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Socio-ecologic Situation in the Aral Sea Region

Bachelor thesis

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Certification

I, Eva Korbelová, hereby declare that this thesis submitted in partial fulfillment of the requirements for the degree of Bc. in the Institute of Tropics and Subtropics of the Czech University of Live Sciences in Prague is wholly my own work unless otherwise referenced or acknowledged.

In Prague:

…….
Eva Korbelová

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Abstrakt

Aralské jezero, kdysi čtvrté největší, začalo ubývat na objemu vlivem rozsáhlých zavlažovacích systémů, vybudovaných v polovině minulého století Sovětským Svazem. V této práci jsou zpracovány obecné informace o státech, na kterých se jezero rozkládá. Jsou zde uvedeny fyzicko-geografické a klimatické podmínky regionu Aralského jezera. Zavlažování rozsáhlých ploch za účelem pěstování bavlny, nekvalitně postavené kanály odvádějící vodu z řek mnoho kilometrů a snižování přítoků do jezera. To vše vedlo k ústupu pobřeží o desítky kilometrů, snížení biodiverzity vlivem zvýšené salinity, zdravotní problémy obyvatel vyvolané nedostatkem čisté vody a jedovatého prachu v ovzduší. Jsou zde uvedeny organizace, zabývající se touto problematikou a také jejich kroky k vylepšení stávajícího stavu.

Klíčová slova: Aralské jezero, Kazachstán, Uzbekistán, Syrdarja, Amudarja, zavlažování, desertifikace.

Abstract

Aral Sea, once the fourth largest lake, began to wane due to a large volume of irrigation schemes, built in the middle of last century by the Soviet Union. In this thesis there is general information about countries in which the lake is situated. There are also mentioned physical-geographical and climatic conditions of Aral Sea region. Irrigation of vast areas for cultivation of cotton, poorly constructed channels that carry water from rivers many miles have been causing reduced inflows into the lake. All this led to a retreat of lake coastline for tens of kilometers, reduction of biodiversity due to increased salinity, health problems of population caused by lack of clean water and toxic dust in the air. There are also organizations that are dealing with this issue as well as their moves to improve current situation in this region.

Keywords: Aral Sea, Kazakhsatn, Uzbekistan, Syrdarya, Amudarya, irrigation, desertification.

List of figures

List of acronyms

ASBP	Aral Sea Basin Program
BVOs	Basin Water Management Organizations
CIS	Commonwealth of Independent States
EU	European Union
GEF	Global Environmental Facility
ICWC	Interstate Coordination Water Commission
IFAS	International Fund for the Aral Sea
SPD	Sustainable Development Policy Institute
USSR	Union of Soviet Socialist Republics
WEMP	Water and Environmental Management Project
WHO	World Health Organization

TABLE OF CONTENT

1. Introduction

The Arak Sea is located on the territory of two landlocked countries of Central Asia, Kazakhstan and Uzbekistan. Both of these states belong to the post-communist countries and after the collapse of the Soviet Union in 1991 entered into the Commonwealth of Independent States. Kazakhstan is one of the most developed countries of the former Soviet bloc in the Central Asia. The social level of the population is at a higher than in neighbouring Uzbekistan. Industries are important for export to other countries and even in agriculture has been extended mechanization. Uzbekistan, which lies on the southern border with Kazakhstan, is less extensive, but the population and population density exceeds most states in Central Asia. Many ethnic minorities live there. Two-thirds of Uzbekistan occupy deserts and semi-deserts, except for the area around the Amudarya and the eastern tip of the country. In the secondary, the agrarian sector works the largest percentage of the population. In the western part of the country and southern half of the Aral Sea is an autonomous republic of Karakalpakstan, here is the worst situation for residents due to the deteriorating living conditions due to drying up of the Aral Sea (Britannica, 2012; Central intelligence agency, 2012).

Before 1960 the Aral Sea was the fourth largest lake in the world. It took places after the Caspian Sea, Great Lakes and Victoria Lake (Gore, 2000). It lies between large deserts – Karakum and Kyzylkum, and between the sea ports Muniak and Aralsk – famous for fishery (Procházka, 1962). The rivers Amudarya and Syrdarya, water-supply for Aral Sea, were know for their biodiversity, fishery, muskrat rearing and reed production. Local people found work in the spheres associated with water infrastructure (Aquastat – FAO, 2012).

But since 1960 water of Amudarya and Syrdarya has been used for watering of agricultural lands and generating of artificial water reservoirs. Water balance was broken and conclusive alternations in regime of the sea later escalated into the large ecological disaster. During the last 50 years we could have observed the degradation of the lake (Kostianoy, Kosarev, 2010). The area of sea has diminished from 68,478 km² in 1960 to 13,500 km² in 2009. Amount of salt (g/l) has heightened tenfold in 50 years (Water info, 2011). During drying the Sea has

been separated into three parts: the Small Aral Sea, Western Large Aral Sea, and Eastern Large Aral Sea. In 2009 the Western and Eastern Large Aral Sea were still jointed by narrow channel. The local people now suffer by a lack of fresh water, salinization of soils, dust and salt storms, also various illnesses ((Kostianoy A., and Kosarev A.N., 2010).

For many years no one cared about drying water surface of the Aral Sea, decreasing number of fish, which led to the ending of the fishery and about the deteriorating health of the inhabitants of coastal areas. After the collapse of the Soviet Union in 1991, the situation around the Aral Sea became more public. The developed countries became interested in the issue of the deteriorating environment around the Aral Sea. World organizations began supporting projects to help local people to restore biodiversity and improve living conditions.

I have chosen this topic, because I'm interested in environmental impacts and disasters with anthropogenic origin, so I was partially familiar with the issues around the Aral Sea, and I wanted to find out whether there is a chance to save the salt lake.

2. Background and Reference Analysis

2.1 Geographic and Demographic Situation

2.1.1 Kazakhstan

Official name The Republic of Kazakhstan It lies in the central Asia and on the west side of the Ural River interferes to the Europe. Kazakhstan´s borders are with the Russia in the northwest, the People's Republic of China in the east, the Kyrgyzstan, the Uzbekistan, the Turkmenistan in the south. The Caspian sea lies in the west.(Encyclopedia Britannica, 2012).

This state is the second largest of the former Soviet Republics and one of the most influential member of CIS – Commonwealth of Independent States (Gardner P. et al., 1999). The Republic of Kazakhstan covers an area of 2,724,900 sq km, it is the largest landlocked country (Chisholm M., et al., 1999).

Kazakhstan has a very rugged surface. In the west is the Caspian Basin, which is 28 m below sea level. The Turan Plain lies east of the Aral Sea. The Kazakh platform is located on the east; it was built by volcanic igneous rocks. High mountains the Altaj, the Tarbagataj, the Altau and the Tian-Shan with the highest mountain (Chan Tengri – 7,010 m) are on the border to China. The Karatau lines southern boundary. The Kyzylkum and the Mojynkum deserts are near the Lake Balkhash and they cover large areas. The rest of the country is semi-desert and steppe.

Rivers flow mainly in peripheral areas, like the Ural, the Syrdarya and the Irtysh. The largest lakes is the Balkhash, which is divided into salty and fresh water part, the Zaysah and northern part of the Aral Sea (FAO-aquastat, 1998; Gardner P., et al., 1999).

The capital city is the Astana since 1997 instead of the Almata. Population is 16,473,000 (01.03.2011) and population density is 5.96 inhabitants per km². Natural increase is 4.3. Ethnic composition: The Kazakhs 62%, the Russians 23%, the Ukrainians 2%, the Uzbeks 1.5% and the Tatars, the Uighurs, the Germans (1.1.2010). The Kazakhs profess to the Islamic offshoot. The European origin people profess the Orthodox Christianity. The official language is Kazakh

but Russian is also well known (Businessinfo, 2011). The human development index was 0.745 in 2011 (Human development reports, 2011).

2.1.2 Uzbekistan and Karakalpakstan

Official name is The Republic of Uzbekistan, lies in central Asia east of the Caspian Sea. It´s one of two a doubly landlocked country in the world. This means that all neighbors are inland. Uzbekistan borders with Kazakhstan in the north, Turkmenistan and Afghanistan in the south, with Kyrgyzstan and Tajikistan in the east (Encyclopedia Britannica, 2012).

Republic covers an area of 447.400 km² (Chisholm M., et al., 1999). Nearly half of the population of central Asia lives in Uzbekistan (Businessinfo, 2011).

The surface of this country is ether lowland, mostly desert and semi-deserts. The Ustyurt Platform and drying the Aral sea lie in the west with the lowest point (12 m below sea level), into which the Amudarya river comes. The Kyzylkum desert stretches from the lake to the Pamir. The fertile Fergan valley is located to east from the capital city of Tashkent, irrigated the Syrdarya River. The most eastern part of the state lies in the mountains of Tian-Shan, Alaj and Pamir with the highest point (Khazret Sultan – 4,643 m) (FAO-aquastat, 1997).

Surface is characterized by uneven distribution of rivers. The Syrdarya and the Amudarya are glacier source. Other large lakes are the Ajdarkul, the Sarykamysh lakes and the Aral Sea (Gardner P., et al., 1999).

The capital city of Uzbekistan is the Tashkent. Population 28,234,000 (01.01.2011), year a year increases for half of a million. Population density is 63.1 inhabitants per km². The most people live in the Fergana Valley, in the capital city of Tashkent and in the Tashkent region, while large areas in the center and on the west of the country are sparsely populated. The Uzbekistan is a multinational country with more than 100 nations and nationalities. Ethnic composition: 84% the Uzbeks, 4.7% the Tajikistians, 2.8% the Russians, 2% the Kazakhs and the Karakalpaks, the Koreans, the Tatars (1.11.2011). The republic is very religiously tolerant country. Moderate Sunni Islam with 88% prevails, then approximately 9% of Orthodoxy and there are also other religions such as Catholics, Jews, Buddhists, Shiites, etc. In country are registered 16 religious denominations. The Uzbeks official language speaks about 75% of population. The second most

common language is Russian (Businessinfo, 2011). Human development index was 0.641 in 2011 (Human development reports, 2011).

Karakalpakstan is autonomic republic in Uzbekistan, with its own government and parliament (MZV-ČR, 2012). Karakalpakstan is situated south from the Aral Sea. This country lies on the west part of the Kyzylkum desert, with shifting sands. The middle part is situated of delta of the Amudarya river, with the next water resources and watering channels. The Ustyurt Plateau trenches to the west part of the republic. There are equal tops with elevation above sea-level about 292 m (Encyclopedia Britannica, 2012). The climate is continental with cold winters and hot and dry summers. The average precipitation is to 100 mm (Weatherbase, 2012).

Area of the republic is 165,600 km². Population is 1,680,000 inhabinants (MZV-ČR, 2012).

2.1.3 The Aral Sea

The Aral Sea is situated deeply inside of Eurasian continent between the sandy deserts of Uzbekistan and Kazakhstan at elevation of a few dozen metres above the level of the World Ocean. Evolution of the Aral, and its absolute isolation from the World Ocean, governed the natural specialities of this water body that connected the features of a sea and a lake (Procházka V., 1962).

The Aral Sea basin is located from the Turgai plateau in the north to the mountains of Hundu Kush and Pamir – Altai in the southeast and from Ustyurt plateau in the west to Central Tian-Shan in the east. The surface of all basins (with rivers Amurdarya and Syrdarya) is circa 1.83 million km^2. The Aral Sea was filled with water from the Amurdarya (3/4 from runoff) and Syrdarya (1/4 from runoff).

The sea had quite high and reef coasts in the west and northwest and was low and equal in the east and south. The bottom of the sea was quite rough. In its west part the underwater Arkhangelsky ridge extended southwards. Some of its segments rose over water-level and has created islands Vozrozhdenia, Lazareva and others. Western of this ridge a narrow and deep ditch Bering, the deepest point in the Aral (69 m).

The total area of the Aral Sea completely with the islands was 68,320 km^2, the water-level was 53 m a.s.l.. The average depth was 16,1 m. The width of the

sea was 292 km and length 424 km. There were more than 1,000 islands, the biggest of them were Kokaral, Barsakelmes, and Vozrozhdenia. The smaller part of the Aral Sea in the north was separated by Kokaral island and was named the Small Aral Sea. It wasn't deeper than 28 m. The Large Aral Sea lies south of the island Kokaral. The ridge has split the Large Sea into two sections with dissimilar physic-geography specifications. The westward of the ridge was a narrow zone of sea deepness. The eastern side from ridge was supplied by dissymmetrical depression with average depths of 22 m. More than 500 islands were situated in southeast part of the Aral Sea with shallow places (Kostianoy A., and Kosarev A.N., 2010).

Figure 1: Physical-geopraphical map of the Aral Sea from 1950 (Esri.com, 2010)

2.1.4 Syrdarya

This river flows through three Central Asian republics, Uzbekistan, Tajikistan and Kazakhstan (Uzbekistan national reports, 2011). The Syrdarya begins by junction of the Naryn and Karadarya rivers in eastern Fergana Valley.

The river flows west and leads into the Aral Sea. The Syrdarya is the longest river in Central Asia with extent 3,019 km. However it is less watery than the Amudarya. Its river basin is not clearly defined, except upper reaches which contain 462,000 km². Most of the Syrdarya´s inflows in the Fergana Valley don´t flow in because they are used fully for watering. West of the Fergana Valley, the river has three tributaries from the right side, the Akhangaran, Chirchik and Arys rivers (Encyclopedia Britannica, 2012). The Syrdarya forms the northeast border of the Kyzyklum desert (Columbia Electronic Encyklopedia, 2011). In its middle and lower reaches it forms meanders and periodical rivers. The upper reaches are supplied by water from snow and glaciers, and higher amount of water is observed from April to September. Large quantity of silt is deposited in neighbourhood of Qazaly, Kazakhstan. The lower reach is frozen from December to March (Encyclopedia Britannica, 2012).

2.1.5 Amudarya

This river is formed by the junction of the Vakhish and Pyandzh rivers (at this point it begins to be known as the Amudarya) and run west to its estuary on southern shore of the Aral Sea. The river flows by the frontier of Afganistan, Tajikistan, Uzbekistan and Turkmenistan. The Amudarya has more than 1,400 km, but with its source, the Pyandzh river in Pamir has 2,500 km (Columbia Electronic Encyklopedia, 2011). The Amudarya basin is situated between 34° 30 ' - 43° 45 ' north latitude and 56° 15 ' - 75° 7 ' east longitude. Close by the confluence of the Pyandzh with the Vakhsh, the Amudarya contacts with three affluents: from the left by the Kunduz river and from the right by the Kafirnigan and Sukhan rivers. On west of the highland, the Amudarya flows through by the Turan Plain, where it flows through the Karakum desert on the southwest and the Kyzylkum desert to the northeast. The greater part of the water from the river evaporates, seeps or is used for irrigation. The total area of Amudarya´s basin is 465,500 km² (Encyclopedia Britannica, 2012).

2.2 History and Recent Development

2.2.1 Kazakhstan

The first Turkish tribes penetrated into the present day Kazakhstan in the 6th century. Local empire has been disrupted and attached to the golden horde by Genghis Khan in the 13th century. The Kazakhs name appeal in the 16th century, when there was a unification of the empire in great khanate. The eastern part was conquered in the 17th century by the Dzungars. The Kazakhstan was captured in 1919 in civil war by Russians. The Kazakh Soviet Socialist Republic was established in 1936. In 30´s and 40´s, many people fled to the China and to the Afghanistan. The communist regime built in the central Kazakhstan the space base Bajkonur. On the east they built a large nuclear polygon for testing. (Gardner P. et. al., 1999).

2.2.2 Uzbekistan and Karakalpakstan

Beginning of history falls to the Persian Empire. In the 8th century the area was conquered by the Arabs and in the 12th century by Genghis Khan. In the 16th century the nomadic Uzbeks penetrated to this area and created several Khanates. In the second half of 19th century Russia conquered this country. In 1924 the Uzbekistan became the Federal Republic of Soviet Union. After the collapse of the Soviet Union, Uzbekistan became a member of the CIS - Commonwealth of Independent States (Gardner P. et al., 1999).

The first historical mention of the Karakalpaks dates from the 16th century. During the following two hundred years they colonized in the Amudarya region. In 1920 the Karakalpaks integrated into the Soviet Union. At first Karakalpakstan was autonomous part of Kazakhstan and in 1936 of Uzbekistan (Procházka V., 1962). In 1991, Soviet Union came apart and Karakalpakstan got an independence. The inhabitants are mainly Karakapaks, Uzbeks and Kazaks. Circa half of the inhabitants are urban. The capital city of Karakalpakstan is Nukus (Encyclopedia Britannica, 2012).

2.2.3 Paleogeographical History of the Aral Sea

The Aral Sea basin was created as an outcome of connection action of tectonic subsidence and actions of arid denudation. The basin has an irregular grand topography, with depressions splitted by an oblong elevation treacly from north to south. Parts of marine terraces are founded locally at 54 – 72 m a.s.l. on the coasts. The marine sediments originate from Akchagylyian and Apsheronian from Caspian Sea of the Khorezmian suite – Holocene (11,700 years ago). The lower layers contain gypsu mand shells of brackish-water and freshwater molluscs. The upper part of sedimentary contains shells of *Cerastoderma glaucum (Cardium edule)*.

The history of the Aral Sea has two sections – long-standing prehistory and a short era of the modern (pre-1961) sea basin. The first epoch of the Aral dates back to the Late Pliocene when its lake was loaded of water from Akchagylyian and Apsheronian seas. This was followed by eras in the Pleistocene, its environment survives in to basin.

The late marine period was rather short, it persisted only the Holocene. It started with a lacustine-brackish water stage. At that time, lakes of different salinity existed within basin. Sometimes They dried up and were replaced by solonchak desert. In the mid-Holocene water from Amudarya turned away from Sarykamysh depression and started to flow into Aral basin by the Akchadarya canal, that way began last epoch of the Aral Sea´s history. At that era the Aral was intensified brackish water body of marine type submitted to drastic irresolution of sea level (20 m) and sizeable growth of salinity (up to 10‰) .

Next evolution of the Aral Sea was followed by a many factors such as climate, hydrology, tectonics and human. The climate took primary importance, because it takes control of the hydrologic cycle in basin, evaporation from surface of the sea, and outfall from the Syrdarya and Amurdarya rivers. The later was first-rated in the poorly flooded Aral depression into the basin (Kostianoy A., and Kosarev A.N., 2010).

2.3 Political and Administration Issues

2.3.1 Regional Water Management in Central Asia

Interstate Coordination Water Commission (ICWC). Dependence of the Central Asia Republics economics on irrigated agriculture led to the necessary interstate stabilization. At the end of 1991, the leaders of the Republican water sectors signed a new agreement - On Cooperation in the Field of Joint Management and Conservation of Interstate Water Resources-. This agreement determined rational use and protection of interstate water resources. ICWC oversees the management in the Amudarya and Syrdarya basins. It also makes decisions about the allocation of water and monitoring.

Basin Water Management Organizations (BVOs). It is an executive organ in the ICWC. The BVOs´ duties are these: plans for ware allocation to users in the Amudarya and Syrdarya basins; control of major hydraulic structures on both rivers and reservoirs; measurement of water flow; construction, repair and operation of hydraulic structures; water quality.

But water delivery to the Aral Sea is based primary on the principle of „whatever is remaining. “

International Fund for the Aral Sea (IFAS). The main activities are: raising funds for protection of air, water, land resources and fauna and flora; financing of ecological research; solution of social and ecological problems; establishing of a regional environmental programs for saving the Sea.

Sustainable Development Policy Institute (SPDI). This is group, which works on saving the Aral Sea. SPDI focuses on transboundary water management and the environmental, economy and energy. Its' headquarter is located in Pakistan. It is also points out the need of equitable distribution of water resources (McKinney D.C., 2003).

Aral Sea Basin Program (ASBP). International assistance has proceeded in three phases. Phase One (1992-97): development of the regional program, creation of regional institutions, and initiation of a series of technical studies.

Phase Two (1998-2003) implementation of the Water and Environmental Management Project (WEMP), which was executed by the World Bank. Phase Three (1997): overlapping support by the Bank for in-country operations in each of the five riparian countries (Bargouti S., 2006).

2.4 Climate and Climate Changes

The area of the Aral Sea basin is located in the centre of Eurasia near to the north frontier of the subtropical zone. The extended solar radiation of 2,700 – 3,100 hours per year and a high level of ultraviolet radiation with the situation of sea and a distance from orcans are the results aridity and continentality of the region. Precipitation is circa 100 mm per year, with top in late spring and autumn. Summer is very dry and hot with total precipitation about 15 – 30 mm per three months the average temperature is 29 - 30°C in July. Evaporation in this region is as much as 1,500 – 1,600 mm on an annual basis (Khan et al*.,* 2006; Weatherbase, 2011).

Humans' induced changes of regional atmospheric circulation and climatic conditions in the Aral Sea basin have taken from 1950s. The changes of atmospheric circulation are regional and have characteristic features on the plains and in the mountains of the basin of Aral Sea. The range of anthropogenic changes of climate is circa 100 km², and climate changes in the deltas of Amudarya and Syrdarya and shore of the Aral Sea vary from 1,000 to 10,000 km².

Natural changes of local climate consist from short and long term positive and negative trends. These changes are instable and statistically unimportant. But anthropogenic changes of local climate are stable and detectable (Glantz M., 2004).

In the 1950s, pollution in the Aral Sea basin had increased and poverty of water caused that new irrigation facilities were built. First changes of regional atmospheric circulation were observed. In the 1960s, the volume of the mountain rivers has decreased and the amount of water for irrigation has increased. Interest about the Aral Sea ´s problem grew. Reduction of air humidity was recorded during the following decade. Disquietude regarding the drying Sea deepened.

During the 1980s, the negative effects of reduction in river flow changed the local climate. Salt and dust storms were formed on the dried bottom of the Aral Sea. And in the 1990s, the crisis deepened, but scientific recommendations on extenuation of this crisis were developed (Huang X. et al., 2011).

Changes of local climate:

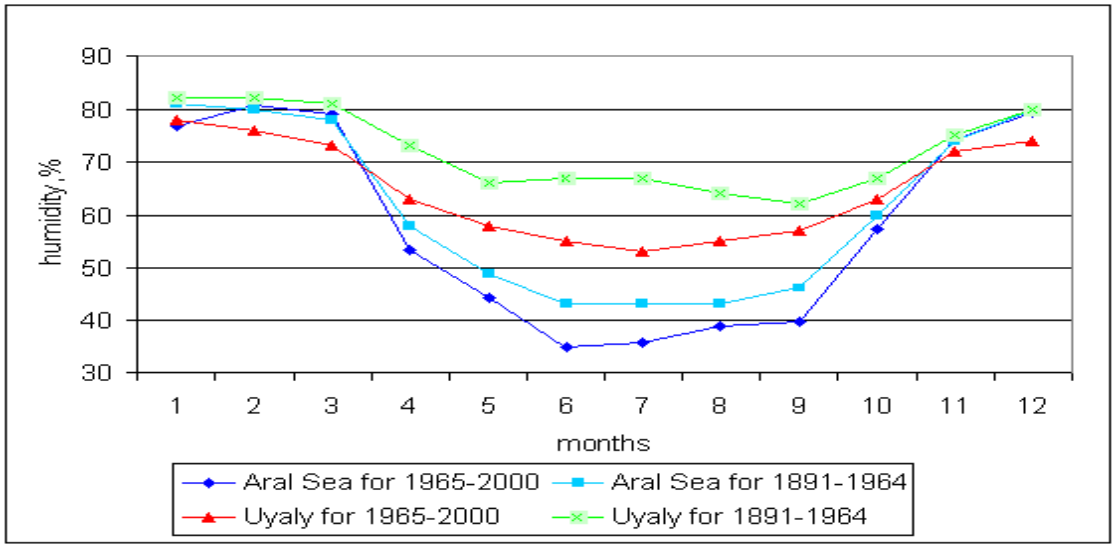

Figure 2: Changes of humidity on the “Aral Sea” and “Uyaly” station in the 19th and 20th century (Cawater-into.net, 2011)

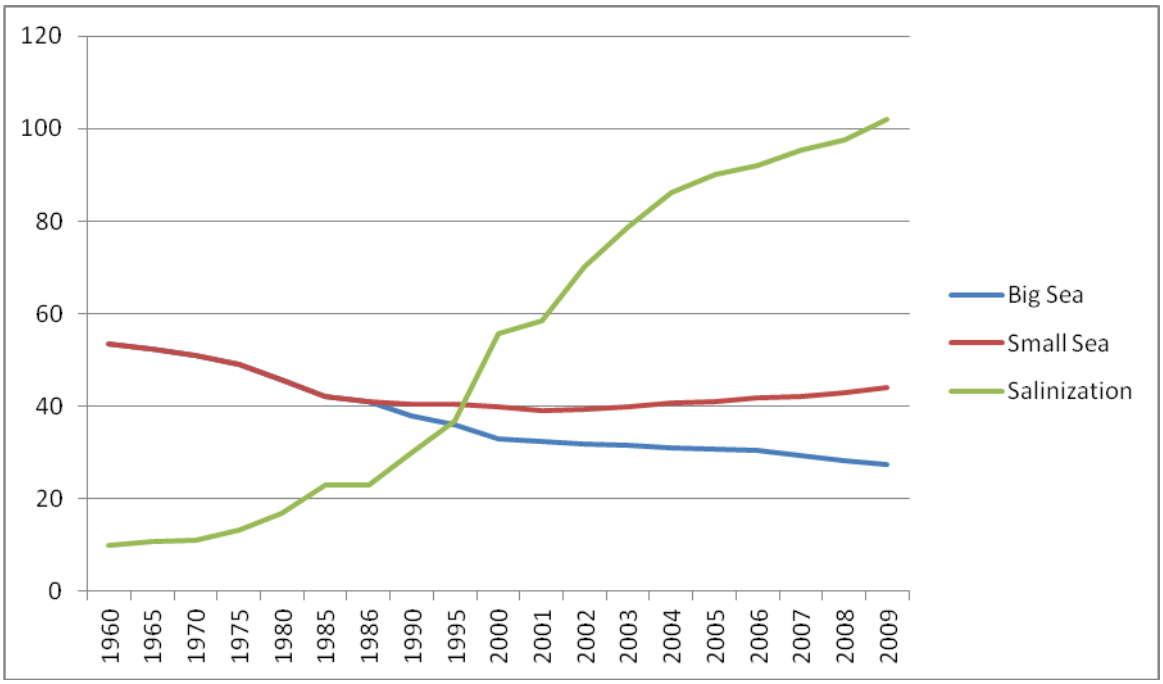

Figure 3: Changes of the Aral Sea level and salinization from 1960 to 2009 (Cawater-into.net, 2011)

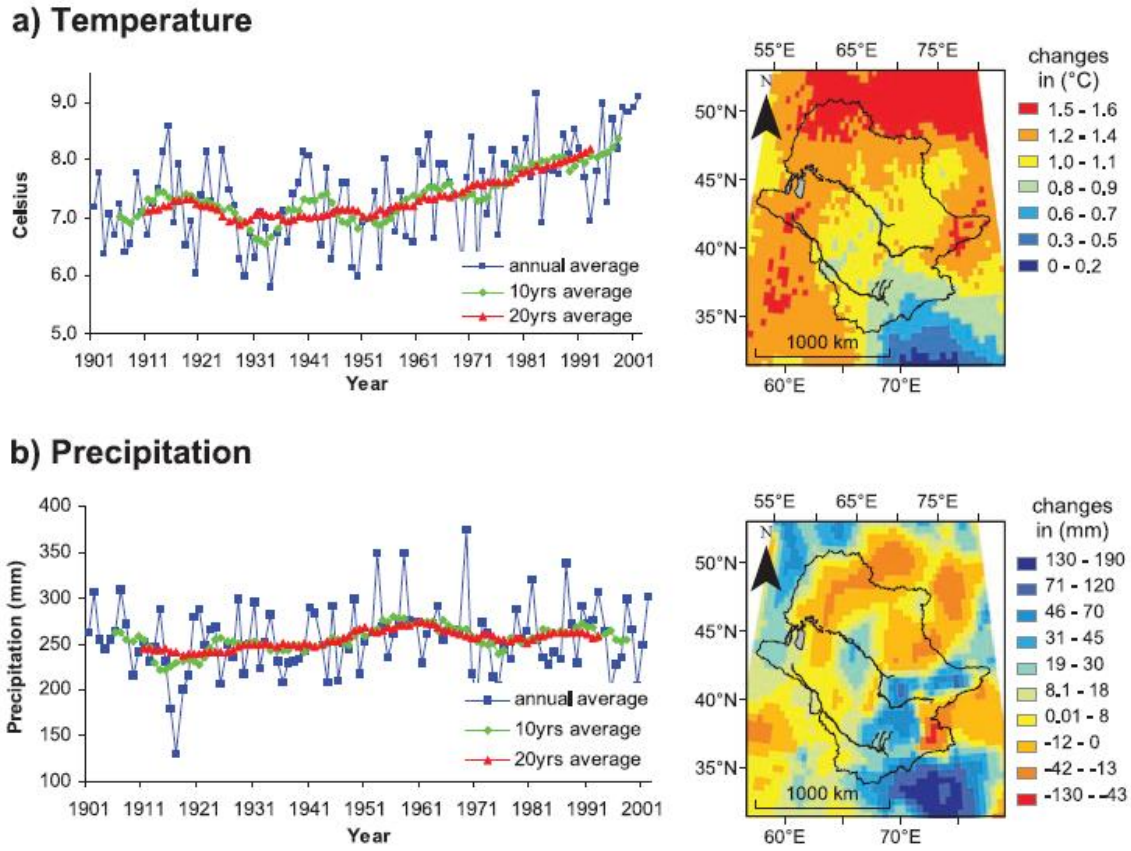

Figure 4. (a) Temperature and (b) precipitation data within the Aral Sea basin (left) Temporal trends.(right) The spatial distribution of change between the temporal (50 years) average pre-1950 condition and the recent 20 years (1983 – 2002) average condition (Severskyj I., et al., 2005).

2.5 Social and Economic Situation and Perspectives

2.5.1 Kazakhstan

In the agriculture, the livestock production predominates with cattle and sheep. The Kazakhstan is a large producer of grain, although the yield per hectare is low. In the irrigation area in the south are grown cotton, rice, tobacco, sunflower, vegetables and fruits. The Kazakhstan has huge coal reserves in the northeast, oil and natural gas in the Caspian region. State has world significant deposits of chromium, copper, lead, iron, bauxite and phosphates (Gardner P., et al., 1999). In 2002 the Kazakhstan decreased an investment-grade credit rating. Between 2000 - 2007, economy grew for 9% per year. Mainly due to mining industry.

Obstacle for the export is the poor infrastructure. The Kazakhstan suffers from the so-called „Dutch disease“. In late 2007, capital inflow into the state was frozen by financial markets. This has led to large economic fluctuation in 2008. The consequence was the fall of oil and commodity prices. This is the proof of depending on World prices. Kazakhstan has began with an ambitious program focused on development of transport, food, telecommunication, pharmaceutical and petrochemical. GDP – real growth rate in 2010 was 7%. (Central intelligence agency, 2012).

2.5.2 Uzbekistan

Uzbekistan is one of the largest exporter of cotton all over the Word. It is caused by the irrigation systems in Fergana Valley. There are grown vegetables, fruits, rice and cereals in the east. Mining of natural gas, gold and copper is very important. 80% of electricity comes by incineration of oil and coal. Industry is presented by metallurgy -fabrication of the agricultural machinery (Gardner P. et al., 1999). Uzbekistan´s GDP grown for 8% during the last few years, mainly due to rising world prices of major export commodities – natural gas, cotton and gold. The U.S. automotive company opened a new factory in Tashkent last year. It moved Uzbekistan closer to the global financial market. (Central intelligence agency, 2012).

2.5.3 Karakalpakstan

The agricultural sector predominates. The main crop is cotton, which is grown along the Amudarya and is worked at Chimbay, Beruniy, Mangit and in several other cities (Karakalpak, 2012). Next crops are alfalfa, rice and maize. Karakul sheep and cattle are bred in the desert. There are exploited oil, limestone, gypsum, asbestos, marble (Encyclopedia Britannica, 2012; Procházka V., 1962).

Location along the Aral Sea and the Amudarya, during the 50 years republic had become an area with very poor environment. The soil is heavily salinized due to over-watering and dust from the uncovered bottom of the sea. High

concentration of chemicals like fertilizers, defoliants, insecticides is very dangerous for human health. The reducing of the area of the sea changed climate, it is harsher and growing season is shorter (Encyclopedia Britannica, 2012).

2.5.4 Demographic characteristics of the Aral Sea region

Actual population growth number may not be representative for future trends. Deceleration in population growth is likely but not known when and by much. Probably, smaller families will be located in cities and larger villages. And for farmers would be better to have larger families with more than three childern. Which will help with the work in the field. At all events, in the next 25 years the population in this region will grow due ti the age structure of the present population.

The Figure 5 shows the ethnic distribution of population in the area, except Afganistan. There are three dominant ethnic group. More than 40% of the population is represented by Uzbeks, almost 17% by Kazakhs and 13% by Russians. Local residents dominate in most of Uzbekistan and Tadjikistan.

State	Ethnic group (%)								
	Kazakh	Kyrgyz	Uzbek	Tajik	Turkmen	Russian	Ukrainian	German	Other
Kazakhstan	53.4	-	-	-	-	30.0	3.7	2.4	8.0
Kyrgyzstan	-	52.4	-	-	-	18.0	2.5	2.4	11.8
Uzbekistan	3.0	-	80.0	5.0	-	5.5	-	-	6.5
Tajikistan	-	-	25.0	64.9	-	3.5	-	-	6.6
Turkmenistan	2.0	-	9.2	-	77.0	6.7	-	-	5.1
Total	16.80	4.31	40.3	9.63	6.17	13.40	2.26	0.88	7.26

Figure 5: Ethnic composition of the population in the Aral Sea region (Severskiy, I., 2005).

In addition to Kazakhstan, the region is characterized by quite high population growth, negative balance of migration and a high infant mortality, which is caused by poor drinkikg water. The demography of Kazakhstan is different due to low population growth, the highest negative balance of migration in this region (-6.16 migrants/1,000 inhabitants) and very low propotion of the population living below the poverty line (26%). In the other coutries of the region propotion reaches 34% - 80%.

The table xy2 shows that Kazakhstan has the lowes percentage of young people under 15 years old, only 26% from the population, while in the others countries is percentage higher (34% - 40 %). Kazakhstan has the highest percentage of people over 65 year, the lowest birth rate and death rate. This numbers may induce social and economic problems in the future. Also Kazakhstan relatively good social welfare. But then, Kyrgystan has the lowes number of eldery people (1%), probably due to the low level of social welfare. Tajikistan has the highest level of infant mortality and the greatest percentage of population loving below the poverty line.

In the Aral Sea region, the population is unevenly spread, the most of people live around water areas. After the fall of the Soviet Union, the rate of population growth decreased. Since 1991 to 1995, the population in the region increased by 150,000 people and in 1996 – 2000 period only by 86,000. In 2002, more than 1,5 million people lived in this region. Emigration is one of the factors that affect the number and composition of the population. The migration balance for the last 12 years made –45,500 people. The current migration differs in age group. In the past years, migration for education purpose predominated, therefore, about half of the migrating people consisted of youth below 30 years old (Severskiy, I., et al., 2005).

2.5.5 Employment in the Aral Sea coastal region

The fisheries have been one of main sources of food for local people since the ancient times. During the era of the Soviet Union, the fishing industry was a main branch of the economy of the whole Karakalpakstan autonomous republic. The local inhabitants used to catch fish and process them in the Muynak Fish

Canning Factory. The city Muynak traditionally had three main types of employment: fishermen, fish cannery workers and cattle breeders. In 1981, there were about 1 200 fishermen involved in 12 capture fishery farms. They had 113 fishing boats and caught about 75% of total fish in Uzbekistan.

The Muynak Fish Canning Factory was an importatnt employer and was equipped with modern fish processing equipment from Germany. There were five other smaller fish processing plants located on the southern and southwestern coastlines of the Aral Sea. During the years of positive hydrological conditions, Muynak Fish Canning Factory was a major producer of canned fish and other fish products. In 1974, production had been cut by half and other factories had ceased to exist to 1980. The supplies of frozen oceanic fish imports from Russia dried up and the factory became uneconomic. It continued to function on a reduced scale using locally produced silver carp. In 2011 the factory was practically out of operation.

In those days, many people worked in ship service factories, the Aral shipping company or in other departments of local industry engaged in fishing or fish processing. A few were in the coastal tourism industry.

It is not possible to divide employment data between aquaculture and capture fisheries. In the 1980s, more than 70 farms and establishments were active in the fisheries sector and 5 600 to 5 800 people were employed by the establishments of the republican Fisheries Committee, Uzbekribvod (the Commission for the protection of fish resources) and Ribsbit (Fish trade). All of them worked as full-time employees. About 100 – 150 specialists worked at the Central Asian Branch of Gidroribproekt (Institute for the promotion of fisheries projects) and the Central Asian ichthyo-pathological laboratory (both situated in Tashkent).

After the fall of the Soviet Union, in the period 1994–2003, important changes took place in the sector, job security and payments were low and there were not new possibilities. After the start of the privatization process, the companies left the sector. Other establishments followed and only a few fish farms remained active. As a consequence of the number of people employed in the sector decreased, mainly in the early years of the privatization process.

When the privatization of fisheries was permitted, the number of establishments increased as existing enterprises were split into several smaller units and new were created. The number of people employed in the sector also slowly increased. It is about 5 700 people were employed in 2007 in fisheries activities. More than 2 000 worked in 21 fish farms. Most of those with diplomas in fisheries, fish breeders, mechanics, technical and engineering employees can be found in Tashkent. In 2008–2009, there were 2 022 people employed ful-time in fish farming in Uzbekistan (Karminov B., 2011).

3. Objectives

3.1 Main objective

The main objective of this BSc. Thesis is a detailed description of (especially) ecological and social situation in the Aral Sea area including both main affluents – Amu-Daria and Syr-Darja rivers. It is based on the geographic and demographic background and disasterous evolution of couple of recent decades.

3.2 Specific objectives

The specific objectives of this thesis focusing on the socio-ecological situation in the Aral Sea region are:

Firstly: description of natural conditions, history and economy of countries where the Aral Sea is located (Kazakhstan and Uzbekistan together with the autonomous republic of Karakalpakstan).

Secondly: description of the physical geologic an gegraphic conditions of the lake in its original size, which had before 50 years of the last century.

Thirdly: description of the climate change that occured during the second half of the 20th century due to the excessive irrigation including two rivers which bring water into the Aral Sea, Amu-darya and Syr-darya and irrigation systems and canals, which were built by the Soviet Union.

Forthly: description of what kinds of aquatic animals occured and ocure now in the area, what are the changes over the years. It is important because due to the excessive irrigation which is still expanding in the agricultural areas, the Aral Sea water level is steadily decreasing which leades to disasterous biodiverzity damages.

Fiftly: characteristics of environment deterioration influencing the health status of the population living around the Sea drying area. Also demographic situation and population migration during the last 60 years are attached.

Finally, I would also like to present programs and organizations which are engaged in the Aral Sea problem and describe their activities and results.

4. Methodology

The basic method for the elaboration of this work was the analysis and word processing of literary sources on a given topic. For its internet search I used full-text database SpringerLink, Web of Knowledge (Web of Science, Journal Citation Reports, Current Contents Connect), Science Direct and Scopus. As a factual source I used FAOSTAT. From the websites of Ministry of Foreign Affairs I used the information in order to prepare the chapters about the countries Kazakhstan and Uzbekistan. The I used specialized publication as a sources of information for physical-geographical description of the Aral Sea. The climatic phenomenon information I gathered from official meteorological sites WEATHEBASE lakes and the facts about changes of Aral sea I took from the statistical Database of Aral Sea and the FAO-AQUASTAT, I also found there information about rivers bringing water into the sea and irrigation. The website of the World Health Organization worked as a informational source of data and statistics about health status of the population. The background data for the chapter on programs and institutions dealing with lakes drying up I have found on the website of the World Bank and the World Health Organization.

From a methodological point of view, I firstly gathered many articles, technical literature and web sites and I gradually studied them. The intention was to find as many good sources of information as possible to process the goals that I have identified.

Because this Thesis is a compilation one, I have cited much text from different references. The citated text is properly provided with references (in parentheses) and metioned in the List of references.

5. Results

5.1 The Aral Sea Disaster

5.1.1 Irrigation in the Aral Sea basin

Before 1960, the level of the Sea was quite stationary. The average flow rate of the Amudarya and Syrdarya rivers to the sea was about 48 km³/year plus 5 km³/year of groundwater and 6 km³/year of precipitation over the sea. The total volume of evaporated water is circa 60 km³/year.

In the 1960s, Central Asia has become a major producer of cotton in Soviet Union. Large area of the deserts began to be irrigated. The progression of watering of the Aral Sea basin was dramatic. From 1960 to 1995 the area of irrigation has increased almost twice, the population and water withdrawal too (FAO-aquastat, 2012).

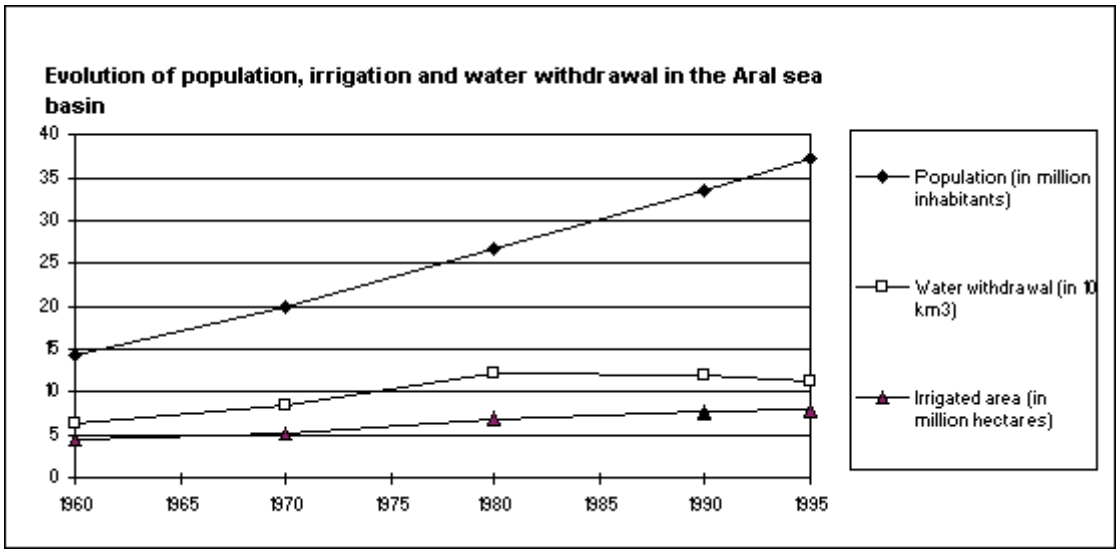

Figure 6: Evolution of population, irrigation and water withdrawal in the Aral Sea basin (FAO-Aquastat, 2012)

Karakum canal is located in Turkmenistan. Its build-up begun in 1954 and finished in 1967 with length of 840 km from Amudarya to Gökdepe, westward of Ashgabat along the Karakum desert. The construction was completed in 1988 with length circa 1,400 km. Canal is navigable for 450 km. It carries 13 km³ per year of water from the Amudarya river. There was cultivated mainly cotton

monoculture. Water losses from the Karakum canal in the first years were estimated for circa 50% (Britannica, 2012). In 1989 such a complex was situated on 200 000 – 250 000 ha. This canal is in principle the third largest river in Central Asia (Glantz M. and Zonn, 2005). Delivery of large number of water from Amudarya caused rise of solonchak ecosystems (diffuse secondary salinisation in the fields). Changes in landscape similar to that in the Amudarya offered in the Syrdarya basin, namely the Kairakkumskoe Reservoir (Fergana Valley) and the Chardar'inskoe Reservoir (Glantz M., 2004).

There are several consequences of affected irrigation: some tributaries have been used too much, so they didn´t achieve the core flux. They are found in the Amudarya basin - the Zeravshan and Kashkadarya, and in the Syrdarya basin - the Arys and Akhangaran. The main reasons of soil degradation (major water logging and salinisation) form small per cent of tight channels (circa 25%) and poverty of sewerage system. More than 50 lakes in the Amudarya and Syrdarya deltas dried up and traditional ecosystems were destroyed. The content of minerals in the water has quadruplicated to 40 g/l (Kostianoy A. G., Kosarev A. N., 2010):. This quantity keeps the survival of most of the species of fish and zooplankton. The commercial fishing has concluded in early 1980s. Sand and dust, contaminated with pesticides, are taken by the wind in amount of 15 – 75 millions t/year up to a distance 250 km. The climate has changed, now it is more continental. The growing season is shorter, on average 170 days per year. Number of desert storms increased up to more than 90 days a year (Gore A., 2000).

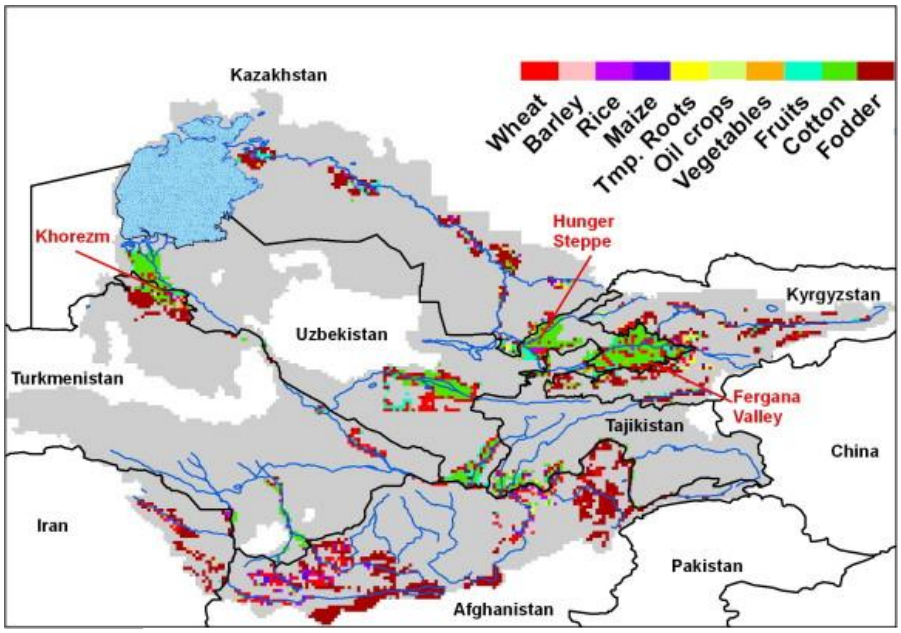

Figure 7: Crop specific irrigated areas in the year 1960. Black lines depict country borders. White spaces within the Aral Sea basin are sinks, which are not connected to the Amu and Syr Darya Rivers. Grey areas show non-irrigated parts of the Aral Sea basin. Red notations show irrigation hot spots. (Sciencedirect.com, 2011)

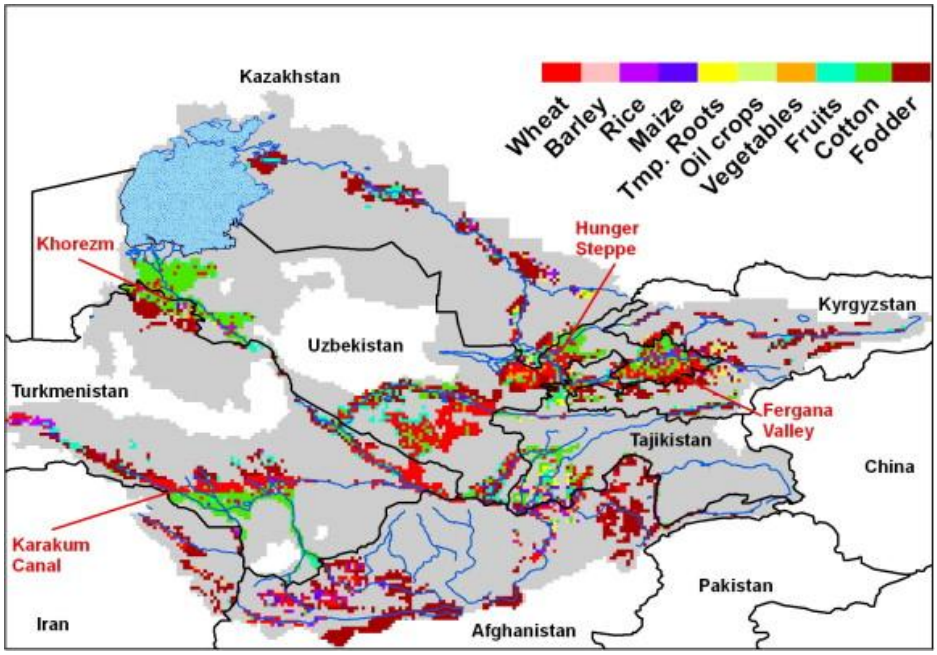

Figure 8: Crop specific irrigated areas in the year 2000. Black lines depict country borders. White spaces within the Aral Sea basin are sinks, which are not connected to the Amu and Syr Darya Rivers. Grey areas show non-irrigated parts of the Aral Sea basin. Red notations show irrigation hot spots (Sciencedirect.com, 2011)

5.2 Ecologic Consequences

5.2.1 Biodiversity

The Aral Sea´s fauna and flora biodiversity has existed in relative stationary, brackish conditions, up to the 1950s. Until the end of 1960s the Aral Sea fish catch accounted for up to 7% of the total catch of the former USSR´s inland waters and 13% of its valuable fish species (Glantz M., 2004). Salinity of water varied between 10 and 12‰, with unimportant vacillation of level and salinity over the years. Fresh-water fauna occurred in the open part of the Aral Sea. The euryhaline and drimophiluses species (the organisms dwelling in conditions of a high salinity - in seas, brine lakes, saline lands etc.) lived in gulfs with higher salinity. Until 1950s there have lived 33 species of fishes, 61 of invertebrates (zoobenthos), 49 of zooplankton, 306 of phytoplankton (including bento-planktonic micro- algae) and 37 of macrophytes (Kostianoy A. G., Kosarev A. N., 2010). The ichtyofauna of the Aral Sea was poor in species diversity. In terms of flora and fauna biodiversity, the Aral Sea ranked last among the brackish seas of the Soviet Union (Glantz M., 2004).

The main angled species of fish were roach (*Rufilus rutilus aralensis*), sazan (*Cyprinus carpio aralensis*) and bream (*Abramis brama orientalis*). The 80 – 85% of the total catch was composed of aral barbel, bream, aral carp, pike-asp.

In the 1960s' salinity of the Aral Sea began to elevate and ecosystem has changed. Most of the water inhabitants disappeared from the Sea. Fishes, invertebrates, zooplankton and macroalgae kept fine for longer period than microalgae and phytoplankton that disappeared earlier.

From 1960 to 1980 new species were put into the Aral Sea. It has been started with brackish organisms; marine species came after and as last organisms resistant against high level of salinity were set in there (Kosarev and Kostianoy, 2009). Starred surgeon (*Acipensez stellatus*) was the first of introduced species. During the 1927 – 32 campaign for introduce new species failed, but this experiments were repeated in 1948 and 1962 when of 12 million larvae and fry and 3 million bastard strurgeon were released into the deltas of the Amudarya and Syrdarya. Informations about their fate is not recorded in any literature. The next

species were introduced too. Alosa caspia (eggs and larvae) in 1929– 32, baltic herring (*Clupea harengus membras*) (eggs) in 1954– 59, two species of grey mullet, (*Mugil auratus* and *M. saliens*) (fingerlings) in 1954– 56, and grass carp (*Ctenopharyngodon idella*) in 1960– 61 (Glantz M., 2004).

Polychaeta *Hediste diversicolor* and bivalva *Syndosmya segmentum* were appointed from the Azov Sea in 1960 – 1962. Planktonic euryhaline copepods were introduced like food for fish in the 1960s – 1970s. During this time crab *Rhitropanopeus harrisii tridentata* was accidentally transferred into the Aral. Most of them just vanished due to a critical concentration of minerals. Introduction of new euryhaline species was necessary due to the declining national economy (Kostianoy A. G., Kosarev A. N., 2010).

The invaders have played positive role since the middle of the 1970s when salinization has grown up to 12 - 14‰ (Ermakhanov Z.K., 2012). This percentage amount means death for all fresh-water animals (for them, the border quantity of salinization is 8 - 10‰). Until 1970s, 70% of species in the Aral Sea were gone. In this period only euryhaline tittlebat from the Zov Sea was able to survive in the Aral. The stocking of flounder provided continuation of the fishery in this stage of salinization. In the first half of the 1980s, only gloss flounder, tittlebats, silverside and Baltic herring outlived in these harsh conditions (Kostianoy A. G., Kosarev A. N., 2010).

Anthropogenic (man-made) acclimatisation was finalized at the end of the 1980s. After the isolation of the Small Aral Sea, only 7 species of fish, 7 of zooplankton, 11 of macrozoobenthos and 52 of phytoplankton occupied the Large Aral Sea. *Artemia parthenogenetica* (type of shrimp) has firstly appeared in the Large Aral Sea at the end of the 1990s. Since 2002 it has predominated between zooplankton with 99% of the total biomass. In 1994, macrophytes contained these species: *Zostera noltei, Ruppia cirrhosa, Chaetomorpha linum, Cladophora glomerata and Cladophora fracta.* At the seabed there could be found polychaete worm *H. diversicolor*, bivalves *S. segmentum* and *Cerastoderma isthmicumand,* and gastropod *Caspiohydro-bia* sp., also two species of fish, *Latichtis jesus Iuscus* and *Atherina bueri* along with 50 species of phytoplankton, mainly diatoms and cyanobacteria (Pavlovskaya L. P., 1995)..

Since 1988, the Syrdarya´flow reached the Small Sea after long time. After construction of Korakal dam the Small level sea incresed and biodiversity too (Ermakhanov Z.K., 2012).

In 2002, P. Zavialov led group, which has investigated the Large Aral Sea. They have found groups of dying *Ruppia cirrosa.* From gloss flounders have survived only adults, but population of silversides has included adults as well as youngs. In 2004 when salinity achieved 90 ‰, no fish were located in the Large Aral Sea. The salt content continued to rise. In 2009, salanita climbed to 102 ‰. (Kostianoy A. G., Kosarev A. N., 2010) .

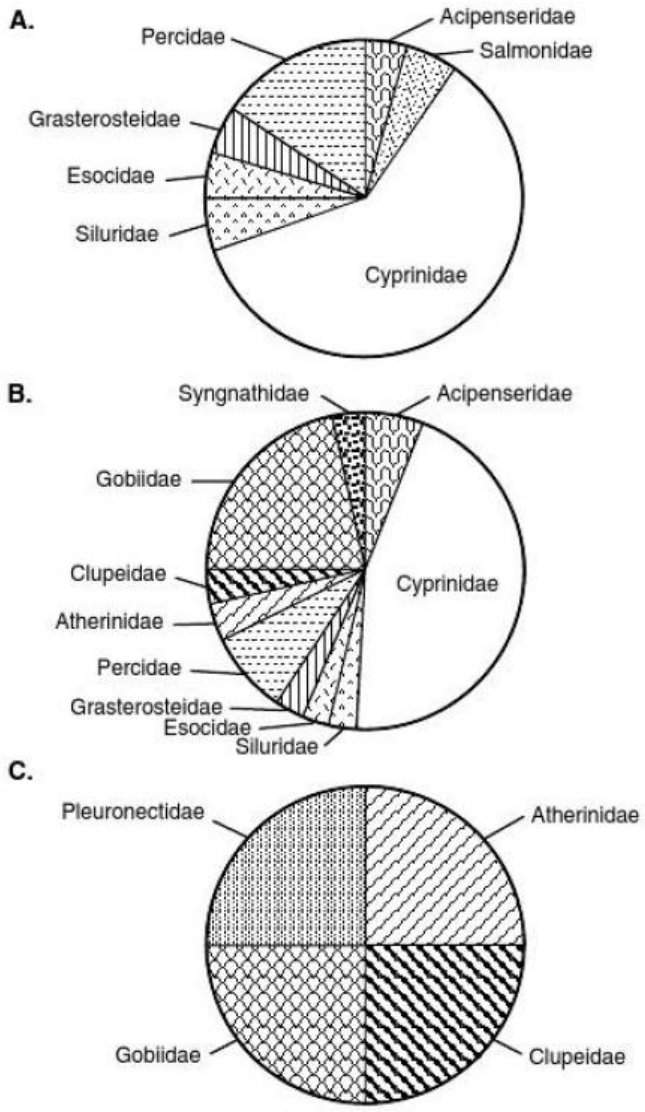

Figure 9: Anthropogenic transformation of the Aral Sea ichtyofauna. A: Native ichtyofauna composition in the 1930s. B: Ichtyofauna composition in 1950-70. C: Ichtyofauna composition in the 1990s. (Glantz M., 2004)

5.3 Impact on Social Situation

5.3.1 Public health status of the Aral Sea coastal region

A comprehensive analysis in 1991 of the public health status of the 1970s and 1980s was carried out for the Aral Sea coastal region.The analysis was performed by at the Water Problems Institute (1991) in cooperation with a number of specialized public health research institutes of the USSR. Their findings pointed to the fact that the medical and biological conditions that developed in the coastal region of the Aral Sea were characterized by a high level of morbidity from intestinal infections and an increase in noninfectious pathology, oncological, cardio-vascular, organs of secretion, digestion, and hemogenesis and respiratory system problems.The pathology related to pregnancy was also identified as was a high rate of infant morbidity and mortality.Malformation and other genetic problems were observed more frequently than had been the case in the past. (Small I., 2001).

Health problems of the population in the Aral Sea basin region depend on the excessive use of fertilizers during the last 60 years. The amount of fertilizers used per year were thousands tons. Circa 54 kg/ha of herbicides, defoliants, etc. have been using in the past in Uzbekistan. The USSR used fertilizers in the 10 – 15 fold doses than was normal dose. Now, pesticides contaminate water resources such as drinking water, the air, milk of the animals and even mothers (Glantz M., 2004).

In 1979 - 85 in Karakalpakstan, from 1.3% to 37% of the food products contained pesticides. The lower number was found in grain products, fruit and vegetables. To the end of the 1980s, hexachlorocyclohexane, DDE and DDT were included in the bodies of fish (perch, carp). In procedure of processing of 1000 t of raw cotton, the amount of dust, that contains pesticides, is circa 31 t.

The occurrence of typhoid fever increased up to 29 times, hepatitis 7 times and paratyphoid 4 times in Kyzyl-Orda during 1973-88. More than 60,000 inhabitatns of this region were stricken with virar hepatitis in this era and more than 70,000 suffered intestinal diseases. Typhoid and paratyphois infections and viral hepatitis were recorded annualy in 30 villages in the region. This data corresponded to 40% of hepatitis and 45% of typhoid fever from total number of

infected from whole Kazakhstan. During 1976 – 80 the annual index of thypoid fever morbidity represented 58.9 cases per 100,000 person, and in 1981 – 85 it was 75.4 cases per 100,000 person (Glantz M., 2004). Almost 75% of those infected were children. Hypercalciuria is frequent in child population (Kaneko K. et al., 2002). The infant mortality in this period reached 30%. Very frequent illness has been tuberculosis and epidemics of infections.

Number of level of kidney diseases has tripled and cardiovascular system problems have been doubled. Cancer of the oesophagus has occurred most in this region, mainly in Kazakhstan. Circa 70% of mothers suffered of anaemia, many of the pregnant women have problems with kidneys and with cardiovascular system. These results tend to high morbidity and mortality of the newborn. Serious diseases of children in this area are hypotrophy, anaemia and rickets.

In Kyzyl-Orda region appearance of parasitic diseases tripled in the years from 1980 to 1990. From 100,000 of habitants 150 – 220 people have suffered form of helminthiasis (kind of tapeworm, roundworm or pinworm). The intensity of parasitic infection at the population depends also on the hygienic conditions. And number of the parasitic diseases during the 1980s are listed in the table .

	Morbidity rate (per 100 000 people)					
Disease	*1980*	*1986*	*1987*	*1988*	*1989*	*1990*
Visceral leischmaniasis	1.2	1.4	0.6	0.5	0.5	0.6
Dermal leischmaniasis	–	–	4.0	45.0	223.9	255.4
Malaria	–	0.3	–	0.5	0.1	0.1
Echinococcosis	–	–	–	0.6	0.8	0.1
Taeniorhynchus	3.1	1.7	2.8	1.2	1.4	1.2
Enterobiasis	283.4	700.8	844.9	966.0	1223.0	1053.0
Hymenolepiasis	188.2	195.4	544.1	157.1	137.6	121.7
Ascariasis	4.4	4.6	2.8	4.7	3.3	1.8
Scabies	–	31.1	11.7	15.4	12.2	3.5
Crimean hemorrhagic fever	0.3	1.4	0.9	0.9	1.2	0.5

Figure 10: The incidence of parasitic disease in the Kyzyl-Orda region in 1980s (Glantz M., 2004).

Epidemic of typhoid fever struck Karakalpakstan in 1981-85. In the north zone in the average 67 cases per 100,000 persons (30 and 26 in the south and

middle zones of Karakalpakstan) were observed. Thanks to the extraordinary measures and medical treatment of bacili carriers the cases of thypid fever have decreased. In this region the appearance of salmonellosis doubled in 1986-90. In the same time period the rate of morbidity with enteric infection raised in Karakalpakstan almost by 10% an in Kyzyl-Orda region by 50% (Glantz M., 2004). And the appearance of hepatitis A and B increased by 22% - 25%. The morbidity of measles increased by 25% and poliomyelitis cases grown up to 80%. Morbidity of tuberculosis was double in the 1990s (WHO, 2011).

The airborne infections like measles, the number of morbidity raised average by 50% and poliomyelitis, the number of morbidity raised average by 60%. The number of tuberculosis morbidity has doubled between 1970 – 90.

In 1988-89, the research has shown morbidity of 66% adult and 61% of the children population in Karakalpakstan region. The threefold growth of deaths from acute infection of respiratory organs mainly tuberculosis a new type – anti drugs resistent (WHO, 2008), twofold growth of liver cancer was found there. Between 1981 – 87 deaths from infection of respiratory organs raised nearly threefold, the figure of liver cancer occurrences doubled and esophageal cancer raised by 25%. From number of the cases of oesophageal cancer, 43% were comparatively young people. 70% of ill died within one year of the date of assessment diagnosis. And number of the parasitic diseases during the 1980s are listed in the table.

	Morbidity rate (per 100 000 people)					
Disease	*1981*	*1986*	*1987*	*1988*	*1989*	*1990*
Ascariasis	6.9	4.7	5.0	3.0	4.4	3.2
Taeniorhynchus	153.7	138.01	120.3	117.2	87.1	87.2
Echinococcosis	–	–	–	–	2.9	8.0
Strongyloidosis	–	–	–	–	1.5	0.7
Hymenolepidosis	503.1	686.8	855.0	604.4	685.1	649.4
Enterobiasis	899.9	1591.8	1787.2	2121.8	1769.4	1802.3
Trichocephaliasis	–	0.3	0.3	0.2	0.2	0.5

Figure 11: The incidence of parasitic disease in the Karakalpakstan region in 1980s (Glantz M., 2004).

In 1985-90 maternal mortality has grown threefold. In 1989, infant mortality was 52 per 1,000 live births, in 1965, it was 34.6. Statistics of mortality of children up to one year of age show that 26% of them died of respiratory diseases (majority of acute pneumonia), 30% of infectious and parasitic illnesses, 7.6% of congenital abnormalities, and 36% were other causes. In Karakalpakstan, more than 80% of women in fertile age suffered of anaemia, many of them had extra genital diseases too. The abortions have occurred in 30% cases of pregnant women. In 1988, the Ministry of Public Health of Uzbekistan released a report, that at-risk amount of children population formed only 8.9% and population of diseased children only 1.2%. The actual number of sick children was 45.6%. In this way data were disfigured for public (Glantz M. 2004; WHO, 2011).

At Tashauz region in Turkmenistan, in the 1980s, morbidity of the inhabitants reached level of above mentioned regions. The acute enteric infections harmed from 55 to 528 per 100,000 people. During 1980 and 1989, morbidity of hepatitis increased from 378 to 706 per 100,000 people and tuberculosis affected on average 300 individuals from 100,000 inhabitants.

The infant mortality in the end of 1980s (numbers of children that died in age under one year of life) was 49 in Tajikistan, 46 in Uzbekistan, 59.9 in Karakalpakstan, 56.4 in Turkmenistan and 75.2 in Tahauz region for 1,000 newborns. In the same time in Tahuz region there has been an acute lack of doctors, only 22 per 10,000 people. On that of the results of the statistics, 74% of the population of the Aral Sea region were suffering from some form of disease (Glantz M., 2004).

5.4 Solution of the Present Constraints

Many people believe that solution of water deficiency in the region is the increase of flow of the rivers to the Aral Sea. However this would be only part of the solvent, because demand of water will rise for local residents, agricultural and industrial uses.

The beginning of cultivation of cotton in larger extent had been the primary reason for expansion of the irrigation for increasing harvesting areas. Cotton was

used for textile manufacturing, ammunition and rocket fuel. The salinity of the irrigated lands escalated, therefore it was necessary to increase the amount of water needed to flush salt from the soil. Because of that the cotton is considered as the main cause of the disaster. The main culprit is nevertheless technology used in the construction of canals. Canals are unlined, open-ditched and this causes great loss of water infiltration into the soil and evaporation.

Planning the possible diversion of north-flowing Siberian rivers to the arid part of the Central Asia was considered. These contemplations have emerged in the 1970s. The water from the diverted rivers should be used for more intense irrigation of cotton fields and rice paddies. In this time, it was believed that engineering proficiency could overcome the constraints imposed by the natural environment. Many Soviet geographers and paedologist have disapproved of diversion. This plan could possibly lead in next disastrous impacts into the environment, for example increasing the salinity of the Arctic Ocean would lead to the melting of Arctic Sea. Project was abandoned in the late 1980s.

A part of the Aral Sea basin lies in the Afghanistan. During the last three decades, Afghanistan has not been significantly connected to negotiations about the Amudarya River water resources, nor about the future of the Aral Sea. Future development activities of the upper basin states (Tajikistan, Kyrgyzstan and Afghanistan) can have major impacts for quality and quantity of water in the rivers downstream (Glantz M., 2004; WMO, 2005).

5.5 Existing International and National Programmes

Pre-Independence

Soviet water management in the region. Spurred by major directives for land fertilization and increaced agricultural production beginning in the 1950s. Soviet planners developed complex plans for utilization of Central Asia´s river basins. Within this period, central planning organizations and ministries in Moscow directed water management in Central Asia. Each republic developed five year plans that were coordinated by the state planning agencies and through the republican or summary budgets of the Soviet Union. For boundary basins, such as those in Central Asia, basin projects were developed by regional design

institutes and included inter-republic and aspects, as well as assignation of water for several uses. For the Syrdarya Basin, the last plan of the Soviet period was autorized in 1982; for the Amudarya Basin, in 1987. Plans contained limits for water allocation between Republics and aims for the development of irrigated lands within these limits.

During dry years in the 1970s, local government was in the way in water allocation among the Aral Sea Basin Republics. In the Syrdarya Basin, the situation became intense that Moscow had to send authorities to provide that water from the upper and middle flows to the lower flows.. Next to provide concensus with inter-republican water distributions, region-wide Basin Water Organizations (BVOs) were established in 1986 in the Amudarya and Syrdarya Basins. The BVOs were to manage water resources of the Basins in agreement with to the plans voted by the Soviet Ministry of Water Management.

Post-Independence

Interstate Coordination Water Commission (ICWC). Given the heavy dependence of economies on irrigated agriculture of the Republics of Central Asia, it was fundamental to stabilize interstate water relations after independence. In October 1991, the heads of the Republican water sectors developed a regional water resources management mechanism to replace the centralized system. The independent states signed an agreement “On Cooperation in the Field of Joint Management and Conservation of Interstate Water Resources.” This agreement appointed ICWC for control, use and protection of water resources in this region. The agreement approved the rights of membeshipr states to use, and their amenability to protect, the interstate water resources of Central Asia. The agreement acknowledged the continuance of existing Soviet structures and principles of interstate water allocation, and was acknowledged by the Presidents of the Central Asian Republics. The Presidents later signed a agreement confirming the validity of previously signed agreements on water resources in the Aral Sea Basin.

The ICWC is the highest level of boundary water resources management in Central Asia. The ICWC makes resolution related with water allocation,

monitoring, and management. Scientifics and information support to the ICWC is ensured by the Scientific Information Center (SIC).

Basin Water Management Organizations (BVOs). Working as the executive organs of the ICWC, the BVOs Amudarya and Syrdarya are accountable for operation of the main water supply facilities in the rivers basins. The BVOs' duties include the following:

- Development of plans for water allocation to users in the rivers basins, distribution of water, and reservoirs
- Water supply to users
- Operation of all major dams on both rivers, including reservoirs
- Measuring of water flow through the water intakes and across national borders
- Design, construction, reparations and operation of dams, head water intakes, and canals
- Service of water quality in the rivers

Using prognosis from the Central Asian Hydrometeorology Services, the BVOs prepare water allocation plans for ICWC approval at drying period during the year. These plans set the water releases from reservoirs and delivery to each water management region. The water allocation to each republic is established in accordance with schemes devised during Soviet times. Water delivery to the Aral Sea and its coastal areas is based primarily on the principle of "whatever is remaining." Even though the BVOs have the responsibility to monitor water quality, they do not solve these obligations. In addition, they are not responsible for water use in each country.

International Fund for the Aral Sea (IFAS). The International Fund for the Aral Sea (IFAS) was created for attract resources to coordinate and finance regional programs to overcome the problems associated with the drying-out of the Aral Sea. In the same year, the Presidents established the Interstate Council for the Aral Sea (ICAS) to manage regional programs. The following year, the Central Asian Presidents approved a "Program of Concrete Actions" on improving the situation in the Aral Sea Basin. The program for the development of a general strategy for: (i) water sharing from among the states, (ii) rational water use,(iii) conservation of water resources, (iv) interstate legal acts on the use and protection of water resources from pollution. In 1997, ICAS and IFAS were connected and

began as a new IFAS under the rotating speakership of the President of one of the five member states The new IFAS' primary activities include:

- Raising funds for joint measures to conserve the air, water and land resources, the flora and fauna
- Financing ecological research, programs and projects aimed at saving the Aral Sea and improving the ecological situation in the region surrounding the Sea and social and ecological problems of the region.
- Regional environmental monitoring system in the Aral Sea Basin
- Interesting in international programs on saving the Aral Sea and improving the ecology of the Basin.

The Board develops priority measures for alleviation of the Aral Sea problems and organizes and coordinates of all regional programs associated with the problems of sustainable development in the Aral Sea Basin countries.

These regional water and energy institutions have very limited capacity and function on that of to sometimes contradictory principles. The operation modes of water systems in the Aral Sea Basin are determined and approved by ICWC. The operation plans are realized by the energy sector without participation of the water sector. All of the executive boards of these organizations are located in Uzbekistan, and their staffs are composed of Uzbeks. These organizations have the status of interstate organizations, yet they do not rotate management staff or hire specialists from other Republics (McKinney D., 2003).

Aral Sea Basin Program (ASBP). The ASBP's four stated objectives were to:

- Stabilization of the environment of the Aral Sea Basin
- Rehabilitation of the disaster area around the sea
- Improvement of the management of the international waters of the Aral Sea Basin; and
- Creation of the capacity of institutions at the regional and national level to advance the program's aims.

First two phases: The first phase lasted from 1992 to 1997, developed the regional program. In plan was eight themes through some 19 projects. In 1996, the World Bank recommended changes in the structure and operations of the program and its regional institutions. The review led to the preparation of the Water and

Environmental Management Project (WEMP). It was funded by the Global Environmental Facility (GEF) and three other investors and managed by the World Bank. The second phase of the ASBP, 1998 to 2003, implemented WEMP.

Financing for Phases One and Two: With in these two ASBP phases, international investors provided $46 million in grants and technical assistance for technical studies and pilot activities, also for create regional institutions and coordination plan.. At the time of design, the total estimated cost of WEMP was $21.2 million, of which $12.2 million was from the GEF. The five Central Asian republics agreed to pay $4.1 million, plusthree investors—the Netherlands, EU, and Sweden—provided $4.9 million. During the time, the five republics did not make their full contributions. The total amount was only $15.5 million.

The WEMP began in September 1998 and was closed in 2003. The project was unsatisfactory for three reasons: poor financial management; wrong leadership; and poor realization, which failed to reduce water withdrawal from the two (Barghouti S., 2006).

In 1997, the World Bank began a third phase containing the financing of operations in each of the five republics. With these investments, the World Bank became the largest funder. The World Bank has supported more than 16 loans and projects worth having about $1 billion. The operations financing to improve drinking water supply, irrigation and drainage, land and water management, land registration, area development, biodiversity, and several sector reform projects (Barghouti S., 2006; The World Bank, 2006).

Improvement of the Quality of Drinking and Irrigation Water in the Aral Sea Region by Cleaning Equipment and Sorbents Produced in the Czech Republic

This project originate from the Czech University of Life Sciences in Prague, the Institute of the tropics and subtropics. The project coordinator was Doc. Vladimir Krepl and technical implementer Ing. Radomir Mališ. The project budget was € 550,000 and lasted four years, from 2004 to 2008.

First phase: Drinking water treatment ALFA 2.2. The station is intended for the treatment of surface water with an output of 2,200l/h. It is able to operate in automatic, semi-automatic or manual mode, with the option of takimg a sample

from each stage of purification. The next was Anaerobic sewage treatment plant 200. Wastewater treatment plant consist of four stages (coarse filter, anaerobic reactor and biofilter retention tank). And last was Garden irrigation system, which working on water recycling system.

Second phase: The mobile experimental system was equipped with instruments for laboratory analysis and purification of water. This technologie has been used for puricication of drinking water in the Aral Sea area.

Third phase was Children tuberculosis sanatorium in Nukus. To make implementation of the reconstruction sanatorium was prepared complete contruction project involving the reconstruction of drinking water and water treatment, reconstruction of the sewerage system, extension of sanitary facilities (toilets and showers) in winter boys and girls hostels, reconstruction and renovation of the kitchen block block income patients (Progressive Technology, 2012).

Saving the northern part of the Aral Sea

In the 1990s' the dam was built between the northern and southern part of the Sea. However in 1999, the dam fell down under pressure and also because of usage of not very quality material. In 2003 the building has begun again. The new concrete dam, Kokaral, has been finished in 2005. Thanks to that it is possible to regulate the level of the Small Aral Sea. During one year, the level rose to 38 m and in 2008 to 42 m. In 2010 the river flow has increased due to higher rainfall so that also amplified the level of water amount and allowed excess of water to go to southern part of the Sea. During last years, the government of Kazakhstan has decided to financially support the construction of a new dam (Aviso, 2012). From 2006, the fishery increased tenfold as well as salt-tolerant new species have occurred there such as pike, perch and bream. Local residents began to build new houses (The World Bank, 2006). The sea was far from the harbour, up to 100 km. In 2009 the distance was just about 6 km from Aralsk (Aviso, 2012).

At this point the next phase is to improve the irrigation efficiency of 2/3 of the fields in Kazakhstan. The water-station should be built to renewal of wetlands and fishing lakes in the delta.

The furute of the south-east Aral and south-west Aral basins

The water level of the both parts has decreased by 50 cm/year. In 2009 the level of the south-eastern part dropped so much, that in this part the water completely disappeared. Whole former south-part is called Aralkum Desert. In 2010 the excess rainfall (after 20 years) increased the level onto 1.4 m. This situation will not probably repeat in the near future. It is possible that the parts will get absolutely separated.

Discussions about wetland restoration, rising of water level and annual water supply from the northern part of the Aral Sea had not had good results so far. Uzbekistan is not interested in to leaking water from the Amudarya to the Aral Sea, because it would reduce production of cotton. Uzbekistan would rather investigate into the drying of South Aral seabed because of the earth oil. The understatement of desertification includes planting vegetation, but intermittent flooding and devalued soil make it impossible (Aviso, 2012).

Figure 12: Satelite photo of the Aral Sea from April 2012 (Mediarostra.com, 2012)

6. Summary of Results

Since 1960, at the Aral Sea region mass growing of cotton has begun. It drew a lot of new people who were looking for work. In 1960, the population in the Aral Sea basin was 14 million and in 1995 the population increased to 37 million. Residents, to support themselves, started to expand irrigated areas. For 30 years, the irrigated area increased from 4 to 8 million ha (Figure 1 *). For enlargement of the irrigated areas water channels were built many kilometres from riverbeds. The largest of these channels is the Karakum channel. Due to poorly constructed irrigation channels that were sprinkled with gravel and not concreted, huge amounts of water was lost by infiltration without having arrived at the destination (field).

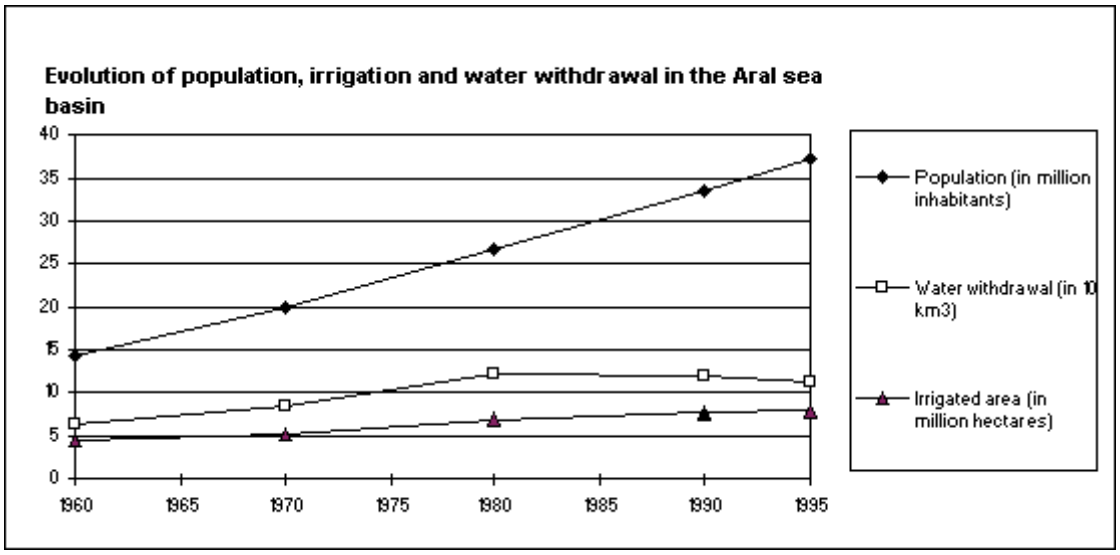

Figure 1*: Evolution of population, irrigation and water withdrawal in the Aral Sea basin (FAO-Aquastat, 2012)

As the demand of water for irrigation was increasing, the less remained in the rivers and only a part of the original amount has reached into the Aral Sea. This resulted lowering of water level, with declining water volume and with higher fertilizer additions salinity (Figure 2 *) and the content of hazardous substances started to increase. Consequence of this other symptoms has started to manifest.

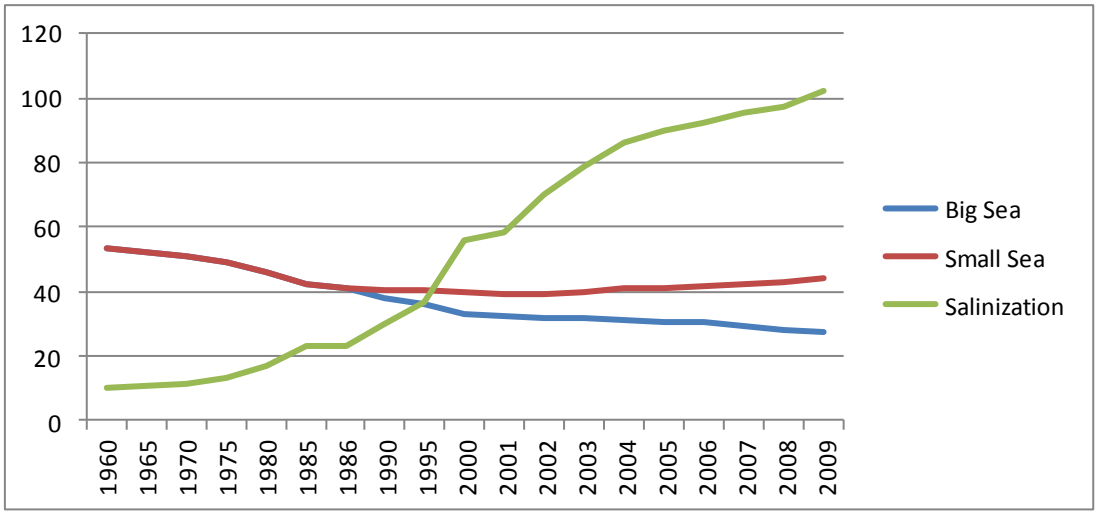

Figure 2*: Changes of the Aral Sea level and salinization from 1960 to 2009 (Cawater-into.net, 2011).

One of the symptoms appeared in the fishing industry, the quantity of caught fish was reduced due to the increasing salinity. Previously there lived brackish and freshwater fish, they were able to live and reproduce up to salinity 10-12 ‰. When this limit was exceeded fish stopped mopping, adults were fished out and there were no longer of young fish. The 80-85% of the total catch was composed of aral barbel, bream, aral carp and pike. Over the years new species has been plant out, rather the sea types, in an effort to restore biodiversity. Several families (Gobiidae, Atherinidae, Pleuronectidae, Clupeidae) managed to acclimatize, but after rising of salinity above 90 ‰ no animal except bacteria survive . In the Northern part of after construction of Korakal dam restoring of the fishery is succesful. The Figure 3 shows a rapid decline in catches since 1960.

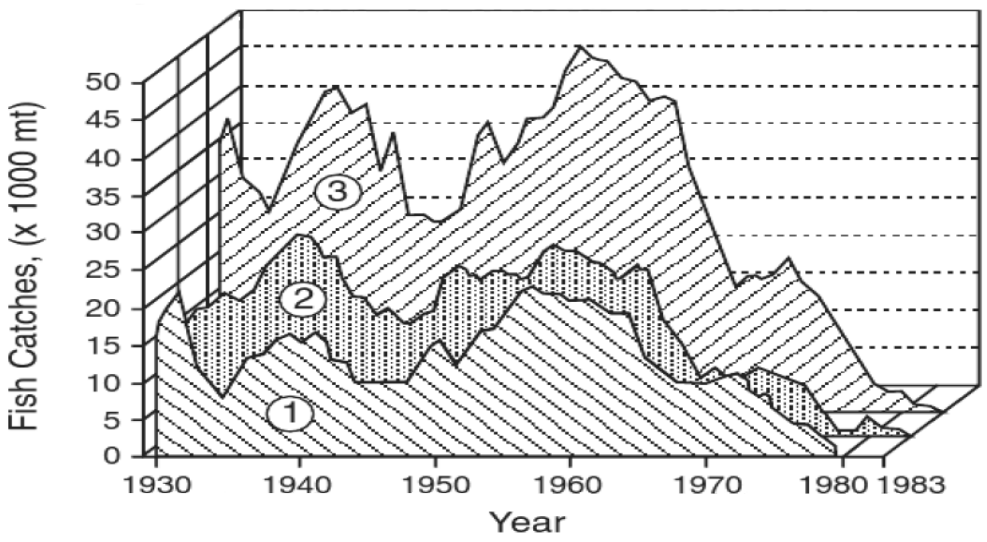

Figure 3*: Dynamics of commercial fish catches in the Aral Sea. (1) North region; (2) South region; (3) total fish catch. Fish catch in the northern part of the Aral Sea was terminated in 1979, and in 1984 in the south (Glantz M., 2004)

Another manifestation of degeneration of potable water and soil deterioration is worse health status of the population of the Aral Sea region. In the 1980s, pesticides and fertilizers (DDE, DDT, Hexachlorocyclohexane) were found not only in potable water, but also in food products and fish bodies. In Kyzyl-Orda region of Kazakhstan, in the years 1970 to 1988 the number of disease Typhoid fever has raised 29x, hepatitis7x, parathypoid 4x. More than 70% of the mothers suffered from anemia, and it resulted 30% of infant mortality. Another large increase was recorded in disease of kidney 3x, cardiovascular system 2x. In Karakalpakstan, in the years 1981 to 1985 there was epidemic outbreak of typhoid fever. In the next four years in this region occurrence of disease salmonellosis doubled, enteric infection increased by 10% (in Kyzyl-Orda up to 50%) and Hepatitis type A and B grown by 22%. There has also appeared a new type of tuberculoses - antidrug resistant. Liver cancer has increased twofold with mortality about 70% within one year. Up to 80% of the mothers suffered from anemia, the appearance of abortions was about 30%. A child mortality rate climbed to 20%. After the disintegration of the USSR in 1991 a project to help sick people has started there, health care was improved, but there is still lacks of doctors.

After the collapse of the Soviet Union, several organizations that contribute to help the local people were established. Interstate Coordination Water

Commission (ICWC) stabilized the international water relations among republics in 1991. Basin Water Management Organizations (BVOs) has the task of drawing up plans for water distribution, water supply to users and operation of dams on rivers. In the recent past, plans for the even distribution of water did not work. To attract resources and investors International Fund for the Aral Sea (IFAS) was created. Its role is to coordinate and fund other programs and research related to Aral sea. Stabilization and rehabilitation of the environment is one of the main objectives of the Aral Sea Basin Program (ASBP). In the first two phases (1992 - 2003) $ 46 million were gain from investors for grants and technical activity. Among the donors were included the EU, the Netherlands and Sweden. After 1997, the World Bank began the third phase, financing operations in the Aral Sea region countries. With the World Bank Korakal dam (Figure 4*) could be rebuilt, separating the northern part from the southern. The building was completed in 2005. And in recent years there has been rebuilding of the dam, its increase and extension which should lead to a complete rehabilitation of the northern part of the lake. Probability of success is high, as in 2009, it has rose to 42 m and it continues to increase (Figure 2 *). On the contrary, southern part of the lake level continues to fall due to poor water management in Uzbekistan with its Karakum canal. Institute of Tropics and Subtropics at CULS Prague in 2004 – 2008 led project in Uzbekistan. It was about the usage of purifiers of water and sewage, irrigation systems and even mobile water purifier, also reconstruction of tuberculosis sanatorium in Nikus. To make Implementation of the Reconstruction sanatorium was prepared complete contruction project Involving the Reconstruction of drinking water and water treatment, Reconstruction of the sewerage system, extension of sanitary facilities.

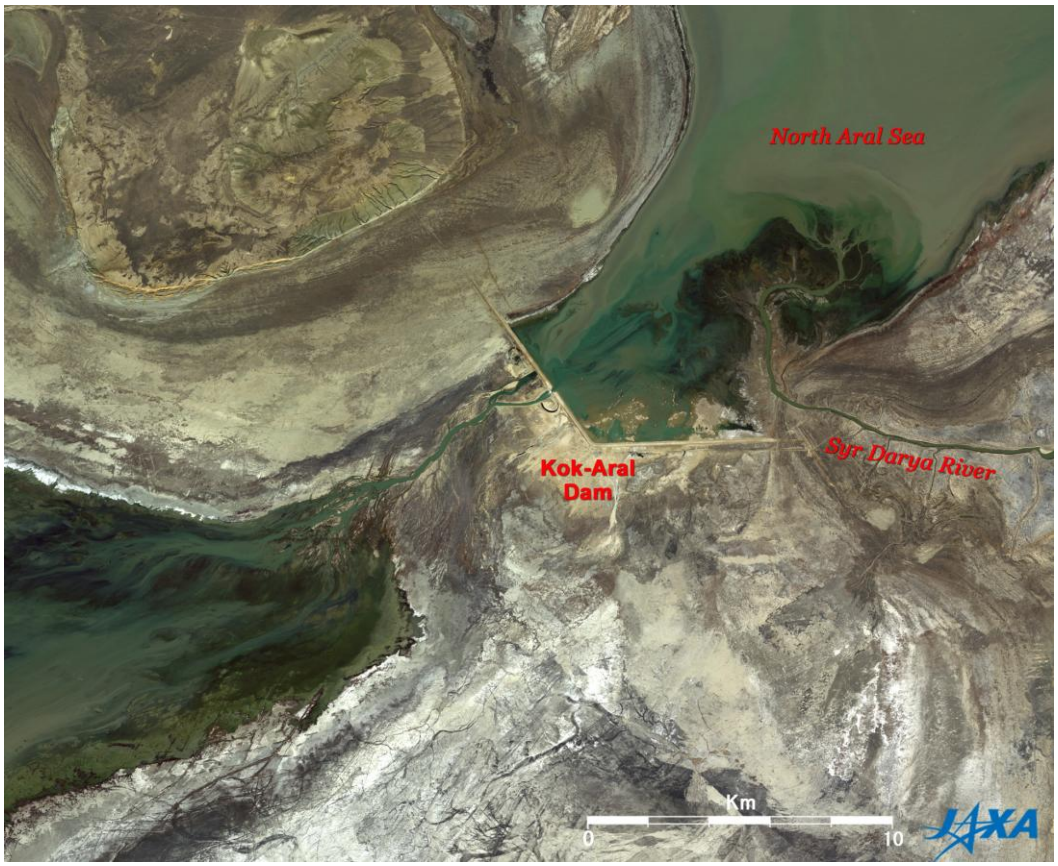

Figure 4*: Expanded image around Kok-Aral Dam (EORC, 2006)

7. Discussion

As Kostianoy A.G.,Kosarev A.N. (2010) stated in their book, usage of chemical fertilizers was excessive and dangerous. These fertilizers were used in all states of the Soviet Union and even in those plagued land and crops, so the result was predictable. However, the combining of these factors top off in Kazakhstan where are several factories for the production of fertilizers today. With the necessary flushing of water from rivers is also related the issue of building further expanding channels. Glantz M. (2004) mentioned the lack of technology of their construction of irrigation in the early beginning of the 1950s. The bottom of the channel was built of gravel and clay, which was washed off after several years and seepage of water on the field has increased. The channels are relatively wide and shallow and that accelerates evaporation. Today's effort is to remake channels and reduce water loss. That although has to deal with the necessary considerable financial subsidies, there is not still sufficient amount of them.

Thanks to the Fund for the Aral Sea (IFAS) Aral Sea Basin Program (ASBP) and the World Bank in the northern part of the sea there was managed restoration the fauna and flora. Yet nothing is 100% fine, but there is a high probability that this section could enlarge to original area and the purity of the water would return to normal. Full release of harmful substances will take many years and it is possible that some relics will remain. The statement of southern part is according to Kostianoy AG, Kosarev AN (2010) almost irreversible, because in 2009 salanity reached 102 ‰ (cawater-info.net, 2011) and in this environment will survive only the hardiest bacteria that will survive there even when salinity will decrease and after putting in the fish they would infect new species.

According to Glanz M. (2004) and WHO survey, the region's population morbidity is caused by chemicals in the water, dust, fruits, vegetables and meat and milk even from nursing mothers. This is of course the main reason of many diseases and increase of their occurrence. Tuberculosis is resistant to common antibiotics and, therefore, is often fatal. In a greater extent, there also occurs cancer. People have no money for medication and yet there are not adequate plans developed to help the people, especially in Karakalpakstan.

Regarding to cooperation between organizations, M. Glanz (2004) and McKinney DC (2003) basically share the idea that until the end of the 20th century the predominating problem was in communication between the heads of states / organizations and ordinary people living near the Aral Sea. Therefore, the first actions and plans have soon failed. It would be also suitable and needed for all six states in which the Aral Sea Basin is situated to work together. In present Afghanistan still does not show too much interest in any solution of this problem. It is necessary to agree on the amount of water which should be left by upstream communities for downstream inhabitants. Nevertheless the progress can be found from the part of Syrdarya basin.

Theoretical solutions, such as the inlet channel from the Siberia and pumping over the Caspian Sea have occurred during the era of the Soviet Union, when the problem became a disaster and the Union was probably about to appease the public and residents of the region that the problem would be solved. None of the objective authors has said anything about that.

The World Bank (2006) funded the construction of Korakal dam between the northern and southern part of the lake, which will expand and raise the sea level. Also it has participated in the restoration of biodiversity and in the future it could support financially health backup, probably with cooperation with the WHO, which could be great benefit for the region.

8. Conclusions

The main goal of this Bachelor Thesis was survey and description of the socio-ecological situation in the Aral Sea region which belongs to the Republic of Uzbekistan and Kazakhstan. On the basis of the analysis done in this Thesis the following conclusions can be formulated:

The main factors leading to desiccation and death of the Aral Sea is excessive irrigation of rive areas. This started by a large population movement into river area that begun in the 1960s. With increasing population density even more food was needed, so the irrigated areas for cultivation have been expanding. That reduced the amount of water flowing in the river deltas leading into the lake. Another aggravating factor was the excessive use of fertilizers as DDE, DDT, which contained toxic substances. These substances devalued potable water in the region came up to the Aral. Later, these substances were found in foods, grown crops and even in the fish bodies. So they come into contact with humans, which led to a rapid deterioration of the health status of the entire population, and even higher mortality.

The general public has some knowledge about the situation of the Aral Sea, but mostly there are of a general nature only. Situation isn't seen as a real disaster in all its essence. They know that the Sea has reduced its volume to less than a quarter. However only few people found out more information, such as industry fertilizers and what impact it had on the ichthyic fauna with relation to declining fisheries, also the health status of the population from coastal areas and growth of variety of serious diseases such as respiratory diseases, acute intestinal infections and high infant mortality. This information was not accessible until the fall of the USSR for general public. In the nineties, several programs has been developed that not only help people, but also broke the embargo.

General opinion that in the Aral Sea fishing has ended for good has been disproved by the northern part of the Aral Sea for several recent years. It is possible to anticipate that its level will continue to rise and eventually will reach up to the original level at the Port of Aralsk. On the other hand, unfortanalely, there is

little hope to save the souther part of the Aral Sea that is likely going to disappear over some years. It is because Uzbekistan does not want to reduce the amount of irrigation water, or impose changes in crop rotations and agricultural intensification. Rather, it now began to be interested in the oilfield in the south-eastern part of the lake.

Programs helping in the rehabilitation of the lake and surrounding regions should continue and also create new projects. The main concerns for the future are cleaners of potable water and waste water and health care programs for residents.

9. Recommendation

The lake restoration will surely take many years. The main role plays the water, so the channels must be changed or rebuilt to avoid such losses as leaking and evaporation. They should be narrower, deeper and more preferably concreted. The pipelines would not be very appropriate there, because almost all residents live near the entire river basin and they need direct access to water.

Usage of water should be charged, to avoid the excessive waste, and plants would receive only the necessary amount (economic irrigation). It would not be detrimental to replace highly demanding crops for other plants that require less moisture. This concerns mainly rice, which could be replaced by other cereals. Also the construction of reservoirs would be profitable. They could store excess water (in the winter) which could be used during dry year periods.

There is generally lack of safe drinking water in the whole Aral Sea basin. This problem has not been resolved yet, due to contamination of groundwater and soils to great depths, but this could improve the situation by building reservoirs, which would be supplemented with imported water. If the agriculture was intensified, it would save space, water and soil. Although Kazakhstan is one of the largest grain producers in the former Soviet Union, yields per hectare are very low. Over-fertilization is now stopped after the collapse of the Union, so that the soil had the time and care to recover.

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Figure1: http://www.esri.com/news/arcnews/fall07articles/fall07gifs/p17p1-lg.jpg
Figure8:http://www.sciencedirect.com/science?_ob=MiamiCaptionURL&_method=retrieve&_eid=1-s2.0-S1474706511000489&_image=1-s2.0-S1474706511000489-gr2.jpg&_ba=&_fmt=full&_orig=na&_issn=14747065&_pii=S1474706511000489&_acct=C000059211&_version=1&_urlVersion=0&_userid=2930208&md5=cf3d342d067d7274d0fcc28240dc1f40
Figure9:http://www.sciencedirect.com/science?_ob=MiamiCaptionURL&_method=retrieve&_eid=1-s2.0-S1474706511000489&_image=1-s2.0-S1474706511000489-gr3.jpg&_ba=&_fmt=full&_orig=na&_issn=14747065&_pii=S1474706511000489&_acct=C000059211&_version=1&_urlVersion=0&_userid=2930208&md5=2da174d11d79e3d9148d0f6e43ec0ad2
Figure 12: http://mediarostra.com/2012/04/18/water-wars/aral-sea/
Figure 4*: http://www.eorc.jaxa.jp/en/imgdata/topics/2007/tp071226.html

Annexes

Figure 13: The Central Asia (Sitesatlas.com, 2011)

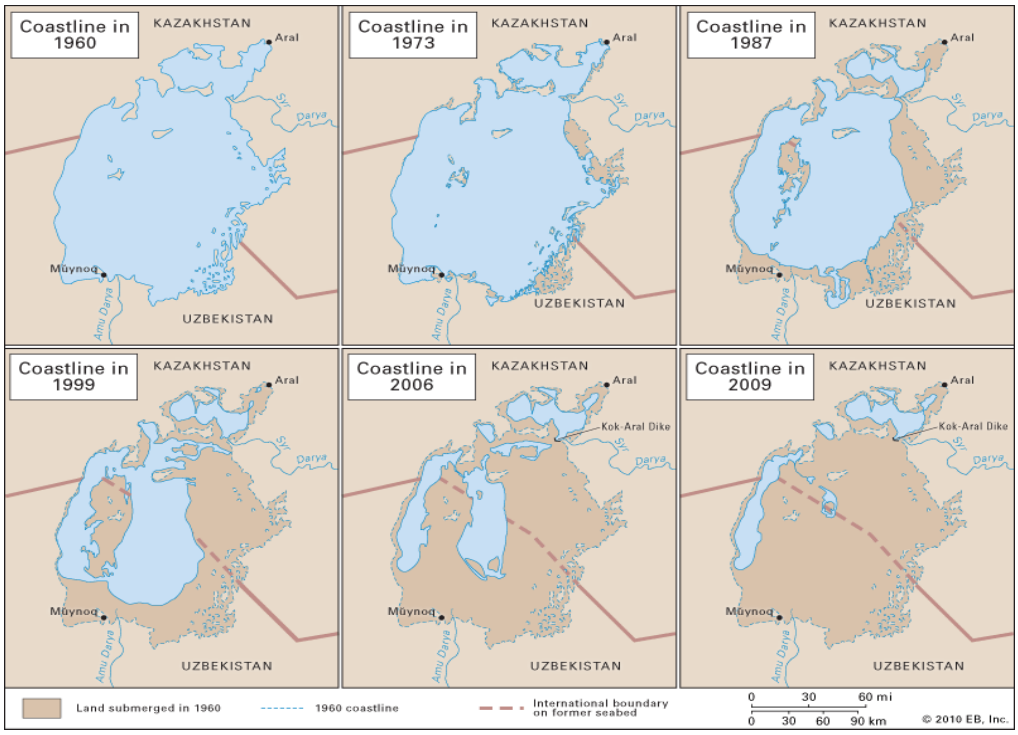

Figure 14: The Aral Sea during the years (Britannica.com, 2011)

Figure 15: Coast of the Aral Sea (Englishrussia.com, 2009)

Figure 16: Coast of the Aral Sea II (Englishrussia.com, 2009)

Figure 17: The boat in the the Aralkum desert (Englishrussia.com, 2009)

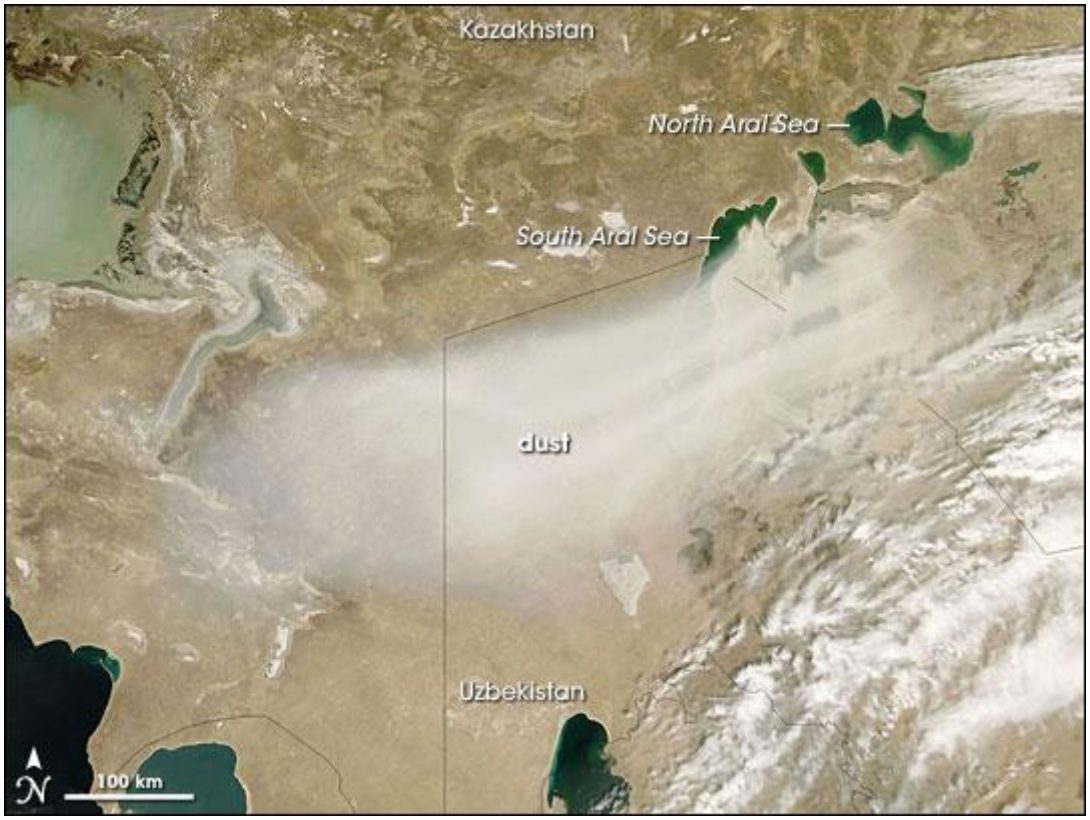

Figure 18: The dust strorm (Levendehav.dk , 2006)

Figure 19: Kokaral dam (Earthobservatory.nasa.gov, 2006)

Figure 13: http://www.sitesatlas.com/Maps/Maps/802r.gif

Figure 14: http://www.britannica.com/EBchecked/media/8524/Shrinkage-of-the-Aral-Sea-1960-99

Figure 15: http://englishrussia.com/2009/06/15/the-aral-sea/

Figure 16: http://englishrussia.com/2009/06/15/the-aral-sea/

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Figure 18: http://www.levendehav.dk/uk/uk.htm

Figure 19: http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=19853