflowing/outflowing rivers, i.e., the Aral Sea, Lake Balqash and Lake Qinghai in China, and Mono Lake in the USA);
2) accelerated siltation (as a result of soil erosion due to overuse of farming and grazing lands, deforestation and other reckless activities in lake catchment areas, in China, India, and other developing countries in Africa and around the world);
3) acidification (as a result of acid air pollutants, i.e. acid rain and dry fallout directly on the lake surface or indirectly through inflowing rivers, i.e. in Scandinavia, Central Europe, North America);
4) eutrophication (as a result of increased fertilizer use in crop fields, deforestation, as well as input from industrial sites and urban sewage systems);
5) toxic contamination (heavy metal contamination i.e. mercury poisoning, which led to Minamata disease, or defoliants such as butifos or other agrochemicals);
6) extinction of ecosystems and biota (the total collapse of aquatic ecosystems and the loss of biodiversity in natural lakes are the ultimate result of the above-mentioned disruptions.

The consequences are also multifaceted:

1) decrease in freshwater reserves;
2) degradation of water quality;
3) loss of biodiversity;
4) damage to fisheries;
5) disturbed surface for water transportation;
6) change in regional climate, desertification;
7) economic damage (i.e. reduction in the size and productivity of agricultural land and crops);
8) social (loss of traditional jobs and incomes from fishing, hunting and related industries, increased unemployment) and health problems (higher infant mortality, maternity deaths, shorter life expectancies);
9) and other direct and indirect negative effects.

The most vivid example of nearly all of the above-mentioned disruptions and consequences is the Aral Sea - one of the lar gest environmental catastrophes to have occurred in the 20th century. The problem has been intensively discussed [see, 6, pp. 394-398]. This paper examines the most recent data available on the use and withdrawal of freshwater resources in Central Asia from the viewpoint of their quantity and contamination sources and attempts to evaluate the progress made during the 1990s to deal with the Aral Sea crisis.

The Withdrawal and Use of Freshwater Resources in Central Asia.

1. Lakes, Rivers and Water Reservoirs

Central Asian states have a variety of rivers, lakes, as well as man-made water reservoirs, but they are not evenly distributed across different parts of the region.

There are more than 48,000 lakes in Kazakhstan (including Balqash, Zaisan, and Tengiz) and about 3,000 lakes in Kyrgyzstan (including Issyk-Kul, Song-Kul, and Chatyr-Kul). Uzbekistan and Kazakhstan share the Aral Sea, and approximately half the coastline of the world's largest lake, the Caspian Sea belongs to Kazakhstan and Turkmenistan.

The region's main rivers are the Syr Darya (together with the Naryn, 3019 kilometers) and the Amu Darya (together with the Pyanje, 2540 kilometers). As for their length they were the sixth and seventh longest rivers in the former Soviet Union (FSU) yielding in this respect only to the Ob, the Amur, the Lena, the Yenisei and the Volga. The Syr Darya's basin amounts to 219,000 square kilometers and includes the Naryn, Karadarya, Chirchik, Akhangaran, Sokh, Isfara, Akbura, Isfairamsai, Shahimardan, Gavasai and Kasansai rivers. The Amu Darya's basin is 309,000 square kilometers and includes the Zeravshan, Kashkadarya, Tupoloangdarya, and Sherabad rivers. The Amu Darya's volume amounts to 1.2 cubic kilometers while the Syr Darya's volume is 1.0 cubic kilometers.

Glaciers and snow in the mountains are the main sources of water in most of Central Asia's rivers. There are innumerable glaciers in Kazakhstan, Uzbekistan, Kyrgyzstan and Tajikistan with the largest ones, Fedchenko and Zeravshan, situated in Tajikistan.

All of Central Asia's states possess many water reservoirs. There are 21 water reservoirs larger than 0.5 cubic kilometers in the region with a total volume of 141 cubic kilometers. The ten largest, holding more than 100 cubic kilometers of freshwater, are situated in Kazakhstan and Kyrgyzstan [5, pp. 101-103].

2. Freshwater Resources

Freshwater resources in any particular country refer to renewable water sources, which include rivers and groundwater from rainfall in the country. *World Development Indicators* - 1999 also includes river flows from other countries in its calculations, so its figures are not comparable with those published in previous years, which exclude external sources [10, p. 139]. However, they fully coincide with the indicators for "renewable surface and groundwater resources" used in FSU and CIS statistics, because the latter also includes river flows from outside countries [5, p. 105]. Moreover, in recent Russian Statistical Committee official publications the term "renewable surface and groundwater resources" was replaced with "*resursy presnoi vody*" which is equivalent to "fresh water resources" [see, e.g., 9, pp. 18- 19]. It is interesting to note that the above- mentioned sources give a similar meaning to this indicator and give per capita data on freshwater resources. These statistics are important for analyzing the situation in different countries with respect to freshwater resources availability.

Table 2. Freshwater (Renewable Surface and Groundwater) Resources* in Central Asia (cubic meters per capita)

	1989	1995	1997
	(*Environment in the CIS*, 1996)	(*Rossiia i strany mira*, 1998)	(*World Development Indicators*, 1999)
Kazakhstan	14,000	7,551	8,696 *
Kyrgyzstan	14,000	10,786	2,509
Tajikistan	18,000	16,330	...
Turkmenistan	18,500	15,528	3,950 *
Uzbekistan	6,000	4,725	5,476 *

* Total resources include river flows from other countries.

Sources: *Environment in the CIS*. Statistical Compendium, Interstate Statistical Committee of the CIS, Moscow, 1996, p. 105; *Rossiia i strany mira*. Ofitsial'noe izdanie. Goskomstat Rossii, Moskva, 1998, pp. 18- 19; *World Development Indicators*, *1999*, World Bank, Washington D.C., 1999, pp. 137- 138.

However, the estimates made by these respected sources vary quite widely from each other. According to the CIS Interstate Statistical Committee, in 1989, the Central Asian nations possessed the following amounts of surface and underground renewable freshwater resources. The total annual volume of underground water was estimated at approximately 87 billion cubic meters. It varied from 500 cubic meters per capita in Turkmenistan, to roughly 1,000 cubic meters in Tajikistan and Uzbekistan, and up to 3,000 cubic meters per capita in Kazakhstan and Kyrgyzstan. This was in addition to the total annual volume of renewable surface water resources which amounted to 449 billion cubic meters. The annual flows were unevenly distributed among the countries, however. On a per capita basis, Turkmenistan was endowed with 18,000 cubic meters, Tajikistan - 17,000, Kazakhstan and Kyrgyzstan - 11,000, and Uzbekistan - 5,000 cubic meters. Overall, it is not difficult to calculate that, in accordance with CIS data, Uzbekistan was in the worst situation. It has less than half of Kazakhstan and Kyrgyzstan's per capita renewable water resources and less than one- third of Turkmenistan and Tajikistan's (Table 2, column 1).

The data given in *Rossiia i strany mira* is different and can not be explained by population dynamics between 1989- 1995. Still, with regards to per capita freshwater resources, Uzbekistan is far behind the other Central Asian states (Table 2, column 2).

The 1997 per capita estimates by the World Development Indicators- 1999 on freshwater resources for the Central Asian states differ significantly from both series of data mentioned above (Table 2, column 3). It is noteworthy that the figures approximately match only in Uzbekistan (taking into consideration population growth), but vary widely for Turkmenistan, Kyrgyzstan and Kazakhstan (no data was given for Tajikistan).

One can see that the data for Turkmenistan in the first two cases looks rather exaggerated and believe that the country with the least rainfall and largest desert area might have the least freshwater resources.

How to explain the low level of freshwater resources in Kyrgyzstan according to the second source? The country is one of the richest with regards to water resources in the region. It is known, however, that there is an agreement between the five Central Asian states on sharing surface and groundwater (reached during the Soviet era and retained after independence). According to this agreement, Kyrgyzstan allows over 75% of the river water originating in its territory to flow into neighboring republics for their use [7, p. 9]. Even considering this fact, it appears that the World Development Indicator underestimated Kyrgyzstan's resources.

It is interesting to note that Kazakhstan, which has rather abundant freshwater resources in relation to its decreasing population, and much more rainfall than its southern neighbors, also saw its data revised downward compared to 1989; but it is more or less comparable for 1995 and 1997. The same judgment could be correct to a different extent for Tajikistan's 1989 and 1995 estimates. One could expect that this mountainous republic, with the region's largest glaciers and many rivers, including both Amu Darya and Syr Darya, has the greatest per capita freshwater resources in the region.

3. Freshwater Withdrawals

Annual freshwater withdrawals refer to total water withdrawals, not including evaporation and other losses from storage basins. Withdrawals also include water from desalination plants in countries where they are significant source of water withdrawals. Withdrawals can exceed 100% of renewable supplies where extraction from nonrenewable aquifers or desalination plants is considerable or where there is significant water reuse. (There is no explanation why in the World Development Indicators- 1999, this was applied to Turkmenistan's case, which uses water repeatedly much less than Uzbekistan.)

Table 3. Share of Withdrawals Compared to Freshwater Resources, 1997 (%)

Kazakhstan		Kyrgyzstan		Tajikistan		Turkmenistan		Uzbekistan	
1995	1997	1995	1997	1995	1997	1995	1997	1995	1997
30.2	27.6	24.0	94.9	13.2	...	32.6	123.9	76.4	63.4

Sources: *World Development Indicators*, 1999, World Bank, Washington D.C., 1999, pp. 137- 138; *Rossiia i strany mira*. Ofitsial'noe izdanie. Goskomstat Rossii, Moskva, 1998, pp. 18- 19.

Table 4. Freshwater Withdrawals in Central Asia (billion cubic meters)

	1985	1990	1991	1992	1993	1994	1995	1997
Kazakhstan	39.0	35.2	34.9	32.7	32.3	30.8	37.9	37.9
Kyrgyzstan	9.3	10.9	11.1	11.2	11.0	11.0	11.0	11.0
Tajikistan	12.9	13.7	13.7	12.8	13.1	13.5	12.6	12.6
Turkmenistan	24.2	22.6	26.7	24.9	25.7	24.0	22.8	22.8
Uzbekistan	70.6	69.0	69.8	71.2	71.5	...	82.2	82.2

* Data for Turkmenistan in 1992- 1997 does not include water losses in the Karakum canal.

Sources: *Environment in the CIS*. Statistical Compendium, Interstate Statistical Committee of the CIS, Moscow, 1996, p. 108; *Rossiia i strany mira*. Ofitsial'noe izdanie. Goskomstat Rossii, Moskva, 1998, pp. 18- 19; *World Development Indicators, 1999*, World Bank, Washington D.C., 1999, pp. 137- 138.

Again, the largest disparity between the data from the different sources is linked to Kyrgyzstan and Turkmenistan. There are smaller disparities in the case of Uzbekistan and especially Kazakhstan (Table 3). It is also worth noting that the differences are solely connected with varying estimates of freshwater resources, but not with the absolute quantities of water withdrawals themselves.

Moreover, the data given in different sources for 1995 and 1997 are completely identical. This coincidence is easily explained by the fact that both sources used the indexes given by World Resources Institute. The question is that they are referring to different years with a two- year lag. Secondly, and it is significant to note, for Kazakhstan and especially for Uzbekistan, the difference between indexes given by these sources for 1995 and 1997, and statistics published by the CIS Statistical Committee based on official state information in previous years are rather big. In 1990- 1993, total average annual withdrawals were nearly 153.8 billion cubic meters compared to 166.5 billion cubic meters in 1995 and 1997; the latter figure is more than 10 billion cubic meters greater than the figure for 1985 (Table 4).

In absolute terms, Uzbekistan consumed the largest amount of water, but on a per capita basis, Turkmenistan consumed 1.6- 1.9 times more, even without including major losses in the Karakum canal (Tables 4 and 5).

Table 5. Per Capita Freshwater Withdrawals in Central Asia (cubic meters)

	1985	1990	1991	1992	1993	1994	1995*	1997*
Kazakhstan	2,473	2,111	2.077	1,936	1,911	1,841	2,269	2,369
Kyrgyzstan	2,333	2,494	2,521	2,509	2,467	2,458	2,476	2.389
Tajikistan	2,836	2,583	2,530	2,305	2,333	2,365	2,179	2,169
Turkmenistan	7,508	6,193	7,139	6,482	6,513	5,933	5,121	5,057
Uzbekistan	3,899	3,380	3,350	3,338	3,271	...	3,646	3,512

* Data for 1995 and 1997 calculated on the basis of the previous table using population statistics from *Commonwealth of Independent States in 1998,* Statistical Abstract, Moscow 1999, p. 116.

4. Water Use

Total water withdrawal includes water delivered, i.e., consumed and lost. Water consumption statistics are grouped into three main sectors: water withdrawals for agricultural, industrial and domestic use. Withdrawals for agriculture are used for irrigation and livestock production. Withdrawals for industry are used for processes such as cooling thermoelectric plants. Domestic withdrawals are used for drinking water, municipal use or supplies, as well as public services, commercial establishments and homes.

Table 6. Water Withdrawals by Sector in Central Asia (%)

	agriculture	industry	domestic
Kazakhstan	79	17	4
Kyrgyzstan*	95 (90)	3 (7)	2 (3)
Tajikistan	88	7	5
Turkmenistan	91	8	1
Uzbekistan	84	12	4

* Data in brackets from *Rossiia i strany mira*. Ofitsial'noe izdanie. Goskomstat Rossii, Moskva, 1998, pp. 18- 19 (only differences between two sources seen in Kyrgyzstan).

Source: *World Development Indicators, 1999*, World Bank, Washington D.C., 1999, pp. 137- 138; *Rossiia i strany mira*. Ofitsial'noe izdanie. Goskomstat Rossii, Moskva, 1998, pp. 18- 19.

It can be noted that the structure of water use among the Central Asian states is typical for the majority of low (Kyrgyzstan, Tajikistan, Turkmenistan) - and middle income countries (Kazakhstan, Uzbekistan). It is also obvious that in each of the republics, the largest amount of water was used and lost in agriculture, which is mainly based on the irrigation of arable land.

It is astonishing but true, that in the mid- 1980s, in Tajikistan the amount of water lost was larger than the amount consumed. In Turkmenistan the amount of lost water was larger than Uzbekistan's, although the irrigated area almost

3.5 times less. In relative terms, Kyrgyzstan wasted a lot of water too, more than one- third of all water delivered was not consumed productively. The volume of water lost was larger than the amount for Kazakhstan, which had an irrigation area nearly twice as large as Kyrgyzstan's. In Kazakhstan and Uzbekistan irrigation water use efficiency was much better than in the other Central Asian republics and average in the Aral Sea Basin, although the latter had more than half of all the irrigated areas and used about half of the total delivered water in the region (Table 7).

Table 7. Efficiency of Water Used for Irrigation in the Aral Sea Basin, 1984

Index	Uzbek-istan	Kyrgyz-stan	Tajik-istan	Turkm-enistan	Kazakh-stan	Total
Irrigated Area (1000 ha)	3577.9	336.8	588.4	1039.9	634.2	6177.2
Water Consumption (billion m^3)	37.8	2.3	5.5	11.0	7.4	64.0
Actual Water Delivered for Irrigation (billion m^3)	42.3	3.6	11.4	17.9	8.2	83.4
Water Losses (billion m^3)	4.5	1.3	5.9	6.9	0.8	19.4
Losses/Water delivered (%)	10.5	36.7	52.6	38.5	9.8	23.3

Source: Putyato, N.S., "Irrigation water use efficiency in the Aral sea basin," *Melioratsiia i vodnoe khoziaistvo,* 1991, 3, 19- 21.

In the 1990s, according to the Interstate Statistical Committee of the CIS, annual water losses in transportation and irrigation canals, even without counting losses in the Karakum canal, were approximately 20- 25 billion cubic meters. So, the problem is not only how to make more effective use of water for production and domestic purposes but also how to cut losses as much as possible. Maintenance of irrigation canals and water reservoirs needs to be improved drastically. Elements of more rational water use based on cost effective payments for water need to be introduced.

Some measures will require rather large capital investments, but some improvements could be made at a low cost. Basic principles aimed at better efficiency and water conservation practices, if implemented properly, could result in diminished water losses.

Key elements of the water distribution infrastructure are antiquated, including pump stations, diversion works, and reservoir facilities. As a result of a lack of maintenance, repair and replacement, the irrigation capacity and the volume delivered have declined. This failure to adequately fund general operations and maintenance has badly affected agricultural production, one of the most important sectors of the economy in all the Central Asian states.

There is also clear evidence that irrigation systems and water reservoirs in Central Asia are susceptible to siltation. The main cause is landslides. High seismicity, unstructured fragile soils, steep slopes aggravated by inappropriate livestock management, and the loss of protective vegetation have contributed to soil erosion. Mudslides are very dangerous for local residents; the damage they cause to irrigation infrastructure causes drainage problems and a loss of storage capacity. In addition, the soil's water storage capacity is low, and streams and rivers have extreme seasonal cycles that lead to destructive floods and water shortages.

On the whole, there are sufficient quantities of good quality freshwater available for domestic and agro-industrial use, provided the water resources are properly managed. But without significant improvement in the rural and urban distribution networks, efficiency improvements in the agricultural use of water, and initiation of a major effort to increase water conservation in all sectors, water scarcity will be constraint to future development.

A large group of problems is connected with the quality of water supplies.

5. Water Resources Quality

Large- scale irrigation projects undertaken during the last three decades of Soviet rule in Central Asia resulted not only in the diminishing and wasteful use of water resources, but also a rapid degradation in their quality.

Agriculture in Central Asia has not only been the main user of freshwater, but also its main source of contamination. Considerable quantities of polluted wastewater have been discharged, after irrigating cotton fields, into rivers contaminating them and the lakes they flow into, including the largest ones, the Aral Sea, Issyk Kul, and others. In addition, municipal wastes and organic substances, heavy metals, etc. have contributed to this problem. Especially high levels of contamination were observed downstream of major rivers. Accumulated concentrations of salts were sometimes beyond all standards, leading to further soil salinization, which in turn requires additional efforts in leaching (washing) the soil with extra water, installing drainage systems and other large investments.

In the 1980s, only in the Amu Darya basin were the average annual drainage flow volume greater than 20 cubic kilometers/year with salinity from 0.7g/l in Tajikistan's upstream to 14.2 g/l in Turkmenistan's mid-and-downstreams (Table 8). This drainage water was returned mainly to the respective rivers flowing into the Amu Darya and eventually to the Aral Sea, or to smaller lakes contaminating them too, or to the different depressions that lost water and polluted the land around them.

Due to funding shortages since independence, the maintenance, rehabilitation, repair, replacement, and modernization of drinking water and irrigation water supply infrastructure has been insufficient. These problems have been inevitably growing as the existing infrastructure ages, and functions deteriorate

Table 8. Drainage Flows in the Amu Darya Basin Irrigation Region, 1989

Irrigation Region	Drainage Flow Volume (km^3/year)	Average salinity (g/l)	Main Recipients of Drainage
Pyandzh	1.35	1.0	Kzylsu, Pyandzh
Vakhsh	2.67	1.8	Vakhsh
Kafirnigan	0.70	0.7	Kafirnigan
Surkhan- Sherabad	0.95	2.4	Surkhandarya, Amudarya
Turkmen	2.31	3.5	Amudarya
Tuyamuyun	4.71	4.0	Sarykamysh Lake
Takhiatash	2.35	4.1	Depressions
Karshi	1.22	7.7	Amudarya
Samarkand	0.75	1.0	Zaravshan
Navoi	0.49	2.3	Lakes
Bukhara	0.98	4.2	Lakes
Murgab	1.20	10.5	Depressions
Tedjen	0.44	14.2	Depressions

Source: Chembarisov E.I., "Flow and Mineralization of Water of the Large Main Drains of Central Asia," *Water Resources*, 1989, 1, pp. 61- 70.

further, including intakes, pumps, and disinfection and purification equipment. The deterioration of these systems has direct health and economic consequences.

Their inability to provide safe drinking water creates contamination risks and associated health risks. The contamination of water with leftover food and beverages, heavy metals, oils, and sanitary wastes is especially high near industrial sites and cities. Surface water sources are unprotected from agro- chemicals and fertilizers as well. The capacity of municipal wastewater collection in a majority of towns and villages is inadequate. All these factors have contributed to a rapid increase in untreated pollution infiltrating underground aquifers and surface water channels.

The regulation of land and water use, as well as enforcement of pollution prevention in some areas has been completely inadequate for years. Health damage due to poor quality drinking water in irrigated areas with contaminated water can be seen primarily in the increase in epidemics caused by hepatitis- A, gastro- enteritis and rotavirus infections, and other waterborne diseases. Negative health consequences can also be seen in the increased morbidity and mortality rates among the population, especially children, due to polluted water supplies.

Emissions of organic water pollutants from industrial activities are a major cause of water quality degradation. They are measured in terms of biochemical oxygen demand, which refers to the amount of oxygen that bacteria in water will consume in breaking down waste.

Emissions per worker are the total amount of emissions divided by the number of industrial workers. Industry shares of organic water pollutant emissions refer to emissions from manufacturing activities according to International Standard Industrial Classification (ISIC) standards.

Table 9. Water Pollution in Kyrgyzstan, 1996

Emissions of organic water pollutants		Industry shares of emission of organic water pollutants							
kilograms per day		%	%	%	%	%	%	%	%
total	Per worker	1	2	3	4	5	6	7	8
20,700	0.16	13.7	0.2	0.9	54.8	0.4	21.0	1.0	16.0

1- Primary metals
2- Paper and pulp
3- Chemicals
4- Food and beverages
5- Stone, ceramics and glass
6- Textiles
7- Wood
8- Other

Source: *World Development Indicators, 1999*, World Bank, Washington D.C., 1999, p. 141.

Unfortunately, data is only available for one Central Asian country according to this classification - Kyrgyzstan (see, Table 9). The CIS Committee has collected some data on pollution discharges into natural surface water in Kazakhstan, Tajikistan and Uzbekistan. The total volume of polluted water discharges has been decreasing in Uzbekistan since 1985, in Kazakhstan since 1990, and in Tajikistan since 1991. However, during the 1990s, in Tajikistan and Uzbekistan, the lion's share of wastewaters were discharged without any purification [5, pp. 116- 123].

Conclusion

Sustainable economic development in Central Asia, especially in the Syr Darya and Amu Darya basins, has been and will be dependent to a large extent in the foreseeable future on freshwater resources and their proper use.

Over-expansion of irrigated land and extreme changes in crop patterns with an emphasis on production of water-intensive crops such as cotton and rice, along with the unreasonably excessive use of agro-chemicals during the 1960s- 1980s resulted in the region's freshwater crisis, leading to one of the 20th century's greatest environmental catastrophes. The negative effects are not limited only to the drying up and death of the over-polluted Aral Sea. These irreversible environmental changes have also had a strong impact on human health and the social development of the whole area surrounding it.

Throughout the 1990s, the newly independent Central Asian states have been working individually and jointly to stop the sea levels from declining, to reduce water withdrawals, and improve their use. In all these countries, especially Uzbekistan and Turkmenistan, cotton field acreages have been reduced in favor of grains. Special projects have been undertaken with the assistance of multi- and bi-lateral donors to deal with the urgent social and health problems in the disaster zones (Karakalpak Republic and Khoresm region of Uzbekistan, Kyzyl-Orda region of Kazakhstan and Dashkhovuz region of Turkmenistan). These efforts, together with a number of wet years in the first half of the past decade and a decrease in the use of mineral fertilizers and pesticides due to sharp price increases, brought some improvement to the situation.

However, drastic declines in cotton production by the major producers (Uzbekistan, Turkmenistan and Tajikistan) have not led to an adequate increase of water inflows to the Aral Sea. This means that seepage and operational freshwater losses are still very high. Continuous increases of ground water as well as the existence of dying or dead lakes such as Sarykamysh in Amu Darya and Arnasai in Syr Darya are vivid indicators of the enormous waste of water. There are not only irreversible losses of freshwater but also further increases of polluted water and potential areas for environmental problems.

Despite the increased runoff of water into the Aral Sea during the 1990s compared to the 1980s, water inflow was far from sufficient to make any drastic changes. The Large Aral Sea's level has continuously declined and the chain of islands (Lazarev, Belingsgauzen, Komsomolskiy and Vozrojdenie) has linked up with Muinak peninsula. Based on the current amount of water flowing from the Amu Darya, the Sea's level could decrease further from 37 to 31 meters in 10-12 years and di vide into Western and Eastern parts. To keep the Small Aral Sea at its present level of 39-40 meters, an annual inflo w of at least 3 cubic kilometers from the Syr Darya is needed. This is more realistic than providing the 28 cubic kilometers needed annually to arrest the Large Aral Sea's decline at its mid-1990s le vel.

Even keeping the Western part of the Large Aral at its 31 meter level will require an inflow from the Amu Darya at least double the 10 cubic kilometers which has been the annual average over the last decade. Doubling the Syr Darya's inflow combined with constructing a proper dam in the Gulf of Berg will increase the Aral to 53 meters above sea level. Larger inflows could also be used to discharge extra volumes from the Small Aral Sea to the Eastern part of the Large Aral Sea to facilitate an equilibrium level in the latter within the forthcoming decade and beyond [1, pp. 62-68].

The "three-lake Aral Sea system" could also serve to decrease salinity step by step, starting with the Small Sea, by way of accumulating more freshwater in it. This trend is being observed now. The goal is to promote further inflows of freshwater to the Large Sea as well. Splitting the Sea could help allow freshwater to accumulate and salinity levels to diminish to the point of restoring biota and fish in one of its parts first.

Thus, to save the Aral Sea as a three-parted interconnected water system and to stabilize the environment around it over the next decade, doubling the water inflow is the most important task that needs to be solved. This is a great challenge for all of the Central Asian states, the Syr Darya, and especially the Amu Darya basins. But it is the only way to repair the biggest environmental catastrophe of the past century. It will require, perhaps, much more time to offset all of its consequences. But to do so, it is necessary to more efficiently solve its main cause, which is the freshwater crisis.

Some urgent measures that could be employed are self-evident, although they are not simple to implement:

1) cut water withdrawals, especially to canals with huge water losses;
2) make more effective use of water, especially in agriculture;
3) protect freshwater from mineral and organic pollution.

To achieve the main goal of doubling water inflows over the next decade, the first step that needs to be taken is that new agreements must be made to encourage smaller withdrawals and freshwater losses. The agreements should contain:

- volumes and general terms for freshwater withdrawal by all Central Asian countries of the Aral Sea Basin;
- specific measures in the respective states of the Syr Darya and the Amu Darya basins to achieve water inflows of six cubic kilometers from the former to the Small Aral Sea and twenty cubic kilometers from the latter to the Large Aral Sea;
- a system of freshwater discharge from the Small to the Large Aral Sea.

Secondly, water use efficiency for agricultural, industrial and domestic purposes needs to be radically improved. To meet the dual challenge of a quickly growing population combined with lower amounts of freshwater availability, it is necessary to:

- introduce more advanced technology in agriculture (for instance stop irrigation in cotton-growing) and agro-technical methods (i.e. crop rotation involving not only grain but to larger extent fruits and vegetables);
- diversify production on the basis of more value-added industries able to produce exportable goods and substitute hard currency revenues from cotton crops with products that require less freshwater consumption (for instance, production of juices and dried fruits with respective packaging);
- decrease freshwater waste in domestic use, especially in urban areas, by installing simple water meters in each household.

Thirdly and lastly, to achieve all of the above-mentioned goals, the introduction of water fees based on the quantity and quality of freshwater is absolutely essential. Of course, it is important to link this with reforms in the price and subsidy systems for cotton production, along with better water management and enforcement of environmental standards.

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