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THE SHRINKING OF ARAL SEA (A WORST ENVIORNMENTAL DISASTER)

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ABSTRACT: Aral Sea is a huge terminal lake which is located in the desert of Central Asia. This lake has repeatedly filled and dried due to both natural and human causes over the past 10 millennia. Today, its rapid desiccation or drying out is one of the planet's most serious ecosystem catastrophes. The main cause of the rapid drying out of this lake is the careless and massive withdrawal of water from two of its main feeding rivers namely Amu Darya and Syr Darya. The process of irrigation alone consumes 94% of all consumptive uses and is situated over 8.5million hectares of land across the Aral basin. In the first decade of 21st century, a very small and shallow portion of it is survived which is still under the threat of further drying out. This rapid drying out and destruction of the Aral Sea has led to a number of socio-economic, climatic and health related problems. There is a little hope in the near future to fully restore the Aral Sea. In the present paper, an attempt has been made to study the causes behind this ecological destruction, its negative impacts and strategies to restore it.

KEYWORDS: Huge, Desiccation, Withdrawal, Shallow, Restore.

INTRODUCTION

The Aral Sea also known as 'Orol Dengizi' in Uzbek and 'Bahri Aral' in Persian (older) was a lake surrounded by seven nations i.e. Uzbekistan, Turkmenistan, Kazakhstan, Afghanistan, Tajikistan, Kyrgyzstan and Iran. Only Kazakhstan and Uzbekistan are riparian on the sea proper, with each possessing an equal length of its shoreline. It is located amid the great deserts of central Asia. Its drainage basin covers about 1.8 million Km^2.

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From-Micklin's' The Aral Sea Disaster'.

The literal meaning of word Aral is roughly translated as 'Sea of Islands', referring to about 1534 islands that once dotted its waters. In old Turkic language the word 'Aral' means 'Island' and 'thicket'.

Formerly, one of the four largest lakes in the world, with an area of 68000 km^2, the Aral has been rapidly shrinking since 1960's as the rivers that fed it were diverted by former Soviet governments for their state sponsored irrigation projects. Presently, it has remained less than 10% of its original size.

The rapid shrinking of Aral Sea has been termed by environmentalists of the world as 'one of the planet's worst environmental disaster.' Once the flourishing and famous fishing industry of the region has been destroyed and it has resulted in large scale unemployment and economic hardships of the region's population. The Aral Sea region is also suffering from heavy pollution. The dying or drying up of water of the lake has caused many local climate changes, with summers becoming hotter and drier and winters colder and longer. The surrounding countries of Aral Sea as well United Nations and its associated organizations are making their efforts to protect the remnants of once a huge lake and are also trying to rejuvenate it.

In the present paper an attempt has been made to study the causes behind the destruction of this lake, its present condition, efforts made by countries to save it from becoming completely vanished.

OBJECTIVES

Following are the main objectives of the study:

1. To study the causes behind the desiccation or drying out of Aral Sea.
2. To study the consequences of the desiccation or drying out of Aral Sea on ecology and society of the concerned areas.
3. To study the measures taken by countries around Aral Sea to restore and protect it from becoming vanished.

METHODOLOGY

The present paper has used information obtained from various sources including articles from newspapers, magazines, internet, numerous books & research papers.

AREA OF STUDY

The Aral Sea is situated in the center of central Asian great deserts (Kara Kum, Kyzyl-Kum & Betapakdala) and the area as a whole experiences high rates of evaporation from its surface. Amu Darya and Syr Darya rivers are the chief water providing rivers to Aral Sea. Location of Aral Sea Basin is given in following map:

Courtesy- Google Images

BACKGROUND

The Aral Sea lies between great deserts of central Asia. Until 1960's, it was the fourth largest fresh water inland lake of the world. Its total area was about 68000km^2 and the volume was about 1056 km^3. The water body used to yield 40,000 metric tonnes of fish, while deltas of its major tributaries hosted dozens of smaller lakes and also many biologically rich marshes and wet lands covering approximately 550,000 hectare. The Aral Sea Basin extends not only to five central Asia countries, but also to Afghanistan and a small part of Iran. The total area of the Aral Sea Basin (ASB) in hectares is 180 million hectares. Out of this total area 7.9 million hectares are irrigated with more than 95 km^3 of water annually [Dukhovny and Sokolov 2003; Kijne 2005; Micklin 2008]. Irrigation is provided through a dense network of canals over an area of 323,000kms [Orlovsky, Glantz and Orlovsky 2000] and water outflow from irrigated fields is channeled through 190,000 km of drainage collectors and drains [Severskiy et. al. 2005]. Most of the people in Aral Sea Basin reside within the area drained by Amu

Darya and Syr Darya. These two rivers once used to flow into the Aral Sea. These rivers originate in Pamir and Tian Shan mountains in Tajikistan, Kyrgyzstan, and Afghanistan.

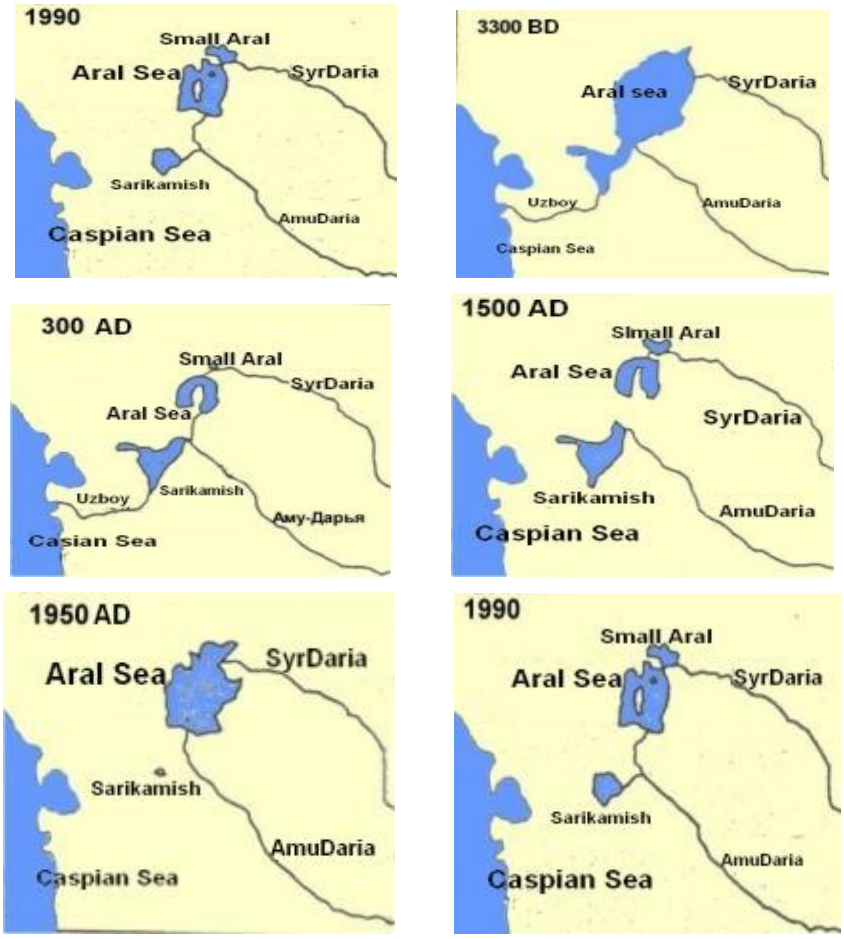
The size of Aral Sea largely depends upon the balance between inflows from the two main feeding rivers and Sea's net evaporation i.e. the difference between evaporation from the surface of sea and precipitation [Micklin 2008]. For centuries, the fresh water of these rivers kept the Aral Sea's water and salt at tolerable levels. In the middle of 20th century the annual water flow of Amu Darya and Syr Darya were approximately 77 km^3 and 34 km^3 but the use of water in Aral Sea Basin (ASB) was117 km^3 annually [Nandalal and Simonovic 2003]. Between 80 to 95 percent of this water was used for irrigation purpose and hence did not reach the Aral Sea.

In the second half of 20th century, the drive for economic development was started in former Soviet Union. This drive led to the expansion of irrigated (cotton) production. For this purpose huge dams were constructed in upper reaches of both feeding rivers to Aral Sea and a vast system of feeding canals was constructed to divert water to most remote regions, mainly to enhance cotton production. The construction of irrigation network brought millions of hectares of land under agricultural production in this arid region. This led to a huge shortage of availability of fresh water, through main feeding rivers, in Aral Sea which led to its drying up.

HISTORY OF ARAL SEA SHRINKING

Historical geography, geophysical and anecdotal evidences suggest that the drying of Aral Sea must have occurred previously. It is said that millions of years ago, the north-western part of the present Uzbekistan and southern parts of Kazakhstan were covered by a vast inland sea. After gradual receding of water, a broad plain with highly saline soil become exposed, with a few remaining intermittent water bodies. One remnant of this ancient sea became Aral Sea.

EVOLUTION OF PERIODIC FLUCTUATIONS OF THE ARAL SEA WATER TERRITORY DURING 10000 BC - 1990 AC

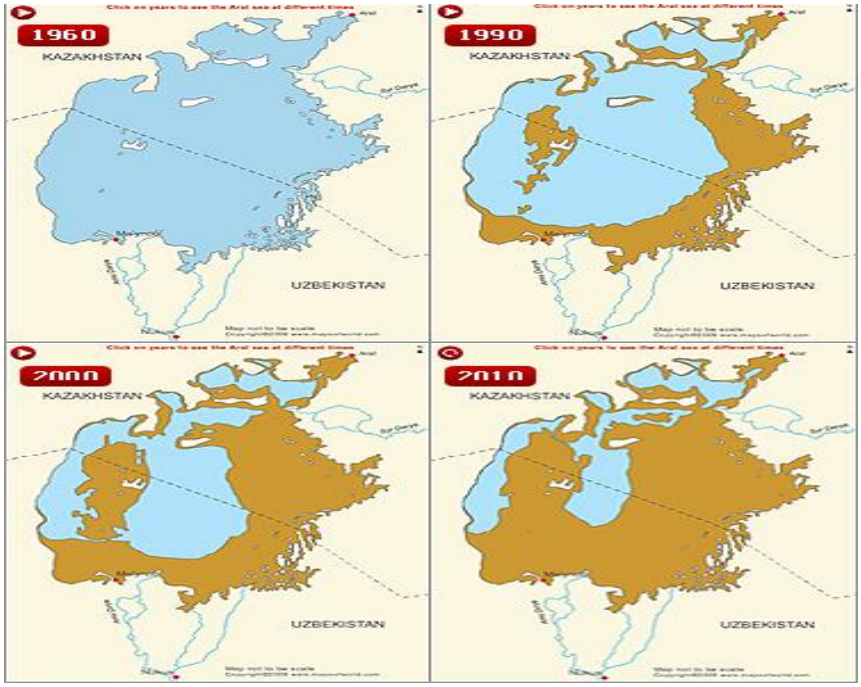


Reference: UNESCO. The Aral Sea Basin. Division of Water Sciences,1999

The evidences further show that in the past 10000 years its surface has been completely or partly flooded and desiccated for at least eight times. But the point of notice is that all previous events of desiccation have been caused by climatic changes and natural diversion of feeding rivers away from Aral Sea. The potential role of rainfall variations is unclear, but their role is generally smaller than of migration of rivers. Anthropogenic activities' contribution in dying up of Aral Sea is also not deniable.

RECENT SHRINKING

Nearly 40 years back from today, Aral Sea was more than 250 miles long and 200 miles wide. In 2004, area of Aral Sea was 17000 km^2 which was only 25% of its size in 1960 AD. The water volume decreased by 80% whereas concentration of salt contents increased by five times. This led to destruction of flora & fauna of Sea. During this period, the Large Aral Sea separated in to smaller water bodies i.e. 'Small' or North Aral in Kazakhstan and 'Large' Aral in Uzbekistan, which later became the 'West' & 'East' Aral. This drying up of Aral Sea floor created another desert called 'Aralkum Desert'. By 2008 AD., it had declined to 10% of its original size. See the following satellite imageries of Aral Sea ranging from 1960 to 2010.



Courtesy-Google Images

With continues water withdrawals from the feeding rivers, the sea is expected to contract further by the second and third decade of the 21st century, but changing climate has further made the conditions worst. But efforts made by Kazakh government and international organizations to restore the 'Small' Aral through the construction in 2005 of the 13 kms long 'Kok-Aral Dam' and dike, which presently regulates the flow from Small Aral into Large Aral. Underground water discharge from the original sources may find its way to the sea through geological layers. But still a lot is needed to be done as these small efforts cannot alone reverse the drying up process of the Areal Sea.

CAUSES OF DRYING UP OF ARAL SEA

Technological advances and large-scale water withdrawals are the culprits of basin-wide desiccations or drying out. The Aral Sea is a terminal lake. It is dependent upon river and groundwater inflow and precipitation in order to maintain surface levels. The Sea's only out take is not by flow, but rather from evaporation [Micklin1988]. As water is withdrawn from Syr and Amu Darya rivers mostly for irrigation purposes, stream and groundwater flows are reduced. As a result the supply of water to the lake impeded. As a result, a situation of imbalance came in to existence. Now there is an excess of evaporation of water over continuous arrival of fresh water in the lake. This has resulted in drastic decrease in surface and volume of water in the lake.

In 1950's and 1960's a massive expansion of irrigation took place in Sea's basin. The former Soviet Union government wanted to:

1. quadruple the production of raw cotton,
2. increase in the production of vegetables & fruits,
3. supply the Central Asian Republics with rice and export that much again,
4. provide employment to local population.

In order to meet these tall & lofty goals, huge quality of water had to be diverted from the area's chief water providing rivers i.e. Amu & Syr Darya. By 1960 AD., over 5 million hectares of land under irrigation in Aral Sea Basin jumped to 6.5 million hectares, and in 1990, an estimated 8.5 million hectares continued to increase consumptive withdrawals [Micklin1988 & 1993].

As a result of water diversion for irrigation, the volume of river discharge has steadily dropped. Before 1960, an average of 56 km^3/ year of water entered the Aral out of 120 km^3/ year of river water forming in source regions on the basin. By 1975, as the withdrawal for irrigation increased, the flow of water in the Sea remained 9 km^3/ year. Since the 1970's, the Amu & Syr Darya have witnessed no reprieve in water consumption. In fact, in some years, there has been virtually no inflow of water in to the Sea [Kotlyakov 1991, 6].

It is true that the agricultural production in this region has increased, thus, the goal of former Soviet planners and present planners of these republics has been achieved. But while observing minutely, we can say that though Kazakhstan and other four republics produce large amount of water guzzling rice and cotton crops but at what cost? Aral Sea is now dying its death which is given to it by the greed of so called 'technologically advanced men'. It's drying up and its complete extinction will have a number of disastrous consequences for the people living in the area of Aral Sea Basin.

CONSEQUENCES

The lake which is supplying water to the inhabitants living in areas surrounding it as well the flora and fauna of Aral Sea basin has suffered a massive set back to its existence due to drying out of water in it at such a rapid rate. The consequences of drying out of Aral Sea are horrible. It has badly affected the ecology, economy and health of the region. A detailed discussion on the consequences is as follows:

A. Environmental Degradation with Increase in Land and Water Salinization

The amount of salt in drainage water from irrigated land in one state and is fully or partially returned to the rivers and passed to downstream states. The Salinization occurred because of salt mobilization in subsoil triggered by irrigation and drainage practices, salt pick-up in upper watersheds and inadequate disposal of drainage water. Increasing Salinization of the land and river threatens entire economy and millions of people throughout the basin and results in:

1. Erosion and Sedimentation, which in turn threatens the basin water regulation infrastructure. As a result of increasing soil erosion in upper watersheds due to deforestation and overgrazing of mountain pastures, changes in performance of the basin water regulation infrastructure that take place that affects the water allocation and distribution in the basin.
2. Soil Contamination: - Heavy usage of chemical fertilizers, insecticides and pesticides were used by the farmers to increase the yield per hectare of various crops. This has resulted in large scale contamination of soil as well as water of Aral Sea basin.
3. Diminition of Wetlands and Biodiversity: - Drying out of Aral Sea has resulted in diminition of many wetlands, small lakes and their associated reed community.
4. Environmental Problems in Mountains:- Mountain areas are the sources of origin of rivers that earlier used to provide water to Aral Sea, are suffering from problems of deforestation, erosion of their slopes especially as conditions by the development of irrigation in alpine valleys.

B. Gradual Drying Up of the Aral Sea and Adverse Socio-Economic and Environmental Effects

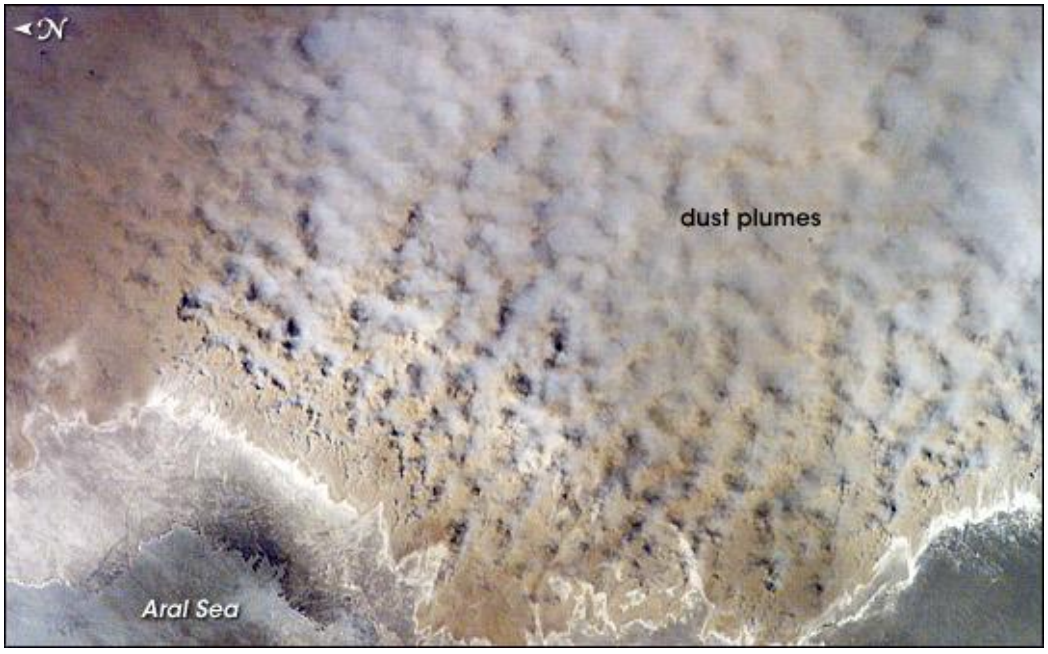
As a consequence of drastically reduced water flow from rivers in to the sea, the Aral sea got separated in to two water bodies in the end of 1988-beginning of 1989- a Small Aral Sea in the north and Large Aral Sea in the south. The Syr Darya flows in to Small Aral while Amu Darya flows into Large Aral Sea. Between 1960 to 2003, the level of Small Aral Sea fell by 13 meters and large Aral Sea by 23 meters. The salinity in small sea is estimated to have doubled whereas in the western part of large sea it has increased by more than 6 fold. The area of both seas taken together diminished by 75% and the volume by

90%. The human induced shrinking and drying out of Aral Sea has had severe negative impacts on ecology, economy and society such as:

1. Desertification: - Greatly reduced river flows through the deltas, the virtual elimination of spring floods in them, due to reduced river flow and construction of upstream storage reservoirs, and declining ground water levels, caused by the falling level of the Aral Sea, have led to extension and intensification of desertification.

Courtesy-Google Images

2. Dust & Salt Winds:- One of the results of drying out of Aral Sea and extension of desert area in it has led to blowing of heavily sand, salt and dust laden winds blowing from its dried bottom. Now it is largely a barren land of desert covering an area more than 50000 km^2. The salt and dust also have adverse effects on wild and domestic animals by directly harming them and by reducing their food supply.



Courtesy-Google Images

3. Changes in Regional Climate: - Due to shrinking of Aral Sea, there is a change in the climate in an area about more than 100 km wide along former shoreline in Kazakhstan and Uzbekistan [Micklin, 1991, P.P. 52-53]. Maritime conditions have been replaced by more continental and desertic conditions.

C. The Gradual Drying Out of Aral Sea and Its Impact on the Health of Population

The population living in 'ecological disaster zone' suffers acute health problems. The local health experts say that the airborne salt and dust are a contributing factor to high levels of respiratory diseases and ailments, eye problems & possibly even throat and esophageal cancer in the near-Aral region. Some British field researchers have indicated that salt and dust blowing from dried bottom of Aral Sea is laden with toxic chemicals (pesticides and defoliants for cotton) in irrigated agriculture, mainly during Soviet era.

The bacterial contamination of drinking water is pervasive and has led to very high rates of typhoid, paratyphoid, viral hepatitis and dysentery. Tuberculosis is prevalent as is anemia, particularly in pregnant woman. Liver and kidney ailments are widespread and it is because of excessively high salt contents of much of the drinking water. Health conditions in the 'Kara kalpak Republic' in Uzbekistan, is the worst in Aral Sea Basin.

D. Other Effects :- Other effects of drying out of Aral Sea are:

1. Shortage of Drinking Water: - This has become a serious problem in Aral Sea area. High levels of salts have affected the water meant for human consumption. There are no proper sources or date available regarding effects of heavily mineralized water on human health as it may affect our kidney and liver. Thus, the region has now insufficient volume of clean drinking water.
2. Increase in Unemployment: - The fishing industry of Aral Sea, which in her heydays had employed some 40,000 small & large scale fishermen and used to produce $1/6^{th}$ of Soviet Union's entire fish catch, has been destroyed completely. This has made thousands of people jobless. Today most of the earlier fishing towns situated along Aral Sea's coast has become 'Graveyard of Ships'.

Courtesy-Google Images

The town of 'Moynaq' is the best example of this destruction, as once a big harbor and centre of fishing industry, that had employed about 30,000 people, now lies miles away from the shore. One can see on its surface many old & abandoned ships lying here and there.

The overall damage can be estimated at 35-40 billion Rubles (£800 million Pounds).

REMEDIES

The Aral Sea basin is in a state of disaster. The natural ecosystem of the area of Aral Sea Basin has been destroyed to an extent that now it is not suitable for living and functioning of human population, as it was once used to be. The urgency of situation has brought about an international focus on restoring the sea. Any international effort to restoration will in involve following characteristics:

1) Replenishment of the Aral Sea's water, 2) Restoration of a stable ecosystem, 3) Decreased salt and dust export by blowing, and 4) Improved microclimates [Government commission on the Development of Measures for Restoring Ecological Equilibrium in Aral Region 1982, P.P. 287]. Following are some remedies suggested by various scholars and environmentalists to protect Aral Sea from becoming extinct. These are:

1. **Inter Basin Transfers**: In order to check the problem of Aral Sea to avoid regional ecological catastrophe was to turn to Inter Basin Transfers (IBT). If Aral Sea is to be saved then more water has to be available to the system [Micklin 1990, P.P.-93]. Several transfers have been explored. One of such Inter Basin transfer suggestion is to transfer water from Caspian Sea in to Aral Sea. It is said because the area of Caspian Sea receives a surplus of precipitation caused by an increase in evaporation in region to the west & south of the basin. But this project doesn't seem to be sound as diversion of water

from Caspian Sea in to Aral Sea will have negative consequences on Caspian Sea. The second suggestion is, to transfer a part of Volga river's run off in to the Aral Sea by the way of dike & canal. Another project suggested is the diversion of some runoff from Siberian Rivers into Aral Sea.

OPTIONS FOR DIVERTING WATER FROM THE VOLGA AND OB RIVERS TO THE ARAL SEA

Source: Ring 2004.
Note : Yellow areas = Elevation above 200 meters.

In all above cases the potential of occurrence of an environment disaster elsewhere in order to ameliorate an existing problem are high. Moreover, such projects require a huge amount of capital investment and land acquisition, with little potential to solve a region's problems. The long term solution for the region will be to reduce the reckless use of water.

2. **Precipitation Enhancement**: - Hydrometeorologists have proposed that an increase in river discharge by enhancement measure would lead to greater inflow of water in to the Aral Sea. Two such projects have been suggested. The first is that an injection of condensation nuclei in to the lower troposphere over the Aral Sea basin. But this method is not only very expensive but also a number of social ramifications are involved which have not been properly studied. The second project asserts that there should be construction of large reservoirs roughly 70000 km^2 in the 'Ob' and 'Yenisey' rivers basins would alter the thermal regime of the area and increase evaporation. As a result of an increase in moisture transfer to southeastern Asia, the volume of water carried in to Aral basin would increase. This project is again criticized as it will submerged a vast fertile area in west of Siberia.
3. **Water Management**: - Currently, only those measures will be successful in Aral Sea basin which involve water management practices. The management program which began in 1980 sought to gain more efficient use of irrigation waters. Irrigation in 1980 accounted for 91% of withdrawals and 94% of consumptive use. Naturally, irrigation was the target for management [Micklin 1988, 1171]. From 1980 to 1987 irrigation ditches were lined, return flows for excess water was built and low yield, waterlogged fields were removed from irrigation. The average withdraws lowered from 18,500 to 13,700 m^3/ha [Micklin 1988, 1171]. Thus, water management holds more promise for the recovery of Aral Sea than the Inter Basin Transfers or precipitation enhancement techniques. IBT's and precipitation enhancements are more suitable for short term solution of problems rather than long term problems. However, as the water rises, more land will eventually be irrigated and the potential for an ecological crisis in two basins still exists. The water management techniques deal with the reality that desiccation or drying out of Aral Sea can only ameliorated by a reduction in use.
4. Another solution is to reduce or even abolish irrigated agriculture in Aral Sea Basin, at least for a period of time, to allow water from its two major feeding rivers i.e. Amu Darya and Syr Darya to flow in to the Sea. This requires compensation from international community as well as the countries surrounding Aral Sea to the farmers of the area for not sowing

anything. About US $30 million annually have to be paid to the farmers for an unknown long period of time. This option would increase the supply of water in Aral Sea by many times than the present.

5. There should be a political will among the nations using water from Aral Sea to implement the water sharing agreements which involve sustainable use of Sea's water, improving the quality of water, avoidance of any policy harming the existence of well being of countries etc. Clauses in the agreements signed among nations to reverse the trend of drying out of Aral Sea's water should be implemented seriously.

CONCLUSION

Aral Sea does not exist in isolation. Rather, it is a highly complex and integrated ecological system. The excessive and careless withdrawal of water from Amu & Syr Darya rivers, which in past were its feeding rivers, has led to planet earth's one of the worst environmental disaster i.e. desiccation or drying out of Aral Sea. It's drying out has negative impacts not only on the sea but also on entire Aral Sea Basin. The consequences of excessive water withdrawals are far reaching. Climate, ground water, natural biota and social conditions may be negatively modified. These negative impacts can only be ameliorated through restoration. However, restoration attempts are too slow and not working. The Aral Sea is a resource which needs to be rationed. The alternative is no resource at all.

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REFERENCES

[1] Dukhovny, V., and V. Sokolov. (2003), "Lessons on cooperation building to manage water conflicts in Aral Sea Basin." PCCP Series No.II. Paris: United Nations Educational, Scientific and Cultural Organization (UNESCO).
[2] Glazovskiy, N.F. (1991)," Ideas on the escape from the Aral crisis." Soviet Geography 73-88.
[3] Gulnara Roll et. al., "Aral Sea: Experience and Lessons Learned Brief."
[4] Gulnara Roll, Natalia Alexeeva, Nikolai Aladin, Igor Plotnikov, Vadim Sokolov, Tulegen Sarsembekov, Philip P.Micklin (2003), "Aral Sea". Lake Basin Management Initiative Experience & Lessons Learned Brief.
[5] Kijne, J.W.(2005), " Aral sea Basin Initiative: Towards a strategy for sustainable irrigated agriculture with feasible investment in drainage ." Synthesis Report. Rome: International Programme for Technology and Research in Irrigation and Drainage (IPTRID) at the Food & Agriculture Organization of UNO.
[6] Kotlyakov, V.M. (1991), "The Aral Sea Basin – A critical environmental zone." Environment Jan/Feb: 4-38.
[7] Kumar, R.S. (2002), "Aral Sea: Environmental Tragedy in Central Asia." Economic and Political Weekly 37 (37): 3797-3802.
[8] Micklin, P.P (1991), "Touring the Aral: Visit to an ecological disaster zone." Soviet Geography: 90-105.
[9] Micklin, P. (1988), "Desiccation of the Aral Sea: A water management disaster in Soviet Union." Science 241(4870):1170-76. http://www.ciesin.org/docs/006-238/006-238.html.
[10] Micklin, P. (2002), "Water in Aral Sea Basin of Central Asia: Causes of Conflict or Cooperation?" Eurasian Geography & Economics 43(7):505-28.
[11] Micklin, P. (2004), "Aral Sea Crisis". In C.J. Nihoul, P.Zavialov, and P. Micklin, eds, "Dying and dead seas: Climatic vs. anthropic causes." NATO Science Series IV: Earth & Environmental Sciences, Vol. 36. Boston: Kluwer.
[12] Micklin, P. (2008), " Using Satellite Remote Sensing to Study & Monitor the Aral Sea and Adjacent zone." In J.Qi and K.T. Evered, eds., "Environmental problems of central Asia and their economic, social & security impacts," NATO Science for Peace & Security Services-C: Environmental Stability. Dordrecht, the Netherlands: Springer.
[13] Nandalal, K.D.W. and S.P. Simonovic (2003)," State of the art report on systems analysis methods for resolution of conflicts in water resources management." Report prepared for Division of Water Science, UNESCO, Paris.
[14] NASA (NATIONAL AERONAUTICS and SPACE ADMINISTARTION) 2010. Earth Observatory: Shrinking Aral Sea.
[15] Orlovsky, N., M. Glantz & L. Orlovsky. (2000), "Irrigation and land degradation in the Aral Sea Basin." In S.W. Breckle, M. Vesle, and W. Wuecherer, eds., "Sustainable land use in deserts," Heidelberg: Springer Verlag.
[16] Rudenko. I., and J.P.A. Lamers (2010), "The Aral Sea: An Ecological Disaster." CASE STUDY #8-6 OF THE PROGRAM:" FOOD POLICY FOR DEVELOPING COUNTRIES: THE ROLE OF GOVERNMENT IN GLOBAL FOOD SYSTEM." 2010. Edited by: Per Pinstrup-Andersen Cornell University, Ithaca, New York.

[17] Severskiy, I. et.al (2005), "Aral Sea: GIWA regional assessment 24. (Global International Waters Assessment)." Kalmar, Sweden: University of Kalmar for United Nations Environmental Programme.
[18] "THE DISAPPEARANCE OF THE ARAL SEA."VITAL WATER GRAPHICS: An overview of the state of the world's Fresh and Marine waters-2nd Edition-2008. Sponsored by United Nation Environment Programme (UNEP) & GRID-ARENDAL.
[19] Tracy H. Allen (1997), "THE ARAL SEA CRISIS: DESICCATION AND PERSPECTIVES ON RECOVERY."
[20] UNESCO, "The Aral Sea Basin Divison of Water Science," (1999).
[21] Wikipedia, the free encyclopedia, "Aral Sea".
[22] Wilson, Philip Whish, "The Aral Sea environmental health crisis." Journal of Rural & Remote Environmental Health 1(2):29-34 (2002).