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ECOLOGICAL AND ECONOMIC PROBLEMS OF THE ARAL SEA REGION DURING TRANSITION TO A MARKET ECONOMY

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Антропогенный пресс экстенсивного использования водных и земельных ресурсов в Приаралье усиливается естественными процессами аридизации экосистем Турана. Обсуждаются возможные направления выхода из экологического кризиса и подходы к решению экономических проблем.

A new law called "Social Protection of the Citizens being Damaged as Result of the Ecological Disaster in the Aral Sea Region" was accepted June 30,1992 in Kazakstan. Why was such a law necessary? What are the main causes for the catastrophe which has attracted wide attention in the Republic and throughout the world?

The Aral Sea region geosystems were in conditions of relatively natural "dynamic equilibrium" prior to 1960. Since then, extensive irrigation development projects and intensive use of agricultural chemicals have resulted in regional environmental deterioration. Deficiencies and mistakes in irrigation water utilization and soil resources of the Aral basin have resulted in a dramatic reduction of water inflow into the Syrdarya and Amudarya river deltas and the Aral Sea itself.

Reservoirs and hydrotechnic structures have changed the hydrologic regime of the Syrdarya and Amudarya rivers. Runoff water regulation and intensive irrigation water use for cotton and rice has changed the historic function of the Aral Sea as the main water and salt accumulation basin for Middle Asia. Currently, the Syrdarya and Amudarya river waters are primarily used for irrigation; runoff into the Aral Sea has practically halted. The sea level has dropped by 16 meters since 1960 and open- water area has decreased by nearly 50 percent. In the past 36 years, the Aral coastline has retreated by 50 to 100 kilometers. Surface salt deposits from former sea bottom sediments have appeared on more than 30000 km ^{2} of the surface.

River water quality has deteriorated to the point that it has been unacceptable for human consumption since 1970. As a result of the aridization and salinization of the hydromorphic delta landscapes, the environmental and social conditions of the local inhabitants have deteriorated.

Desert ecosystems have been forming in the old sea bottom. The dried sediments of the sea are susceptible to wind erosion. There are severe dust storms which transfer dust, in combination with poisonous salts, to adjacent territories. Wind-transported salts and dust are estimated to be 0,2 to 2,0 million metric tons per year. They are carried to distances of 100 to 300 kilometers from the source [1]. The vast territories of the lower reaches of the Syrdarya and Amudarya are now subjected to progressive desertification (table 1).

Table 1. Historic changes for the primary Aral Sea parameters

Characteristic	1960	1990	Change
Sea level, H m, Baltic System	53,4	39,2	- 14,2
Open water area (thousand km^2)	66,1	38,0	- 28,1
Dried sea bottom area (thousand km^2)	0	28,1	+ 28,1
Volume of sea (km^3)	1064	376	- 688
Inflow of rivers (km^3)	58,4	2,0	- 56,4
Average mineralization of sea water (g/L^{-1})	10	31	+ 21

The Aral ecological disaster has resulted in environmental degradation, ecosystem degeneration within the Aral Sea basin, worsening public health, reduction of economic efficiency, and increasing social tension. The Aral Sea has experienced rapid sea level decrease, increased salinity, and whole sea ecosystem degradation [3].

Natural Climatic Influences.

Discussions have centered on the extensive use of water and soil resources as the primary causes of the Aral ecological catastrophe. However, contemporary regional natural climatic variations have also negatively influenced the Aral Sea water balance. It has been proven that even without irrigation water consumption in the Aral basin, the sea level would decrease. The natural climatic factor, which influences river water flow deficiency, has caused 26 percent to the Aral Sea level decrease [7].

Climate changes in an 1800-year cycle most substantially influence Aral Sea development [8]. This 1800-year cycle includes a phase of wetter climate for 300 to 500 years, an intermediate 700 to 800 year phase, and a droughty phase of 600 to 800 years. Presently, the intermediate phase is occurring. During the second half of the third millennium, the phase of drought-afflicted maximum will be expected. It is anticipated that only in the first half of the fourth millennium will the new maximum of wetter climate advance.

According to the latest paleoclimatological data from the first millennium A.D., water usage from the Amudarya and Syrdarya rivers was less than at present. However, the Aral Sea level was lower in the first millennium A.D. than in 1990. Also, during the last millennium the Aral Sea level approximated the present level on three occasions.

The Aral Sea basin ecosystem has experienced this calamity not only by extensive economy but also by natural processes. Natural ecosystem mechanisms result in a dynamic equilibrium regulating sea level fluctuations. Sea level changes do not always correspond to human economic requirements and to the living conditions of local inhabi-
tants [8].

Analysis of historic and current natural processes in the Aral Sea region has led many scientists to the conclusion that the ecological catastrophe is not determined primarily by sea level decrease. Rather, the ecological catastrophe of the region is caused by contaminated river water unsuitable for human consumption and by a lack of human social infrastructure to treat water and prevent water pollution.

Water Regulation and Soil Changes

Syrdarya river runoff had been regulated since the mid-1960s when the Kairakkum, Toktogul and Chardara reservoirs were constructed. Syrdarya water resources are estimated at 37 km^3 per year. Every year 33 to 37 km^3 of water are removed for irrigation, approximating the river's total runoff. Drainage waters are also used for irrigation. The annual Syrdarya river water input to the Aral Sea is now only about 1 to 4 km^3. Syrdarya river water at the sea entrance is return water from a combination of irrigated fields, municipal and industrial sources.

Regulation of the river runoff and extensive utilization of fresh water for irrigation has caused dramatic changes to the river's hydrologic regime. River runoff has been reduced by 70 to 100 percent in dry years [14]. Since the mid-1970s, the lower valleys and more than 2 million ha of hydromorphic meadows and tugai riparian forests in the old and contemporary deltas have dried up. Coincidentally, tamarisk brushwood has spread widely and the undergrowth of reeds has decreased tenfold [10].

General degradation of the flood plain and delta soils has taken place in the region after regulation of river runoff. The processes of drying off, desertification and salinization of soils has been accelerated.

Hydromorphic soil formation processes have been replaced by semihydromorphic and automorphic conditions. Solonchak soil formation has occurred widely. Secondary salinization processes have occurred during the process of drying off and at the beginning stages of desertification of alluvial hydromorphic meadow damp forest soils. Soil desertification has caused a slight decrease in salt content at the expense of "dry drainage"; that is, salts have been removed by deflation and by eluviation to deeper soil horizons. The final consequence of soil desertification is the formation of mound-ridge sands. Marshy and meadow marsh soils of heavy mechanical composition have evolved into takyrs during drying off and desertification. Insufficient water drainage during irrigation has resulted in soil conversion to solonchaks [1].

Physical water characteristics of hydromorphic soils have become worse under drying off and desertification processes. The whole soil profile becomes more compact, and water percolation and total water capacity decreases in the upper one meter of soil. Soil humus content also decreases causing an increase in soil density.

The process of desertification is accompanied by significant soil organic matter losses, particularly in marsh soils. A variation in organic matter quality causes humus losses of 13 to 27 T per ha in the upper 0,5 m of meadow soils, and 33 to 53 T per ha in the upper 0,5 m marsh soils during desertification.

A significant factor causing environmental change in the lower Syrdarya river is increased river water mineralization from 0,3 to 0,5 g/L^{-1} in the 1960-s to greater than 2 g/L^{-1} today. Mineralization contributes to additional salt accumulation in soils and aquifer water. Soil salt balances are positively maintained. Salt distribution becomes more widespread including solonchaks and irrigated soils. Salinization of meadow soils increased fourfold and marsh soil salinity increased from 0,28 to 1,25 percent. At present irrigation annually increases salinity of surrounding soils by 3 to 5 times.

The soil salinity increase is accompanied by a change in salt chemistry from a chloride-sulfate system to more toxic, chloride dominated system. Annual salt accumulation on irrigated areas can be as high as 14 T per ha [9].

The salinization and decreasing soil productivity in irrigated arid regions are accompanied by negative ecological consequences. For instance, chemical contamination by pesticides occurs in most irrigated areas [5].

Prior to river runoff regulation, about 25 million T of salts per year were delivered into the sea by surface water flow. Now these salts have accumulated in the soils of irrigated plains, along river channels and in many artificial reservoirs. Such regional salt redistribution leads to an increase in secondary salinization processes of irigated fields and adjacent areas. Most irrigated lands of the Syrdarya and Amudarya lower reaches have been subject to secondary salinization processes.

In addition to water contamination by salts, there are several other pollutants, such as nitrates, pesticides, organic and oil products, and increased bacterial contaminants. Therefore, Syrdarya river water is not presently acceptable for drinking water supply and irrigation use. In contrast, there has been a slight degree of river water purification from 1988 to 1994 as a result of decreased industrial activity in the region.

The reed multigrass delta meadows were reliable fodder sources for the local desert area farms prior to water runoff regulation. Annually, these lands produced about 80 T per ha of medium quality hay. However, the productivity of these meadows has decreased by 1,3 to 1,6 T per ha during the process of drying off, and by an additional 0,5 to 0,6 T per ha during desertification.

Socioeconomic Influences on Agriculture

The social, economic and ecological consequences of the Aral Sea catastrophe are extensive. Transition to market demands the establishment of some new principles of interaction between environmental health and human societal needs. A cost must be attached to the use of natural resources, including penalties for willful environmental deterioration and destruction. Shortages in high quality water and arable land will cause a quality of life deterioration for the region's human inhabitants.

Because of water deficiencies in the lower Syrdarya river, many scientists have come to the conclusion that it is necessary to replace cotton and rice production with crops such as vegetables, fruits and berries, which have lower water requirements. Rice has a high water requirement and therefore should be replaced by other crops. For instance, under existing conditions in Middle Asia and Kazakstan, one ha of rice annually consumes from 25,000 to 55,000 m^3 water. Decreasing rice production in the region by 200,000 ha will save about 4 to 5 km^3 of water annually. It is important to analyze the production of rice, cotton, vegetables, fruits and berries taking into account their water requirements.

It should be noted that local inhabitants consume meat, milk, and fruits at a rate of 26 percent, 42 percent, and 53 percent of normal consumption. Presently, the highest infant mortality rate in the world exists here. To make matters worse, 80 percent of all human diseases have been directly linked with drinking polluted water [4].

There are new property ownership schemes now being developed in Kazakstan. There is a transition from state and state - collective farm property to cooperative, stockholder and private ownership [12]. Coincidentally, a system of natural resource use payments should be instituted. The changing social structure demands the creation of new structures of production, governance, control and monitoring. In agricultural enterprises urgent measures have to be taken to shape effective economic mechanisms for the governance and control of all cultivated lands, especially irrigated lands. Future landowners must practice better stewardship in the management and use of soil and water resources.

According to Voropaev (1992), two principles must be considered during reconstruction and water utilization projects in the Aral region:

- creation of land parcel sizes according to the minimal territorial-natural - economic complexes. Parcel size establishment within these recognized complexes will enable solutions to many land reclamation problems with minimal negative influences upon water sources and adjacent areas;

- understanding of the relationships among the technical organizational, legal and social measures is required to establish stable economic development and social protection for local inhabitants, taking into consideration the interactions among neighboring territories and higher - level regional relationships [2].

Such territorial natural complexes essentially are the division of natural economic taxonomic units by regions, based on an inventory of water quantity and quality and an understanding of fundamental economic production considerations, social conditions and cultural lifestyles. The developing "Food Program" for the Aral region has as its highest priority to supply good quality food and water to the inhabitants. The program should contain measures for land privatization, environmental improvement and wise soil management. The farmers would no longer have to act within the framework of a "state plan or government order", but now will have freedom of choice relative to their land use practices [6].

Water Transfer Projects

The present situation in the Aral Sea basin and within the sea itself is disturbing and alarming not only in Kazakstan and the Middle Asia Republics but throughout world. Scientists of the "International Soviet - American Conference for Problems of Aral Sea" who have discussed the existing conditions and potential methods of improvement, support and restoration of the region and sea have come to the conclusion that it is not feasible to develop projects to transport river water from Siberia to Middle Asia (Bloomington, 1990).

American ecologists have proven that Siberian river water transfer will result in new suffering and misfortune for many people and will hasten the ecological collapse of this region. The potential water transfer would have only short term effects and would eventually lead to the increased soil salinization, irrigation system degradation and continued ecological deterioration. Unfavorable ecological and economic factors would be inevitable. Siberian river water transfer projects do not consider political changes associated with independent countries and a new system of market form economy. Greater environmental understanding is necessary before recommending water redistribution projects.

It is also unwise to develop projects to transfer Caspian Sea water into the Aral Sea. At present there is not a reliable long term forecast for sea level fluctuations. Delivery of the salty Caspian water can also negatively alter the Aral Sea salt balance. As stated earlier, about 25 million T of salts are delivered annually by river water into the Aral Sea. Caspian Sea water delivery would increase the flow of salts into Aral Sea by 300 million T annually. The present sea level (53 m BS) would have a corresponding salinity of 50 g/L^{-1}. More study is necessary to consider the effects of salts and residual chemical products on the marine flora and fauna of the sea. It is known that the sea lost its fishing industry when water salinity exceeded 20 g/L^{-1}. During project implementation it is necessary to conduct numerous environmental investigations to establish the socioeconomic and ecological grounding for any proposed project.

Irrigation Effects on the Environment

Expansion of irrigated practices often results in increased agricultural production. Increased production is reached at the expense of increased water soil resource utilization, placing increased demands upon the natural environment. The consequences of such development are well documented.

For example, irrigation water removal from the Amudarya and Syrdarya rivers exceeds their total runoff volume. This is the primary reason for the regional ecological crisis. In the irrigated zone, the total area of anthropogenic ecosystem disturbances resulted in approximately 5 million ha damaged due to flooding, waterlogging and salinization.

At the current loss rate of irrigated lands (about 5% per year), the land base of irrigable soils will be depleted in 20 to 30 years. Therefore, wise use of water and land must direct future development projects in order to alleviate the present crisis. Presently, the rational use of natural resources to maintain a stable environment is excluded from discussions concerning water resources redistribution among the Republics. During discussions, the orientators should consider modern water consumption indexes of the developed world countries. For example, water consumption in the USA for each unit of total national product is 5 times lower than in the former USSR countries.

At present, the primary topic of discussion has been "where to direct water received by the application of different water conservation measures; to the Aral Sea or to irrigated land development?" Many scientists consider that the received water should be used only for improvement and development of irrigated soils, to increase soil productivity and to improve the living conditions of local inhabitants.

Another opinion is that if the Aral Sea is refilled with water, all negative phenomena would disappear and living conditions for people would be improved. Those who hold this opinion do not take into account that the present ecological disaster has continued for many decades. The main causes of the ecological disaster are the increased mineralization levels in the Syrdarya and Amudarya rivers, making the water unsuitable for human consumption, the expansion of saline soils, and a shortage of high quality food products. Filling the Aral Sea with water will not alleviate these problems. E.Frost pointed out, that the frog in the Aral may be happy with all the water, but far more people will be negatively impacted by stopping the irrigation. Studying problems in the context of the whole system almost always provides a better answer than looking at only a portion of the system [11].

These two challenges (i.e., improving human living conditions in the region and maintaining open water in the Aral Sea) are different in their scientific technological essence. The first challenge includes:

- supplying the local inhabitants with high quality drinking water;
- improving human housing conditions;
- documenting and reducing the extent of desertification;
- revegetating selected areas of the dried sea bottom to decrease deflation of salts and to improve the extent of vegetated pasture;
- revegetating of the delta regions to increase biomass production.

The second challenge includes:

- reducing the irrigated land area in the Aral Sea basin by one million ha by fallowing saline, swamped and contaminated soils;
- reducing of total cotton and rice production;

- reducing irrigation water consumption and implement water conservation technologies.

Implementation of the aforementioned challenges will require large monetary expenditures. Nevertheless, unless fundamental changes occur, it will be impossible to solve ecological problems and improve environmental conditions in the Aral arid territories. The following measures and policies should be considered and appropriately implemented: classify and prioritize lands according to the irrigation suitability; enforce the reduction of irrigation water use rates; educate farmers in the practices of soil and water conservation; implement a policy of agricultural land appraisal according to soil and water value; enforce criminal penalties for persons who willfully pollute water supplies; and enforce financial penalties for farmers who waste irrigation water. Other measures may have additional merit if they serve to improve environmental quality [13], reduce water wastage and maintain a productive agricultural land base in the region [15].

Conclusions and Recommendations

The anthropogenic pressure upon the Aral Sea region has exceeded reasonably permissible bounds too long. As a result of extensive water and land resource use, the regional ecology has been disrupted. The region is presently subject to potentially irreversible environmental degradation. Under existing conditions stabilization of the situation may be only achieved by applying modern land use management methods. Wise water resource distribution among water users in the different countries is possible under improved development conditions and acceptance of appropriate legal mechanisms.

Abundance of solar energy (238 M J/m^2 per year) and windy days in the region imply that solar and wind energy development projects in the former sea bottom would be successful. Such projects should be implemented when feasible.

The use of natural resources incurs environmental and financial costs. Wise land use must consider the ecological and socioeconomic divisions within the region. Disturbed areas with unprofitable or unsuitable agricultural productions must be evaluated and perhaps taken out of production. All infertile lands should be excluded from agricultural production and should be converted to permanent pasture or wildlife habitat. Optimal rotational grazing systems should be used in the deltas. A scientific soil fertility improvement program should be implemented. Rice and cotton cultivation on fields adjacent to human population centers should be discontinued. Finally, all productive irrigated lands should be privatized by the local farmers.

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