DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

GENERAL ASSESSMENT OF SURFACE AND SUBSURFACE WATER QUALITY IN SOUTHERN KAZAKHSTAN REGION

by
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İZMİR

GENERAL ASSESSMENT OF SURFACE AND SUBSURFACE WATER QUALITY IN SOUTHERN KAZAKHSTAN REGION

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"GENERAL ASSESSMENT OF SURFACE AND SUBSURFACE WATER QUALITY IN SOUTHERN KAZAKHSTAN REGION"** completed by **NURBOL KOKISHEV** under supervision of **ASSIST. PROF. DR. ORHAN GÜNDÜZ** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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GENERAL ASSESSMENT OF SURFACE AND SUBSURFACE WATER QUALITY IN SOUTHERN KAZAKHSTAN REGION

ABSTRACT

This study is proposed to provide a general overview of surface and subsurface water quality in Southern Kazakhstan region. In order to review the hydrological and hydrochemical properties of the surface and subsurface water resources, some case studies are selected and analyzed in this thesis. These cases studies included the Syr Darya River, Aral Sea and Balkhash Lake as surface water resources as well as groundwater resources of Kentau and Turkestan cities. According to the result of the Syr Darya River water quality data obtained from 7 monitoring stations during 1970-2010, the river waters were found to be highly contaminated by heavy metals particularly after Aralsk station. Degradations water quality of Syr Darya River was the first reason for the alarming conditions of Aral Sea Basin as the river is one of the main sources of water inflow to the Sea. Based on water quality data of Small Aral Sea in 1994-2010, the distributions of substances are determined within the Small Aral Sea using 15 monitoring stations. The water quality of Balkhash Lake is then reviewed based on the data of Kawabata (1999) and obtained the distributions of substances in western parts of Lake. As a result, the numerous parameters were found to be above the standard values. The subsurface water quality of Kentau and Turkistan cities is better than surface water quality. Only Pb and Ni concentrations were above the standard in Kentau region. Furthermore, groundwater resources of Turkestan city were also contaminated mostly by Pb, SO_4 and Mg. These impacts could cause an environmental disaster, especially when necessary mitigation and rehabilitation activities are not implemented. Finally, possible rehabilitation techniques for surface and subsurface water resources were explained and were recommended the possible necessary activities to mitigation of the water quality conditions.

Keywords: Syr Darya River, Aral Sea, Balkhash Lake, Turkestan city, Kentau city, monitoring stations.

GÜNEY KAZAKİSTAN'DAKİ YÜZEY VE YERALTI SU KALİTESİNİN GENEL DEĞERLENDİRMESİ

ÖZ

Kazakistan şu anda yüzey ve yeraltı suyu kalitesi ile ilgili ciddi sorunlarla karşı karşıyadır. Bu çalışma Güney Kazakistan bölgesinde yüzey ve yeraltı su kalitesi hakkında genel bir değerlendirme sağlamak için önerilmiştir. Yüzey suların hidrolojik ve hidrokimyasal özelliklerinin genel bir değerlendirmesi için Syr Darya Nehri, Aral Denizi ve Balkhash Gölü seçilmiş; yeraltı su kaynaklarının değerlendirilmesi için de Kentau ve Türkistan şehirleri seçilmiştir. Syr Darya ile ilgili su kalitesi verileri 1970–2010 yıllar arasında 7 izleme istasyonundan elde edilmiştir. Sonuç olarak nehrin su kalitesinin oldukça kirlenmiş olduğu ortaya çıkmış; özellikle Aralsk istasyonundan sonra suyun daha çok kirlendiği tespit edilmiştir. Göl suyunun büyük kısmı Syr Darya nehrinden geldiğinden, Syr Darya nehrinin kirlenmesi aynı zamanda Aral Golü'nün de kirlenmesi anlamına gelmektedir. 1994–2010 yıllar arasında küçük Aral Denizi'ndeki 15 izleme istasyonundan elde edilen su kalitesi verilere göre Aral Denizi çoğunlukla ağır metallerle kirlenmiştir. Ayrıca, Balkhash Gölü'nün su kalitesi de Kawabata (1999) verilerine dayanarak gözden geçirilmiş ve gölün batı kısmında çeşitli parametreler için dağılım haritaları elde edilmiştir. Sonuç olarak, bazı parametreler standart değerlerin üzerinde bulunmuştur. Kentau bölgesindeki yeraltı su kalitesi incelendiğinde suyun genelde Pb ve Ni ile kirlenmiş olduğu görülmüş ve bu parametreler için su kalitesinin standart değerler üzerinde olduğu tespit edilmiştir. Benzer olarak Türkistan şehri yeraltı suyunun da yüksek SO_4, Pb, ve Mg değerleri belirlenmiştir. Sonuç olarak, yüzey ve yeraltı su kaynakları için olası rehabilitasyon teknikleri açıklanarak su kalitesi koşullarının iyileştirilmesi için mümkün gerekli çalışmaları tavsiye edilmiştir.

Anahtar Kelimeler: Syr Darya Nehri, Aral Denizi, Balkhash Gölü, Türkistan şehri, Kentau şehri, izleme istasyonları.

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CHAPTER ONE
INTRODUCTION

1.1 Problem Statement

Kazakhstan is well-known for his rich ecosystem that contains many inland water bodies such as seas, lakes, rivers and wetlands. The water availability in Kazakhstan is about 7120 m^3/year per capita and it is, thus, considered to be a water rich country. This wide range of water bodies is distributed within the country from western territories of Caspian region towards the Chinese border to the east as well as from southern deserts of Kyzylkum towards the northern border with Russia. This large area includes many key water ecosystems such as the Aral Sea; Balkhash, Alakol and Zaysan lakes; Syr Darya, Irtish, Ile, Tobol, and Buhtirma rivers in addition to numerous reservoirs that are inundated for water supply, flood protection and energy production.

Kazakhstan currently faces severe problems related to surface and subsurface water quality, some of which are at global scale (Bazarbaev, et al. 2006). Following the disintegration of the Soviet Union in 1991, countries including Kazakhstan obtained their independence. These new states experienced economic, administrative, social and environmental problems. Particularly in the field of environment, these countries have inherited a fairly poor record of environmental protection from the Soviet era. Furthermore, the economic conditions and scientific know-how of these states were not suitable for immediately addressing most of these environmental problems. Thus, time, money and personnel are still needed for conducting scientific research to detect, mitigate and monitor such problems.

One of the many environmental problems experienced in Kazakhstan territory is the “loss” of Aral Sea, which has been considered by the United Nations as a global scale environmental disaster (Anderson & Robert, 1997). The surface area of Aral Sea has declined from approximately 70000 km^2 in 1960s to about 8000 km^2 in 2009 (Micklin, 2007). This drastic decline is an ecological and sociological catastrophe that is believed to bring many detrimental consequences for years to come.

Subsurface water resources are non-uniformly distributed on the territory of the Republic. Basically more than 50% of subsurface water resources are concentrated in the Southern Kazakhstan Region along the foothill plains of Dzhungarskogo, Zailinskogo, the Kyrgyz Ala-Tau and Karatau Mountains. The water quality status of the subsurface waters is influenced from industrial establishments and mines situated in the region.

Another environmental problem of global scale is the Semipalatinsk Nuclear Test Site, which is also known as the well-known “Semey Polygon” that is situated in northeast steppes of Kazakhstan. The site was selected by the former Soviet era administration to be the official test site for nuclear weapon research of the country. Until 1991, when the site was closed to test, a total of 467 nuclear test of various size and extend were conducted in the facility. The negative impacts, however, is still being experienced by not only within the 18,000 km^2 test site but also in a large territory neighboring the site. Last but not the least of the many environmental problems experienced in the country is the improper use of Syr Darya River waters for irrigation purposes. Construction of massive irrigation schemes during the Soviet period for irrigating cotton and rice fields have caused ecological damage to the area, with the river drying up long before reaching the Aral Sea. The inappropriate irrigation practices in this region and the associated environmental and social impacts are currently one of the largest problems of Kazakhstan.

1.2 Objectives of the Study

With an areal coverage of 2,724,900 km^2, Kazakhstan is the ninth largest country in the world (Abiev, et al. 2004). The total population of the country is 16,196,800 based on 2010 census results. Of this total, about 5,146,100 of the population inhabits in the southern parts of the country where approximately 60-70% of the water resources are found (Veselov, V. et al. 1999). Thus, the quality and quantity of these resources are of utmost importance for not only the local people living in the area but also for regional ecosystem components. It is this motivation that initiated this study, which is aimed to provide a general review of surface and subsurface water quality in Southern Kazakhstan region. Implementing this study in Southern Kazakhstan region is deemed crucial due to the fact that a general assessment of surface and subsurface water quality of this particular area has not been previously reviewed from a general perspective. Thus, the main objective of the study is to describe the surface and subsurface water quality in Southern Kazakhstan region and to investigate the reasons, which contributed to the degradation of water quality and to determine the associated negative impacts of such pollution. As the deterioration of water quality in regional water resources is directly related to water quantity, this study also included information on water quantity issues of the region.

Based on this fundamental understanding, the thesis is formulated to include numerous case studies, some of which are accepted to be of global extent. In essence, the water quantity and quality status of Syr Darya River, Aral Sea and Balkhash Lake are presented as case studies representing distinct hydrological systems such as an inland sea, a river and a natural lake. In addition, some of the problems associated with these systems are further complicated by their trans-boundary characteristic in central Asia. Understanding the anthropogenic influences effecting the quality and quantity of these systems are crucial in proposing environmentally-sound and practically feasible solutions to these problematic issues. The link between water quality-quantity and human health is also of significance that needs to be addressed as a part of this general assessment. Shrinking of the surface water resource and aggravating their quality is considered one of the most dramatic examples destroyed human activities. Diseases such as circulatory system are 24%, diseases of the respiratory system are 148%, and malignant neoplasms are 72% higher in Kyzyl Orda Region than the rest of Kazakhstan.

The first case study is the transboundary Syr Darya River that passes through five countries including Kyrgyzstan, Turkmenistan, Tajikistan, Uzbekistan and Kazakhstan. The river initiates from Kyrgyzstan territory and crosses these five independent states and discharges to Aral Sea. In Soviet era, these countries had equal right to water consumption and allocation rights were primarily controlled by Moscow. Despite of uneven distribution of natural resources, the general principle in

Soviet administration was to supply the requirements (such as coal, fuel, water etc.) of all countries of the union. However, after disintegration of the Soviet Union, water allocation problems started to emerge particularly in Central Asia where water is a scarce commodity. One of the main reasons which lead water shortage problems was associated with the operational issues of Toktagul reservoir in Kyrgyzstan, which resulted in decreased water flows to downstream countries in summer season during which agriculture in these countries requires the highest amounts of water from upstream. This situation has created significant economic losses and environmental problems in downstream counties of Uzbekistan and Kazakhstan. International agreements were signed between these counties to alleviate the tension associated with water allocation. These agreements were mostly based on the general principles of “money for water” or “energy (coal and/or fuel) for water”. When combined with the decreased water supply due to climate change, both quantity and quality related problems of Syr Darya River continue to influence the general environmental status of the riverine ecosystem as well as the quality of human life along its flow path.

The second case study is selected from the world renowned Aral Sea. The loss of Aral Sea and deterioration of its water quality is now considered to be a global-scale international problem. Both the causes and the solutions thus need international cooperation of not only the regional states but also of all partners of the United Nations. Today, the territory of the Aral Sea is under sovereignty of Uzbekistan and Kazakhstan. However, the transboundary waters of Syr Darya and Amu Darya Rivers that supply fresh water to Aral Sea pass through the territories of Kyrgyzstan, Turkmenistan, Tajikistan, Uzbekistan, Kazakhstan and Afghanistan, which further complicates the problem due to political instability in the region. Over the past four decades, this water body has rapidly and steadily shrunk. In 1960, the area of the sea makes up 68480 km^2, a volume of 1093 km^3 and the level 53.6 m. Nowadays, Aral Sea's surface area is only 8112 km^2.and volume is contain about 15 % from original source (Gaybullaev, B. 2008). The primary reasons include the increasing population coupled with increased amounts of water used in irrigation and water supply as well as decreasing precipitation amounts in the last several decades. In addition to problems associated with quantity, Aral Sea also faces water quality problems, which are partly related to decreased water inflow but mostly related to anthropogenic influences such as uncontrolled wastewater discharges and irrigational return flows. Today, Aral Sea waters are highly contaminated with chemical substances such as heavy metals and trace elements (i.e. Zn, Cd, Ni, Pb, Cu, Co, Cr,), some ions (i.e., SO_4^{2-}, NH_4-N, NO_3^-) and organic constituents (Friedrich & Oberha, 2004, and Grishaev & Grishaeva, 2010).

The negative impacts of Aral Sea brought not only ecological depression but also economical and socio-economical degradation of Southern part of Kazakhstan, particularly in local cities of Kyzyl Orda, Kazalinsk, Aralsk and several others. The ecological catastrophe in the Aral Sea area is now followed by deteriorating health of the local population in these cities. Children are particularly affected from poor water quality and some diseases such as anemia, tuberculosis, kidney and liver illnesses, respiratory infections, allergies, cancer, chronic bronchitis, atrophic gastritis, urolithiasis, secondary immune deficiencies and anemia demonstrates an increasing trend (Oral, A. & Ataniyazova, M. 2003).

The third case of this study is from Lake Balkhash, which is one of the largest freshwater bodies in the world (Sopozhnicov, 1951). Currently, the lake faces similar problems with that of Aral Sea such as declining water levels and water pollution issues. The increasing population inhabiting around the lake and the associated increased water demands due to irrigation. The lake's watershed is an international watershed with 15% of its area being located in China. Ile River is a transboundary river between China and Kazakhstan, which finally confluences Lake Balkhash, and is the primary water inflow to the lake. Recently, Chinese government declared that they would increase their use of Ile waters for irrigation purposes. This situation would certainly influence the hydrology of the lake and could result in another environmental catastrophe similar to Aral Sea since about 85% of lake waters come from Ile River. Considering the fact that about 77% of total water in Ile River originated from Chinese territory in the year 2000, any increase in consumption on the Chinese part would likely to create further declines in Lake Balkhash levels. It is estimated that a 10 to 15% increase in withdrawal from Chinese part would result in shallowing and salinization of Lake Balkhash and will provoke environmental disasters similar to Aral Sea with serious social and economic consequences (Anonim, 2008). According to forecast, the deficiency of water in China will increase every year and withdrawal from transboundary rivers will grow on a steady pace further complicating the Lake Balkhash situation (Kreuzberg, n.d). A supporting evidence for this situation occurred after the construction of Capchagay Dam in the Ile River. Accordingly, a water level decline of 14 m was observed in Lake Balkhash during the inundation of the Capchagay reservoir, which created significant temporary changes in lake-ecosystem. Nevertheless, this situation is an indication of things to occur if Chinese withdrawal from the river and reservoir exceeds sustainable thresholds. Nowadays, the lake is divided into two parts: western lake and eastern lake, with different water quality.

The final case study is related to the groundwater quality in Kentau and Turkestan cities of Southern Kazakhstan. Kentau city is one of the main industrialized regions of the former Soviet Union. The city currently has 9 big industries and 341 enterprises that maintain the local economy (Bolat, et al. 2004). There is a large mine site in the city, which extracts industrial minerals and processes them in a number of metallurgical plants. The underground mine was closed in 1997 when the pumps were shut down and the mine galleries were left to inundate with rising groundwater.

These case studies provide a general review of surface and subsurface water quality in Southern Kazakhstan region. Distinct problems with characteristic consequences make this area the primary concern for Kazakhstan government with regards to water issues. Together with the support from international community, Kazakhstan is searching tools and methods for solving these unique water-related problems in an environmentally friendly manner while guaranteeing economic and social welfare.

1.3 Scope of the Study

With the above mentioned objectives, this thesis is organized in seven chapters. In Chapter 1, a problem statement and an objective of the study is presented. The following section, Chapter 2, presents the morphological, meteorological, hydrological characteristics as well as demographic, economic and tourism features of the country with special emphasis on Southern Kazakhstan region. In Chapter 3, national and international water quality standards are presented. In this regard, local water quality criteria of Kazakhstan are compared with international quality criteria that are specified in Turkish standards and in EPA and WHO guidelines. Besides, water management structure and international water agreements of Kazakhstan are also discussed in this chapter. In Chapter 4, three case studies representing the surface water quality in Southern Kazakhstan region are presented with reference to Syr Darya River, Aral Sea and Balkhash Lake where the current status of these water bodies are given and problems related to their water quality are detailed. In addition, the impact of contaminated water quality on the health and economic situation of local people are also investigated. Chapter 5 covers two case studies from Kentau and Turkistan provinces that discuss the subsurface water quality in Southern Kazakhstan region and the influence of anthropogenic activities such as mining. The outcomes from these case studies are then summarized in Chapter 6 where a general assessment of surface and subsurface water quality in Southern Kazakhstan region are presented. Finally, Chapter 7 concludes the thesis with major conclusions of the study and recommendations for further investigations.

CHAPTER TWO

GENERAL CHARACTERISTICS OF SOUTHERN KAZAKHSTAN REGION

Administratively, Southern Kazakhstan Region has four administrative provinces: Almaty, Zhambylsky, South Kazakhstan and Kyzyl Orda (Figure 2.1). The total population of these four provinces are 6.3 million according to 2009 census results. Southern Kazakhstan Region covers an area that is bounded by the mountain of Dzhungar in the east to the Aral Sea Basin in the west and by the deserted Betpak-Dala plateau to the north to the republics of Uzbekistan and Kyrgyzstan and including the northern parts of Kyzyl Kum desert to the south. The territory ranges 700 km from north to south and about 2000 km from east to west. This region also has important subsurface and surface transboundary waters. Accordingly, about 50-60% surface water in form seas, lakes, rivers and wetlands are situated in this region. The rivers Syr Darya, Chu, Or, Karatal, Aksu, Lepsy and the lakes Balkhash, Sasykkol, Alakol and Aral Sea are located in this region.

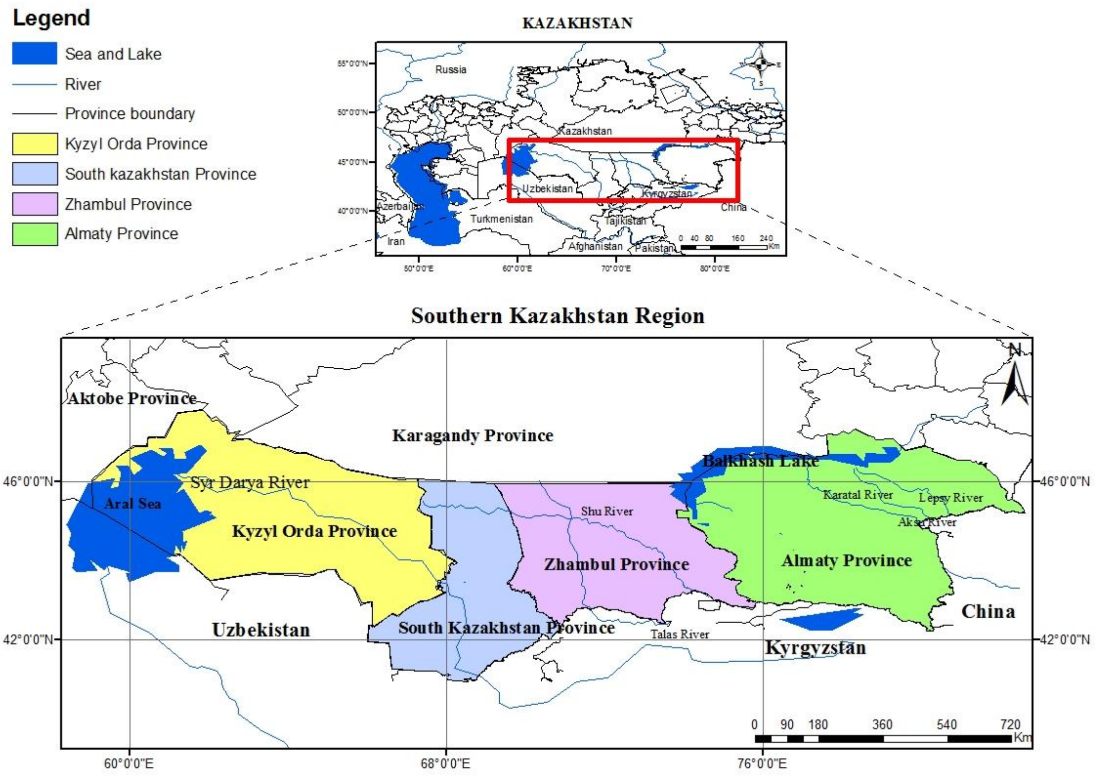

Figure 2.1 Southern Kazakhstan Regions.

The region is also called Zhetysu (Land of Seven Rivers) which is mythologically believed to hold many mysterious secrets. For centuries, the region has been a place where the trails and historical fates of many tribes cross. The a large section of the Great Silk Road run through this land. Currently, the region represents a unique complex of historical, architectural, and cultural memorials. The fundamental characteristics of this region is discussed in the following section according to the current administrative division.

2.1. Almaty Province

2.1.1 Morphology

Almaty province is situated in the center of the Eurasian continent on the southeast of the Republic of Kazakhstan in longitude 77 East and 43 latitude North on the bottom of Zailiisky Alatau and Tyan-Shan (Figure 2.2). The center of Almaty province is the Almaty city, which was formerly known as Verny (1855-1921), the ex-capital (1929-1998) of the Kazakhstan and is currently one of the largest metropolitan areas of Kazakhstan. The basic part of city is located at height from 600 up to 900 m above sea level. At the beginning of the 20th century officially decides of the Russian Committee the capital of the Kazakh Autonomous Soviet Socialist Republic Kyzyl Orda transfer to Alma-Ata city. In 1993 the government made a decision to rename Alma-Ata to the new name as Almaty. On 1 July 1998 was passed the Law concerning the special status of Almaty as a scientific, cultural, historical, financial and industrial center of Republic.

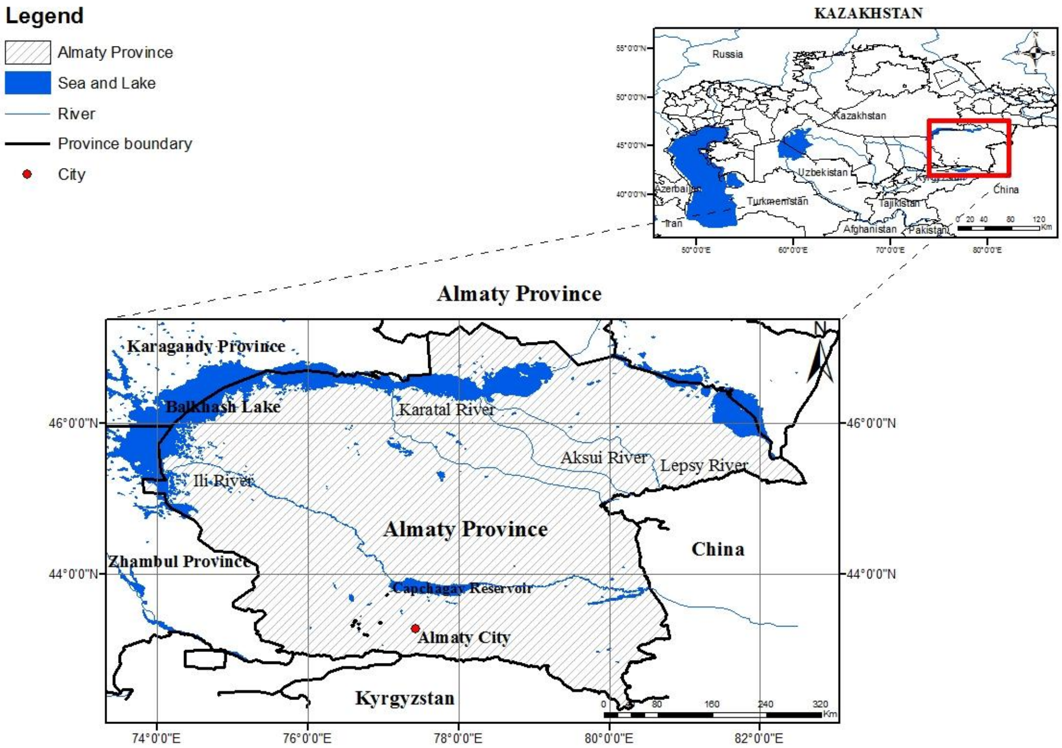

Figure 2.2 Almaty Province

2.1.2 Meteorology

The climate of the province is charecteraized by typical continental climate with dry and hot summers and wet and cold winters. The coolest days in the region is experienced in January, whereas, the hottest days are observed in July. In winter, the average temperature is -13^{o}C. Furthermore, the average temperature in summer contributes +22^{o}C. The average precipitation in the provience containes to about 700 mm.

2.1.3 Hydrology

Almaty province a total of about 800 rivers and channels exist in the region among of them, 18 are considered as transboundary water resources such as Ile, Charin, Chilek, Turgen, Issik, Kaskelen Rivers and Sairam with an average depth of 12.1 m. Furthermore, number of lakes and reservoirs also situated in the region, some of which are Balkhash, Alakol, Sasikkol, Zhalanashkol, Kolsayskye, Bolshoe

Almatinskoe Lakes and Reservoirs. The Kapchagay reservoirs is the one of the largest reservoir in republic, with the general capacity of the reservoir is 28.14 $км^3$. Moreover, in the Province located Bartagoyskoe and Kurtinskoe reservoirs.

2.1.4 Population

Almaty is the most populated region in Kazakhstan, with a population of 1348500 according to 2008 census results. By the year 1906, the population of the region contributed to 27,000. After the transfer of the capital of Kzyl Orda to Almaty in 1929 and by the completion of Turk-Sib Railway in 1930, the number of population in the region rapidly increased. The population of Almaty growth from 46,000 to 221,000 between 1926-1939s. Today, the population consists of a wide range of ethnic background with Kazakhs having the majority with 55%, followed by 25% Russians, 5.8% Uygurs, 2% Tatars, 2% Koreans and 10% from other nations.

2.1.5 Economy

Almaty province is one of the largest industrial and agricultural centers of the Republic. Mechanical engineering and metal working areas are historically strong here. Furthermore, furniture manufacturing, polygraphic, pharmaceutical and food-processing industries are successfully growing. According to the official statistics, foreign trade in the province increased by 46.1% in 2004. Export increased by 40.2%, as a result of the increases in world market price for natural resources such as coal, metal and oil. Moreover, the imports also increased by 56%.

2.1.6 Tourism

Historically, a great variety of unique sites developed in the region and this well-developed infrastructure has made it possible to create convenient tourism routes for nature lovers. Nowadays, 470 tourism companies are incorporated in Almaty, it’s about 65% of all tourist companies throughout the Kazakhstan and employing about 3000 staffs. In 2003, these tourism companies services 100-250 clients. At present the ongoing arrangements aimed to develop and as results in 2002 visited 20,700 tourists and in 2007 this number increased to about 42,000.

2.2. South Kazakhstan Province

2.2.1 Morphology

South Kazakhstan Province is situated to the southern parts of the country and at the center of Southern Kazakhstan Region (Figure 2.3). Its capital is Shymkent city which also has the highest population density in the province. The Province found on latitude 42 North and on longitude 69 East in between Badam River and Sairam River. The altitude over the sea level is 500 m. The name Shymkent means "city of grass or green city" as it comes from two words, Shym meaning turf, and Kent meaning city. Shymkent was founded in the 12th century as a caravanserai to protect the Silk Road town of Sairam. The province includes local cities of Turkestan, Sayram, Kentau, Arys, Shardara, Jetisu, Saryagash and Lenger. There are lots of historical places some of which are Turkestan, Otrar and Sayram. Sayram are well known not only within Kazakhstan territory but also in Central Asia countries.

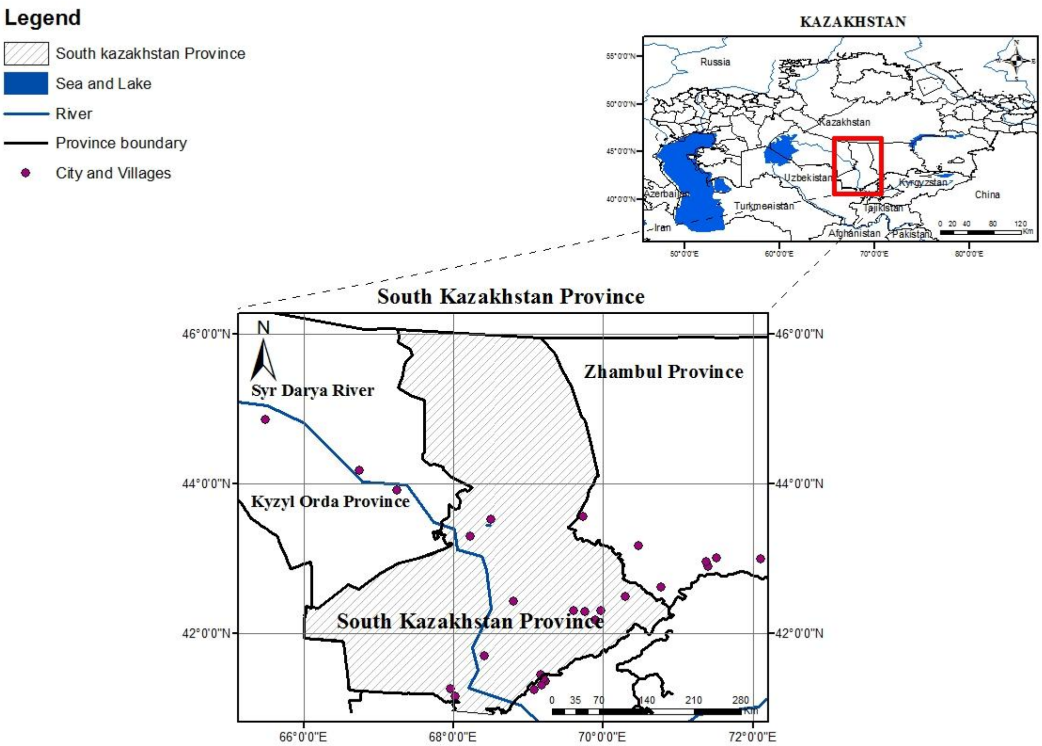

Figure 2.3 South Kazakhstan province

2.2.2 Meteorology

Continental climate prevails in the region. The average temperature in the region during winter -10°C and during summer +35°C. Vegetative period 230-320 days, average annual rainfall vary between 100 and 450 mm, which could go as high as 800 mm in mountain regions. Occasionally, the summer temperatres in the province could rise to above +50°C. In July, the wind is directed to the north and northeastern part of region with average velocity 22-25 m/s. Whereas, in January it is directed to the east and southeast with the average velocity about 24-32 m/s.

2.2.3 Hydrology

In essence, in the province situated about 127 rivers (with the total length of 5000 km), 34 lakes, 30 reservoirs, 29 groundwater aquifers and 5 mineral water resources. Annual total surface water stream source in the Region is 34 billion/m^3. The large and longest river in the province is the Syr Darya River which begins from the Kyrgyzstan, flows through South Kazakhstan and Kyzyl Orda Provinces and discharge into the Aral Sea. Moreover, Arys River is the main river which originates from the Alatau Mountain and discharges into the Syr Darya River and has a total length of 378 km. Furthermore, in the region situated lots of rivers such as Badam Rivers (145 km), Boralday (130 km), Aksu (133 km), Keles (102 km) and Mashat (60 km), (Bolat, et al. 2004). In addition to rivers, there are numerous small lakes and some reservoirs. One of the biggest reservoirs in the province is the Shardara reservoir. The water basin is formed in 1966. The area of 900 km^2, volume of 5.7 km^3, length 48 km, width 20 km.

2.2.4 Population

South Kazakstan is one of the fastest growing province and one is the birthrate among traditional Kazakh and Uzbek families, where families of five to eight childrens the government well pay every months as sallary. Population of South Kazakhstan is 2,283,000 according to 2007 census. Today, the population consists of a wide range of ethnic background with Kazakhs having the majority with 65%, followed. Other groups include Russians, Uzbeks and Ukrainians. The South Kazakhstan Province is the most densely populated area of Kazakhstan and average density of population is 17 per/km.

2.2.5 Economy

The leading industries of South Kazakhstan region are the nonferrous metallurgy, textiles and food. Lead and zinc are mined in Karatau Mountains and lignite in Lenger area is well developed. Beside the industrialization, to support local socio-economics conditions agriculture is widely developed. Mainly growing crops are cotton, grains (including rice), fodder, and vegetables, and there are extensive vineyards and orchards. Analysis shows that the gross regional product of South Kazakhstan Region for the last 3 years increased by 25%, and the number of small and medium business entities has almost doubled. Currently, private business entity numbers in the region about 113 thousand. Their tax payments have increased from 5.6% till 13%. Development of cotton and textile industry is crucial for the South Kazakhstan Region. Cotton fiber production volumes are increased. Currently, the majority of the cotton fiber produced in Kazakhstan 98% is exported. Only 2% of cotton fiber is used by local companies for production needs. Creation of companies with deep processing of cotton fiber will ensure independence of Kazakhstan producers from Russia and China where our cotton is currently processed. Besides, development of internal cotton processing capacities permits creation 15 thousand new jobs in the region.

2.2.6 Tourism

South Kazakhstan Region is rich not only with historical memorials but also with unique and wonderful nature of the Western Tien-Shan Mountain. Furthermore one of the most famous attracted place in the Region is the Aksu Zhabagaly. The place was founded in 1926, and was the first Nature Reserve in Central Asia. As part of the Talaski Alatau Ridge in the Western Tien Shan mountains, rising to over 4,200 m at

Syramsky Peak. Among the natural treasures of the region, remarkable for their unique beauty such as Burgulyk Gorge, Kyzyl-Kol Lake and Balyktin. All these unique natural treasures last years attracting more and more tourists to the region. In the Region approximately works 50-100 tourist companies and the numbers are steady increasing.

2.3. Zhambul Province

2.3.1 Morphology

One of the huge provinces in Southern of Kazakhstan Region is the Zhambul Province. The province borders with Kyrgyzstan in the southeast and less part of Uzbekistan in the south. The Province is also borders three other provinces: Karagandy Province to the north, South Kazakhstan Province to the west and Almaty Province to the east (Figure 2.4). The Province occupies huge territory, the total area is 144,600 km^2. The capital of the Province is the Taraz City. The land is flat with an elevation of about 500 m above sea level. Up untill now the Taraz city is called Talas, Zhambyl, Dzambul and Aulie-Ata. The province during the Soviet era was named after the Kazakh akyn (folk singer) Jambyl Jabayev. The city lies at the junction of Talas River and Turk-Sib Railway. Taraz city is one of the oldest cities of Kazakhstan. A city known as "Taraz" or "Talas" is recorded since 568. However the historical period begins with the establishment of Aulie-Ata later renamed Zhambul and eventually Taraz again on the same site.

2.3.2 Meteorology

The climate of the province also is charecteraized by typical continental climate with dry and hot summers and wet and cold winters. The difference between average January temperatures on the northeast and southwest mountainsides of Karatau is 4-6'C, because of the influence of a warm mass of air from the southwestern mountainsides. Average annual atmospheric precipitation is 300mm. The quantity of atmospheric precipitation on the southwest mountainsides is 150-300mm more than on the northeast.

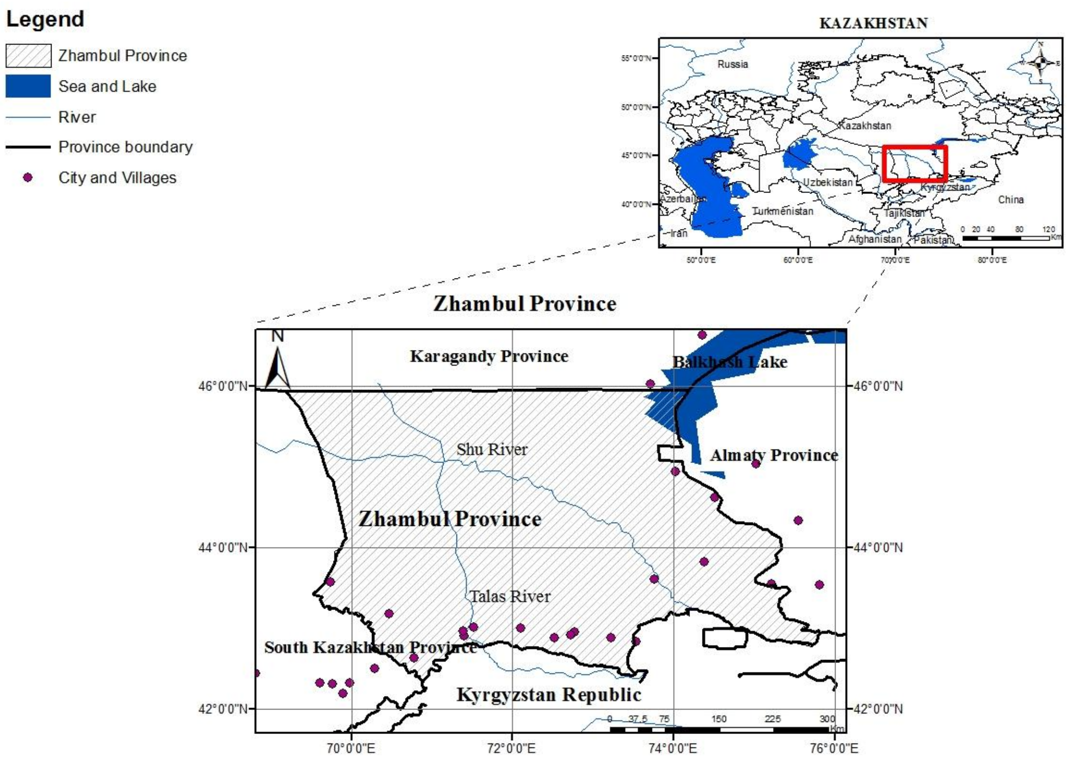

Figure 2.4 Zhambul province

2.3.3 Hydrology

In the Province the surface water sources are not distributed equal. The rivers mainly come from the Southern parts of the Kyrgyz and Talas Alatau Mountains. The biggest and longest river in the Region is Shu River (1186 km). The river startes from the Kyrgyz and Tian-Shan mountains and in the province territory is prolonged to about 800 km. One of the most nourishment of the Shu river in territory province is Koragaty river. Moreover, The second river in the province is consider the Talas and the length of river in province is about 253 km. The River began from the mountains of Kyrgyz and Talas Alatau, from these mountains originates two rivers such as Karakol and Ushkosha. A confluence of the two rivers is named as Talas. Moreover, in the Province situated lots of rivers such as Shabakty, Boralday, Burkitty, Teris, Shalsu, Karakistak all of these rivers are ariginated from Kyrgyz Alatau and Karatau mountains.

2.3.4 Population

Population of the province is steadily increasing year by year. As emphasized that a big part of population is situated in capital Taraz City. Number of residence in the province is 1,000,000. As, the last census showed that in the capital of the province the number of residens is growth to about 315,000 in 2006, and in 2009 it's incresed to about 380,000. The region hold various kind of nations and majority residence is Kazakhs and the rest of are Russians, Tatars, Kirgizs, Gemans, Ukrains, Uzbeks and Greks.

2.3.5 Economy

In the region approximately 72 % of balance stocks of Kazakhstan phosphorites is concentrated, and 68% of fluor-spar mineral occupied. Important industries include rock phosphate mining around Karatau. As well known this region is so rich with their various kind of minerals which is producting not only in area of republic but also exporting to the another countries. Here occupied lots of industries with different productions. Chemical sector "Kazphosphat", producting approximately thirds value of industrial production in area of province. In 2008s comparing with previous years enterprise putting more value quantitive of minerals in order to exporting mineral fertilizing (in 2.3 folds more), phosphorous acids (in 3.9 folds), tripoliphosphats sodium (in 3.2 folds), yellow phosphor (in 2 folds) increased. In the province the Shu river valley is one of the important areas of irrigated agriculture. During the pasrt few years, agriculture sector has developed significantly. In 2008, a total budget of about 6.5 billion tenge were used to develop agriculture in the province, which is 2.7 folds more than 2007.

2.3.6 Tourism

The ambient of the Region is obtained the world beauties, the snow tops and deep canyons, wide steppes, the mountain rivers and lakes in desert, modern settlements and ruins of ancient cities all these possible to see in rather small territory. At present time, 13 tourist companies are present in the Province. There is a large quantity of landscape and biological territories which have value for development ecotourism. For instance, Northern region of Western Tian-Shan in Zhambyl area the unique flora and fauna, many plants from which are brought in the Red book.

2.4. Kyzyl Orda Province

2.4.1 Morphology

Kyzyl Orda Province area 226,000 km^2, which is contributed 8.3% of Republic territory. The province borders in the south neighboring country Uzbekistan, as well as three other provinces: Aktobe Province to the west, Karagandy Province to the north and South Kazakhstan Province to the east (Figure 2.5). The province borders with the Aral Sea to the west part. The Province consist of 8 administratively cities Aral, Kazaly, Karmakshy, Zhalagash, Syr Darya, Zhusaly, Shyeli and Zhanakorgan. The capital of Province is the Kyzyl Orda city. Kyzyl Orda was founded in 1820 and was renamed as Perovsk after its capture by Russians in 1853. After the October Revolution, it got back the name of Ak-Mechet but in 1925 was renamed as Kyzyl Orda, when it became the capital of Kazakhstan, a status that it lost to Almaty city in 1929. Kyzyl Orda city is located near the Syr Darya river.

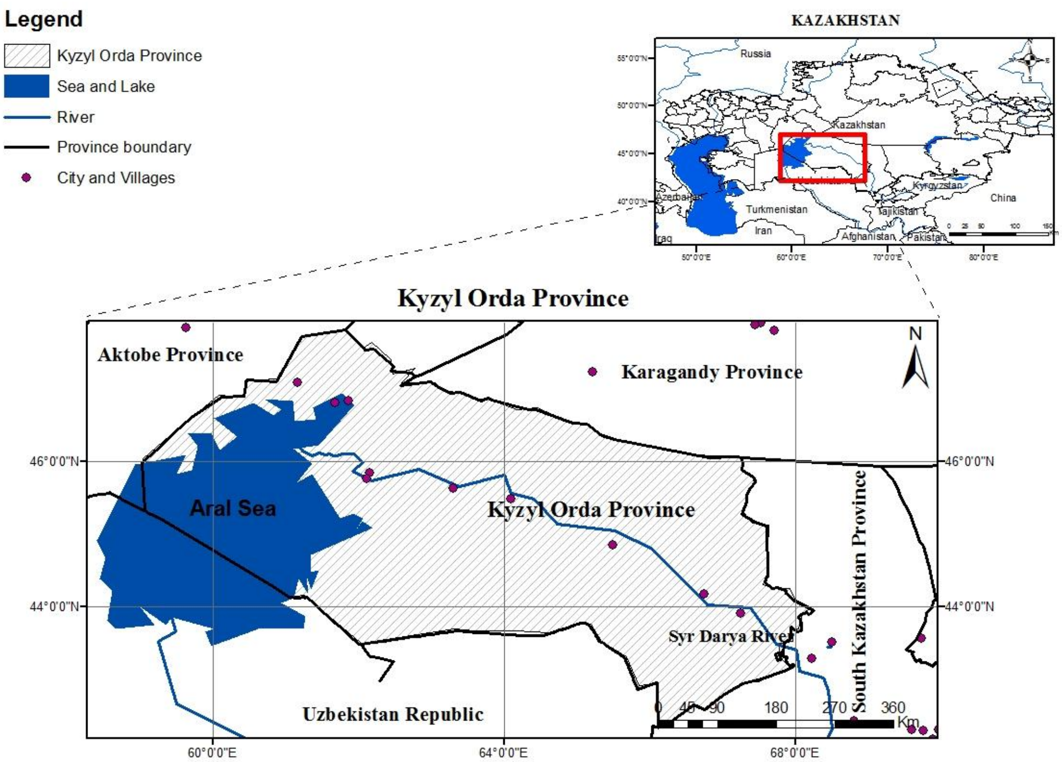

Figure 2.5 Kyzyl Orda province

2.4.2 Meteorology

The climate is continental in the Region. In summer is hot as well as in winter is very cool. The average temperature is -20^{o}C and the maximum temperatute is reached to -36^{o}C in winter. Whereas, the average temperature is 25^{o}C in summer and maximum temperature is achieved to 40^{o}C. The Region is dry and the hot temperature contributed high evopuration, moreover less precipitations all this collapsed ecological disasters of the region. The average precipitation in the region contribues to about 100-150mm.

2.4.3 Hydrology

Kizil Orda region has wide extend surface water resources. One of the well-known surface water resource is the Aral Sea and rivers of Syr Darya, Aris, Bogen and Keles, and some wetlands. The Syr Darya River is flowing from the Tian-Shan Mountains to the Aral Sea, passes through Kyzyl Orda Province. The Syr Darya is the second longest river in Central Asia with the length 2200 km, and in the Region the main tributaries local rivers is the Arys and Keles. They crosses from the territory of South Kazakhstan Province and inflow into the Syr Darya

2.4.4 Population

The population of the province contributes to about 600,000. Accordingly to 1999 censusin Kyzyl Orda city the number of population contributes to about 157,400. Nevertheless, in 2006 the number of local population is increased to 30,5000. In 2009 In the region inhabiting various kind of nations but the main part of residents is hold Kazakhs to about 50-60% from the total and the rest of is contributing Russians, Tatars, Uzbeks, Ukrains and Uigurs.

2.4.5 Economy

There are some food and other light industries in Kyzyl Orda province. In the region all the sectors of economy excepting oil and gas are developed poorly. Furthermore, since 2003 production of hydro-carbon stuff has been falling. There are the sharp ecological problems. Kyzyl Orda is also known with their rice production. There are many hundreds of hectares of rice grown and at least two rice mills operate in the city. Last decades the rice production is not profitable as it was before, because of the degradation of surface water quality and decreasing quantity of River give negetively effect to the agricultural of the region. Therefore the local economic sector is feeble. It is reduced about 40% productivity of rice in the Region last decates.

2.4.6 Tourism

Kyzylorda region is one of the historical centers of the country. Nowadays, the region is well-known with the historical places of the cities some of which are Sauran and Shyganak, archeological monuments and mausoleums of Sunak Ata, Aikozha Ishan, Karasopy, Okshy Ata, Dosball bi, Esabyz, and the mosque Aktas, and the memorial complex of Korkyt Ata and the Baikonur cosmodrome. There are 543 monuments in Kyzyl Orda region 495 of them is of great value as historical and religious monuments. They are architectural, archeological monuments and mausoleums of the outstanding people of the Republic. The regional management of tourism and sport and other tourist companies took part in the Berlin International Tourist Stock Exchange and the International Tourist Fair in Almaty. In purpose to introduce the some unknown historical places. Furthermore, to attract the tourists from another countries and regions.

CHAPTER THREE
NATIONAL AND INTERNATIONAL LEGAL FRAMEWORK

3.1 National and International Water Quality Standards

Since water is essential to sustain life, providing safe surface and subsurface water is of utmost importance for communities. Primarily, access of safe drinking water is imperative as a health and development issue at local, national, regional and international scales. The United Nations (UN) General Assembly declared the period from 2005 to 2015 as the International Decade for Action, “Water for Life.” However, water pollution problems in many countries in the world are at an alarming level. Consequently, approximately 2.2 billion people in developing countries lack access to safe drinking water and about 2.7 billion lack access to sanitation services by the end of 20^{th} century (Gilbert, 1998). Thus, one of the priorities of local goverments is to make necessary efforts to achieve an acceptable water quality. To achieve this objective, countries have determined distinct water quality standarts for different uses such as domestic, industrial and irrigational supply and for maintaining a satisfactory quality for ambient waters. Accordingly, the first water quality standard was accepted in the beginning of the 20^{th} century. Since then, numerous quality standards have been accepted and modified according to the needs of the society and the living conditions, and control of water pollution has reached primary importance in all developed and in some developing countries.

Water quality criteria are developed by scientists and provide basic scientific information about the effects of water pollutants on a specific water use. They also describe water quality requirements for protecting and maintaining an individual use. Many water quality criteria set a maximum level for the concentration of a substance in a particular medium, which will not be harmful when the specific medium is used continuously for a single and specific purpose.

The nature and form of drinking water quality standards may vary among countries and regions. There is no single approach that is universally applicable. It is essential in the development and implementation of standards that the current and planned legislation relating to water, health and local government are taken into account and that the capacity to develop and implement regulations is assessed.

The World Health Organization (WHO) water quality standard guidelines are intended to support the development and implementation of risk management strategies that will ensure the safety of drinking water supplies through the control of hazardous constituents of water. These strategies may include national or regional standards developed from the scientific basis provided in the Guidelines. WHO guidelines for drinking water quality are currently considered to be international reference points for standards setting and drinking water safety. In 1983–1984 and in 1993–1997, WHO published the first and second editions of the Guidelines for Drinking Water Quality in three volumes as successors to previous International Standards of the organization. WHO's Guidelines for Drinking Water Quality (WHO, 1993) have served as international reference points for setting the national standards in many countries of the world. In 1995, the decision was made to pursue further development of the Guidelines through a process of rolling revision. This led to the publication of addenda to the second edition of the Guidelines. Also, between 1998 and 2002, the publication of a text on Toxic Cyanobacteria in Water was realized on chemical and microbial aspects of water. The latest edition of the guidelines was published in 2004 (WHO, 2004) and serves as the final point of reference for international drinking water quality. The WHO standard values for selected parameters are given in Table 3.1.

The United States Environmental Protection Agency (EPA) has also issued a set of water quality standards that has later became a reference point for many national standards throughout the world. The Safe Drinking Water Act (SDWA) authorizes the United States Environmental Protection Agency (US EPA) to set national health-based standards for drinking water to protect individuals against both naturally-occurring and man-made contaminants that may be found in drinking water. SDWA was originally passed by the Congress in 1974 to protect public health by regulating the nation's public drinking water supply. The law was later modified in 1986 and 1996. These standards require many actions to protect drinking water quality and its sources: rivers, lakes, reservoirs, springs, and ground waters. EPA is seeking a new approach to expand public health protection for drinking water by going beyond the traditional framework that addresses contaminants one at a time. The current approach to drinking water protection is focused on a detailed assessment of each individual contaminant of concern and can take many years. This approach not only results in slow progress in addressing unregulated contaminants but also fails to take advantage of strategies for enhancing health protection cost-effectively, including advanced treatment technologies that address several contaminants at once. The outlined vision seeks to use existing authorities to achieve greater protection more quickly and cost-effectively. The EPA standard values for selected parameters are given in Table 3.1.

Turkish water quality standards are classified in two major groups: (i) water quality standards for waters intended for human consumption and (ii) discharge standards of major industrial operations and water quality standards for ambient water bodies inluding rivers, lakes and seas. The quality standards of waters intended for human consumption also cover the drinking water quality criteria and are specified in the Regulation for Waters Intended for Human Consumption (ITASHY, 2005). The drinking water standards of Turkish legislation for selected parameters are given in Table 3.1. The discharge and ambient water quality standards, on the other hand, are described in Water Polution Control Regulation and its Ammendments (SKKY, 2004). This legislation classifies water bodies into four major groups (Classes I to IV) according to the levels of several quality parameters. Accordingly, the use of these waters for some designated purposes are limited based on this legislation. The ambient water quality standards of Turkish legislation for selected parameters are given in Table 3.2.

Table 3.1 National and international drinking water quality standards

Parameters	Unit	WHO	EPA	Turkey	Kazakhstan
pH	-	(6.5-9.5)	6.5-8.5	6.5-9.5	6-9
Temperature	ºC	-	-	-	-
Turbidity	NTU	-	<5	-	-
Nitrate (NO_3)	mg/L	50	44.3	50	45
Nitrite (NO_2)	mg/L	3.0	3.3	0.50	-
Sulfates (SO_4)	mg/L	(500)	250	250	500
Fluorides (F)	mg/L	1.5	2.0	1.5	1.5
Chloride (Cl)	mg/L	(250)	250	250	350
Sodium (Na)	mg/L	(200)	-	200	-
Ammonia (NH_3)	mg/L	-	-	0.50	-
Chlorine-residual (free)	mg/L	5	4	0.5	0.3-0.5
Residual ozone	mg/L	-	-	-	0.2
Aluminum (Al)	mg/L	(0.2)	0.2	0.2	0.5
Barium (Ba)	mg/L	0.7	2	-	0.1
Beryllium (Be)	mg/L	-	0.004	-	0.0002
Boron (B)	mg/L	0.5	-	1	0.5
Iron (Fe)	mg/L	(1.0)	0.3	0.2	0.3(1.0) org
Cadmium (Cd)	mg/L	0.003	0.005	0.005	0.001
Manganese (Mn)	mg/L	0.4	0.05	0.05	0.1(0.5)
Copper (Cu)	mg/L	2	1.0	2	1
Molybdenum (Mo)	mg/L	0.07	-	-	0.25
Arsenic (As)	mg/L	0.01	0.01	0.01	0.05
Nickel (Ni)	mg/L	0.02	-	0.02	0.1
Mercury (Hg)	mg/L	0.001	0.002	0.001	0.0005
Lead (Pb)	mg/L	0.01	0.015	0.01	0.03
Selenium (Se)	mg/L	0.01	0.05	0.01	0.01
Strontium (Sr)	mg/L	-	-	-	7
Chromium (Cr)	mg/L	0.05	0.1	0.05	0.05
Cyanides (CN)	mg/L	0.07	0.2	0.05	0.035
Antimony (Sb)	mg/L	0.02	0.006	0.005	-
Zinc (Zn)	mg/L	(3)	5	-	5
Uranium (U)	mg/L	0.015	0.03	-	-
2,4- D	mg/L	-	0.07	-	0.03

* No health-based guideline is set. Values in parenthesis are recommendations for optimum use above which may affect acceptability of drinking water.

Table 3.2 Water quality classes according to Water Pollution Control Regulation (SKKY, 2004)

	Water Quality Classes			
	I	II	III	IV
Temperature (^{o}C)	25	25	30	> 30
pH	6.5-8.5	6.5-8.5	6.0-9.0	<6.0 or >9.0
DO (mg/L)	8	6	3	< 3
Oxygen saturation (%)	90	70	40	< 40
Cl^- (mg/L)	25	200	400	> 400
F^- (mg/L)	1	1.5	2	> 2
Na+ (mg/L)	125	125	250	> 250
NH4+-N (mg/L)	0.2	1	2	> 2
NO2--N (mg/L)	0.002	0.01	0.05	> 0.05
NO3--N (mg/L)	5	10	20	> 20
SO_4 (mg/L)	200	200	400	> 400
TDS (mg/L)	500	1500	5000	> 5000
Total P (mg/L)	0.02	0.16	0.65	> 0.65
TOC (mg/L)	5	8	12	> 12
Al (µg/L)	300	300	1000	> 1000
As (µg/L)	20	50	100	> 100
B (µg/L)	1000	1000	1000	> 1000
Ba (µg/L)	1000	2000	2000	> 2000
Cd (µg/L)	3	5	10	> 10
CN (µg/L)	10	50	100	> 100
Co (µg/L)	10	20	200	> 200
Cr (µg/L)	20	50	200	> 200
Cr+6 (µg/L)	ND	20	50	> 50
Cu (µg/L)	20	50	200	> 200
Fe (µg/L)	300	1000	5000	> 5000
Hg (µg/L)	0.1	0.5	2	> 2
Mn (µg/L)	100	500	3000	> 3000
Ni (µg/L)	20	50	200	> 200
Pb (µg/L)	10	20	50	> 50
S (µg/L)	2	2	10	>10
Se (µg/L)	10	10	20	> 20
Zn (µg/L)	200	500	2000	> 2000

Kazakhstan water quality standards are defined in Kazakh Law on Environmental Protection and was established on the Russian Standard of (Sanitary norms and rules) SNIP 2.1.4.559-96. This law and the associated standards are the main regulatory instrument for managing water resources and controling water quality in surface and subsurface water resources. The Kazakh water quality standards for selected parameters are given in Table 3.1. The Republic of Kazakhstan also accepted the Water Code in 1993 after obtaining independence from Soviet Union. This law, together with Kazakh water quality standards, provides the legal framework for the regulation of domestic, industrial and agricultural water use and highlights the protection measures to be implemented against pollution.

3.2 International Interactions Regarding Transboundary Waters

Inadequate water quality and quantity might lead to dramatic consequences among countries. In Central Asia, surface water resources such as Aral Sea, Syr Darya River and Balkhash Lake are international waters that are under the jurisdiction of more than one country. In this regard, Kazakhstan is "water neighbour" with Russia, Kyrgyzstan, Turkmenistan, Tajikistan, Uzbekistan and China. Thus, the water quality and quantity of these transboundary water resources are of concern for all these countries. In essence, increasing population and associated anthropogenic consequences intensify the problem and bilateral and trilateral conflicts occur between these countries. One major reason for these conflicts is the vast amounts of water use of the agricultural sector in an area of uneven temporal distribution and limited water resources. Extensive water consumption for irrigation purpose not only creates water quantity problems but also is responsible from degraded water quality due to return flows from agriculture.

The quality and quantity conflicts experienced between Kazakhstan and its neighbours (Kyrgyzstan, Turkmenistan, Tajikistan and Uzbekistan) have lead to the signature of a number of treaties in order to minimize the water-related tensions between these nations. Kazakhstan is relatively active in international environmental cooperation and since 1993, the country has ratified 12 international environmental agreements (EPR, 2008). The main objective in these agreements and in international environmental cooperation is to use international mechanisms and experience for the promotion of national environmental policy and legislation.

Before the falling of the Soviet Union Socialist Republic, the water resources in Central Asia were equaly shared among the Republics and centralized to the Ministry of Land Reclamation and Water Resources of Moscow (Roll, et al. 2003). Each Republic developed five year plans that were coordinated by the state planning agencies and funded through the republican or central budgets of the Soviet Union. For transboundary basins, such as Aral Sea and Syr Darya river, plans were developed by regional design institutes and included inter-republic and multisectoral aspects, as well as allocation of water for various uses. For the Syr Darya Basin, the last plan of the Soviet period was approved in 1982. These plans included limits for water allocation between Republics and targets for the development of irrigated lands within these limits. During drought years in late 1970s, local authorities interfered in water allocation among the Aral Sea Basin Republics. In the Syr Darya River, the situation became tense enough that Moscow had to send authorities to ensure that water from the upper and middle reaches of the Basin reached the lower reaches. In order to achieve compliance with inter-republican water allocations, region-wide Basin Water Organizations (BWOs) were established in 1986. The BWOs were to manage water resources of the Basins according to the plans approved by the Soviet Ministry of Water Management. Moreover, the BWOs had the responsibility to monitor water quality.

Under the Soviet system, water management was highly centralized. However, with independence, water issues like many others rapidly became a national rather than a regional concern. The situation has changed drastically since 1991, when independent states were established in Central Asia. Because of complications in intergovernmental relations and account settlements, introduction of national currencies, and growing prices of oil, coal, natural gas and transportation, the supply of fuel and electricity to Kyrgyzstan from the other Republics become more difficult. This radically affected to the structure of the Kyrgyz fuel-and-energy balance.

Kyrgyz Republic, due to lack of fuel resources, started to use the Naryn cascade, part of the infrastructure created in the Soviet times, in order to gradually replace expensive organic fuel by cheap hydroelectric energy. With this objective, they changed the mode of the Naryn’s regulation from an irrigational (accumulating water in winter and releasing it in summer) operation to a hydro-energy production operation (accumulating water in summer and releasing it in winter) (Dukhovny & Sokolov, 2007). Thus, intensive use of water resources for power generation by the Kyrgyz side, along with changes in the Toktogul operating regime created serious problems in the Syr Darya Basin.

Beginning in 1995, to alleviate these problems, Kazakhstan, Kyrgyzstan and Uzbekistan signed interstate protocols and agreements on the use of water and energy resources in the Syr Darya Basin. Based on these agreements, Uzbekistan and Kazakhstan receive excess energy from Kyrgyzstan generated by Toktogul reservoir in the summer, and in winter they provide Kyrgyzstan with energy, respectively, by deliveries of natural gas and coal.

Moreover, in 1997, the four countries of Kazakstan, Kyrgyzstan, Tajikistan and Uzbekistan signed another agreement on the use of the Syr Darya waters. This agreement occurred recognizing these countries had lived together for many generations. They therefore have common interests in developing efficient and coordinated water regime in the Syr Darya Basin taking into account the many environmental problems of the Aral Sea. The agreement is based on the proposed management and maintenance of the five reservoirs (i.e., Toktogul, Karakum, Charvak, Chardara, and Andizhan) in the Syr Darya basins. The agreement is as follows: Kyrgyzstan receives 1.1 billion kWh of power in electricity or coal, valued at $22 million, and 400 million kWh of power plus 500 million cubic meters of gas, valued at $48.5 million, from Kazakstan and Uzbekistan, respectively. In return, Kyrgyzstan delivers 3.25 cubic kilometers of water from the Toktogul Reservoir in monthly flows and 1.1 billion kWh of summer hydroelectric power to both Kazakstan and Uzbekistan (Akmansoy & McKinney, 1997).

In 1998, Syr Darya agreement has achieved a modest success in relieving tensions over water and energy use in the Basin. The signing of this agreement by the four Prime Ministers demonstrated a show of support for cooperative management of the Basin's resources. This has provided an impetus for the parties to conduct difficult and serious negotiations each year since 1998 and also provided the most needed determination for the implementation of the Agreements. The agreement between Kazakhstan, Kyrgyzstan and Uzbekistan was later renewed with new items due to conflict of interests between energy and fuel supplier countries. The rules of this agreement were later not fulfilled by the counterparts, which lead to the abolishment of the deal.

In January 2004, the government's representative of Kazakhstan, Kyrgyzstan and Uzbekistan met in the City of Chimkent which located in South Kazakhstan province to tackle the issues of excessive water discharging from the Toktokul Dam and the problems connected to seasonal flooding. Consequently, the Chimkent agreement, signed on 4 January 2004, stipulated that Kyrgyzstan was to cut water discharge into Kazakhstan's Chardara Water Reservoir from the Kyrgyzstan owned Toktokul Dam to the level 500 m^3/s (Birgit & Schlyter, 2005). Kazakhstan pledged to compensate for potential Kyrgyz energy losses resulting from such a cut, by providing fuel oil to Kyrgyzstan. Both Kazakhstan and Uzbekistan remain displeased with the Kyrgyz and Tajik energy-generation policy, because annual excessive spring-water discharge from Kyrgyz, Tajik Dams and the recurrent threat of flooding affect the lives of 800000 residents in Kazakhstan and 3 major regions in Uzbekistan (Birgit & Schlyter, 2005) and the Government of Kazakhstan annually wastes about 30000 US Dollars to evacuate the residents from the flooded areas.

Development of the mechanism and procedures for the interstate cooperation in the Aral Sea Basin is one of the main challenges of today. The growths of water demand significantly effected to decreasing water level of Aral Sea. In addition, after the insubordination of the States, an uneven water consumption emerged among the countries, where upstream countries utilize extensive amounts of water which in turn results in further degradation of the Aral Sea and suffering of downstream countries.

Numerous organizations, institutions, programs and projects are realized in order to prevent these problems. Concerns to create a mechanism for regional collaboration in organizing and financing water resources management have arisen since independence. The newly independent countries signed an agreement “On Cooperation in the Field of Joint Management and Conservation of Interstate Water Resources” dated on February 18 1992, and approved by the heads of state on March 23 1993 (Dukhovny & Sokolov, 2007). This agreement established the Interstate Coordination Water Commission (ICWC) for control, rational use and protection of interstate water resources. The agreement acknowledged the equal rights of member states to use and their responsibility to protect, the interstate water resources of Central Asia. The agreement affirmed to continuation of existing Soviet structures and principles of interstate water allocation and was approved by the Presidents of the Central Asian Republics. The Presidents later signed a declaration confirming the validity of previously signed agreements on water resources in the Aral Sea Basin. The ICWC is the highest level of transboundary water resources management in Central Asia. It is responsible for water management in both the Amu Darya and Syr Darya Basins which inflow into Aral Sea. The ICWC took over responsibilities for water management in both basins directly from the former Soviet Ministry of Water Resources (Dukhovny & Sokolov, 2007). The ICWC makes decisions related to water allocation, monitoring and management and it meets quarterly to determine water allocations to member counties. Decisions of the ICWC are by consensus, with each State having an equal vote in decisions. Scientific and information support to the ICWC is provided by the Scientific Information Center (SIC) (McKinney, 2003). Since 1992, the ICWC has been responsible for short and long-term water development and allocation planning, water quality control, conservation and environmental protection. The momentum for regional cooperation was maintained by the establishment of four other intergovernmental institutions between 1993 and 1995. These institutions were:

1. The interstate Council on the Aral Sea Basin (ICAS), intended to set policy, provide intersectoral coordination and review the projects and activities conducted in the Basin;

2. Executive Committee of ICAS (EC-ICAS), intended to implement the Aral Sea Program;
3. The International Fund for the Aral Sea (IFAS), entrusted with the coordination of financial resources provided by member states, donors and international organizations;
4. The Sustainable Development Commission (SDC), designed to ensure that economic, social and environmental factors are given equal weight in planning decisions (Vinogradov & Langford, 2001).

Later, in 1993, with the Aral Sea Basin Program extension, two new organizations were established. Those were: the Interstate Council for the Aral Sea (ICAS) set up for program coordination and the International Fund for Saving the Aral Sea (IFAS), which had the purpose of raising and controlling funds. Later these two bodies were merged into one in 1997. IFAS is headed by one of the presidents of five states by rotation. The executive committee of IFAS is comprised of the Prime Ministers of the five states. The Heads of the Central Asian countries established on Joint Activities for Addressing the Crisis of the Aral Sea and the Zone around the Sea, improving the environment and ensuring the Social and Economic Development of the Aral Sea Region. Declarations were adopted in Nukus (Karakalpakistan) in 1995, Almaty (Kazakhstan) in 1997, Ashgabad (Turkmenstan) in 1999, and Dushanbe (Tajikistan) in 2002 on the Aral Sea Basin issues.

The new IFAS primary activities include (i) raising funds for joint measures to conserve the air, water and land resources of the Aral Sea Basin, as well as the flora and fauna; (ii) financing interstate ecological research, programs and projects aimed at saving the Aral Sea and improving the ecological situation in the region surrounding the Sea as well as resolving general social and ecological problems of the region; (iii) establishing a regional environmental monitoring system in the Aral Sea Basin (Allouche, 2007). The International Commission on Water Management Coordination (ICWC) is the technical authority, regulating and supervising the allocation of water resources and related infrastructure. However, the IFAS is the political authority that guides and sanctions the work of the ICWC via principles and policies agreed among the member states.

In 1994 on 19 July resulted in establishment of an Interstate Commission for Socio-Economic Development and Scientific, Technical and Ecological Cooperation, the name of which was later changed to Sustainable Development Commission (SDC), this body also operated under ICAS. In 1994, the Heads of States adopted the Aral Sea Basin Program that was designed to be administered by the new regional institutions. Establishment of the Program was aimed to prepare a general strategy for water distribution, rational water use, and protection of water resources in the Aral Sea Basin. Following the establishment of the Program, Heads of States have met at least once a year during the next 6 years to further develop, approve and express support to the Program. Furthermore, in 1999 the Heads of States adopted Ashgabat Declaration where they stressed their support to joint actions to address shared environmental problems in the basin and promote better quality of life for people living in the Aral Sea Basin. At the summit of the Head of States in 2002 in Dushanbe, main directions of a program of specific measures aimed to improve socio-economic and ecological situation in the region for the period until 2010, were adopted. The latest summit of the Heads of the States members of the Organization of Central Asian Cooperation (Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan) took place in Almaty, Kazakhstan, on 5-6 July 2003. In the adopted joint statement Heads of the States stressed the importance of the regional and international cooperation in the water, energy and transport sectors. Up until now, there are about 25 agreements signed in the two last decades on joint usage of the Syr Darya water resources and Aral Sea Basin. In addition, an important role is played by the efforts of international organizations aimed at the solution of regional problems, among which water problems are foremost. Well-known projects of the World Bank, UNEP, UNESCO, UNDP, and number of researches and applied projects funded by INTAS, NATO, TACIS, INCO—COPERNICUS, have greatly contributed to the understanding of the situation from regional to local levels (Igor, 2004).

Global Environment Agencies has contributed to the financing and implementation of various kind of projects in the Syr Darya and Aral Sea. The World Bank was the first major agency to become involved. In the early 1990s, the Bank cooperated with Aral Sea Basin governments to formulate an Aral Sea Basin Assistance Program (ASBP) to be carried out over 15 to 20 years. The initial cost estimate for this effort was set at 250 million USD, which was later increased to 470 million USD. The main goals of the program were (*a*) rehabilitation and development of the Aral Sea Disaster Zone, (*b*) strategic planning and comprehensive management of the water resources of the Amu Darya and Syr Darya and (*c*) building institutions for planning and implementing the above programs (Igor, 2004). Later, the Kuwait Fund for Arab Economic Development provided a technical assistance grant for the project amounting to US$ 1.2 million. Moreover, in 2003, the World Bank started a new project that supported efforts to revive the northern part of the sea, known as a Small Sea, while giving up on the largely dead Big Sea to the south. The Project funding is 85 million USD. Work on the project, a 12 km dike started in July 2003 (Micklin, 2004).

European Union initiated a major aid program for the Aral Sea Basin States in 1995 known as the Water Resources Management and Agricultural Production in the Central Asian Republics Project (WARMAP). United Nations Educational, Scientific and Cultural Organization (UNESCO) funded a research and monitoring program for the near Aral region from 1992–1996 focusing on ecological research and monitoring in the Syr Darya and Amu Darya deltas. United Nations Development Program (UNDP) has also been very active in Aral Sea region activities (Micklin, 2004). This organization has had two primary focus: strengthening regional organizations that have been established to deal with the Aral crisis and promoting sustainable development to improve conditions for the several million people who live in the so-called disaster zone adjacent to the sea. The United Nations Childrens Fund (UNICEF) launched the Aral Sea Project for Environmental and Regional Assistance (ASPERA) in 1995. It provides assistance to the disaster zone around the sea and focuses on health, nutrition, health education, water and environmental sanitation, sustainable development to improve conditions for the several million people in the parts of Kazakhstan, Uzbekistan, and Turkmenistan which are closest to the Aral Sea.

The North Atlantic Treaty Organization (NATO) has also become involved in Aral Sea region activities through its Scientific and Environmental Affairs Division. The first NATO sponsored event was an Advanced Research Workshop (ARW) on "Critical Scientific Issues of the Aral Sea Basin: State of Knowledge and Future Research Needs" held in Tashkent, Uzbekistan, during May 1994. Besides, one of the biggest regional projects was implemented with the financial support of the Global Environment Facility (GEF), and Dutch and Swedish governments to save Aral Sea Basin. The total budget of the project was 21.5 million US dollars.

More active participation of international partners in the implementation of concrete programs and projects that directed to improvement of ecological situation of the Aral Sea Basin could render the assistance to normalization of eco-system of the Aral Sea. However, there are numerous unresolved disputes and tensions over water among the Central Asian states and some of their neighbours. The IFAS–ICWC system is not functioning effectively for a number of reasons (Allouche, 2007). The most important one is that these institutions have mainly been created under the impulse of international agencies (in particular the World Bank) and states have been quite reluctant to cooperate.

Regional cooperation in Central Asia is important, as the countries share many common physical, social, economic and historical problems. The five republics have already signed a number of agreements declarations and implemented some programs and projects on environmental issues. However, it is questionable how much impact and commitment these agreements really have. Most of the initiatives seek international funding or are only implemented, where immediate economic or security interests are at stake. The regional agreements on transboundary watercourses mostly concern the quantity and allocations of water between the countries. There are virtually no agreements on the quality of the shared watercourses, joint monitoring or joint control over polluting activities. Kazakhstan is aiming to ratify the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (United Nation, 2000). The Convention could be a useful tool in solving several of the transboundary water problems in the region. Today, all states are questioning water allocations despite having agreed current allocations. This is primarily because of energy needs in upstream states. As the International Crisis Group (ICG) observes, local conflicts over water rights could escalate into national disputes. Despite a very advanced water cooperation agreement signed by all five independent Central Asian states since 1991, the water has become a source of serious tensions in the region (Allouche, 2007). The problem of optimization of transboundary water resources usage in Central Asia remains complicated and shows a tendency to aggravation.

The most likely solution to the problems is to be sought in political, not the technical sphere. Apparently that goal directed towards growing hydro-energetic powers on transboundary rivers in medium-term prospects, will negatively affect the water supply system, situation in agro-industrial complex and ecological balance in the region. These impacts would first be observed on Uzbekistan, Kazakhstan and Turkmenistan. Therefore, all decisions on the use of water from transboundary rivers, including hydro-energetic structures, must be in obligatory order taking into account these interests. Otherwise the situation could further be aggravated by accelerating the ecological catastrophe of the Aral Sea and making it practically impossible for million of inhabitants to live here in the region. In order to solve this problem, it is necessary to provide the constant inflow of fresh water from Syr Darya and Amudarya Rivers in sufficient volume that will allow saving the established ecosystem in this region. To achieve this objective, it would be necessary to study the question of making relevant changes to draft Interstate agreement on use of water and energy resources between Central-Asian countries.

CHAPTER FOUR
SURFACE WATER QUALITY

The surface water quality of Southern Kazakhstan region is presented in this chapter. Three major surface water resources are selected to be the topic of this part and discussed as case studies.

4.1 Case Study: Syr Darya River

The Syr Darya River is one of the major surface waters of Central Asia that discharge into the Aral Sea. The river is formed by the confluence of 2206 km long Naryn River and 3019 km long Karadarya River in Fergana Valley. The total drainage area of the river is 402,760 km^2, which is divided between four former Soviet States; Kyrgyzstan (Naryn, Dzhalalabadsky and Osh regions), Tajikistan (Sogdijsky area), Uzbekistan (Andizhan, Namangan, Fergana, Tashkent, Dzhizak and Syr Darya areas) and Kazakhstan (South Kazakhstan and Kyzyl Orda provinces) (Figure 4.1). The Naryn branch originates from Kyrgyzstan Mountains and flows to the west towards Kazakhstan. The Karadarya branch originates from Kyrgyzstan and Tajikistan and also flows to the west until it meets with Naryn River in Fergana Valley in Uzbekistan. After this confluence, the river is named as Syr Darya and the river then enters the Myrzashol desert where it flows about 150 km within the desert. The river then enters the into Kazakhstan territory where it runs about 1300 km and finally discharges into the Aral Sea.

The mean annual flow rate of the river is 38.83 km^3 per year, of which 21.9 km^3 (56.3%) per year is contributed from the rivers originating from the territory of Uzbekistan Republic and 3.4 km^3 (8.7%) per year is contributed from the rivers originating from Kyrgyzstan territory. The remaining 35% originates from the territories of Kazakhstan and Tajikistan. The main tributary of Syr Darya is the Narin River that supplies about 13.8 km^3 (35.5%) of the total flow rate. Karadarya River is the second most important tributary which contribute about 12.8 km^3 (32.9%) of its total flow rate. The remaining 12.23 km^3 (31.6%) is supplied by Shyrshyk, Aris, Angren and Keles Rivers.

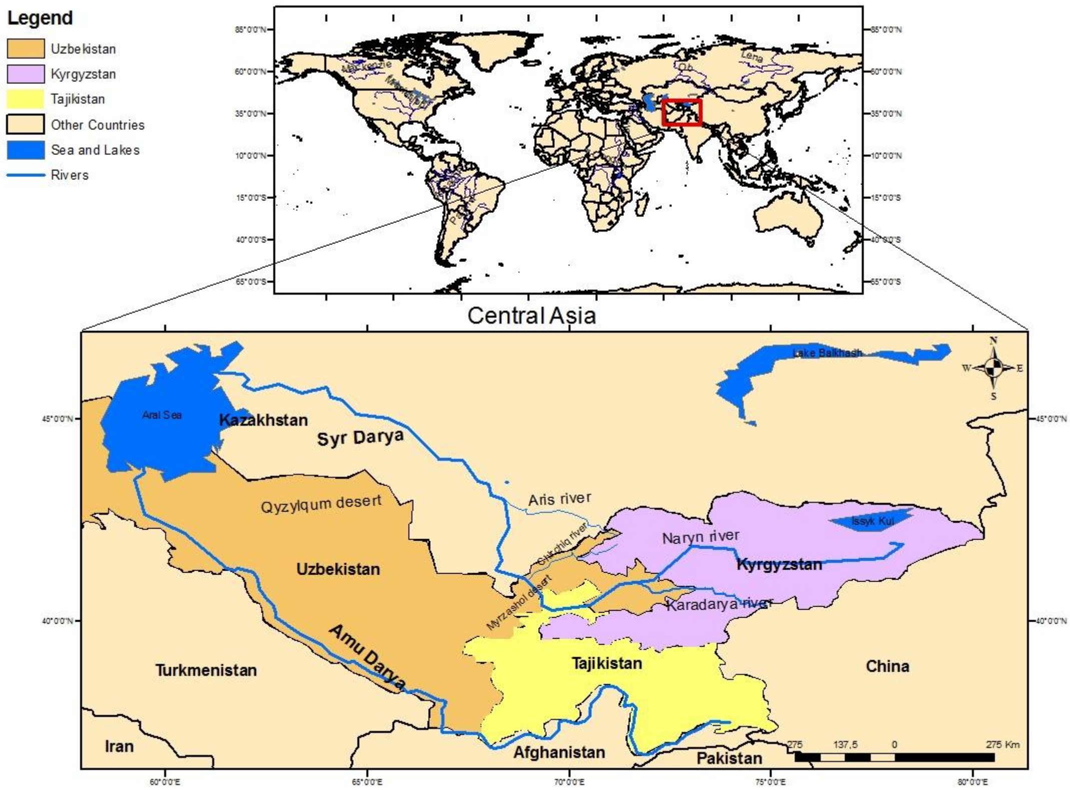

Figure 4.1 Syr Darya River

The Syr Darya drainage basin can roughly be subdivided into two parts: the upper mountainous part, located in Tian Shan Mountains and the lower plain part of the basin that is basically built up of the erosion products of the nearby mountains, with loess in Golodnaya Steppe and sandy loess-like deposits in Qyzylqum desert (Oxana, et al. 2003). In this lower part, Syr Darya River receives virtually no water from tributaries and has a relatively straight and broad valley stretching in the north-west direction towards the Aral Sea. Mountainous terrain above 1000 m, cover an area of approximately one third of the total basin area. The land cover of the Syr Darya River is represented by arid alpine types vegetation of grass and shrubs that covers about 78% of the area and forests that covers about 8% of basin area (Oxana, et al. 2003). Major agricultural land in Syr Darya Basin is about 280,000 km^2, which corresponds to 70% of the total basin area. The arable cropland land is 35,000 km^2

that corresponds to 8.7% of basin area (Oxana, et al. 2003). Of this total, approximately 80% is irrigated.

The population of Syr Darya basin is approximately 22 million, of which 73% lives in rural areas and make their living from agriculture. Population density is about 48 pers/km^2. Approximately 55% of the population is concentrated in Fergana oblasts: Djalal-Abad, Osh, Sogd, Fergana, Andijan, Namangan, and 35% in Southern Kazakhstan Region such as Kyzyl Orda, Aralsk, Zhalagash and Kazaly.

In general, the climate of the basin is hot and arid. Only in the mountainous area, the climate is more cool and humid. Southern parts of the basin, where headwaters of Syr Darya are located, is situated in a subtropical climatic zone. The climate here is strongly determined by alpine vertical zonality. Accordingly, the climate is moderately humid at high elevations and is more arid at the lower elevations. The mid section of Syr Darya Basin is located in maritime climatic zone and is characterized by extra-continental features. This part of the basin is very hot and dry during summer and receives extremely low precipitation, especially in the area where Kyzyl Orda, Kazaly, Aralsk Regions are located. Mean annual temperature is 22ºC on the relatively flat parts of the basin where average precipitation ranges between 125 to 150 mm. Precipitation mostly occurs during spring in the form of rain. The lowest amount of precipitation occurs during June.

4.1.1 Water quantity

The hydrological regime of the basin is mostly determined by the climate in the mountains of Tian Shan that occupies approximately one third of the basin area. An important factor influencing the hydrology of the river is the glaciers. There are 2863 Alpine glaciers in Syr Darya basin covering an area of about 1658 km^2 and containing 81.51 km^3 of ice (Kotlyakov, 1978). The water quantity in the river was stable prior to 1960, but started to deteriorate upon the settlement campaigns of Soviet administration. Migrations of large populations were encouraged to settle along the Syr Darya River where state-organized agricultural production has been initiated. To provide the necessary irrigation water, Soviet administration has constructed several dams on Syr Darya and its tributaries including but not limited to Toktagul, Kajrakumsky, Andizhan, Charvaksky and Chardarinsky Reservoirs. These storage facilities provide long-term regulation of the river flow and stores water primarily for agricultural water requirements. Of these, Toktagul dam is the largest storage structure on Syr Darya (with capacity 19.5 км^3) that is currently under the jurisdiction of Kyrgyz Republic. Although the discharge from the reservoir was mostly stable during Soviet Era, the water releases from Toktagul reservoir started to decline after 1991 (Figure 4.2) when the reservoir started to be operated by Kyrgyz officials according to their own interests following the disintegration of Soviet Union.

Under the Soviet system, water management was highly centralized. However, with independence, water issues like many others rapidly became a national rather than a regional concern. The situation has changed drastically since 1991, when independent states were established in Central Asia. Because of complications in intergovernmental relations and account settlements, introduction of national currencies, and growing prices of oil, coal, natural gas and transportation, the supply of fuel and electricity to Kyrgyzstan from the other Republics become more difficult. This radically affected to the structure of the Kyrgyz fuel-and-energy balance. Kyrgyz Republic, due to lack of fuel resources, started to use the Naryn cascade, part of the infrastructure created in the Soviet times, in order to gradually replace expensive organic fuel by cheap hydroelectric energy. With this objective, they changed the mode of the Naryn's regulation from an irrigational (accumulating water in winter and releasing it in summer) operation to a hydro-energy production operation (accumulating water in summer and releasing it in winter) (Dukhovny & Sokolov, 2007). Thus, intensive use of water resources for power generation by the Kyrgyz side, along with changes in the Toktogul operating regime created serious problems in the Syr Darya Basin. This situation has continued until 1993 when several agreements were ratified among the countries of interest to find a solution to the water quantity problems in Syr Darya. Accordingly, the Interstate Commission for Water Coordination (ICWC) was founded in 1992 to prevent conflicts among the countries and manage the water allocations from the Syr Darya and Amu Darya. Based on the agreements, Kazakhstan would be able to divert 8.8 km^3 water from the Syr Darya River resources (Keith & McKinney, 1997).

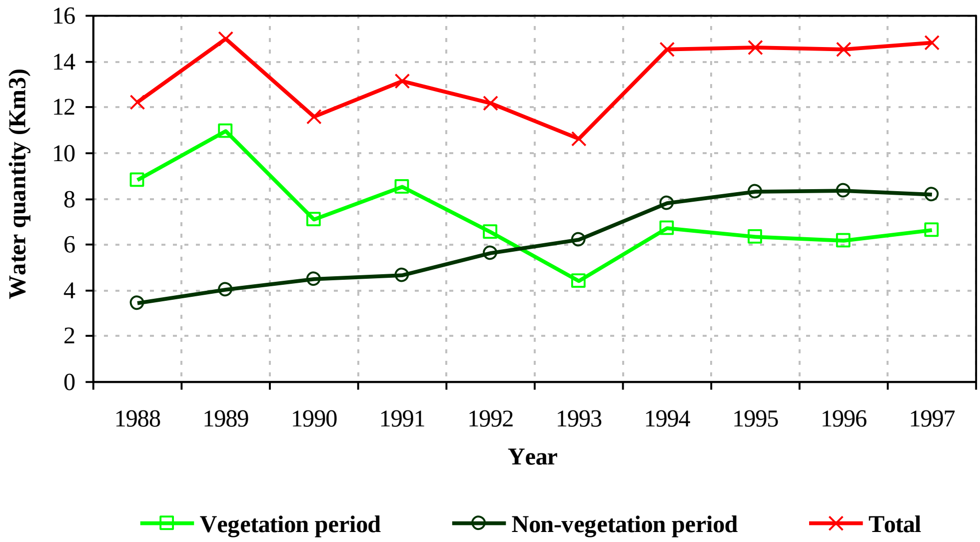

Figure 4.2 Release of water from Toktagul Reservoir to downstream countries

The amount of water in Syr Darya River within Kazakhstan territory is monitored by the 8 stations: Kokbulak, Shardara, Koktobe, Tomenarik, Kyzyl Orda, Zhusaly, Kazaly and Karateren as shown in Figure 4.4. The data from these stations are presented in Table 4.1. For instance: in the Kyzyl Orda station the river discharge decreased from 679.3 m^3/s (between 1942 and 1959) to 252.5 m^3/s (between 1960 and 1980). Although there is no concrete data, the discharge has further declined at this station to values below 200 m^3/s. Moreover, the rive discharge in Kazaly station has also decreased significantly from 516.4 m^3/s (between 1942 and 1959) to 181.9 m^3/s (between 1960 and 1980). Thus, the river discharge at these stations has approximately reduced to its 35% level prior to 1960. Comparing the change in decades, one could see that the greatest reduction has occurred between 1970 and 1975 (Figure 4.3). In essence, water consumption in the region due to irrigation has increased dramatically during this period, which led to catastrophic reductions in river discharge.

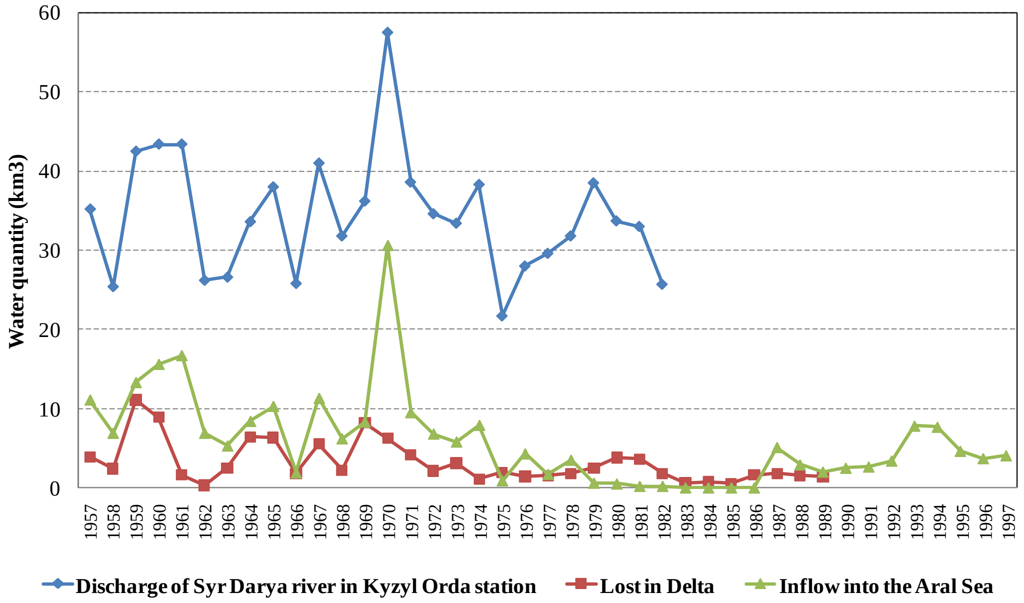

Figure 4.3 Water quantity of the Syr Darya River

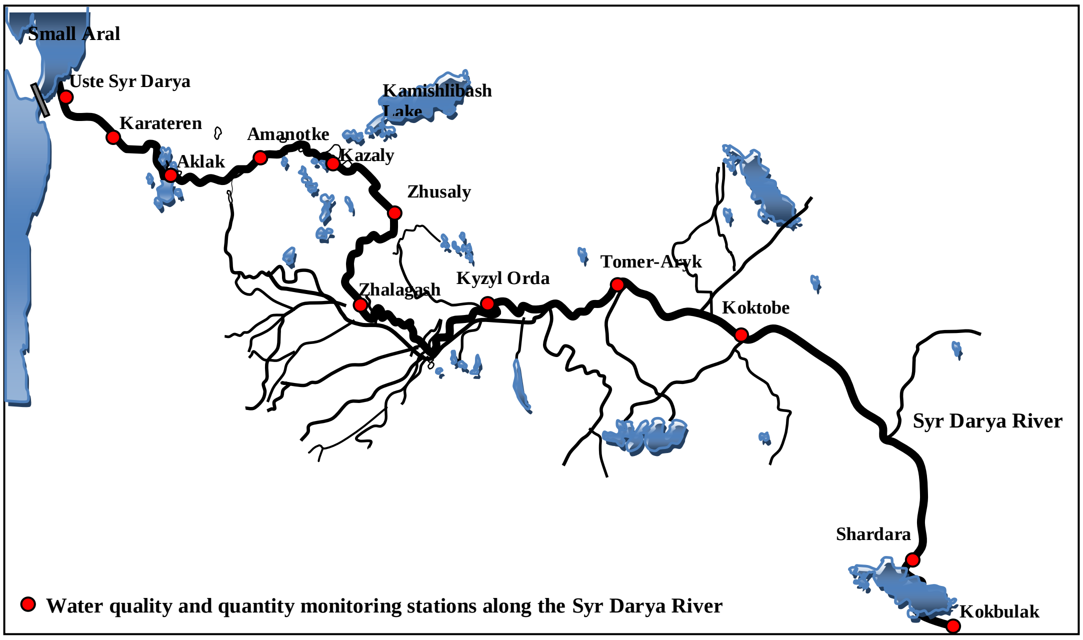

Figure 4.4 Monitoring stations in the Syr Darya River.

Table 4.1 Mean annual discharges of the river Syr Darya at different monitoring stations in Kazakhstan territory (m^3/s), (Aral-Syr Darya department, 2010).

Years	Hydrological monitoring station							
	Kokbulak	Shardara	Koktobe	Tomen-Aryk	KyzylOrda	Zhusaly	Kazaly	Karateren
1942					762	385	524	
1943					630	317	513	
1944					466	224	385	
1945					641	323		
1946					645	302		
1947					508	256	340	
1948					589	301		
1949					741	377		
1950					485	252	419	
1951					888	372	595	
1952					899	379	620	
1953					922	360	670	
1954					662	272	530	
1955					631	264	520	
1956					401	207	300	
1957					744	315	568	
1958					767	294	580	
1959					846	318	666	
1960					352	333		
1961					217	186	184	
1962								
1963								
1964					181	165.6	148.7	
1965					375.7	312.7	304.1	
1966					333.8	275.8	276.7	
1967					327.5	266.1	231.2	
1968					717.5	600	555	
1969								
1970				487.3	395.3	379.4	311.5	
1971		538.5		425.4	295.9	286	259.4	
1972		522.5		444.4	303.8	268.9	221.6	
1973		561.9		504.8	358.7	333.3	282.5	
1974		245.9		201	112.1	92.1	61.3	
1975		166.2		123.4	60.2	41.5	19	
1976		211.4	188.9	149	64.4	41.3	18.1	
1977		225.1	205.1	152.1	68.6	35.7	15.2	
1978		277.5	274	207.9	104	59	24.8	
1979		406.4	447.6	349.2	190.5	134.3	102.2	
1980		338.1	361.9	279	150.5	113.3	79	
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								
1990		461			189.6		111.4	
1991								
1992	524.8	515	480.7				145.8	
1993	674.2	672.1	651.1				288.6	
1994	819.1	627.1	654.8				313	
1995	484.1	410.9	405.2					143.7
1996	506.2	485.4	474.9					177.8
1997	452.4	428.1	427.1					150.6
1998	751.3	635	647.1					245
1999	581.4	538.4	515					191.6
2000	441.5	385.7	375.4		193.2		128	122.7
2001	422.4	389.1	371.9					113.1

To provide an example on the changing water use patterns, the water consumption in Kyzyl Orda region as a function of time is given in Table 4.2. It is clearly seen from the table that the majority of water use is due to irrigational water demands, which approximately correspond to more than 98% of the total water use in this region. Furthermore, the change in irrigational water demand in years starting from 1930s to 2000s is shown in Figure 4.5. Irrigational water use has significantly increased and reached to levels of about 8000 million.m^3. This drastic increase in irrigational water use in the area is almost completely supplied from Syr Darya river resources. Accordingly, the area irrigated by Syr Darya waters has reached to the level 7.8 million ha within the entire Kazakhstan territory.

The monthly average discharges of the river are recorded in the monitoring stations of Kazaly and Karateren between 2001 and 2010 (Figure 4.6). The monthly discharge pattern follows the climatic conditions and irrigation practices. Accordingly, water quantity in the river is significantly reduced during June, July and August as seen in Table 4.3.

Table 4.2 Water consumption in Kyzyl Orda Region (million.m^3).

Water use	Domestic	Industrial	Agricultural	Total
1932	20		1400	1420
1950	40	20	1985	2045
1960	50	40	3256	3346
1972	60	60	7856	7976
1980	70	80	7229	7379
1990	80	100	5249	5429
1992	74.6	28.3	11191	11294.2
1995	23.9	84.37	9076.8	9185.09
1998	38.3	36.37	9437	9512.2
2000	19.85	18.26	7609.4	7648.36
2001	9.74	24.26	7630.9	7665.22

Table 4.3 Monthly average discharges in lower part of Syr Darya River.

Month Year	1	2	3	4	5	6	7	8	9	10	11	12
Kazaly Station monthly average discharge (m^3/s)												
2001	109	329	272	207	71	8	6	8	17	28		
2002				304	312	217	211	280	333	324	228	224
2003	309	405	359	383	371	174	154	246	399	333	347	403
2004							172	168	166	281	489	565
2005	402	370	439	583	281	72	35	118	217	267	446	464
2006						56	19					
2007	338	469	222	382	410	15	40	194				
2008	140	146	118	95	46	4	3	4				
2009	108	114	97	85	37	4	2	3	6			
2010	336	320	408	341	301							
Karateren Station monthly average discharge (m^3/s)												
2001	234	191	267	242	47	13	6	6	11	40	74	110
2002	103	116	108	272	276	200	167	204	259	278	101	249
2003	293	285	310	367	316	199	157	201	311	301	376	372
2004							183	165	183	232	290	
2005				475	416	143	48	137	333	384	417	387
2006	430	375	340	377	175	53	22	38	120	149	229	278
2007	300	281	270	328	185	57	29	147	149	206	289	286
2008	259	255	290	237	99	26	10	6	12	45	34	139
2009	156	180	154	87	105	103	90	80	254	230	80	49
2010	176	267	262	335	283							

Decreasing level of river lead to aggravating of agricultural process in the region. In the beginning of XX century (1928) the irrigated area have been occupied under crops above 70% of all irrigation, rice – 3-10% and cotton production–7-20%. Since 1930 the structure of use irrigating field has started to change increased cotton and rice agriculture field and in 1950 years it s reached about 60-70%. In order to decreasing of the river level, in the region irrigated area and productivity of the agricultural sectors are considerably decreased. In essence, in 1960 the total productivity of the Aralsk region was 3363.7 ton, whereas, in 1997 contributed 682.7 ton (it's 80% reduction). In additionally, the total productivity is significantly declined in Kazaly region from 2836.1 to 523.7 ton (82%), in Karmakshy region 2899.9 to 776.7 ton (73%), in Zhalagash region from 1979.2 to 631.6 ton (70%), in Syrdarya region from 3044.7 to 928 ton (69%), in Shiely region from 1593.3 to 705.4 ton (55%), in Zhanakurgan region from 969.1 to 443.5 ton (54%), in Kyzyl Orda region from 192.6 to 54.9 ton (71%) (Table 4.4).

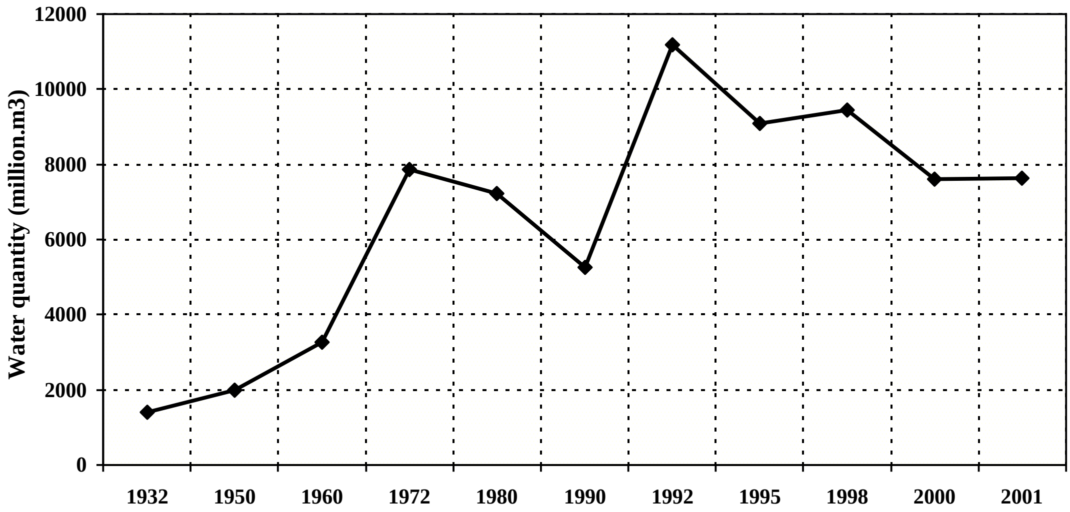

Figure 4.5 Agricultural water consumption from Syr Darya River in Kyzyl Orda region

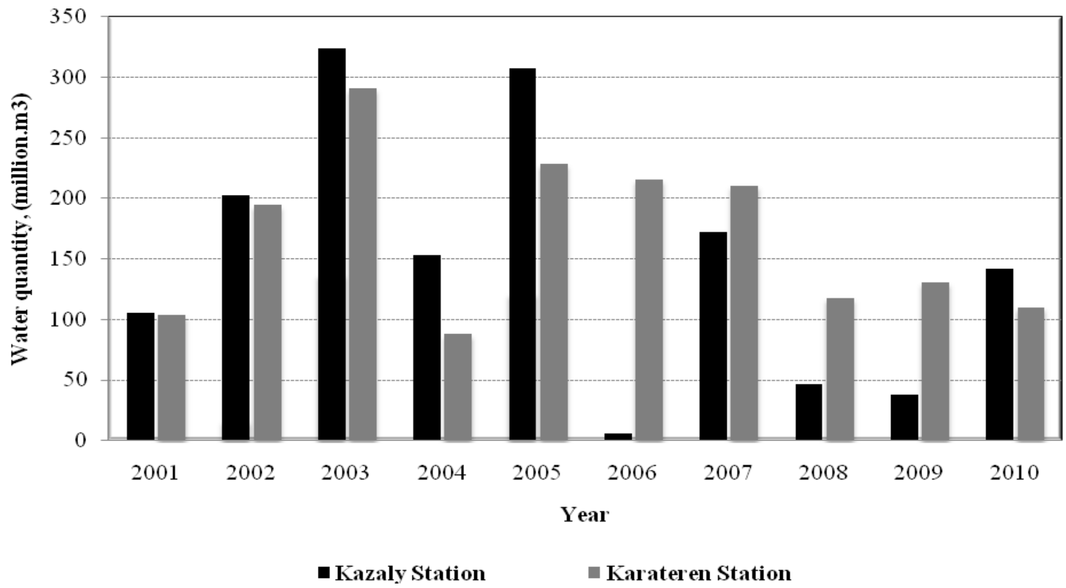

Figure 4.6 Average monthly discharges of Syr Darya River in Kazaly and Karateren stations in 2001-2010.

Table 4.4 Annual losses of animal feed production in Kyzyl Orda Province.

Region in Kyzyl Orda Province	Hay production						Pasture						TOTAL (1000 ton)	
	Area (1000 ha)		Productivity (ton/ha)		Total production (1000 ton)		Area (1000 ha)		Productivity (ton/ha)		Total production (1000 ton)			
	1960	1997	1960	1997	1960	1997	1960	1997	1960	1997	1960	1997	1960	1997
Aralsk	95.6	9.5	3.8	1.9	363.2	18.2	2307.7	2215.4	1.3	0.3	3000.5	664.5	3363.7	682.7
Kazaly	101	28	2.8	1.6	282.8	44.8	1606.5	1596.4	1.2	0.3	2553.6	478.9	2836.4	523.7
Karmakshy	95.6	23.9	2.8	1.6	270.5	38.5	2220.8	2191.2	1.2	0.3	2629.4	738.9	2899.9	776.7
Zhalagash	40.1	11.4	2.3	1.4	92.3	16	1715.4	1718.7	1.1	0.3	1886.9	738.2	1979.2	631.6
Syrdarya	35.5	14.2	2.4	1.5	85.2	21.3	2690.5	2689	1.1	0.3	2959.5	615.6	3044.7	928
Shyely	23.9	11.3	2	1.6	47.8	18	1405	1374.7	1.1	0.5	1545.5	906.7	1593.3	705.4
Zhanakorgan	19	9.5	2.8	1.6	53.2	15.2	704.5	611.8	1.3	0.7	915.9	687.4	969.1	443.5
Kyzyl Orda	18	8.7	2.2	1.4	39.6	12.2	160.5	141.2	1.2	0.3	32.1	428.3	192.6	54.9
TOTAL	428.7	116.5			1233.5	184.2	12810.9	12538.4			15523.4	5258.5	16756.9	5442.7

4.1.2 Water quality

In the region, the problems related to water quality are more serious than problems related to water quantity. Water quality in Syr Darya is generally unsuitable for human consumption and irrigation. Water shortages are often acute and made worse by the uneven distribution of water resources in each country. In Southern Kazakhstan region, surface water resources are typically used for irrigation and drinking purposes. Degradation of river water quality influences agricultural productivity with regards to the amount and quality of the products. Therefore, water quality is playing a significant role in social and economical life of the region.

The water quality of the river at Zhanakurgan, Kyzyl Orda, Kazaly, Aralsk Amanotkel, Aklak and Ust Syr Darya monitoring stations is presented in Table 4.5 thru Table 4.11. According to the data of Aral-Syr Darya Department of Kazakhstan, the river is mostly contaminated by chemical substances such as nitrate, sulphate and heavy metals. Based on this data set, the water quality of the river between 2001and 2007 mostly deteriorated, whereas a significant level of improvement was observed in all stations since 2008.

The water qualities of some parameters along the river are plotted in Figure 4.7 thru Figure 4.16**.** In these figures, the Zhanakurgan station represented the most upstream point and Ust Syr Darya station represented the most downstream point along the river. Thus, these figures characterize to the longitudinal change in water quality in Syr Darya River. In general, the chemical concentrations had the lowest values at the most upstream station and gradually increased as river flows downstream due to anthropogenic influences. These figures also included the corresponding water quality standards to provide a mean of comparison. Here, Kazak standards are used when available and WHO, EPA or Turkish standards are used when no Kazakh standard value existed for a particular parameter.

Table 4.5 Water quality of Syr Darya River at Zhanakurgan Station (Aral-Syr Darya Department).

Sample Station	pH	BOD mg/L	Cl^- mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	Fe mg/L	Oil products mg/L	NH_4^+-N mg/L	NO_2^--N mg/L	NO_3^--N mg/L	Cu^{2+} µg/L	Cr^{6+} µg/L	Pb µg/L	SO_4^- mg/L
1970							0.05			10.00				1205.90
1980								0.16	0.01	0.34	1.00		1.00	
1992	7.10	2.49	145.50	78.00	102.70	0.18	0.03	0.40	0.04	2.98	1.80			440.10
1993	7.20	2.40	109.90	82.00	75.40	0.02	0.04	0.16	0.07	3.87	1.30			431.00
1994	7.05	2.28	120.50	91.00	45.80	0.02	0.07	0.71	0.30	3.72	1.00			401.80
1995	7.15	2.88	116.90	104.00	97.20			0.33	0.02	2.30				364.00
1996	7.20	2.45	116.80	67.60	95.30		0.02	0.20	0.02	4.86		83.00		603.40
1997		2.96	178.80			0.06	0.02	0.32	0.08	6.45				590.00
1998		2.36	162.40			0.12	0.02	0.38	0.02	5.70				676.00
1999		2.72	151.50			0.41	0.02	0.30	0.02	3.50				638.50
2000	7.22	2.24	141.90			0.33	0.02	0.33	0.07	6.87	10.00			654.60
2001	7.35	2.78	166.20	117.00	78.96		0.03	0.36	0.04	6.63	60.00	10.00	20.00	482.30
2003	6.89	2.70	131.60	107.20	72.30	0.25	0.03	0.34	0.05	8.54	10.00	10.00		484.50
2004	7.22	1.80	86.90	56.00	74.20	0.40	0.01	0.42	0.02	7.43	10.00	30.00		
2005	7.20	2.24	102.80	77.33	51.00	0.32	0.02	0.32	0.02	6.18	40.00	42.00		524.00
2006	7.10	2.06	178.20	110.00	63.50	0.22	0.04	0.30	0.01	3.51	20.00	25.00		560
2007	7.07	2.05	162.00	100.00	55.15		0.02	0.26	0.02	4.20	86.00	63.00		422.60
2008	7.25	2.12	128.00	102.00	29.16		0.01	0.34	0.03	4.08	2.50	1.00		416.43
2009	7.22	2.16	175.50	118.00	55.85			0.37	0.02	3.58	1.00	1.00		525.08
2010	7.20	1.92	103.00	84.00	40.09			0.03	0.02	5.92	1.00	2.00		388.50
Minimum	6.89	1.80	86.90	56.00	29.16	0.02	0.01	0.03	0.01	0.34	1.00	1.00	1.00	560
Maximum	7.35	2.96	178.80	118.00	102.70	0.41	0.07	0.71	0.30	10.00	86.00	83.00	20.00	1205.90
Average	7.16	2.37	137.69	92.44	66.90	0.21	0.03	0.32	0.05	5.03	17.54	26.70	10.50	514.13
Std. Dev.	0.11	0.33	28.81	18.87	22.22	0.14	0.02	0.14	0.06	2.28	26.32	28.33	13.44	229.53

Table 4.6 Water quality of Syr Darya River at Kyzyl Orda Station (Aral-Syr Darya Department).

Sample Station	pH	BOD mg/L	Cl^- mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	Fe mg/L	Oil products mg/L	NH_4^+-N mg/L	NO_2^--N mg/L	NO_3^--N mg/L	Cu^{2+} µg/L	Cr^{6+} µg/L	Pb µg/L	SO_4^- mg/L
1980						0.09	0.28	0.32	0.10	4.10	4.00			
1992	7.20	2.30	141.70	77.70	124.40	0.20	0.02	0.39	0.11	3.77	1.70			444.10
1993	7.10	2.28	151.00	89.00	61.40	0.02	0.03	0.33	0.11	5.02	1.30			461.60
1994	7.15	2.11	119.70	70.00	53.90	0.02	0.07	0.30	0.15	3.03				402.50
1995	7.30	2.04	195.00	56.50	98.30	0.04	0.03	0.57	0.11	1.02	1.00			420.70
1996	6.45	2.27	122.10	74.50	88.50		0.05	0.34	0.02	4.10				483.30
1997		2.92	119.30			0.04	0.02	0.31	0.10	6.96				572.00
1998		2.66	127.40			0.25	0.02	0.36	0.01	5.50				540.20
1999		2.23	113.40			0.06	0.02	0.32	0.03	5.69				583.30
2000	7.36	2.21	133.80			0.32	0.02	0.38	0.04	8.02		10.00		444.60
2001	7.32	2.96	193.10	133.20	80.50		0.03	0.49	0.04	6.61	50.00	10.00	10.00	552.00
2003	7.33	2.96	126.80	80.20	62.90	0.33	0.05	0.33	0.03	8.17	21.00	20.00		462.60
2004	7.50	2.80	150.70	88.00	62.60	0.05	0.00	0.36	0.04	11.80	67.00	40.00		496.30
2005	7.20	2.80	155.90	144.00	54.60		0.03	0.39	0.02	7.18	20.00	60.00		-
2006	7.20	1.97	125.20	105.60	62.60	0.21	0.03	0.25	0.02	3.15	170.50	76.00		503.40
2007	7.18	2.15	146.70	90.40	51.41		0.04	0.24	0.04	6.24	28.00	11.00		408.40
2008	7.25	2.12	119.00	87.10	47.68			0.29	0.09	4.94	50.00	1.40		436.22
2009	7.20	1.88	182.00	99.44	50.97			0.37	0.02	3.25	1.00	1.00		452.41
2010	7.15	2.16	183.70	89.82	39.08			0.20	0.02	5.00	1.20	1.00		380.15
Minimum	6.45	1.88	113.40	56.50	39.08	0.02		0.20	0.01	1.02	1.00	1.00	10.00	380.15
Maximum	7.50	2.96	195.00	144.00	124.40	0.33	0.28	0.57	0.15	11.80	170.50	76.00	10.00	583.30
Average	7.19	2.38	144.81	91.82	67.06	0.14	0.04	0.34	0.06	5.45	32.05	23.04	10.00	473.16
Std. Dev.	0.23	0.36	27.16	23.36	23.18	0.12	0.06	0.08	0.04	2.41	47.30	26.65		60.44

Table 4.7 Water quality of Syr Darya River at Kazaly Station (Aral-Syr Darya Department).

Sample Station	pH	BOD mg/L	Cl^- mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	Fe mg/L	Oil products mg/L	NH_4^+-N mg/L	NO_2^--N mg/L	NO_3^--N mg/L	Cu^{2+} µg/L	Cr^{6+} µg/L	Pb µg/L	SO_4^- mg/L
1970							0.04	0.60	0.05	8.00				1032.40
1980						0.06	0.05	0.09	0.02	2.22	2.00			
1992	7.25	3.28	135.70	97.00	129.10		0.04	0.42	0.08	5.48				573.30
1993	7.20	2.70	143.80	65.00	87.80	0.02	0.04	0.43	0.10	6.17				515.70
1994	7.02	2.98	196.60	66.00	71.90	0.03	0.05	0.28	0.04	2.48	1.00			539.60
1995	7.20	2.16	106.40	64.00	97.20	0.06	0.04	0.60	0.15	2.15	10.00			400.20
1996	7.30	2.60	124.10	53.00	110.10	0.06	0.03	0.28	0.03	7.14	1.00			564.20
1997		2.99	215.30			0.07	0.03	0.60	0.12	8.83				663.10
1998		3.09	145.00			0.09	0.04	0.42	0.10	5.74				606.50
1999		3.00	229.20			0.09	0.02	0.80	0.05	8.62				626.40
2000	7.54	3.10	157.50			0.06	0.04	0.50	0.07	10.50	10.00	20.00		574.60
2001	7.58	3.20	184.30	138.40	99.30		0.03	0.48	0.07	12.60	60.00	10.00	15.00	633.80
2003	7.40	3.00	115.60	104.20	63.70	0.06	0.31	0.46	0.07	12.24	20.00	20.00		
2004	7.75	3.20	110.00	104.20	73.10	0.08	0.02	0.34	0.07	14.00	260.00	50.00		
2005	7.30	3.52	159.50	86.00	105.70	0.38	0.02	0.27	0.04	12.70	72.00	53.00		
2006	7.20	2.24	203.50	132.00	88.70	0.22	0.05	0.23	0.02	3.94	67.00	87.00		412.80
2007	7.19	2.64	159.10	107.30	80.30	0.05	0.04	0.30	1.02	88.20	20.00	50.00		513.30
2008	7.20	2.26	126.50	125.00	49.40			0.29	0.03	5.98	2.00	1.00		508.80
2009	7.21	1.98	139.00	103.50	47.39			0.38	0.02	4.70	1.00	1.00		460.28
2010	7.20	2.16	113.40	90.00	44.95			0.38	0.04	5.03	1.00	2.00		406.56
Minimum	7.02	1.98	106.40	53.00	44.95	0.02	0.02	0.09	0.02	2.15	1.00	1.00	15.00	400.20
Maximum	7.75	3.52	229.20	138.40	129.10	0.38	0.31	0.80	10.02	88.20	260.00	87.00	15.00	1032.40
Average	7.30	2.78	153.58	95.40	82.05	0.09	0.04	0.41	0.56	11.34	37.64	29.40	15.00	564.47
Std. Dev.	0.19	0.46	37.87	26.49	25.31	0.09	0.06	0.16	2.23	18.45	69.09	29.14		149.17

Table 4.8 Water quality of Syr Darya River at Aralsk Station (Aral-Syr Darya Department).

Sample Station	pH	BOD mg/L	Cl^- mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	Fe mg/L	Oil products mg/L	NH_4^+-N mg/L	NO_2^--N mg/L	NO_3^--N mg/L	Cu^{2+} µg/L	Cr^{6+} µg/L	Pb µg/L	SO_4^- mg/L
2001	7.45	3.20	172.10	183.50	80.70		0.03	0.48	0.10	10.70	20.00		20.00	663.00
2003	7.33	3.42	182.40	134.00	61.40	0.10	0.30	0.44	0.11	12.40	20.00			
2005	7.20	3.36	166.90	84.00	105.70		0.03	0.31	0.04	8.70	10.00	30.00		
Minimum	7.20	3.20	166.90	84.00	61.40	0.10	0.03	0.31	0.04	8.70	10.00	30.00	20.00	663.00
Maximum	7.45	3.42	182.40	183.50	105.70	0.10	0.30	0.48	0.11	12.40	20.00	30.00	20.00	663.00
Average	7.33	3.33	173.80	133.83	82.60	0.10	0.12	0.41	0.08	10.60	16.67	30.00	20.00	663.00
Std. Dev.	0.13	0.11	7.89	49.75	22.21		0.16	0.09	0.04	1.85	5.77			

Table 4.9 Water quality of Syr Darya River at Amanotkel Station (Aral-Syr Darya Department).

Sample Station	NH_4^+-N mg/L	NO_2^--N mg/L	NO_3^--N mg/L	$PO_{4.}$ mg/	SO_4 mg/L	Cu µg/L	Zn µg/L	Pb µg/L	Cr^{6+} µg/L	Cd µg/L
2004	0.40		0.08	0.03	1838.00					
2005	1.01	0.05	1.99	0.04	1599.00	14.00	18.00	53.00	600.00	6.00
2006	0.58		0.32	0.04	3025.00	36.40	44.10	95.00	729.00	20.40
2007	1.13	0.04	4.80	0.02	1974.00	5.03	4.08	2.13		1.95
2008	0.48	0.01	3.50	0.38	3472.00	11.00	30.00	10.00	10.00	1.00
2009	0.39	0.04	6.43	0.40	3112.00	10.00	25.00	10.00	5.00	1.00
2010	0.19		5.08	0.03	1010.00	40.00	2.00	1.00		
Minimum	0.19		0.08	0.02	1010.00	5.03	2.00	1.00	5.00	1.00
Maximum	1.13	0.05	6.43	0.40	3472.00	40.00	44.10	95.00	729.00	20.40
Average	0.60	0.02	3.17	0.13	2290.00	19.41	20.53	28.52	336.00	6.07
Std. Dev.	0.35	0.02	2.45	0.17	915.89	14.89	16.03	37.84	382.96	8.27

Table 4.10 Water quality of Syr Darya River at Aklak Station (Aral-Syr Darya Department).

Sample Station	NH_4^+-N mg/L	NO_2^--N mg/L	NO_3^--N mg/L	PO_4. mg/L	SO_4 mg/L	Cu µg/L	Zn µg/L	Pb µg/L	Cr^{6+} µg/L	Cd µg/L
2004	2.00		0.70	0.02	2119.00	8.70	29.20	36.00	262.00	3.40
2005	1.21	0.03	2.32	0.02	1510.00	12.00	13.00	40.00	533.00	4.30
2006	1.05	0.01	2.01	0.02	2732.00	25.20	23.60	84.00	567.00	17.20
2007	1.75	0.14	1.40	0.02	2005.00	1.24	9.60	16.00		4.10
2008	0.42	0.01	3.20	0.43	3584.00	10.10	30.00	10.00	10.00	1.00
2009	0.39	0.04	6.45	0.45	3689.00	10.00	25.00	9.00	5.00	1.00
2010	0.38	0.04	5.12	0.02	1060.00	22.00	2.00	1.00		
Minimum	0.38	0.01	0.70	0.02	1060.00	1.24	2.00	1.00	5.00	1.00
Maximum	2.00	0.14	6.45	0.45	3689.00	25.20	30.00	84.00	567.00	17.20
Average	1.03	0.04	3.03	0.14	2385.57	12.75	18.91	28.00	275.40	5.17
Std. Dev.	0.67	0.05	2.07	0.21	999.57	8.21	10.77	28.58	271.63	6.08

Table 4.11 Water quality of Syr Darya River at Ust Syr Darya Station (Aral-Syr Darya Department).

Sample Station	NH_4^+-N mg/L	NO_2^--N mg/L	NO_3^--N mg/L	PO_4. mg/L	SO_4 mg/L	Cu µg/L	Zn µg/L	Pb µg/L	Cr^{6+} µg/L	Cd µg/L
2004	1.40	0.01	0.09	0.03	2580.00	17.30	23.30	71.00	342.00	9.40
2005	0.67	0.05	2.20	0.09	1608.00	13.00	22.00	55.00	408.00	3.30
2006	1.05	0.01	1.06	0.03	2658.00	40.30	52.70	131.00	692.00	14.80
2007	0.04	0.04	4.80	0.07	1230.00	5.92	6.55	1.99		2.71
2008	0.43	0.01	3.70	0.44	4548.00	11.10	20.00	20.00	10.00	1.00
2009	0.38	0.04	6.37	0.39	3961.00	10.00	22.00	10.00	2.00	1.00
2010	0.22	0.01	5.03	0.04	1440.00	17.00	2.00	1.00	2.00	10.00
Minimum	0.04	0.01	0.09	0.03	1230.00	5.92	2.00	1.00	2.00	1.00
Maximum	1.40	0.05	6.37	0.44	4548.00	40.30	52.70	131.00	692.00	14.80
Average	0.60	0.02	3.32	0.15	2575.00	16.37	21.22	41.43	242.67	6.03
Std. Dev.	0.48	0.02	2.29	0.18	1281.47	11.28	16.24	47.82	286.03	5.37

The average sulfate concentration along the river is given in Figure 4.7. As seen from this figure, the river receives sulfate loads along its flow, thus creating a significant increase in sulfate levels. It is seen that the sulfate levels were in the order of the water quality standard value up to Aralsk station. After this point, sulfate concentrations gradually increased 4 to 5 folds above the standard value of 500 mg/L and reached to 2500 mg/L level. This increasing trend in sulfate levels is an indicator for domestic wastewater discharges made to the river along its course and agricultural runoff originating from the fields surrounding the plain.

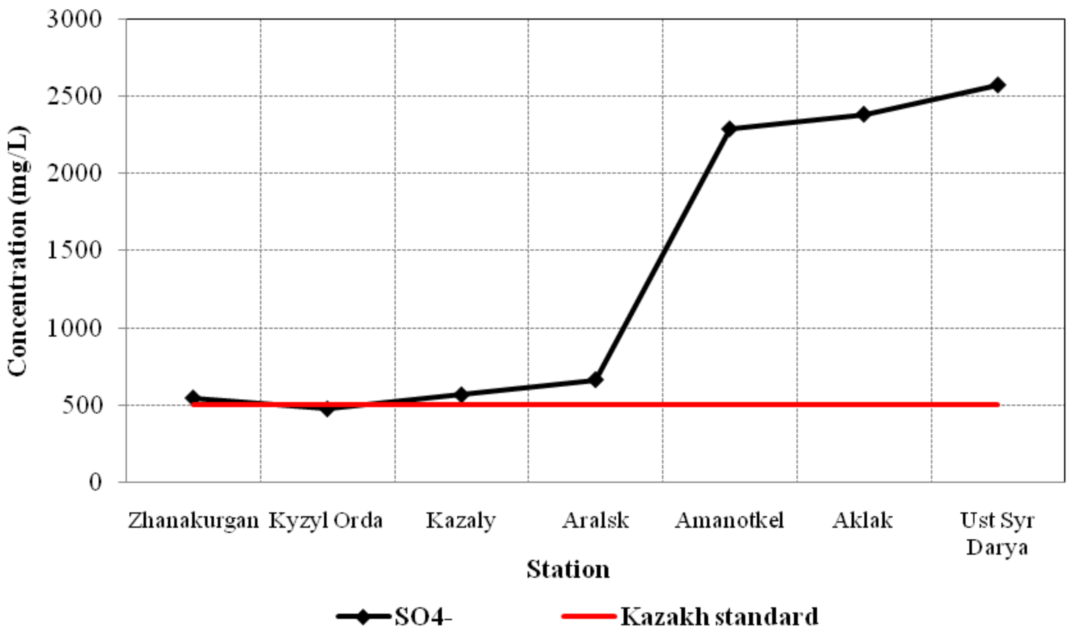

Figure 4.7 Average sulfate concentrations along Syr Darya River.

The time series plot of sulfate in the most upstream and most downstream stations along the river is given in Figure 4.8. Accordingly, the sulfate levels in the most upstream Zhanakurgan station is in the order of 500 mg/L and demonstrate a fairly stable pattern between 1970s and 2000s. These values satisfy the Kazakh water quality standard. On the contrary, the sulfate levels in the most downstream Ust Syr Darya station range between 1200 and 4500 mg/L. These values are above the standard and represent anthropogenic inputs to the river channel.

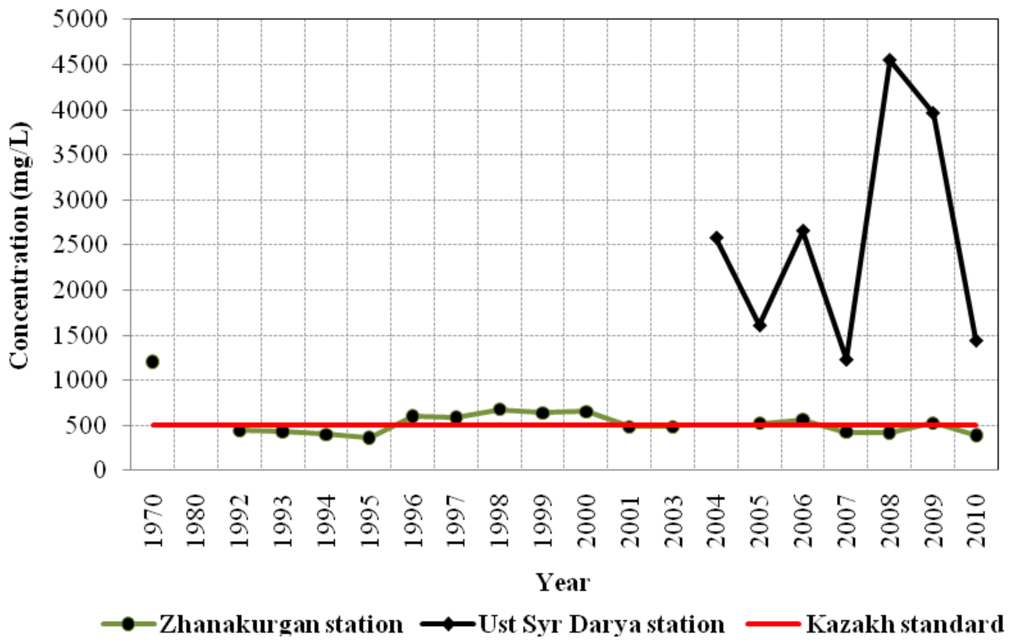

Figure 4.8 Time series graph of sulfate concentration in Zhanakurgan and Ust Syr Darya station.

Being strongly correlated with nitrogen fertilizers and waste discharges, the average ammonium-nitrogen (NH_4-N) concentration is presented in Figure 4.9. As indicated, the average ammonium-nitrogen values range from 0.30 mg/L to 1.10 mg/L by the stations along the river. Thus, it is clearly seen that the river receives ammonium-nitrogen loads along its flow, therefore creating a significant increase in concentrations. When compared to the water quality standard value of 0.41 mg/L, the ammonium-nitrogen levels were around the standard value till Aralsk station, beyond which concentrations progressively increased about 2-3 folds. This increasing tendency particularly between 2004 and 2006 is believed to be an indicator of industrial discharges such as chemistry and petroleum plants and agricultural runoff originating from the fields of surrounding plain.

The time series plot of ammonium-nitrogen in the most upstream and most downstream stations along the river is given in Figure 4.10. As seen from the figure, the river is more polluted in downstream sections. For instance; in 2004 in the Zhanakurgan monitoring station, the value of ammonium-nitrogen was about 0.30 mg/L, whereas, it reached up to the level of 1.40 mg/L in the Ust Syr Darya station.

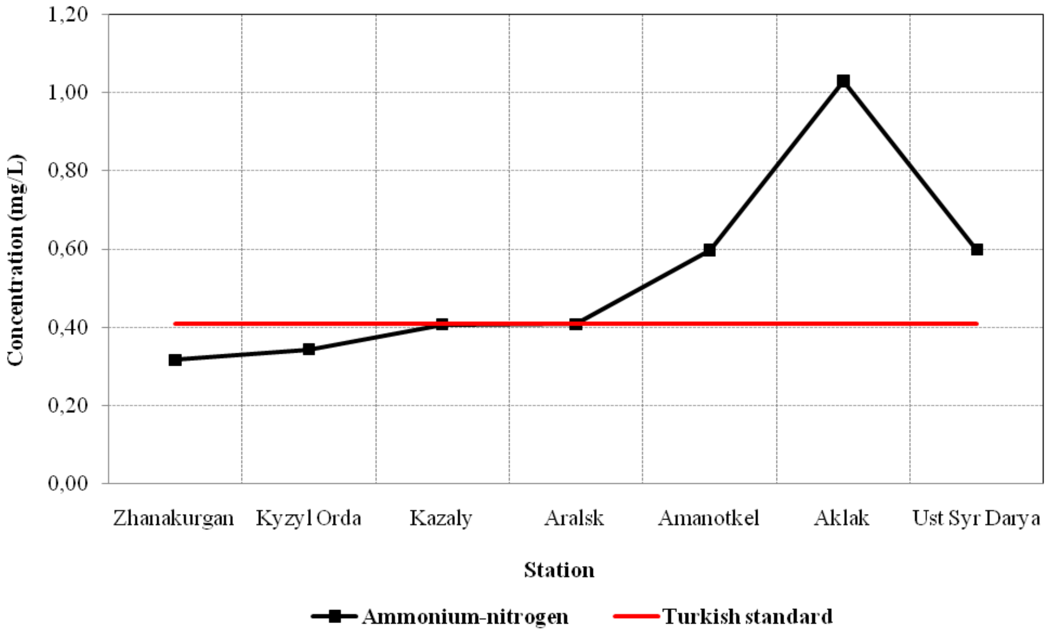

Figure 4.9 Average Ammonium-nitrogen concentrations along Syr Darya River.

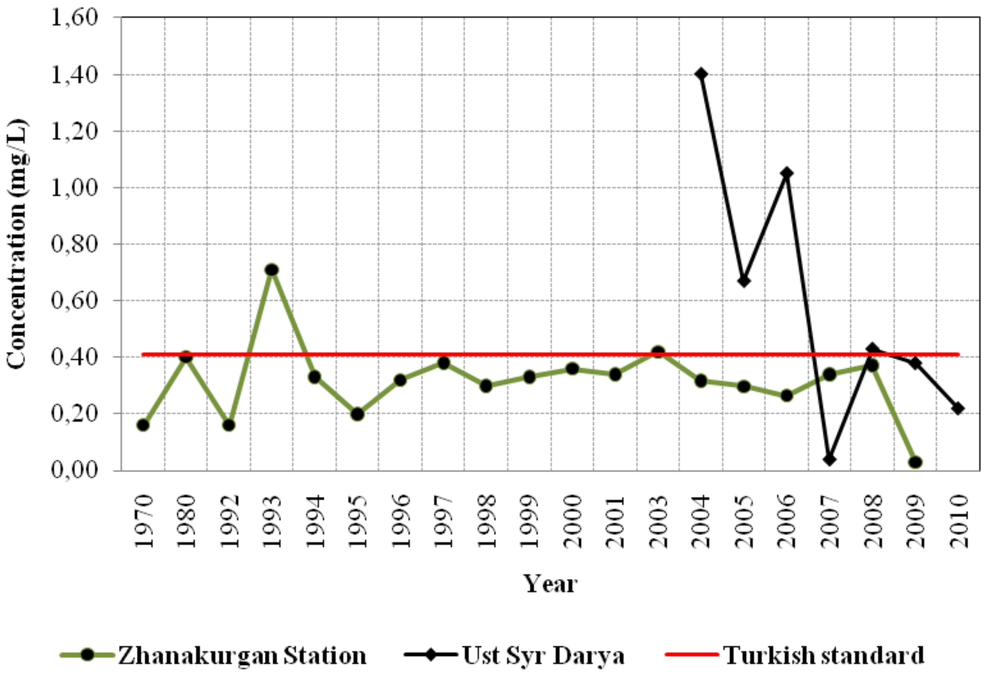

Figure 4.10 Time series graph of Ammonium-nitrogen concentration in Zhanakurgan and Ust Syr Darya station.

Of the several heavy metal species investigated, chromium, lead and cadmium levels are generally above the standard values. The average chromium concentration along the river is given in Figure 4.11. Similar to other parameters, chromium concentrations tend to be below the standard levels up to Aralsk station and dramatically increase thereafter. In Ust Syt Darya station, where the river meets the Aral Lake, the chromium concentrations are detected to be seven times higher than the Kazakh standard value of 50 μg/L. It is believed that these high values are related to uncontrolled industrial discharges from chemical, leather and textile industries situated along the river.

The time series plot of chromium in the most upstream and most downstream stations along the river is given in Figure 4.12. For instance, in 2005-2006 in the Zhanakurgan station chromium value was in the order of the standard, whereas it significantly increases in Ust Syr Darya station reaching to levels of 400-700 μg/L during the same time period. The values in this station then reduce to below standard levels after 2008.

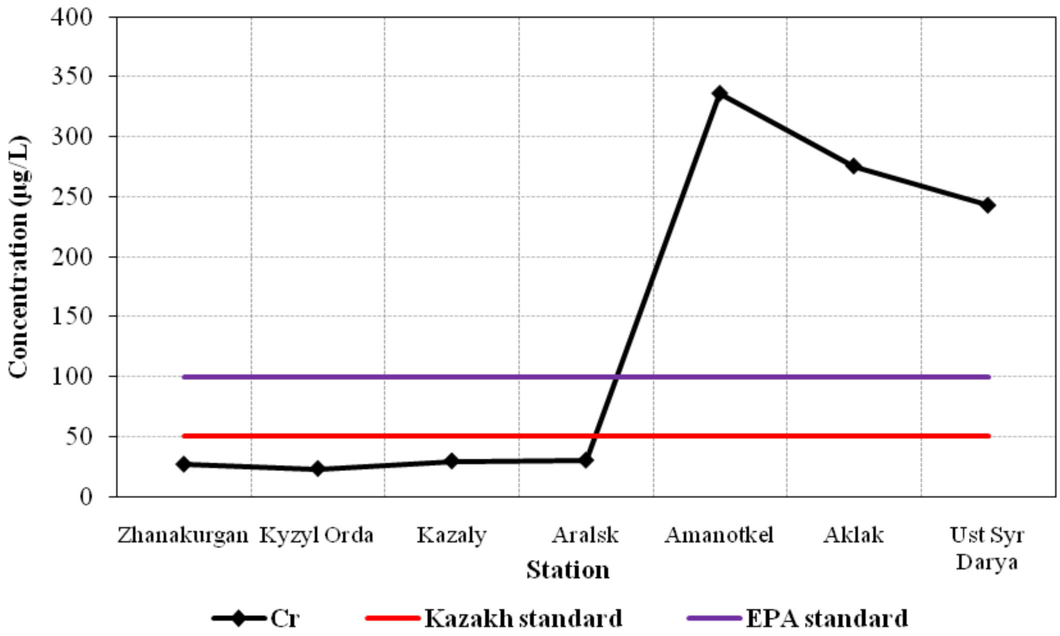

Figure 4.11 Average Cr concentrations along Syr Darya River.

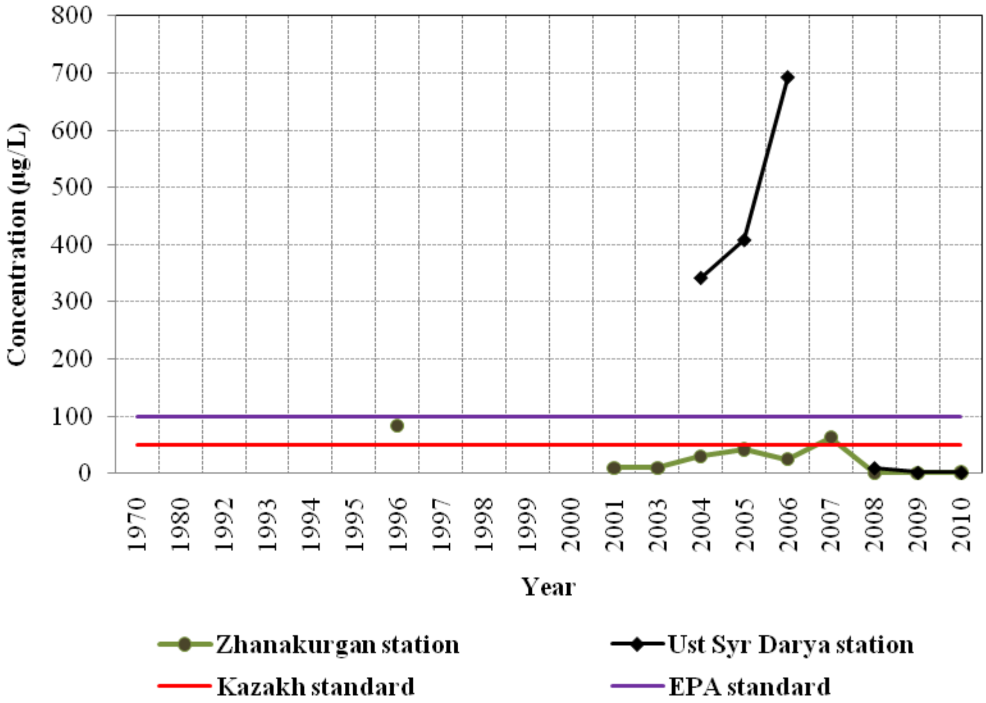

Figure 4.12 Time series graph of Cr concentration in Zhanakurgan and Ust Syr Darya station.

The average lead concentration along the river is given in Figure 4.13. It is seen that the lead levels were in the order of the water quality standard value till Kyzyl Orda station. After this point, concentration steadily increased from 3 to 4 folds above the standard value of 10 μg/L and reached to 43 μg/L level. This increasing tendency of lead levels is an indicator for industrial wastewaters discharges mostly chemicals industries to the river along its course.

The time series plot of lead in the most middle stream and most downstream stations along the river is given in Figure 4.14. Accordingly, variation of lead concentration by time had some noticeable changes. Concentrations in all stations had a radical decline after 2006 and reached to levels below the standard value. However, Ust Syr Darya station concentrations are still higher than their corresponding levels in Amanotkel station.

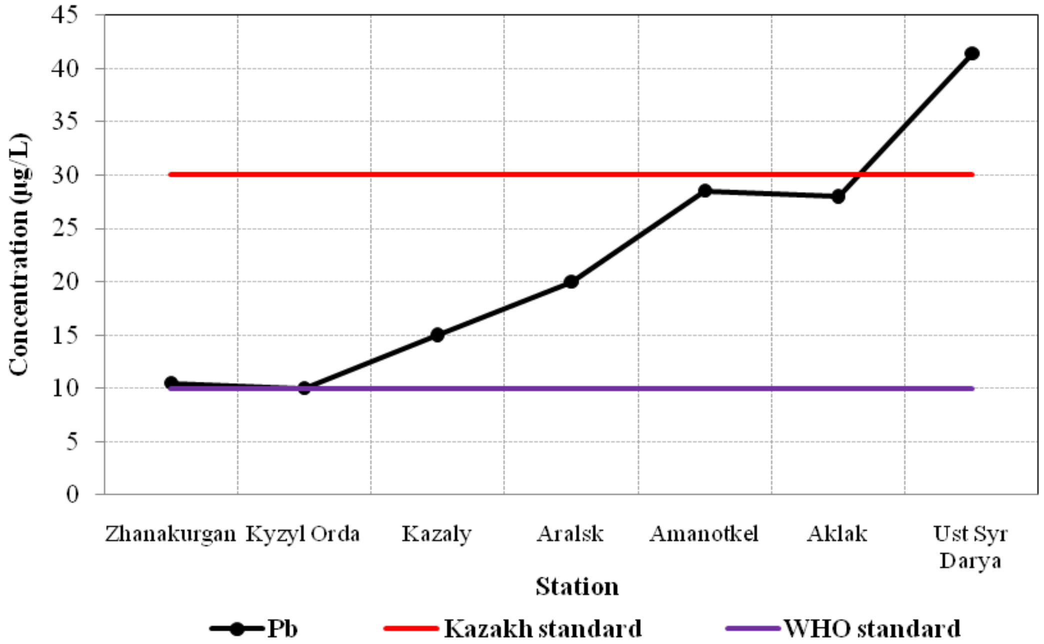

Figure 4.13 Average Pb concentrations along Syr Darya River.

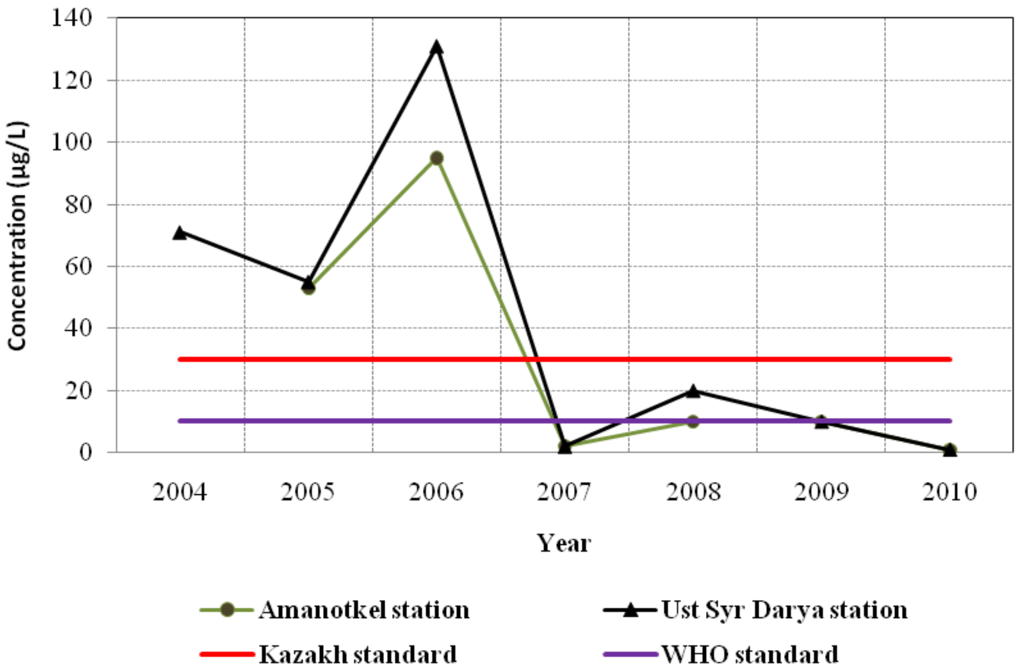

Figure 4.14 Time series graph of Pb concentration in Amanotkel and Ust Syr Darya station.

Finally, the average cadmium concentration along the river is plotted in Figure 4.15. It is seen that cadmium is not measured in the upstream reaches of the river. However, in downstream parts, particularly in the Ust Syr Darya monitoring station, the average concentration is found to be 5 to 6 folds above the required Kazakhstan water quality standard value of 1 µg/L and 2-3 folds above the WHO standard value of 3 µg/L, reaching to 6 µg/L levels. This increasing tendency of cadmium levels particularly between 2004 and 2006 along the river particularly at Aralsk station is suspected to be related to industrial wastewater discharges from chemical and automotive industries.

The time series plot of cadmium in the middle and downstream stations along the river is given in Figure 4.16. As seen from the figure, the cadmium levels also decreased after 2006 following the trend of other parameters, however, started to increase again in 2010.

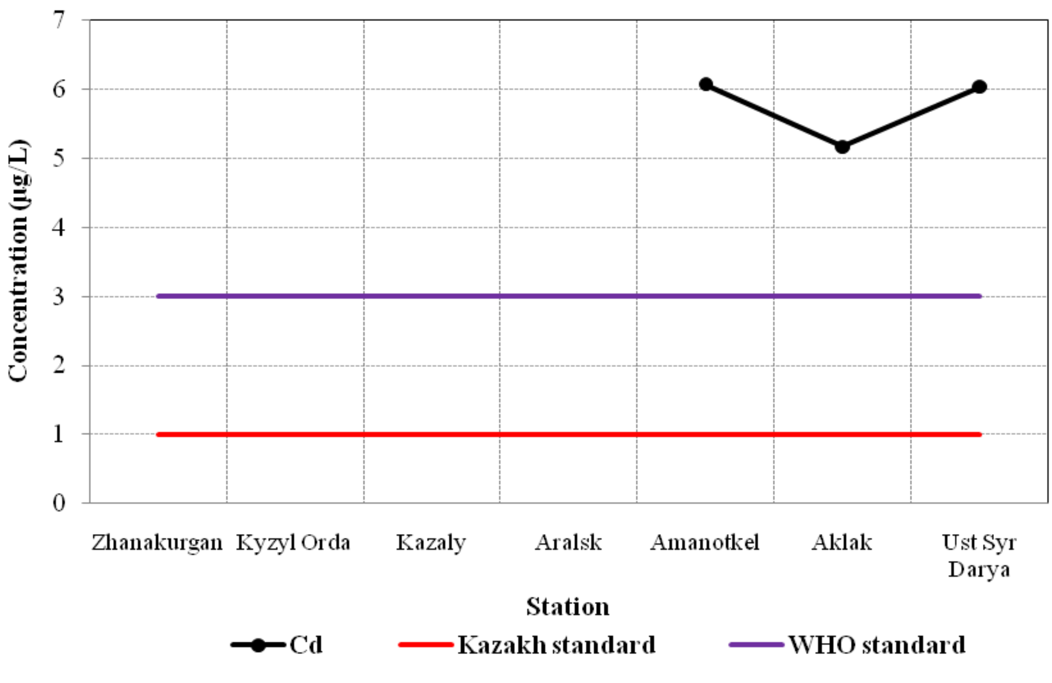

Figure 4.15 Average Cd concentrations along Syr Darya River.

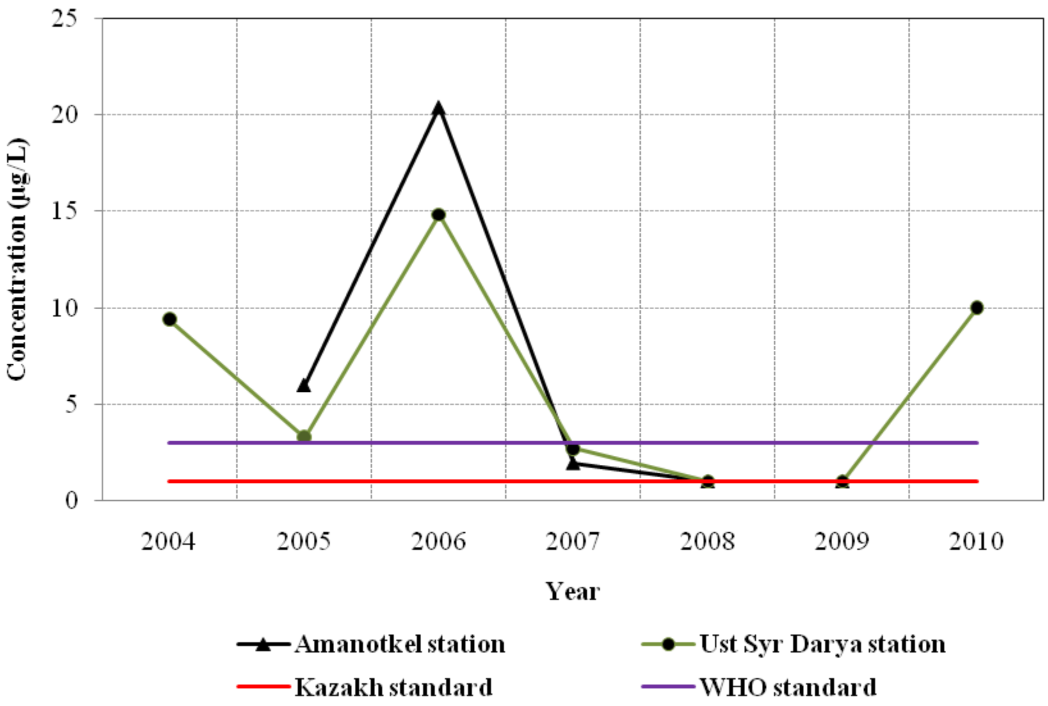

Figure 4.16 Time series graph of Cd concentration in Amanotkel and Ust Syr Darya station.

4.2. Case study: Aral Sea

The Aral Sea Basin is located in the heart of the Asian continent and covers the territory of present Tajikistan, Turkmenistan, Uzbekistan, Afghanistan, Iran, Kyrgyz Republic and the Southern parts of Kazakhstan (Figure 4.17). In essence, up to 25.1% of the entire flow in the Aral Sea Basin is formed in Kyrgyzstan, 43.4% in Tajikistan, 9.6% in Uzbekistan, 2.1% in Kazakhstan, 1.2% in Turkmenistan, and 18.6% in Afghanistan and Iran (Roll, et al. 2004). The territory of the Basin has two main morphological zones: the Turan plain that includes the central and western parts of the basin and the mountain zone that includes the eastern parts f the basin. Within the Turan plain, the Kara Kum desert covers the western and the south-western parts of the Aral Sea Basin, where as the Kyzyl Kum desert covers the northern part. The mountain area includes the Tien Shan and Pamir ranges, with the highest peaks above 7000 meters. Thus, the basin covers a wide range of geographical regions and consists of deserts, foothills, and valley regions with low precipitation and high evaporation as well as mountain areas with high precipitation and low evaporation.

The Aral Sea is an inland sea to which the entire Aral Sea Basin is discharged into. It was the fourth largest inland sea after the Caspian Sea, the Great American lakes and the Lake Victoria in Africa. Currently, the Aral Sea is considered one of the most critical environmental zones in the world. In 1918, the Soviet government decided that the two rivers that fed the Aral Sea, the Amu Darya River in the south and the Syr Darya River in the northeast, would be diverted to irrigate the desert land, in order to attempt to grow rice, melons and cotton. This was part of the Soviet plan for cotton, or "white gold", to become a major export item of the union. In the region, the construction of irrigation canals began on a large scale in the 1940s. Most of the sea's water supply had then been diverted to irrigation canals, and in the 1960s the Aral Sea began to shrink.

Figure 4.17 The Aral Sea Basin

The climate in the region is sharply continental, mostly arid and semi-arid. While the southern parts have a more subtropical climate, the climate in the northern part is continental. In the high mountainous areas, the annual precipitation totals range between 800 to 1600 mm (Klotzli & Stephan, 1994). However, in desert regions, the precipitation totals only sum up to 80 to 150 mm. In the basin, summer temperatures could reach up to +40°C, whereas, the winter temperatures fall to -20°C.

The total population within the Aral Sea Basin was about 42 million in 2000, of which almost 63.6% lives in rural areas. Since 1960 till 2000, the population in the Basin has grown about 35% from 14.6 to 41.8 million people (Table 4.12). The fertile soils were the basis of the prosperity of the rural population. In the region, about 59.4 million hectares are considered to be cultivable, of which only about 17% are actually used. Agriculture, for the most part irrigated, cattle breeding and fishery, have always been vital for the livelihood of population who live in rural areas.

Water demands in Central Asia are dominated by the needs of agriculture, accounting for 92% of the total use, industrial requires 2%, municipal 3% and the remaining 3% are required for rural water supply, fisheries and other miscellaneous uses (Anderson & Robert, 1997). Inefficient irrigation systems and mismanagement of irrigation water diversions have resulted in not only the loss of Aral Sea but also created elevated water and soil salinity levels, widespread environmental degradation and diminished agricultural productivity. Irrigated areas in the Aral Sea basin grew rapidly from 4,510,000 ha in 1960 to 6,920,000 ha in 1980 and to about 8,000,000 ha in 2000 (Table 4.12). Total water intake for irrigation had been rapidly increasing by the beginning of the 1980s.

Table 4.12 The basic parameters of water–land resources development in the Aral Sea Basin.

Indicator	Unit	1960	1970	1980	1990	2000
Population	million	14.6	20.3	26.8	33.6	41.8
Irrigated area	1000 ha	4510	5150	6920	7600	7896
Water diversion	km^3/yr	60.61	94.56	109.69	106.27	85.0

4.2.1 Water quantity

The size and water balance of Aral Sea is fundamentally determined by river inflow and evaporation from its surface. Once the world's fourth largest lake, the Aral Sea has dramatically shrunk since 1960s. In 1900s, the area and the volume of Aral Sea were 68,320 km^2 and 1066 km^3, respectively. The Aral Sea Basin receives the bulk of its water from the two major rivers of the region, the Amu Darya and Syr Darya with a combined average annual flow of 115.6 km^3. The average annual river flow in to the Aral Sea during 1927-1960 periods was stable. The large-scale development of water resources, mostly for irrigation, has changed the hydrological cycle in the region and caused serious environmental problems in the Aral Sea Basin.

Between 1911-1960, the rivers and groundwater discharges into the Sea contributed about 53-54 km^3/year while precipitation contributed about 6-8 km^3/year. However, during the same period, the loss through evaporation was 60-63 km^3/year, and the water deficit was about 1 km^3/year (Figure 4.18). Upon completion of the irrigation projects in the area, the rivers and groundwater discharges into the Aral Sea declined to 11-13 km^3/year and precipitation declined to 3-5 km^3/year in 1971-1980. However, evaporation loss still ranged between 50-52 km^3/year, creating a water deficit of about 34-36 km^3/year. The difference between rivers inflow and net evaporation was particularly pronounced during the 1970s and 1980s, with water balance deficits for both periods was above 33 km^3/year (Figure 4.18). Consequently, the surface area of the sea shrank by approximately 90% and the volume of the sea declined by about 70%.

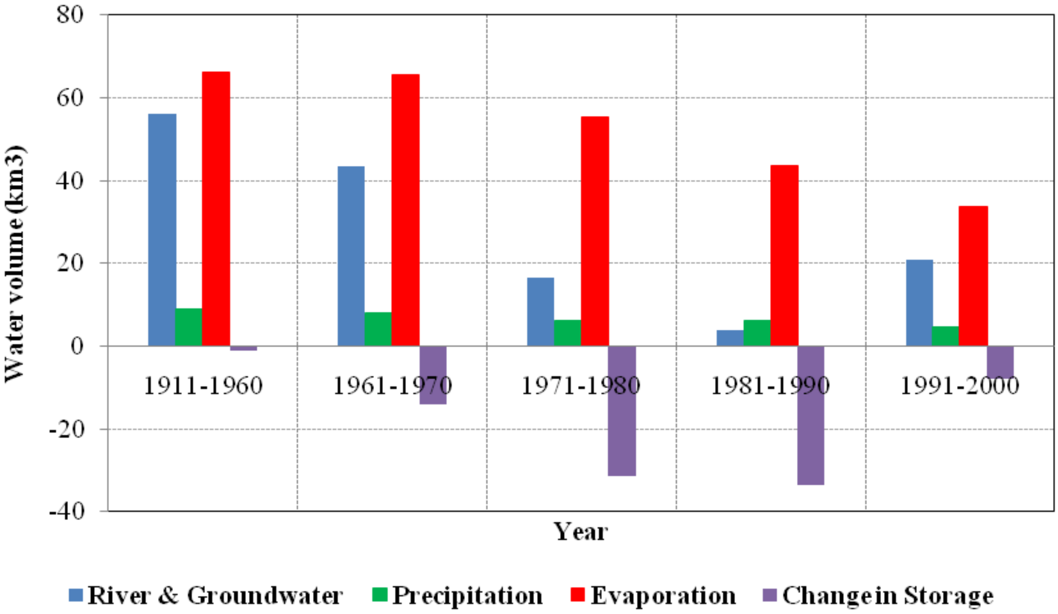

Figure 4.18 Water balance of the Aral Sea between 1911–2000.

The water quantity of two major rivers discharging into the Aral Sea plays the main role in the shrinkage of the Sea. In the regions of Uzbekistan and Kazakhstan, the river resource is mostly consumed for agricultural purposes. The change in water levels of Amu Darya and Syr Darya rivers are given in Figure 4.19 and Figure 4.20, respectively. For instance, in 1960 the Syr Darya river discharge contributed 43.4 km^3 whereas, in 1975 level of the river dramatically decreased to 21.7 km^3. Besides, the river discharge into Aral Sea also decreased significantly from 15.6 km^3 to 0.9 km^3 during the same period. Furthermore, in this period the level of Amu Darya River also significantly diminished from 42.1 km^3 to 11.4 km^3, with an average decline of 75%. In addition, the inflow into the Aral Sea declined from 37.9 km^3 to 10 km^3 during the same period. Comparing the change of the river levels, one could see that the greatest reduction in the both rivers has occurred during 1970s (Figure 4.19 and 4.20). In essence, water consumption in the regions due to irrigation has increased dramatically during the same period, which led to the catastrophic reductions in river discharge.

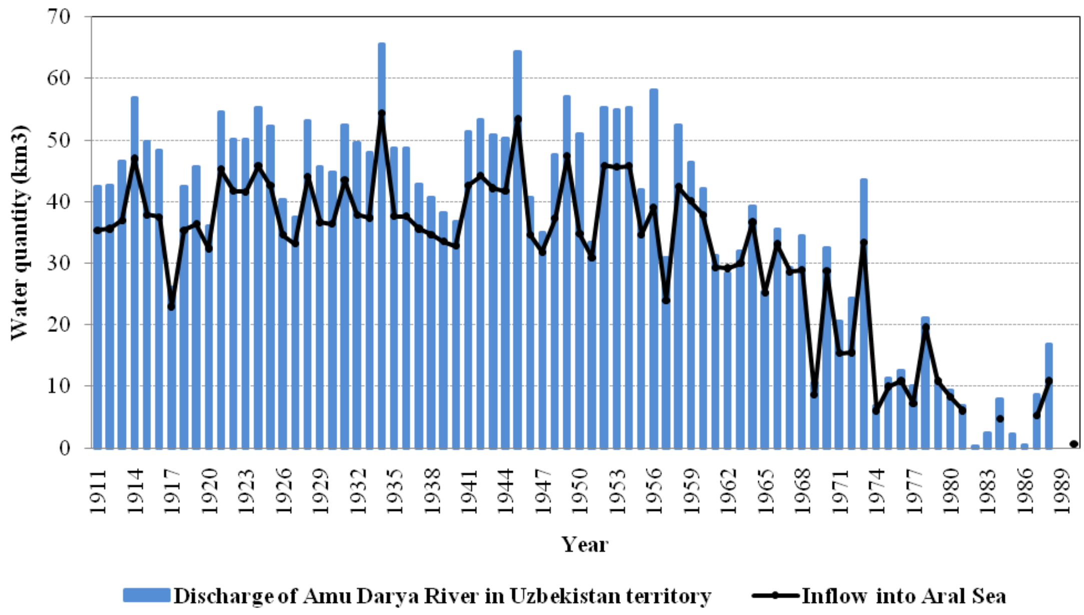

Figure 4.19 Amu Darya river water balance.

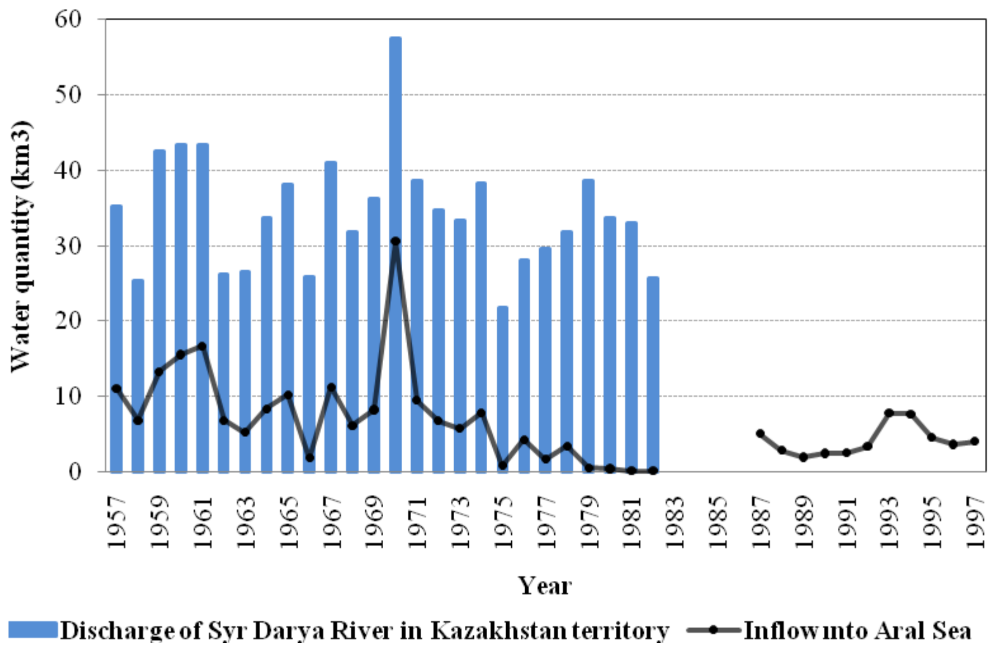

Figure 4.20 Syr Darya River discharge into Aral Sea between 1957-1997.

As a consequence of these reductions in river flows, the level of the Sea fell at an average of 20 cm per year from 1961 to 1970. This rate has approximately tripled to about 50–60 cm per year during 1970 and 1980. By 1980s, this declining trend continued and the sea level reductions further reached to about 80–90 cm per year. The rate of water usage for irrigation continued to increase during these periods and the amount of water taken from the rivers doubled between 1960 and 2000, during which cotton production nearly doubled. Consequently, compared with the status in 1960, the lake in early 1990s had shrunk about half its size and was 16 m below its former level. Furthermore, the surface area of the sea had dropped to 28,687 km² in 1998 (Gaybullaev, et al. 2008), and to 17,160 km² in 2004. Finally, in 2009, the surface area of sea has declined to 8112 km², which corresponded to only 11.8% of original size (Figure 4.21).

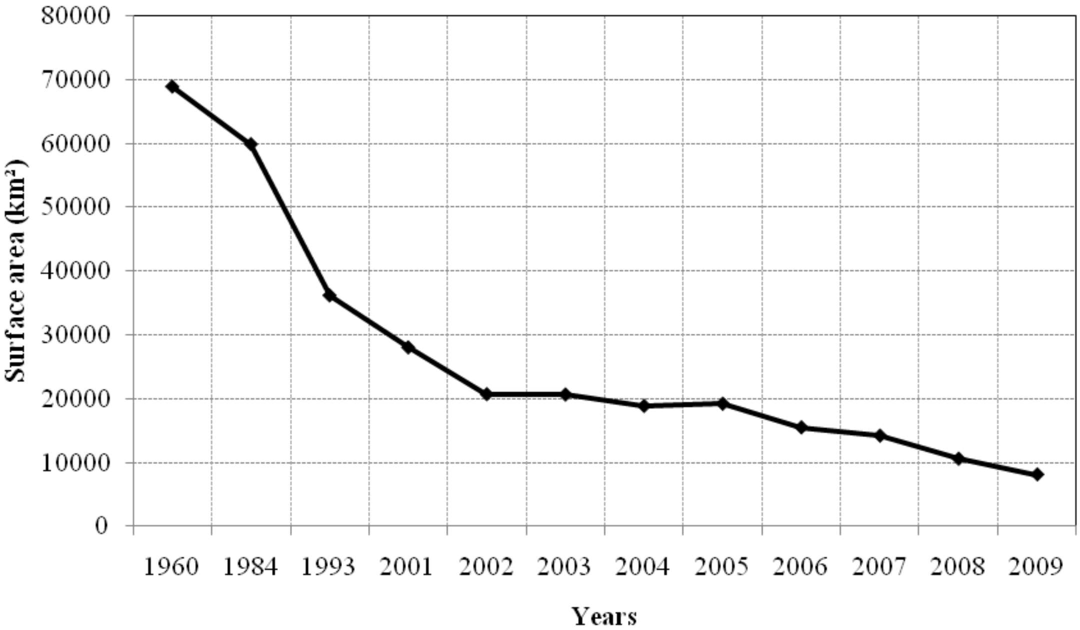

Figure 4.21 The decline in Aral Sea surface area.

Additionally, the volume of the Sea also appreciably decreased. For instance, the volume of the Sea was 972 km^3 in 1970 and decreased to 824 km^3 in 1975 (Figure 4.22). In 1990, the volume decreased to about 250 km^3, which corresponded to about 25% of its original size. The water level of the Sea is plotted in Figure 4.23. As seen from the figure, the level was 51.42 m in 1970, which then reduced to 45.76 m in 1980 and to 38.24 m in 1990.

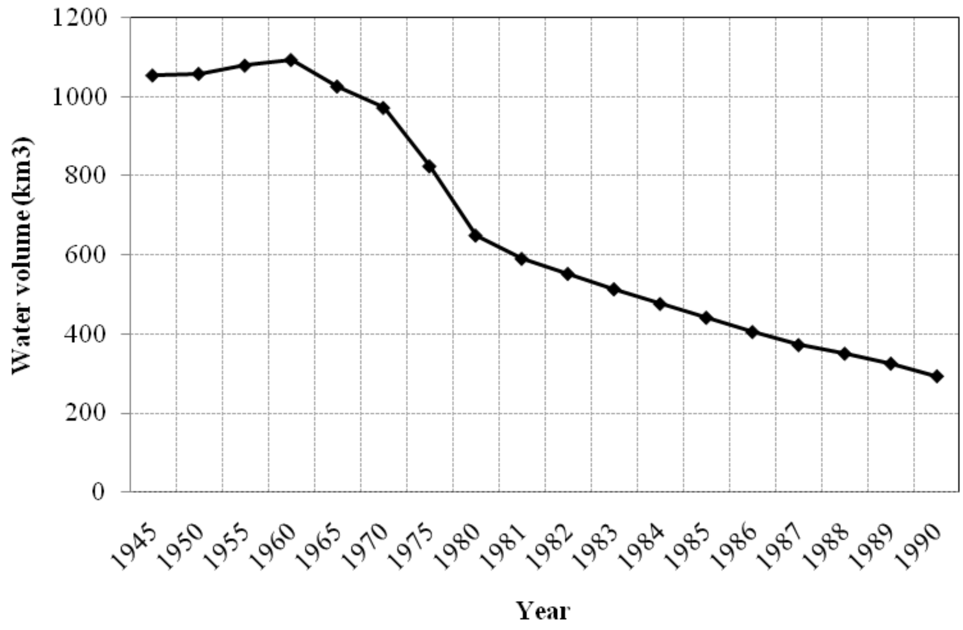

Figure 4.22 Aral Sea volumes before division.

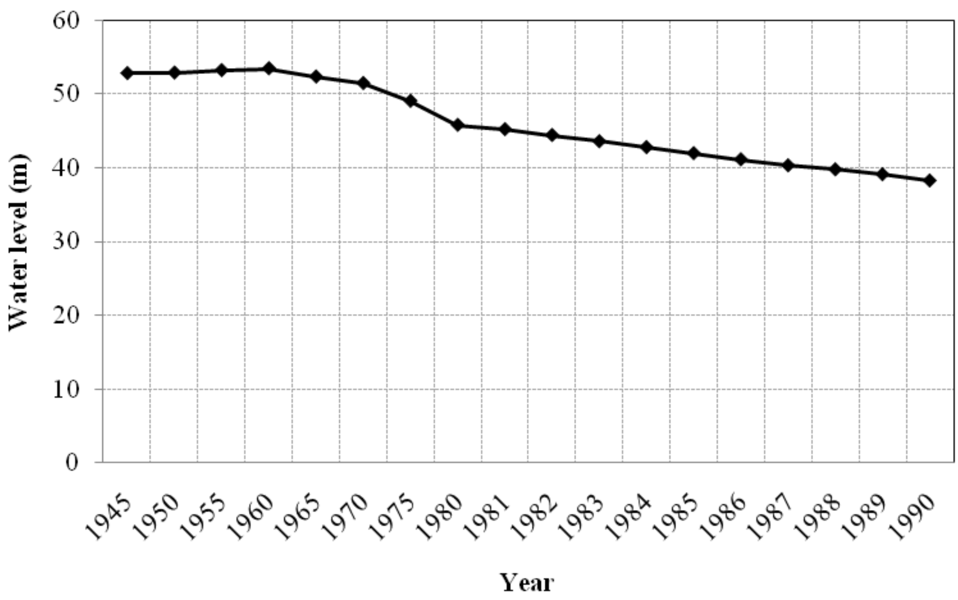

Figure 4.23 Water levels in Aral Sea before division

Consequently, due to the reduction of the volume and shrinking of the surface area, the Aral Sea divided into two parts in 1990 that are named as the Large Aral Sea and the Small Aral Sea. The water levels in the Large Aral Sea continued to decrease after the separation (Figure 4.24). However, the level in the Small Aral Sea has been fairly stable. Average annual inflow into the Small Aral Sea between 1999 and 2001 was near 5 km^3, with nearly 80% provided by the Syr Darya River (Micklin, 2004).

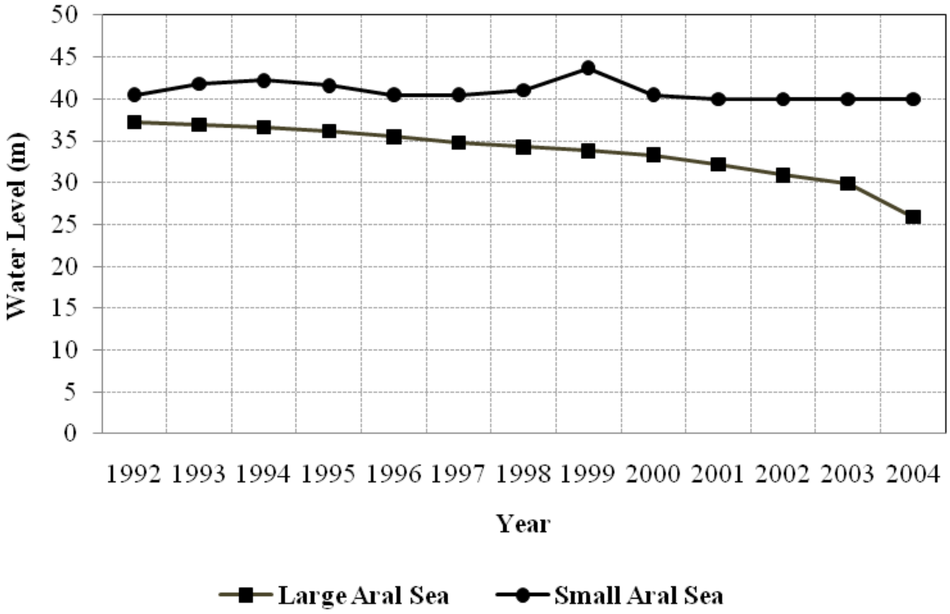

Figure 4.24 Water level in Large and Small Aral Sea

The two lakes have evolved in different ways. The Small Aral Sea, located in the North, receives run-off of the Syr Darya River and began to overfill due to positive water balance. The surface area of this lake is small, and evaporation from the surface is less than inflows from the Syr Darya, atmospheric precipitation and ground waters. As for the Large Aral Sea in the south, the water balance is negative, and evaporation from the huge surface is still higher than the small inputs of the Amu Darya River, atmospheric precipitation and ground waters (Aladdin, et al. 1995). A channel (river) has connected the two lakes, with flow from the Small to the Large Aral. This flow has been primarily during the spring/early summer period when discharge from the Syr Darya to the Small Aral is greatest (Michael, et al. 2005). Consequently, the area of both seas taken together diminished by 75% and the volume by 90%. Some of scientists claimed that if the tragedy continues in such rate then in future the Big Aral may disappear. Currently, the water balance of Small Aral Sea more stabilized. The shrinkage of Aral Sea between 1060 and 2009 is given in Figure 4.25 and snapshots the Small Aral Sea in 2010 is given in Figure 4.26.

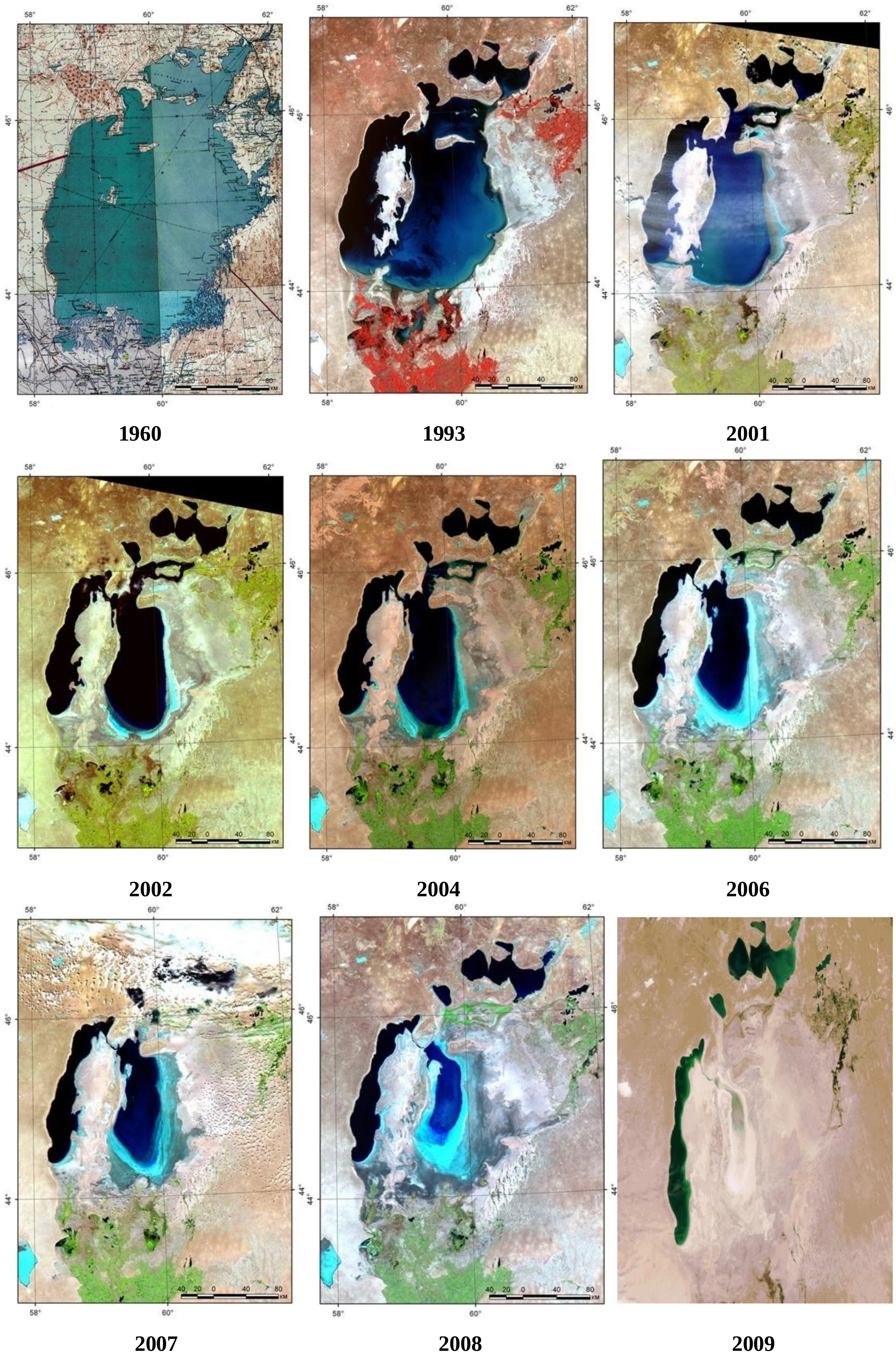

Figure 4.25 Aral Sea between1960-2009

Figure 4.26 Snapshots from Aral Sea in 2010.

This massive decline of the inflow to the Aral Sea has created a myriad of social, economic, and environmental problems. These include increased salinity of the sea by about 6 folds, reduced moderating effect of the Aral Sea on local climate, resulting in hotter summers, colder winters, and decreased growing season. Based on water balance calculations, restoring the Aral Sea to its pre-1960 size would require an annual inflow of about 53 km^3, while stabilizing the Aral Sea at 40-41 m would require an average inflow of 35 km^3/yr.

4.2.2 Water quality

The shrinking of the Aral Sea in Central Asia is considered one of the most dramatic examples of a natural area destroyed by human activities (Oral & Ataniyazova, 2003). The entry of pollutants into the Sea started to change in the middle 1970s, which was associated with a sharp reduction of inflow of heavily polluted river waters. Change of hydrological and hydrochemical regimes of the Sea, have led to the decline of fishery due the deterioration of conditions of fish habitats and critical decrease of reproduction of fish reserves. Regular observations of the chemical pollution of the Sea are made through a network of stations in Small Aral Sea as given in Table 4.13. The results of the water quality monitoring work in these stations between 1992-2010 are presented in Table 4.14 and 4.15.

Table 4.13 Small Aral Sea stations.

Stations	X	Y
25	60,868	46,208
27	61,034	46,220
29	61,184	46,268
7a	61,262	46,359
22	60,77	46,344
10	60,354	46,493
16	60,144	46,576
14	60,162	46,412
20	60,556	46,344
18	60,715	46,715
17	60,73	46,573
12	60,831	46,465
9	60,505	46,518
6	61,078	46,420
4	61,325	46,553

As seen from the data, the heavy metal levels in the Small Aral Sea is high compared to standard values, which is mostly associated with the pollutants entering the sea via Amu Daria and Syr Darya rivers. Particularly in the Small Aral Sea between 2004-2007 the numbers of heavy metal concentrations were excessively higher than the water quality standards. However, since 2007, all substances are significantly decreased.

Based on the data, the ammonium nitrogen is found to have an average concentration of 0.73 mg/L. As seen from the Figure 4.27, concentrations range between 0.02 mg/L to 2.50 mg/L. The values continued to be below the standard value till 2002 and started to increase dramatically until 2005. The concentrations then started to fall back to standard levels afterward. Thus, it is seen that the Sea received some additional ammonium-nitrogen load from the rivers which discharged into the rivers and created a significant increase in concentrations during 2000-2005 period. When compared to the water quality standard value of 0.41 mg/L, the concentrations progressively increased to about 3-4 folds the standard level particularly in 2005.

Table 4.14 Water quality of the Small Aral Sea (Greshev & Gresheva, 2010).

Year	Station	pH	O_2 mg/L	NH_4-N mg/L	NO_2-N mg/L	NO_3-N mg/L	PO_4 mg/L
1992	20	8.3	9.2	0.12	0.020	1.95	0.016
1994	20	8.2	9.8	0.02	0.050	1.80	0.003
1996	20	8.3	10.1	0.05	0.033	0.44	0.007
1998	20	8.4	10.3	0.20	0.067	6.33	0.008
2000	20	8.3	10.6	0.23	0.030	2.16	0.016
2002	20	8.3	13.0	0.04	0.080	0.75	0.080
2004	20	8.3	7.9	1.2	0.038	0.60	0.355
2005	20	8.4	14.6	2.50	0.072	3.40	0.045
2006	15	8.4	8.6	1.21	0.097	4.11	0.206
2007	15	8.4	13.6	1.50	0.255	3.40	0.260
2008	15	7.2	11.4	1.23	0.135	0.59	0.050
2009	16	7.3	12.5	0.83	0.101	0.43	0.025
2010	16	7.3	12.3	0.37	0.039	5.94	0.040
Minimum		7.20	7.90	0.02	0.02	0.43	0.00
Maximum		8.40	14.60	2.50	0.26	6.33	0.36
Average		8.08	11.07	0.73	0.08	2.45	0.09
Std. Dev.		0.47	2.03	0.76	0.06	2.05	0.11

Table 4.15 Water quality of the Small Aral Sea (Greshev & Gresheva, 2010).

Year	Stations	Cu µg/L	Zn µg/L	Pb µg/L	Ni µg/L	Co µg/L	Cr µg/L	Cd µg/L
1993	20							
1994	20							
1996	20							
1997	20							
1998	20							
2000	20							
2001	20							
2002	20							
2003	20							
2004	20	23.40	23.30	77.00	60.00	55.00	470.00	12.50
2005	7	25.40	24.30	93.40	64.00	72.00	680.00	16.10
2006	15	45.60	28.50	71.50	61.60	50.70	596.00	13.40
2007	15	21.50	40.60	5.30				3.70
2008	15	10.40	22.00	13.00			13.00	1.00
2009	16	26.80	17.50	7.30			17.00	0.40
2010	16	38.00	13.00	1.00			10.00	10.00
Minimum		10.40	13.00	1.00	60.00	50.70	10.00	0.40
Maximum		45.60	40.60	93.40	64.00	72.00	680.00	16.10
Average		27.30	24.17	38.36	61.87	59.23	297.67	8.16
Std. Dev.		11.46	8.79	40.24	2.01	11.26	318.57	6.38

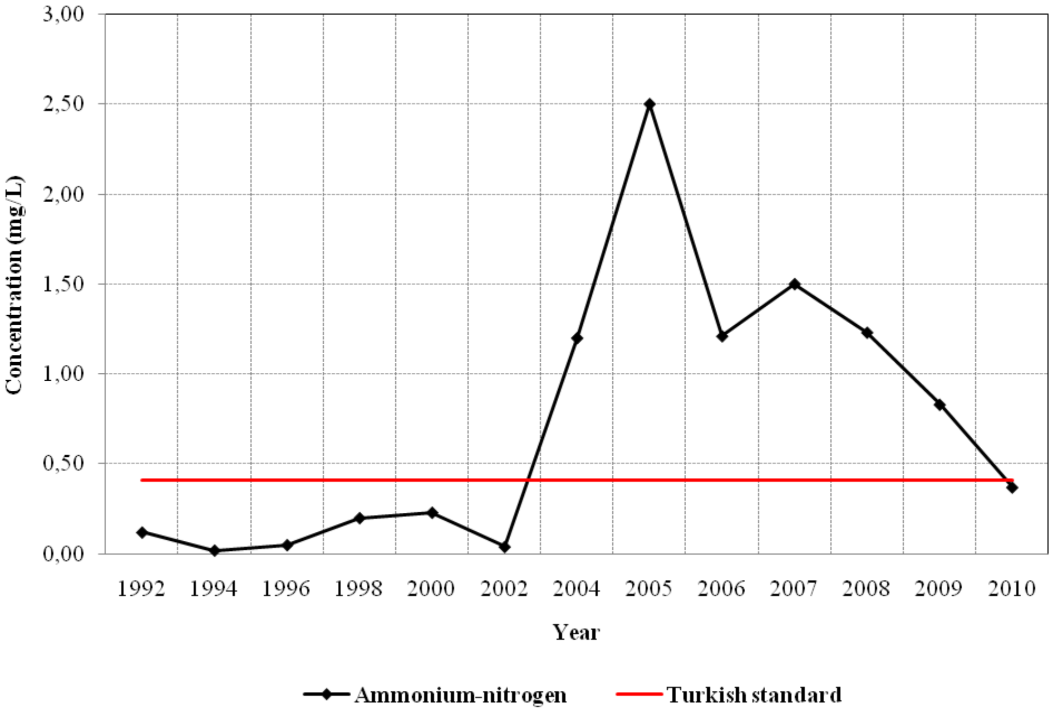

Figure 4.27 Ammonium-nitrogen concentration in Small Aral Sea

Of the several heavy metal species investigated, chromium, lead, cadmium nickel and cobalt levels are generally found out above the standard values. The change in heavy metals values by the year is plotted in Figure 4.28 thru Figure 4.31. For instance, in 2004-2005, the concentration of Pb was 77-93.4 μg/L, which corresponded to about 7-8 folds higher than standard value of 10 μg/L. However, since 2007 it significantly decreased in the order of the standard values and had levels in the order of 5 μg/L as shown in Figure 4.28.

The average Cr concentrations, on the other hand, contributed about 300 μg/L, which is about 6 folds higher than Kazakh water quality standard value of 50 μg/L (Figure 4.29). It is believed that these high values are associated with Syr Darya river water qualities, which directly discharge into the Small Aral Sea. It could further be seen from the Syr Darya water quality given in Section 4.1 that during the same period, the water quality in the Syr Darya River particularly in the Ust Syr Darya station also had high Cr levels that reached up to 700 μg/L. Consequently, poor source quality is the primary reason for degraded water quality in Small Aral Sea.

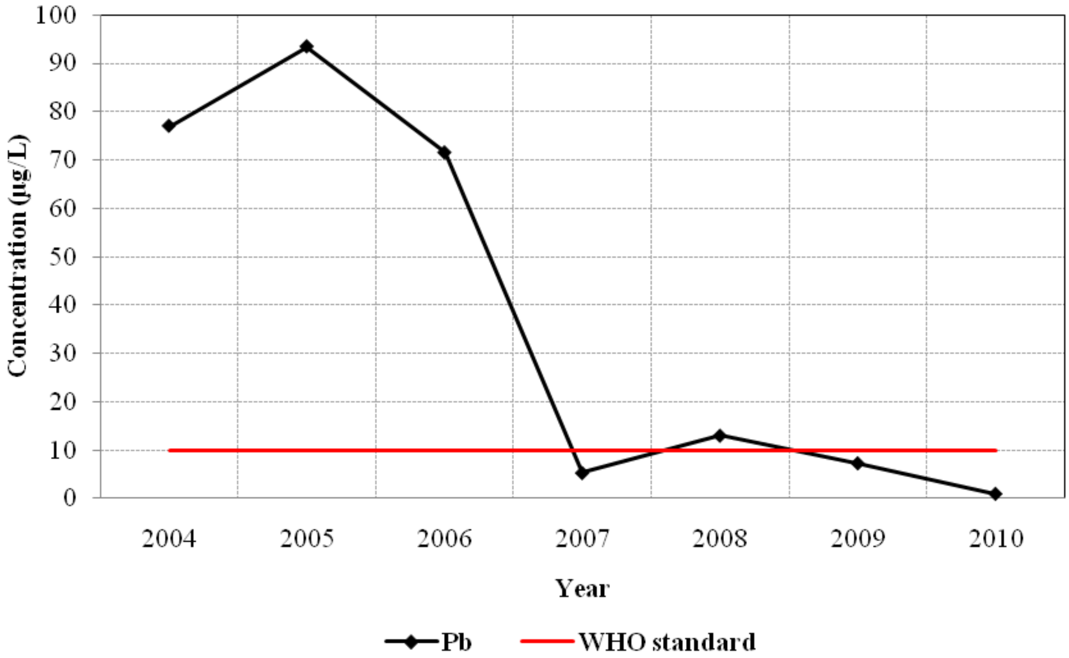

Figure 4.28 Pb concentration in Small Aral Sea

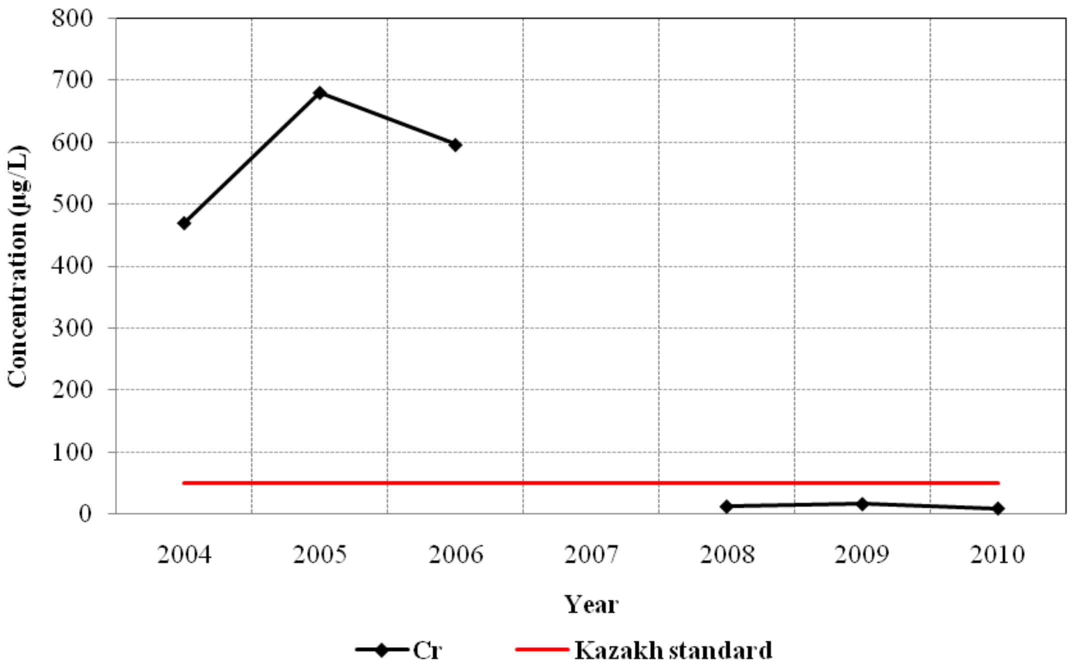

Figure 4.29 Cr concentration in Small Aral Sea

The rest of the heavy metals such as Ni, Co and Cd were also found to be above the water quality standards until 2006 and 2007. Since 2007 there is a significant improvement in water quality of small Aral Sea.

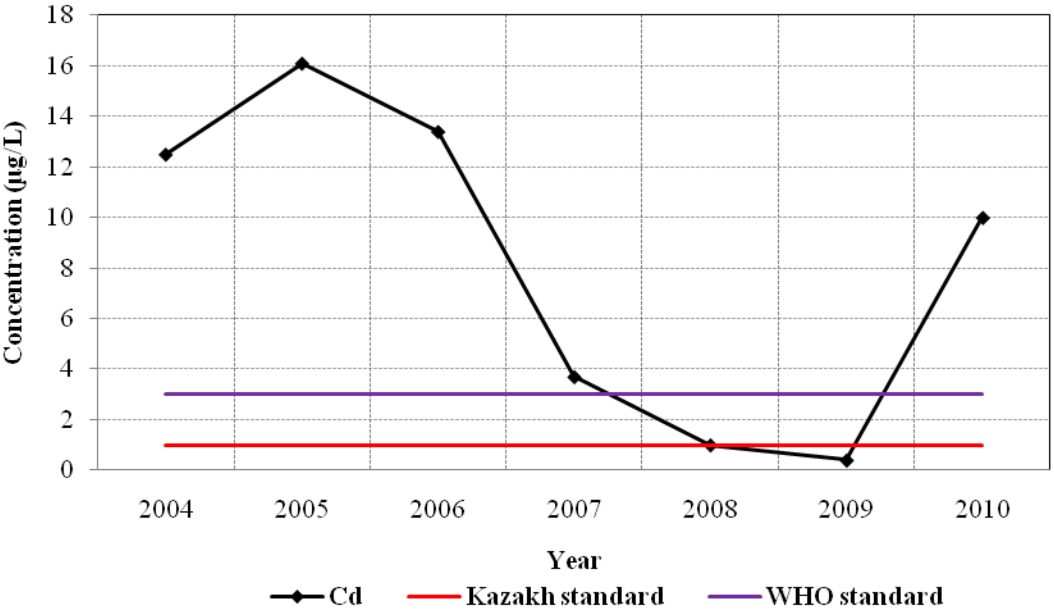

Figure 4.30 Cd concentration in Small Aral Sea

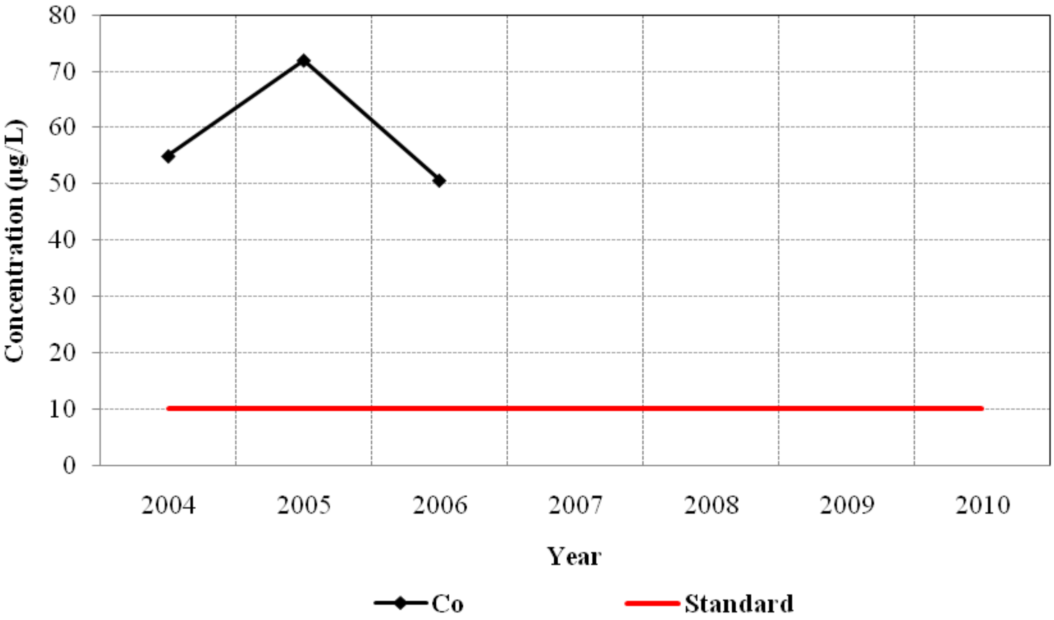

Figure 4.31 Co concentration in Small Aral Sea

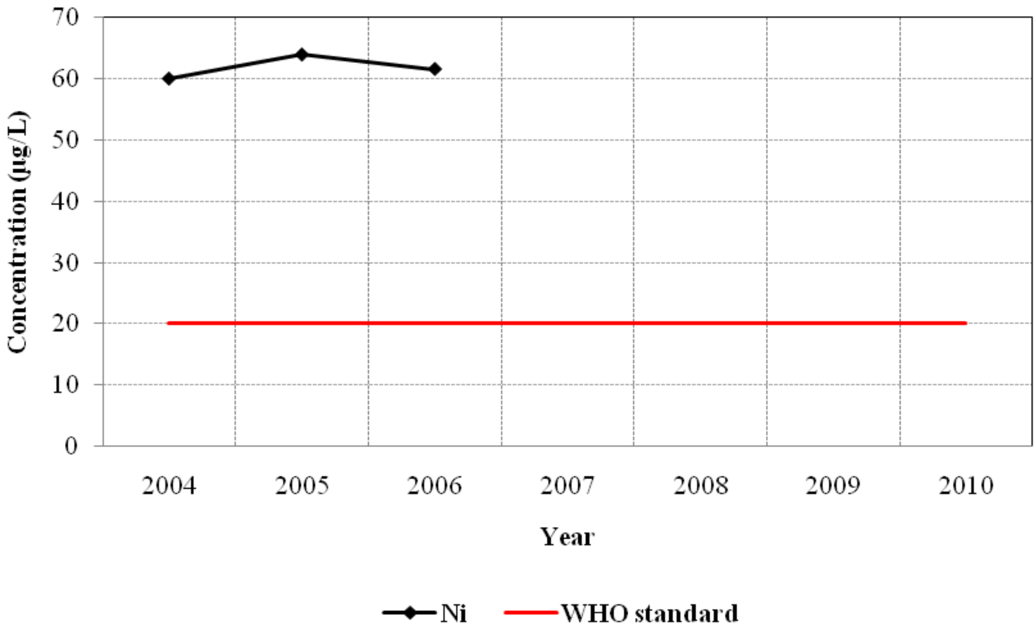

Figure 4.32 Ni concentration in Small Aral Sea

The spatial distribution of some water quality parameters are given in Figure 4.33 thru Figure 4.37. As seen from the figures, the heavy metal levels are found to be high in eastern and southeastern parts of the Sea to which Syr Darya river discharges into. Thus, the heavy metals loads transported to the sea yield high levels of the corresponding metals in close vicinity of the confluence point. It is important to note that these graphs are drawn by using the water quality data of 2009, which was available at all stations giving a distribution pattern. Nevertheless, it is believed that similar patterns were also valid in other years. It should also be mentioned that the spatial distributions were limited to Small Aral Sea where detailed data were available. Unfortunately, there is no data in the Large Aral Sea that would allow a characterization of Sea water quality. Furthermore, the Large Aral Sea has shrunk to such an extend that in many parts it no longer exist as a single piece of water body but rather is observed as small lagoons. Thus, no spatial distribution is provided fort the Large Aral Sea.

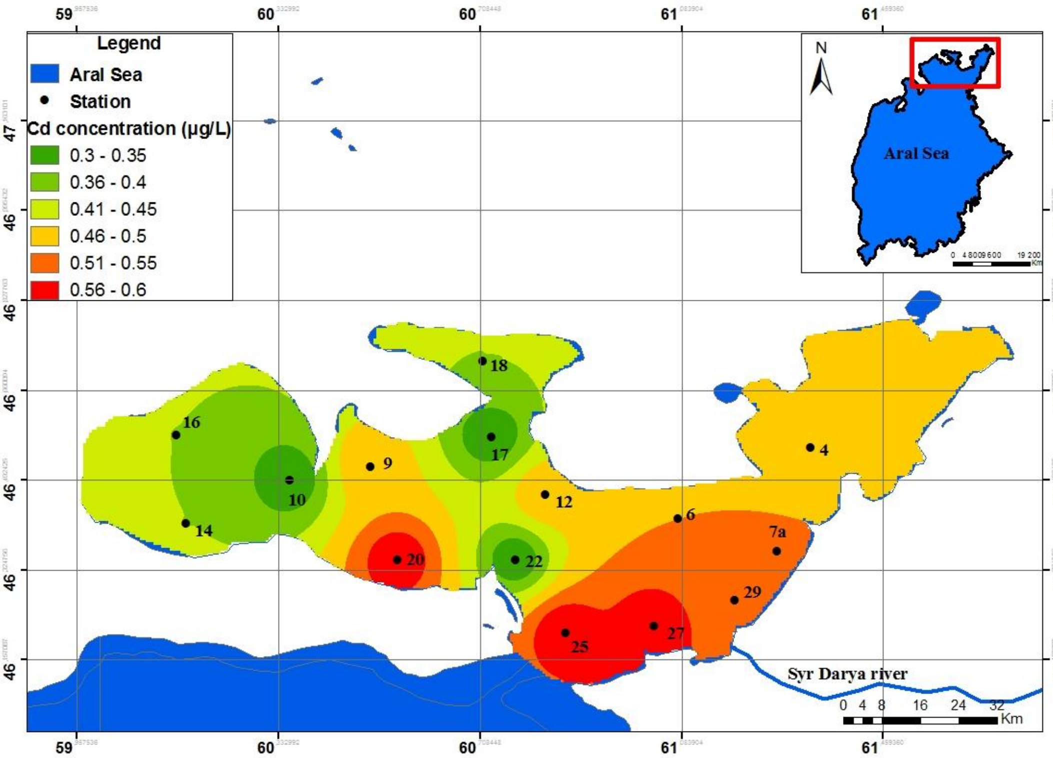

Figure 4.33 Cd concentration in Small Aral Sea Basin (2009 data).

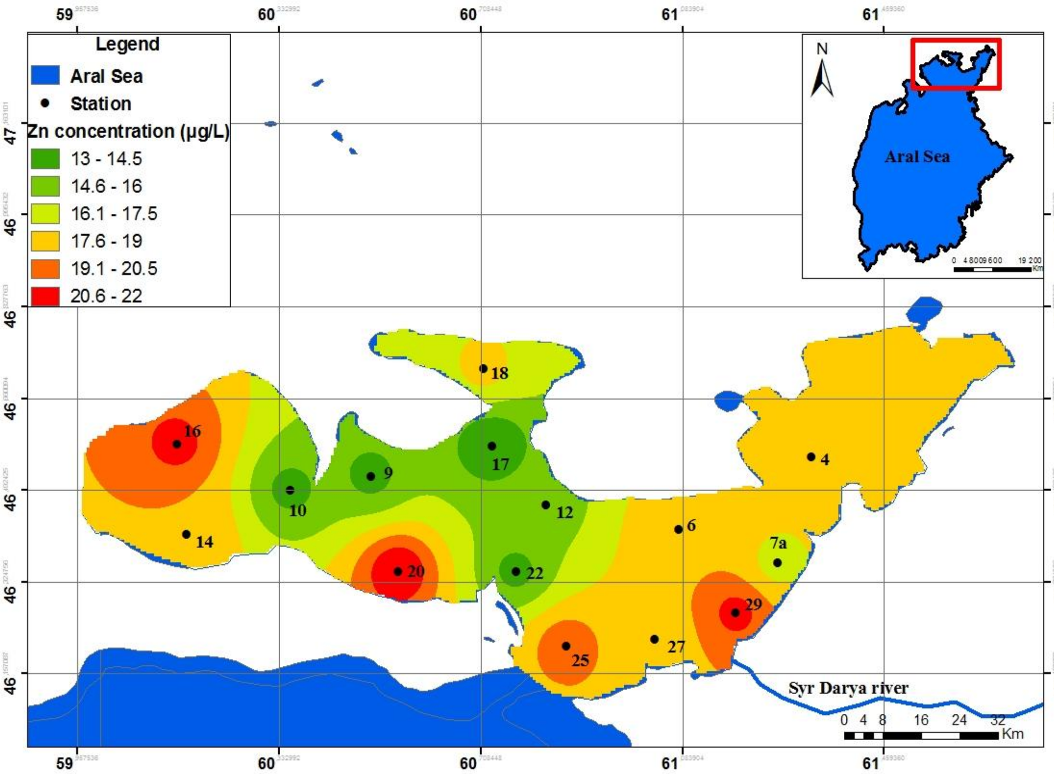

Figure 4.34 Zn concentration in Small Aral Sea Basin (2009 data).

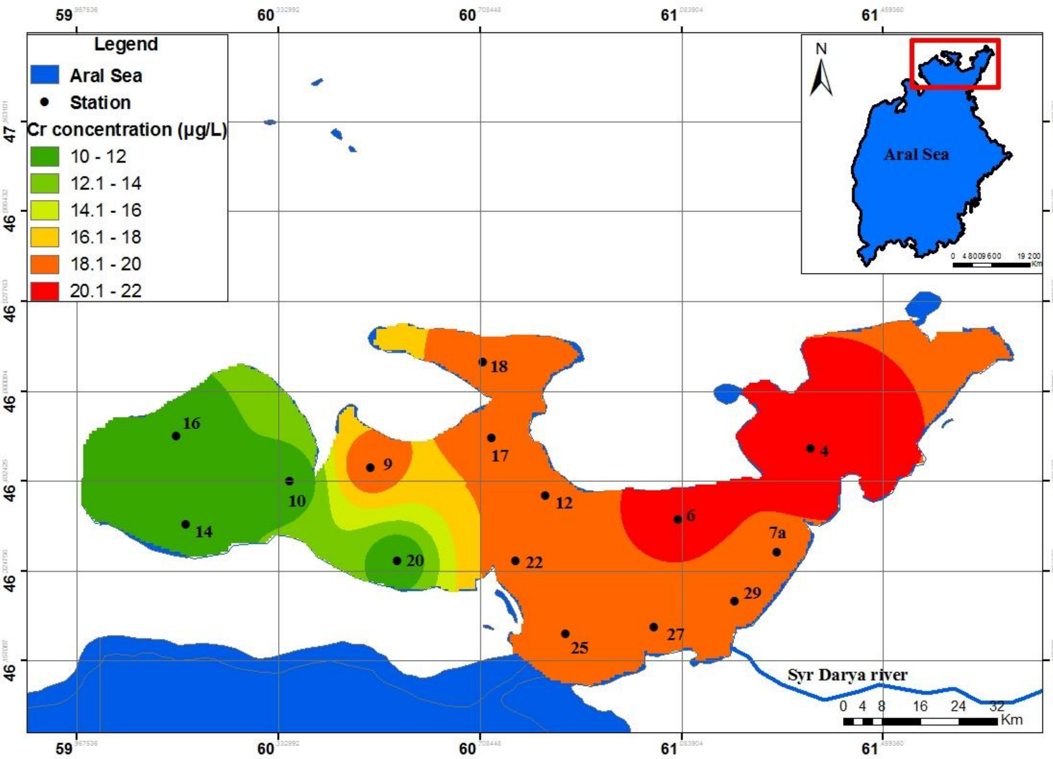

Figure 4.35 Cr concentration in Small Aral Sea Basin (2009 data).

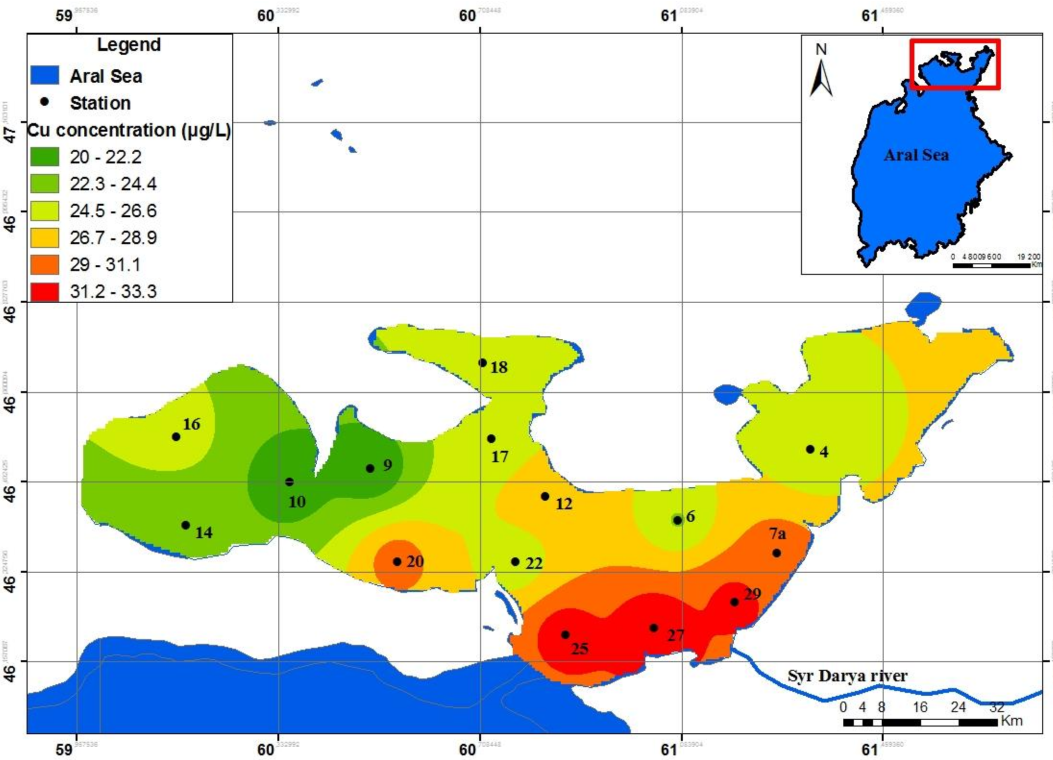

Figure 4.36 Cu concentration in Small Aral Sea Basin (2009 data).

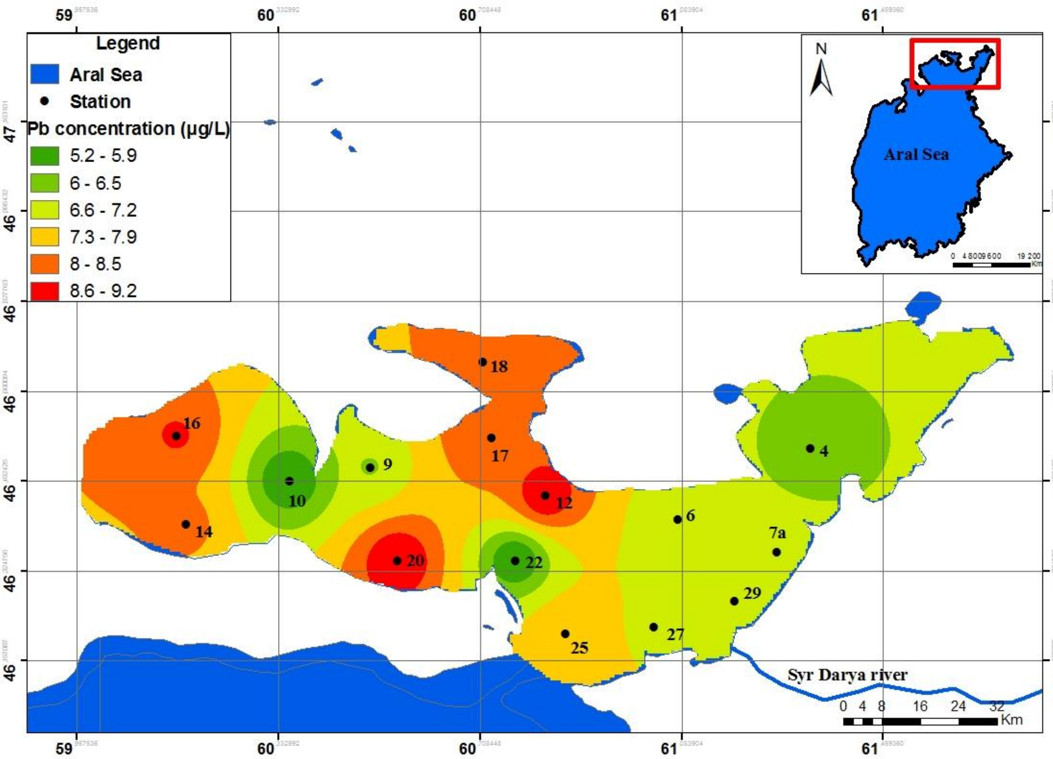

Figure 4.37 Pb concentration in Small Aral Sea Basin(2009 data).

Overall, the reduced water quantity and water quality in the Region has resulted in the loss of access to the Sea's water supply, fisheries, reed beds, and transport functions. This has impacted about 35 million inhabitants of the region. Moreover, far-reaching environmental and ecological problems, such as dust storms, erosion, and poor water quality for drinking and other purposes, have negatively affected human health and economic development in the region. Decreasing water levels and contaminated water resources has reduced the productivity of the region. Due to the shrinkage of the Aral Sea, the fishing industry has been virtually destroyed, and former fishing towns along the original shores have become ship graveyards. This has also resulted in unemployment and economic hardship.

The ecological catastrophe in the Aral Sea area is followed by deteriorating health in local inhabitants, particularly children. Diseases such as anemia, tuberculosis, kidney and liver diseases, respiratory infections, allergies and cancer seem to increase (Akmansoy & McKinney, 1997). From 1985 to 1994, the rate of spontaneous abortions (miscarriages) in Kyzyl Orda has increased by 70%. Average life expectancy in the region has declined from 64 to 51 years. When storms sweep around the sea, the air is filled with dust containing salt, heavy metals and pesticides. It has been calculated that about 140–150 million tones of salty dust annually is transported into the atmosphere. People living in the area are exposed to various toxic compounds when breathing contaminated air.

4.3 Case Study: Balkhash Lake

Balkhash Lake is the largest moderately saline lake in the Central Asia. The volume of the Lake is 105 km^3 with an average length of 600 km. Its width varies between 5 km to 70 km. The lake covers a total area of 413,000 km^2 and is considered the biggest lake ecosystems of Kazakhstan (Sopozhnicov, 1951). The Lake is situated in the southern semi-arid Kazakh uplands and is within the territories of Almaty, Zhambul and Karaganda provinces (Figure 4.38). While the large Betpak-Dala desert is situated to the northwest of the lake, Taukum, Saryesik-Atryan deserts are located to the southwest of the lake.

Morphologically, the Lake is divided with a narrow strait into two parts: western Balkhash and eastern Balkhash that has with different characteristics. In western part, the water is fresh with low salinity values, while the eastern part is fairly saline and has high total dissolved solids. While about 58% of the lake's total surface area is in the western part, only about 46% of the lake's volume is in the western part (Nauka, 1989). The mean depth of the eastern part is about 6 m, it is 1.7 times more than western part.

The major streams feeding into the Balkhash Lake, is the Ili river, which contributes about 78% from the total inflows as well as Karatal (16%), Lepsy (5.5%), Aksu (0.5%) rivers and number of small streams. All these rivers flow from the south and southeastern parts of Kazakhstan.

The climate around the lake is continental, with low annual precipitation that varies between 130-190 mm. The average winter temperature could go as low as about -22°C while in summer, the average temperature could reach to about +27°C. The total number of sunny days ranges between 110-130. Temperature in the lake, on the other hand, varies from 0°C in December to 28°C in July. Annually average temperature in western and eastern parts of lake varies between 9-10°C. The Lake annually freezes and the ice usually hold up from November until the beginning of April.

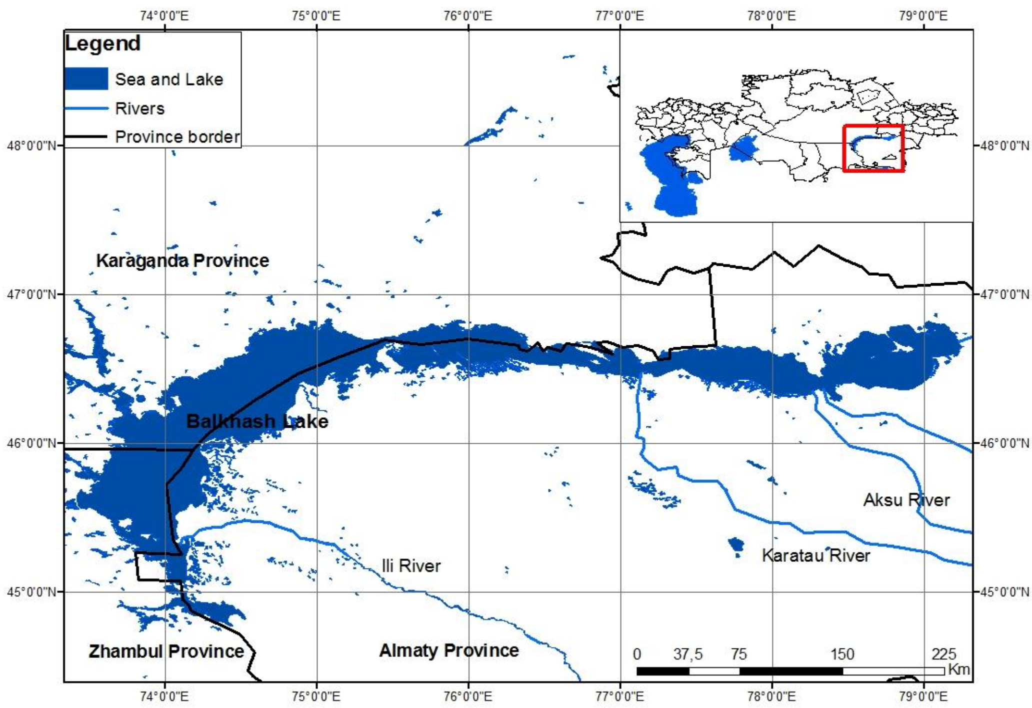

Figure 4.38 Balkhash Lake.

In the area surrounding the lake, the total population is about 3.3 million. This population mostly works in agriculture and industry which lead to excessive consumption of water resources of the Lake. Land use in the region by the different purposes is presented in the Table 4.16. As seen from the table, agricultural land in the region is about 2,45,000 km^2, which corresponds to approximately 60% of the land available around the lake.

Table 4.16 Land use near Balkhash Lake (Nauka, 1989).

Land use	Area [km^2]	[%]
Natural landscape		
- Woody vegetation	35 000	9.97
- Steppe & Semi-desert	63 000	17.94
- Lake and reservoir	7 600	2.2
Agricultural land		
- Pasture	184 000	52.4
- Irrigated crop-field	55 000	15.6
- Hay-making land	6 000	1.7
Others	450	0.13
Total	351050	100

4.3.1 Water quantity

The inflows to the Balkhash Lake originate from Tien Shan Mountains. The area and volume of the lake strongly depends on the changes in river flows and climatic factors such as precipitation to and evaporation loss from its surface. In 1930-1945 period, the surface area of the lake was to about 15,500-16,300 km^2 and the volume was about 83 km^3. During 1958-1969 era, the area of lake increased up to 18,000-19,000 km^2. During this period, the amplitude of the fluctuations of the lake elevation was about 3 m. However, since 1970s, the level of the Lake has significantly decreased due to the reduced river flows discharging into the Lake as a result of increased irrigational water demand and the storage effect of Kapchagay reservoir. Currently, the volume of the Lake is about 22.5 km^3, of which 18.5 km^3 originates from surface water discharges and about 3 km^3 originates from precipitation. Accordingly, the water balance of the Balkhash Lake is given in Table 4.17.

Table 4.17 Balkhash Lake water balance in 2000 (UNDP, 2009).

Water balance	Volume (km^3)
Current volume of the Lake consist of 22.5 km^3	
Surface water inflow	18.5
Groundwater inflow	0.9
Precipitation and ice melt	3.1
Water withdrawal consist of 24.6 km^3	
Evaporation	16.13
Housing and communal services	943.97 (million m^3)
Industry	2251.4 (million m^3)
Agricultural	5238.67 (million m^3)
Fish life activity	32.1 (million m^3)

As the economic development of the region was accompanied by the construction of artificial reservoirs such as: Kapchagay reservoir on Ili River and Bartogay and Kurtinskoe reservoirs on Chilik River. The artificial hydrological network is presented by system of irrigational and drainage channels, where rice irrigation system use about 166 million.m^3 of the water (Kreuzberg, n.d.). After intensive development of economic activity in the basin, the natural hydrological regime of the Lake was changed. The construction of the Kapchagay Reservoir on the Ili River led to additional adverse effects in Balkhash Lake since 1969. Speed of decreasing of water level of the Lake has made about 15.6 cm/year since 1970. The flow rate of Ili River into the Balkhash Lake in 1945-1990 is given Figure 4.39.

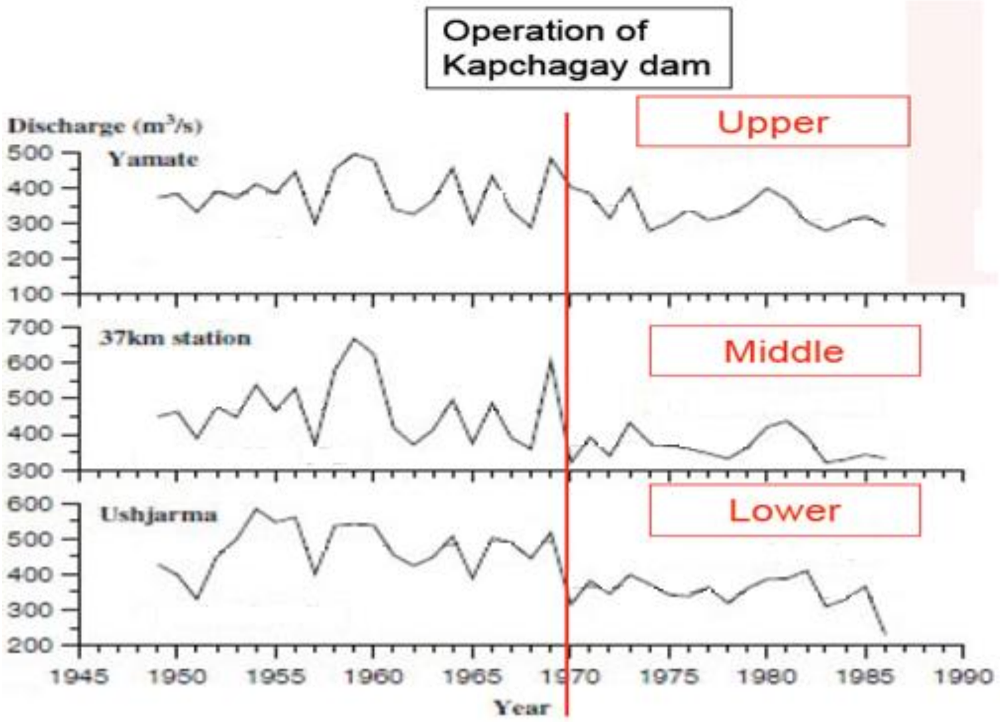

Figure 4.39 Changes in Ili River discharge into the Balkhash Lake, (Jumpei & Kubota, n.d.).

During the inundation of the reservoir, the water balance of the Lake has been changed, which also influenced the water quality in the lake. During 1970 to 1987 period, the water level has decreased about 2.2 m and the volume also declined to about 30 km^3 (Nurgaliev, 1988). Furthermore, changes in the operational mode of Kapchagay reservoir have led to the degradation of Ili river resources. The average annual discharge of the Ili River into the Lake contributed about 15.6 km^3/yr, which was about 84% of total surface discharge to the lake. The decline in water levels of influent rivers as well as the excessive water use for irrigation and industrial demands resulted in negative consequence on the hydrological and hydrochemical regime of the Lake.

In 1991, the total amount of water consumption from the Balkhash Lake increased almost twice and the inflows into the lake decreased that led to degradation of coastal territories, aquatic ecosystems and wetlands. During 1972 to 2001 period, there were about 16 lakes around Balkhash, whereas, only five remains nowadays that demonstrates the detrimental consequences of desertification. For instance, the Ayaguz River that used to discharge to the eastern shores of lake, now practically do not reach the lake. The changes of water level in western and eastern parts of the lake during 1993-2003 are given in Figure 4.40 and Figure 4.41.

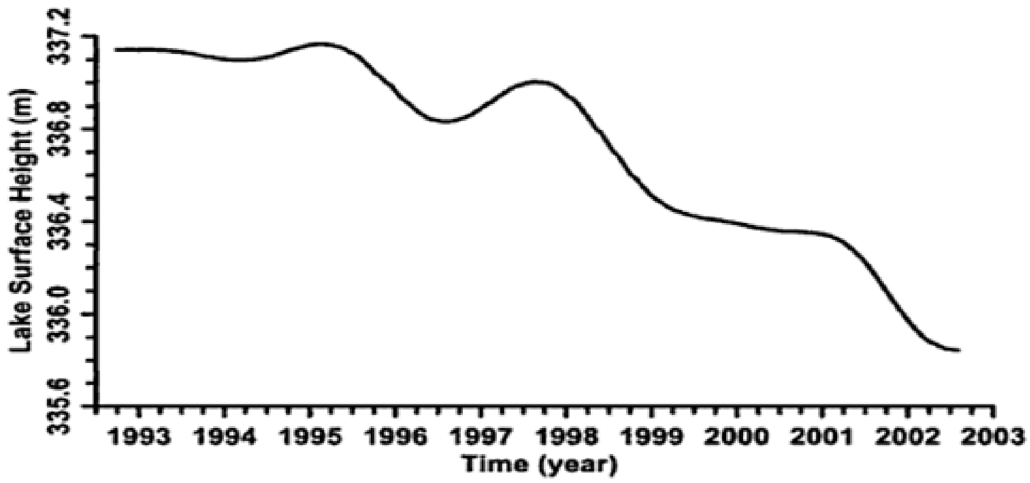

Figure 4.40 Western Balkhash Lake surface, (Kawabata, et al. 1999).

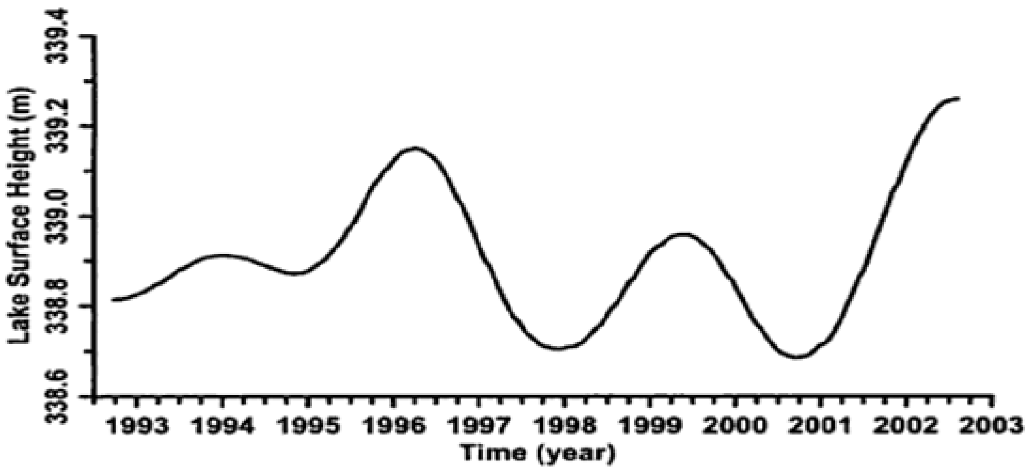

Figure 4.41 Eastern Balkhash Lake surface, (Kawabata, et al. 1999).

The stability of basin water balance depends also on amount of water coming from China territory. Currently, 77% of the average flow of Ili River originates from Chinese territory that corresponds to about 12 km^3. Of this total, about 4.4 km^3/year is used in Chinese territory (Kreuzberg, n.d.). According to forecast, the deficiency of water in China will increase every year, therefore withdrawal from transboundary rivers will grow. In future, the Chinese government plans to increase the withdrawal rate from Ili River to about 3.6 times the current value as a result of the active population growth in Xinjiang-Uyghur autonomous region. Experts say that environmental problems facing in the region could become a reason for social and environmental crisis, just like the one which existed in Aral Sea region. If mitigation measures are not implemented as soon as possible, Aral catastrophe could be repeated again.

4.3.2 Water quality

The morphological distinction of “eastern” and “western” parts of Lake Balkhash is also reflected in water quality. In essence, western part of lake is a typical fresh water resource (with a total mineralization of 0.74 g/L) that is used for drinking and agricultural purposes, while the eastern part of the lake is moderately saline (with a salinity value ranging between 3.5 to 6 gr/L) (Sopozhnicov, 1951). The water quality status of the western part of the lake is presented in Table 4.18. The water quality of the western part of the Lake is investigated based on this data set that included parameters such as pH, CL, Mg, Na, TDS and SO_4.

The spatial distributions of stations and some of these water quality parameters are given in Figure 4.42 thru Figure 4.48. As seen from the figures chemical substances Na, SO_4, CL, Mg and TDS were above the water quality standards commonly in the southeastern parts of the western Balkhash Lake. The Na concentration is lower in the western parts of the lake particularly in the stations of 1, 2 and 15 and contributed to about 40 mg/L. However, in the eastern parts, appreciably higher values of about 1120 mg/L, which is about 5-6 folds the water quality standard, are observed. Moreover, the SO_4 concentrations in this point of the Lake are also above water quality standard value of 500 mg/L and reached to 1318 mg/L. The rest of substances Cl, Mg and TDS concentrations are also higher from standards values and the distributions of the components are the same with previous substances distributions.

Table 4.18 Water quality of Western Balkhash Lake (Kawabata, et al. 1999).

Stations	Latitude N	Longitude E	Depth (m)	Transparency (m)	Temperature (^oC)	pH	Conductivity mS/sm	DO mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	SO_4 mg/L	CL mg/L	Alkalinity (meq/L)	TDS mg/L
St1	46,37015	74,06145			17.9	8.4	0.6	9.2	101.0	77.8	45.3	9.8	140	31	2.8	418.0
St2	46,41774	74,28355			10.9	8.4	0.6	10.3	112.3	80.2	45.3	8.2	157	35	2.8	436.0
St3	46,71678	74,80310			10.5	8.6	0.6	10.0	103.5	77.8	42.0	2.7	148	31	2.1	374.0
St4	45,50000	74,01000	1.7	0.3	21.2	8.8	2.3	7.7	80.2	218.7	468.0	35.6	648.0	322	4.9	1777.0
St5	45,58108	73,46516	5.8	0.3	21.8	8.8	1.9	6.5	83.8	165.2	303.0	18.0	455.9	210	4.0	1257.0
St6	45,76502	73,63312	3.9	0.3	21.9	8.8	1.9	7.2	80.6	162.8	318.0	21.1	451.0	213	4.1	2413.0
St7	45,76502	74,19630	0.3	0.3	19.1	8.8	3.4	9.5	63.0	274.6	732.0	41.0	888.0	483	5.0	2444.0
St8	45,53094	73,63709	1.8	0.4	20.4	8.4	3.4	8.2	76.6	286.7	660.0	42.2	897.0	430	5.8	1424.0
St9	45,38420	73,78780	1.8	0.3	21.4	8.8	2.1	8.6	78.6	182.3	351.0	14.9	535.0	241	4.3	1296.0
St10	46,16559	73,93057	5.8	0.3	22.3	8.8	2.0	7.0	77.0	172.5	321.0	22.7	470.0	217	4.1	2574.0
St11	46,02678	73,78780	0.4	0.4	21.7	9.1	3.6	7.4	70.1	298.9	768.0	54.7	940.0	469	6.2	2489.0
St12	46,03260	74,24544			22.0	9.3	3.6	7.7	66.2	296.5	741.0	49.2	902.0	472	5.9	2918.0
St14	46,07437	74,55324	1.7	0.5	21.4	9.0	4.1	5.8	74.6	342.6	861.0	49.2	1057.0	560	6.8	2519.0
St15	46,74066	75,06882	7.0	0.7	21.7	9.0	3.5		78.2	295.5	741.0	53.6	916.0	448	6.4	2571.0
St16	46,31233	74,78723	4.0	0.5	23.6	9.0	3.7	8.7	75.4	296.5	768.0	59.4	925.0	458	6.4	3603.0
St17	46,50667	75,06882	7.0	0.5	23.1	9.0	5.0	7.9	50.1	432.5	1119.0	90.0	1264.0	707	8.1	3605.0
St18	46,59392	75,32661	3.0	0.5	22.9	9.0	4.8	8.5	54.6	410.7	1110.0	86.8	1311.0	682	8.1	3638.0
St19	46,68911	74,60480	13.6	1.5	21.8	8.9	5.0	6.7	47.7	410.7	1104.0	91.1	1306.0	714	8.3	3740.0
Max			13.6	1.5	23.6	9.3	5.0	10.3	112.3	432.5	1119.0	91.1	1311.0	714	8.3	3740.0
Aver			4.1	0.5	20.3	8.8	2.9	8.1	76.2	251.0	591.0	41.9	747.2	377	5.4	2203.5
Min			0.3	0.3	10.5	8.4	0.6	5.8	47.7	77.8	42.0	2.7	108.0	31.0	2.1	374.0
StDev.			3.6	0.3	3.6	0.2	1.4	1.2	16.7	110.6	352.5	27.2	386.6	218.0	1.8	1095.5

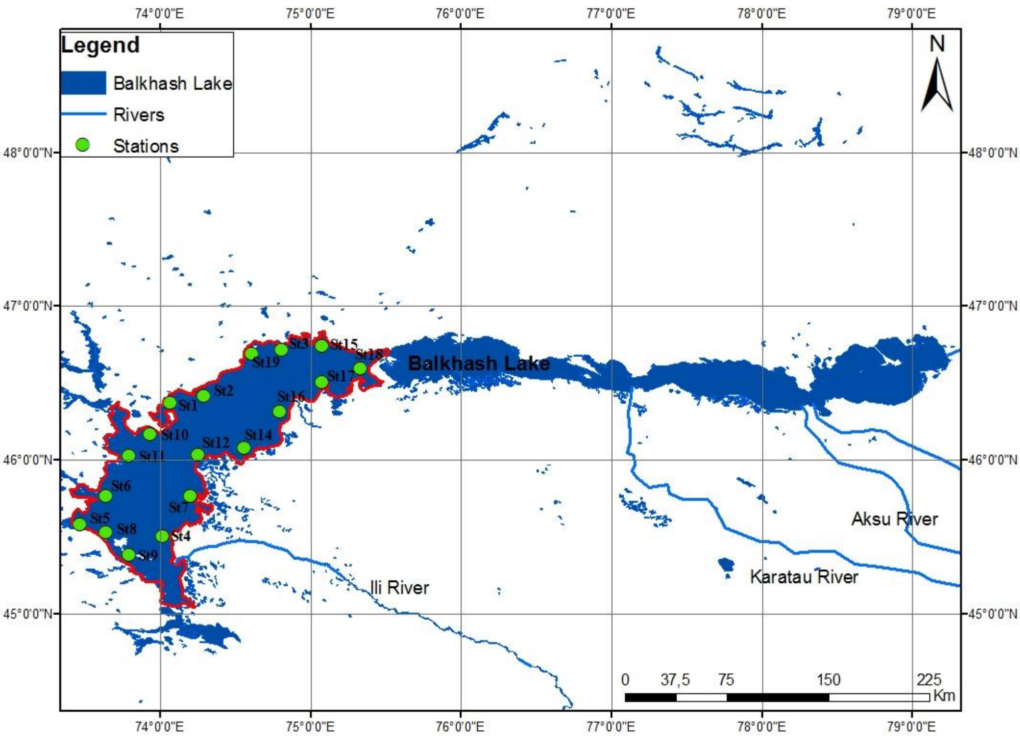

Figure 4.42 Stations in western parts of Balkhash Lake

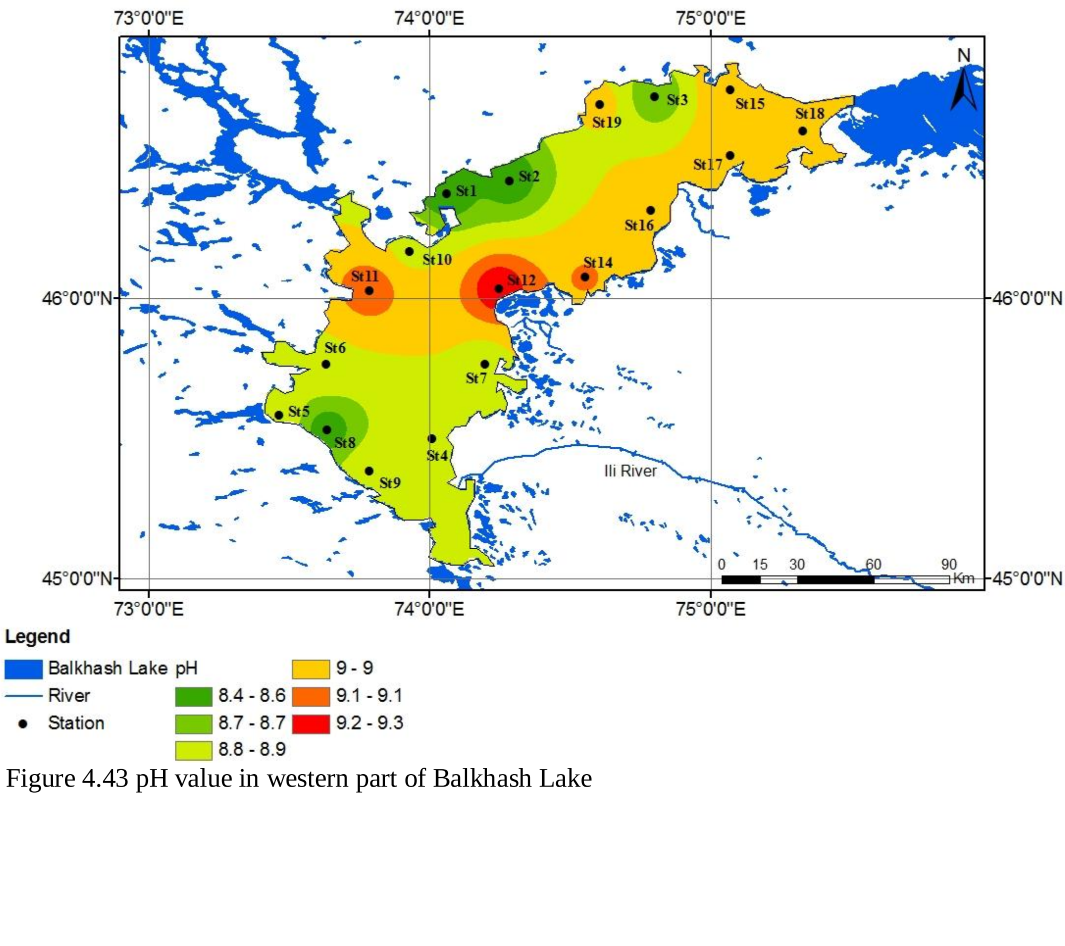

Figure 4.43 pH value in western part of Balkhash Lake

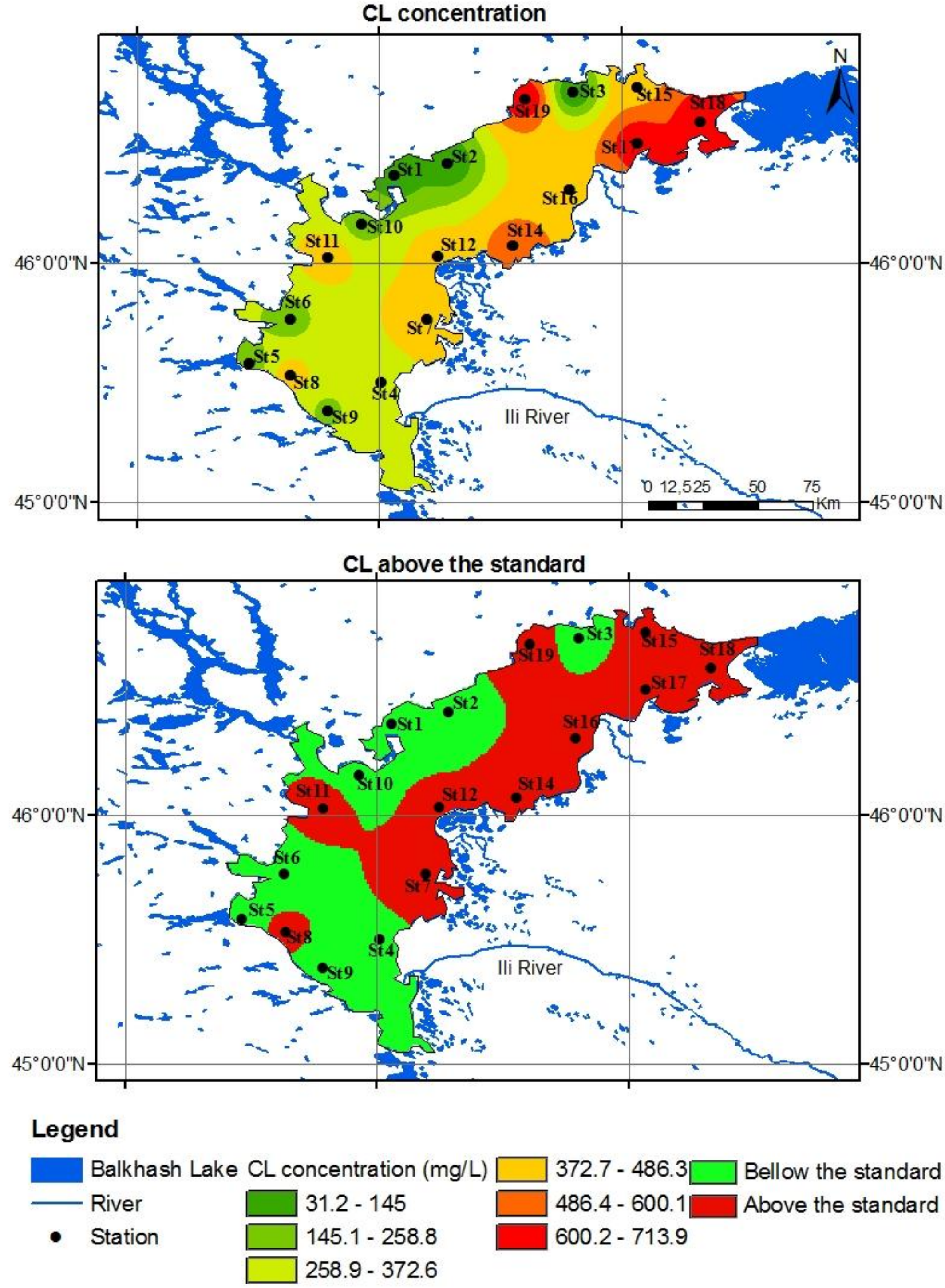

Figure 4.44 CL concentrations in western Balkhash Lake

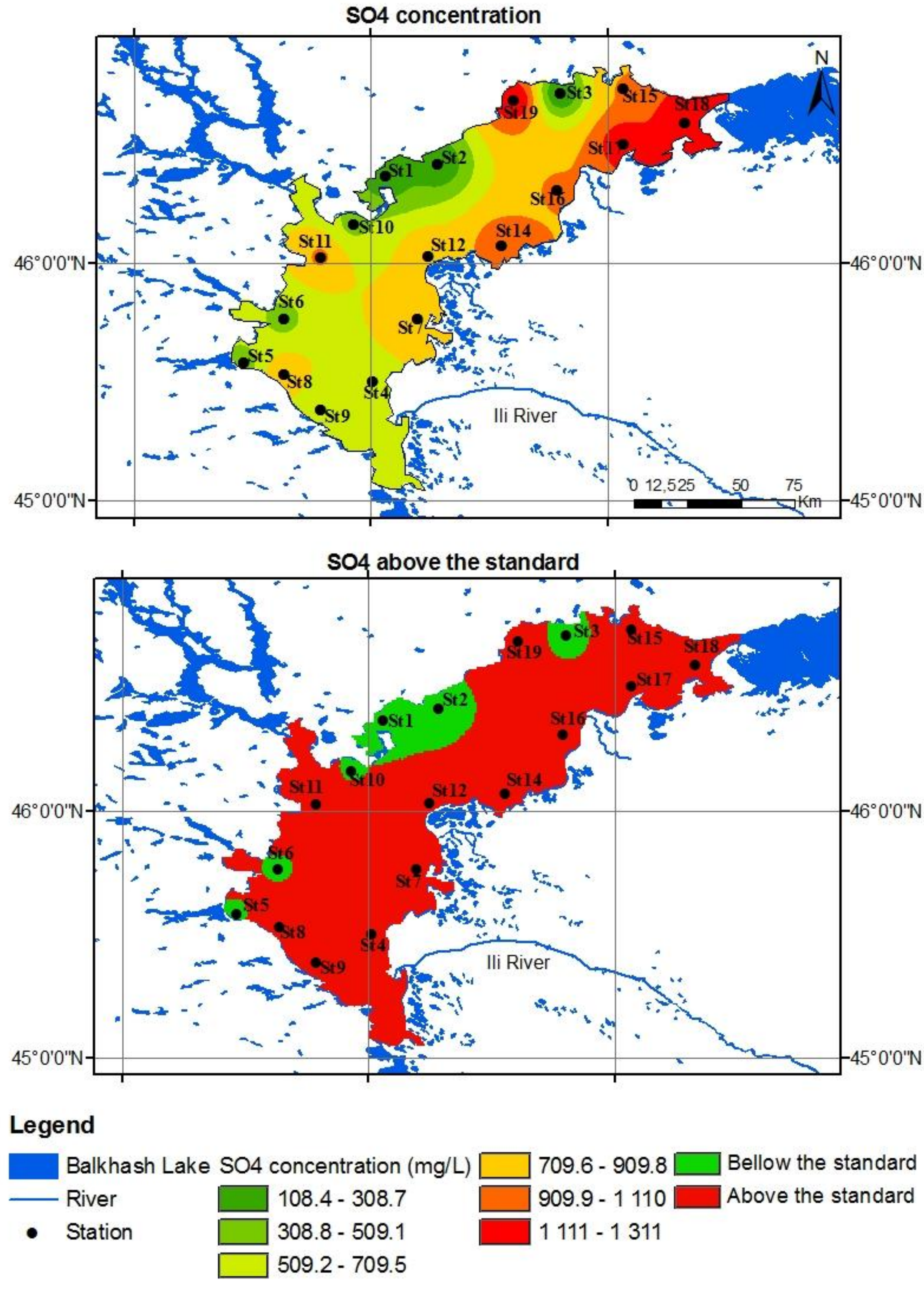

Figure 4.45 SO_4 concentrations in western Balkhash Lake

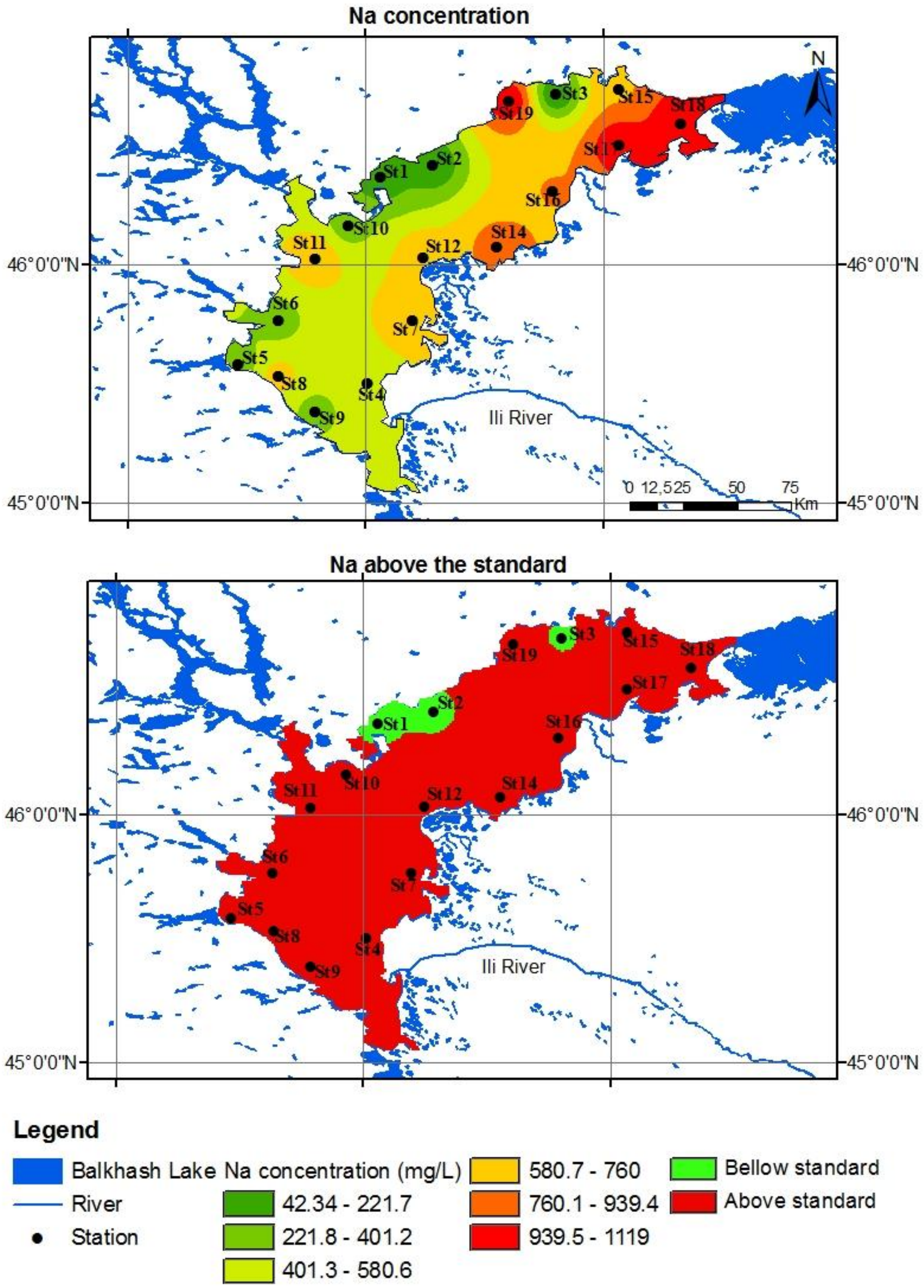

Figure 4.46 Na concentrations in western Balkhash Lake

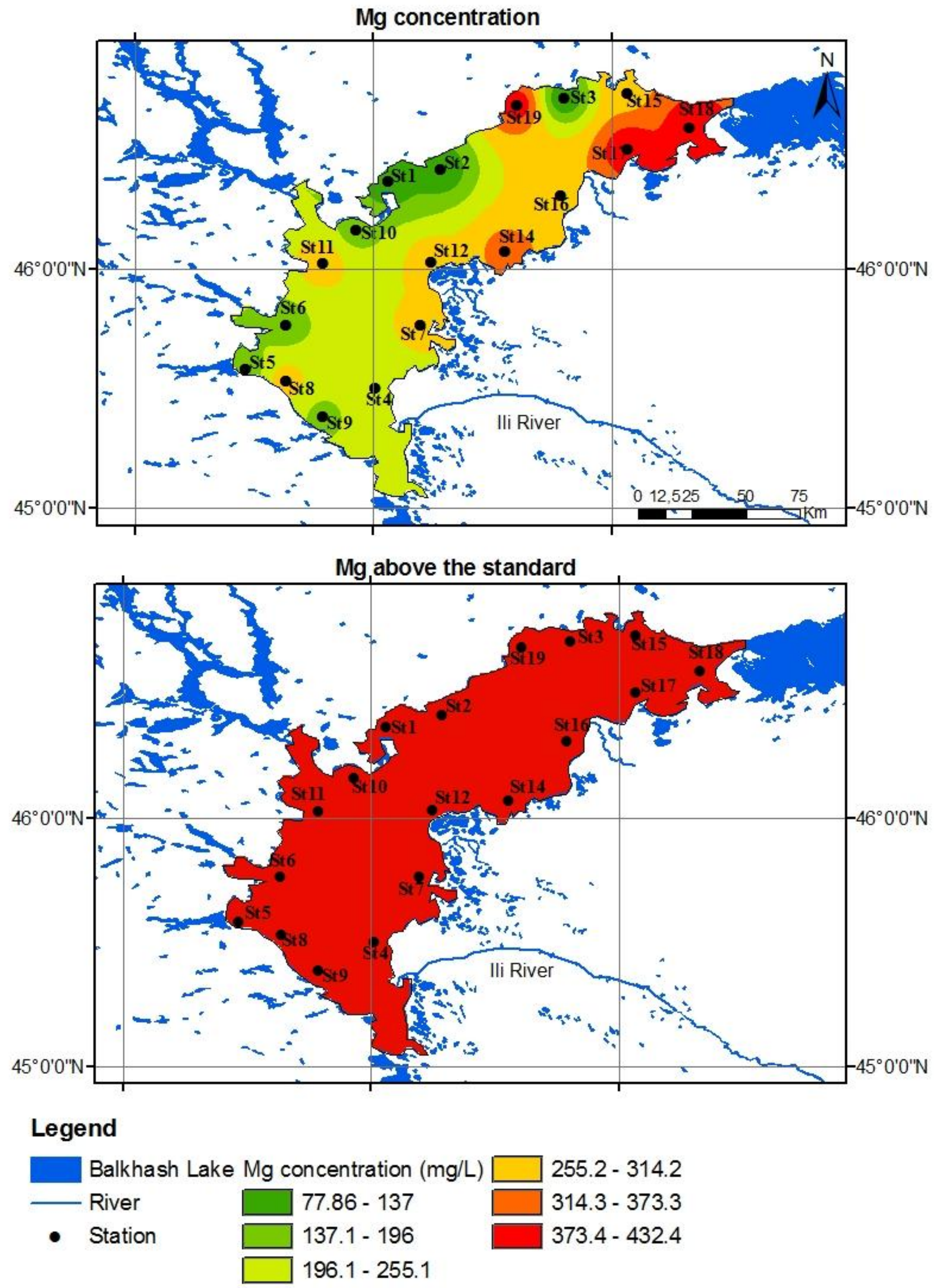

Figure 4.47 Mg concentrations in western Balkhash Lake

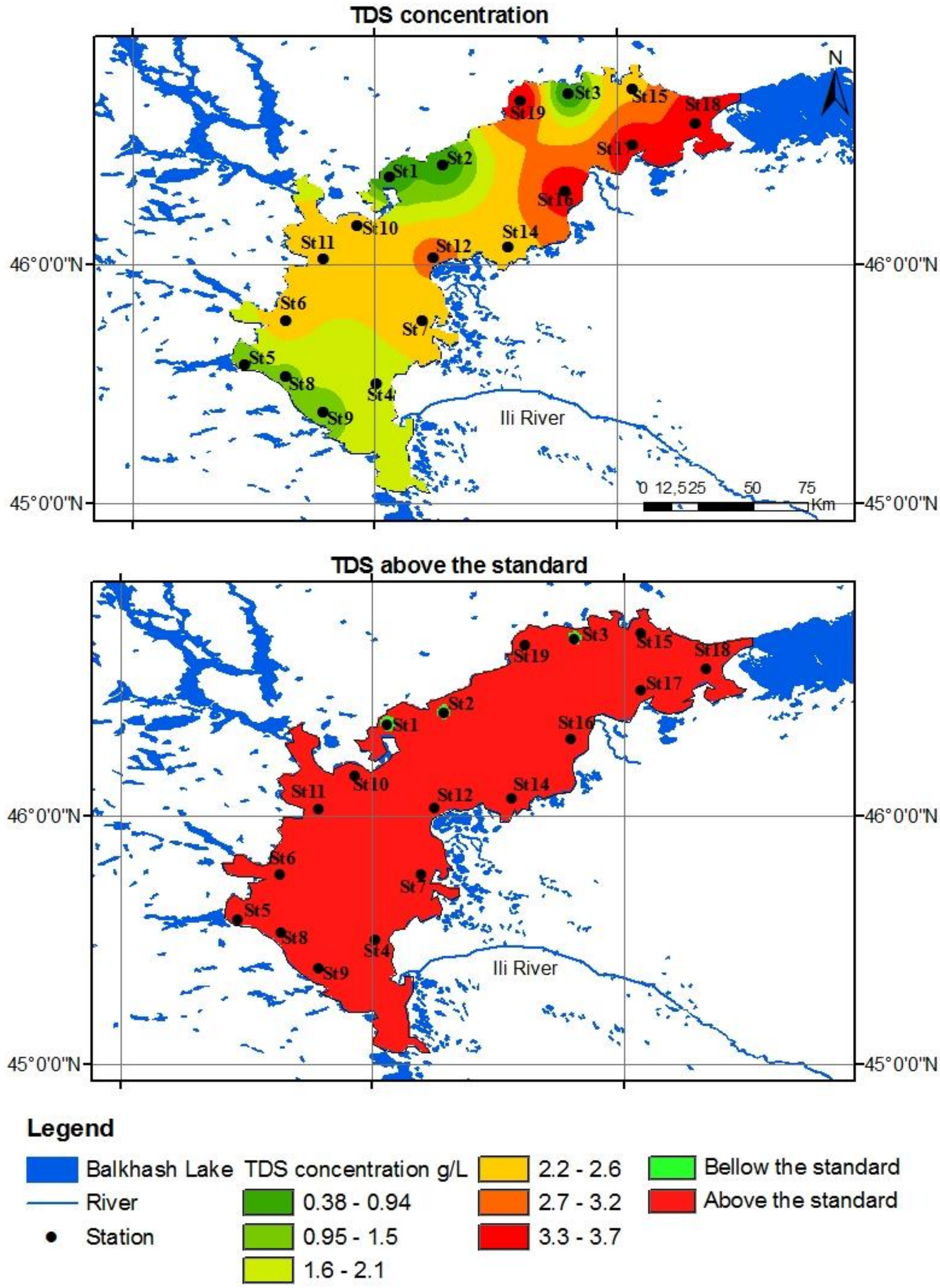

Figure 4.48 TDS concentrations in western Balkhash Lake

Nowadays, around the Lake, many irrigated areas are not being used any more. The productivity of ecosystem is declined. One more factor influencing the ecology of lake is the reservoirs and emissions of Balkhash mountain-metallurgical plant. In the beginning of 1990s, the volume of emissions from the factories made about 280-320 thousand ton/year and on the surface of lake 76 tons of copper, 68 tons of zinc, 66 tons of lead settled (Samakova, 2009). Since then, the volume of detrimental substances has increased almost twice. To improve the ecological conditions of the lake, water releases from Kapchagay Reservoir should be increased, wastewaters of the metallurgical plant should be treated to minimize heavy metal loads to the lake and the irrigational water demands around the lake should be reduced.

Currently, the main problems of the basin could be named as: (i) unsustainable use of water, loss of biological resources and decline in ecosystem diversity; (ii) desertification and loss of agricultural lands and their productivity; and, (iii) continuing pollution of the waters in the lake by industrial wastes.

CHAPTER FIVE
SUBSURFACE WATER QUALITY

Dynamic development of Kazakh economy is directly connected with the rational use of natural resources of the country, among which water resources is of primary importance with regards to the satisfaction of social and industrial needs of the population. As a result of the morphological, geological and hydrogeological conditions of Kazakhstan, there is a non-uniform distribution of surface and subsurface water resources within the country. In essence, more than 50% of subsurface water resources of the country are concentrated in Southern Kazakhstan Region, whereas only 20% are concentrated in Western Kazakhstan and the remaining 30% is distributed non-uniformly in Central, Northern and Eastern Kazakhstan regions.

In Southern Kazakhstan region, subsurface water resources play an important role in regional water supply. The basic resources of subsurface waters of Southern Kazakhstan are concentrated around the foothill plains of Dzhungarskogo, Zailinskogo, Kyrgyz Ala-Tau, Karatau, and Talaskih mountains. In this region, a total of 146 groundwater aquifers (Veselov, et al. 1999) are present that have different capacities and are used to different levels. Of these aquifers, 5 of them are considered to be major aquifer systems with a capacity figure of >1 million m^3/day. Similarly, 5 aquifers are classified to be in the range 0.5-1 million m^3/day; 8 aquifers are classified to be in the range 0.1-0.5 million m^3/day; 31 aquifers are classified to be in the range 0.05-0.1 million m^3/day and the remaining 102 aquifers are classified to be small reserves with capacities less than 0.05 million m^3/day.

5.1 Kentau City

The city of Kentau was formed in 1955 in place of Myrgalimsai village to develop Achisay multi-metallic (Cu, Pb, Zn) deposits, which is also known as Mirgalimsai mine. With an area of about 600 km^2, the city is situated on the southwest slope of the Ridge of Big Karatau Mountain in the South Kazakhstan province (Figure 5.1).

Recently, Kentau population began to grow and reached a value of about 80,000 in 2010. The climate of the city is continental. The average temperature is -24^oC in winter and +14.3^oC in summer. The average precipitation in the region contributes to about 500 mm.

In the Soviet Union period, the Southern regions of Kazakhstan are considered to be industrial centers, particularly Kentau City in South Kazakhstan province. There are a number of large industrial enterprises (including a nonferrous metallurgical plant, thermal power stations, a transformer factory and some textile industries) and one of the biggest industrial mineral deposit areas of the country. The majority of the industrial establishments in these regions was unprofitable and thus was closed after the disintegration of the Soviet Union. In 1991, the Kentau City industrial production made about 7.5% of the total industrial production volume of the Province where as it could barely reach 1% after 2000. During the operational phases of these industrial plants, environment was typically not a concern and no precautionary measures were implemented to mitigate the negative environmental impacts of these plants.

After the disintegration of the Soviet Union, the mine was closed in 1997 and the mine galleries were filled by concrete mixed up with mine tailings. Once the mine drainage pumps were closed, the mine was flooded. The groundwater quality in the Mirgalimsai mine is presented in the Table 5.1 through Table 5.3. As seen from these tables, some organic and inorganic compounds are higher than drinking water quality standards.

Water quality parameters of Mirgalimsai mine during 2003 and 2005s are plotted in Figure 5.2 through Figure 5.6. For instance, the Pb concentration in December 2003 is about 60 µg/L, which are 4-5 folds higher from WHO drinking water quality standard value of 10 µg/L. However, during the same period, in March the concentration values considerably decreased to 8 µg/L probably due to the dilution effect of winter precipitation. Moreover, on November in 2004 Pb concentration drastically increased to about 100 µg/L (Figure 5.4). Additionally, in 2005 the Pb concentration also in December month contributed about 90 µg/L (Figure 5.6).

Furthermore, according to the data, some other parameters such as Ca, Mg and SO_4 are also found to be relatively high.

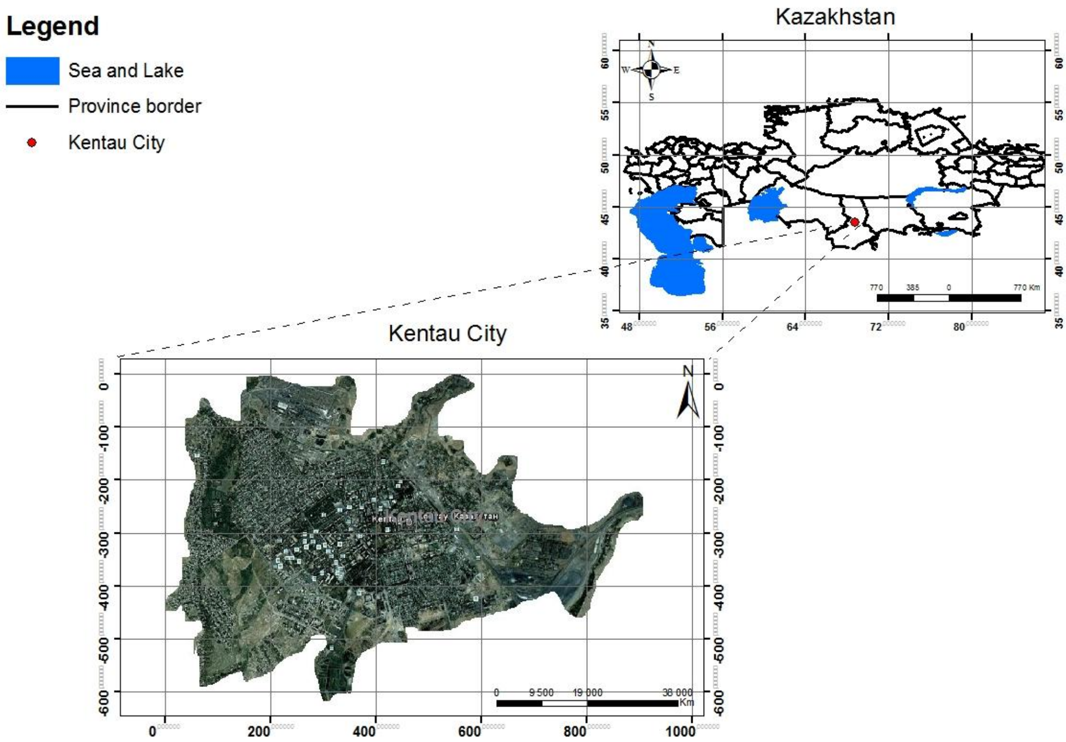

Figure 5.1 Kentau City

Groundwater water quality of Kushata and Karasu regions are given in Table 5.4. Accordingly, the Ni and Pb concentrations are plotted in the Figure 5.7 and Figure 5.8. Both elements are found to be above the standards. In 2003, in the Kushata and Karasu residential area the concentration of Ni was about 5 µg/L. Whereas, in 2004, 2005 and 2006 years significantly increased to about 290 µg/L, which is about 10-15 folds higher than the drinking water quality standard value of 20 µg/L.

Table 5.1 Groundwater quality of Mirgalimsai mine in 2003 (Kentau University laboratory)

Data	pH	CL mg/L	SO_4 mg/L	NO_2 mg/L	NO_3 mg/L	H_4SiO_4 mg/L	Na_xK mg/L	Ca mg/L	Mg mg/L	Fe µg/L	Cu µg/L	Cr µg/L	Pb µg/L	Zn µg/L
December	6.50	12.40	135.80				14.70	82.50	22.80		860.00		60.00	294.00
January	6.50	13.20	206.60				21.90	98.50	28.70		18.00		16.00	181.00
February	7.00	8.56	213.00	0.60			12.70	97.00	32.60		23.00		24.00	130.00
Mart	6.50	19.80	388.70				26.60	145.00	40.73		64.00		8.00	201.00
May	6.50	4.13	484.50	0.02			2.30	193.00	35.87	110.00	15.00		3.00	98.00
July	7.70	8.30	357.00				2.07	150.00	36.48	450.00	27.00		5.00	460.00
September	7.50	13.90	474.00				2.07	180.00	48.60		19.00		58.00	395.00
October	6.40	3.47	466.00	0.01	5.10	9.60	43.20	208.00	7.50	115.00	14.00	18.00	29.00	244.00
December	7.50	9.00	447.10	0.01		10.14	5.98	196.00	45.00	110.00	9.00		13.00	213.00
Min	6.40	3.47	135.80	0.01	5.10	9.60	2.07	82.50	7.50	110.00	9.00	18.00	3.00	98.00
Max	7.70	19.80	484.50	0.60	5.10	10.14	43.20	208.00	48.60	450.00	860.00	18.00	60.00	460.00
Average	6.90	10.31	352.52	0.16	5.10	9.87	14.61	150.00	33.14	196.25	116.56	18.00	24.00	246.22
StDev	0.53	5.12	133.72	0.29	0.00	0.38	13.96	47.79	12.45	169.18	279.26	0.00	21.56	118.85
WHO	6.5-9.5	250	500	3.0	50		200			1000	2000	50	10	3000
EPA	6.5-8.5	250	250	3.3	44.3					300	1000	10	15	5000
Kazakh	6-9	350	500	0.50	45			180	40	200	2000	50	30	
Turkish	6.5-9.5	250	250		50		200			300	1000	50	10	5000

Table 5.2 Groundwater quality of Mirgalimsai mine in 2004, (Kentau University laboratory)

Data	pH	CL mg/L	SO_4 mg/L	NO_3 mg/L	NO_2 mg/L	H_4SiO_4 mg/L	Na_xK mg/L	Ca mg/L	Mg mg/L	Fe µg/L	Cu µg/L	Pb µg/L	Zn µg/L
January	8.00	10.60	576.00	0.67	0.01		17.50	46.50	30.20	30.00	20.00	20.00	150.00
April	7.70	8.60	174.00	5.54	0.02		10.40	124.20	31.60		40.00	40.00	100.00
May	7.90	6.80	145.00	2.20	0.01	6.80	10.12	116.20	29.20	5.00	7.00		378.00
September	8.10	8.70	120.00		0.01	7.80	6.50	120.00	30.00	18.00	19.00	20.00	500.00
October	7.80	7.10	314.00			10.00	8.40	147.00	42.00	21.00	22.00	29.00	460.00
November	7.00	13.00	430.00		0.01	11.00	29.00	204.00	51.00	19.00	10.00	98.00	236.00
December	7.50	15.00	463.00	0.01		12.30	33.00	228.00	63.00	10.00	30.00	17.00	190.00
Min	7.00	6.80	120.00	0.01	0.00	6.80	6.50	46.50	29.20	5.00	7.00	17.00	100.00
Max	8.10	15.00	576.00	5.54	0.02	12.30	33.00	228.00	63.00	30.00	40.00	98.00	500.00
Average	7.71	9.97	317.43	2.11	0.01	9.58	16.42	140.84	39.57	17.17	21.14	37.33	287.71
StDev	0.37	3.07	177.96	2.47	0.00	2.26	10.59	60.34	13.14	8.75	11.29	0.00	157.76
WHO	6.5-9.5	250	500	50	3.0		200			1000	2000	10	3000
EPA	6.5-8.5	250	250	44.3	3.3					300	1000	15	5000
Kazakh	6-9	350	500	45	0.50			180	40	200	2000	30	
Turkish	6.5-9.5	250	250	50			200			300	1000	10	5000

Table 5.3 Groundwater quality of Mirgalimsai mine in 2005, (Kentau University laboratory)

Data	pH	CL mg/L	SO_4 mg/L	NO_3 mg/L	NO_2 mg/L	H_4SiO_4 mg/L	Na, K mg/L	Ca mg/L	Mg mg/L	Fe µg/L	Cu µg/L	Pb µg/L	Zn µg/L
February	7.10	12.40	420.00		0.02	14.00	21.00	96.00	30.00	4.00	50.00	90.00	80.00
Mart	6.50	20.10	389.00		0.02	16.00	27.00	146.00	41.00	2.00	60.00	80.00	180.00
April	7.80	8.90	230.00			9.60	4.97	33.06	5.17	20.00	8.00		32.00
May	7.50	3.40	277.20			12.10	4.95	108.90	26.90	64.00	14.00		12.00
September	7.90	9.60	301.30		0.01	8.20	1.30	105.20	28.40	35.00	60.00	28.00	10.00
October	8.10	6.90	389.30			12.20	10.75	98.20	25.50		40.00	11.00	50.00
November	7.80	9.00	447.10		0.01	10.30	17.50	196.00	45.00	50.00	10.00	26.00	310.00
December	8.00	17.50	456.00		0.01	13.60	20.70	148.00	51.00	100.00	7.80	9.00	260.00
Min	6.50	3.40	230.00		0.01	8.20	1.30	33.06	5.17	2.00	7.80	9.00	10.00
Max	8.10	20.10	456.00		0.02	16.00	27.00	196.00	51.00	100.00	60.00	90.00	310.00
Average	7.59	10.98	363.74		0.01	12.00	13.52	116.42	31.62	39.29	31.23	40.67	116.75
StDev	0.54	5.50	83.83		0.00	2.56	9.32	47.94	14.22	35.21	23.67	0.00	117.85
WHO	6.5-9.5	250	500	50	3.0		200			1000	2000	10	3000
EPA	6.5-8.5	250	250	44.3	3.3					300	1000	15	5000
Kazakh	6-9	350	500	45	0.50			180	40	200	2000	30	
Turkish	6.5-9.5	250	250	50			200			300	1000	10	5000

Table 5.4 Groundwater quality of Kyshata and Karasu regions, (Kentau University laboratory)

Parameters	October 2003 sampling location		May 2004 sampling location		June 2005 sampling location		October 2006 sampling location		Kazakh standard	WHO standard	Turkish standard
	Kyshata	Karasu	Kyshata	Karasu	Kyshata	Karasu	Kyshata	Karasu	6-9	(6.5-9.5)	6.5-9.5
pH	8.25	7.65	7.9	7.95	7.15	7.8	7.8	8.0			
Na (mg/L)	16.2	10.8	17.8	11.4	18.3	14.4	18.6	15.7		200	200
K (mg/L)	1.0	0.6	0.8	0.6	0.9	0.6	0.9	0.5			
Ca (mg/L)	60.1	98.1	64.1	55.1	64.7	57.8	66.1	56.1	180		
Mg (mg/L)	21.3	22.5	23.1	19.5	26.1	19.6	25.5	19.5	40		
HCO_3(mg/L)	164.8	213.6	198.3	210.5	218.3	225.5	213.6	231.9			
CL (mg/L)	19.5	8.5	17.7	8.9	15.9	8.8	14.2	8.9	350	250	250
SO_4 (mg/L)	81.5	138.7	92.8	49.4	96.8	52.7	95.1	51.4	500	500	250
NO_3 (mg/L)	6.4	47.8	15.5	13.1	11.4	8.5	7.9	8.7	45	50	50
F (mg/L)	0.66	0.46	0.43	0.35	0.6	0.44	0.6	0.4	1.5	1.5	1.5
B (mg/L)			0.05	0.01			0.22	0.26	0.5	0.5	1
SiO_2 (mg/L)	9.0	8.8	8.3	10.0	8.4	8.7	7.8	8.2			
Mn (mg/L)	0.01	0.01	0.01	0.01	0.02	0.031	0.028		0.5	0.4	0.05
Fe (µg/L)	300								300	1000	200
Cu (µg/L)	50	50	10	10	50	50	50	50	1000	2000	2000
Ni (µg/L)	5	5	50	70	10	100	10	290		20	20
Pb (µg/L)	15	24	32	50	25	80	20	70	30	10	10
Zn (µg/L)	50	50	70	30	40	100	30	130	5000	3000	
Sr (mg/L)	1.10	0.5	1.2	0.5	1.5	0.9	1.2	0.63	7		
Mo (µg/L)	3	3	5	5	2.5	2.5	2.5	2.5			

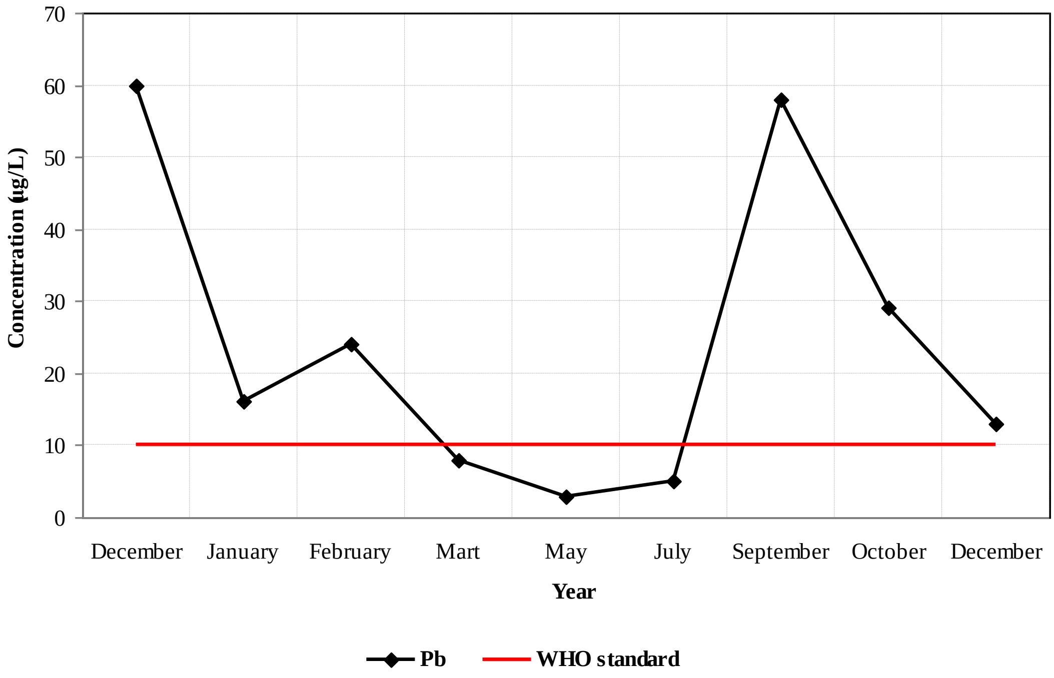

Figure 5.2 Pb concentrations in Mirgalimsai mine in 2003

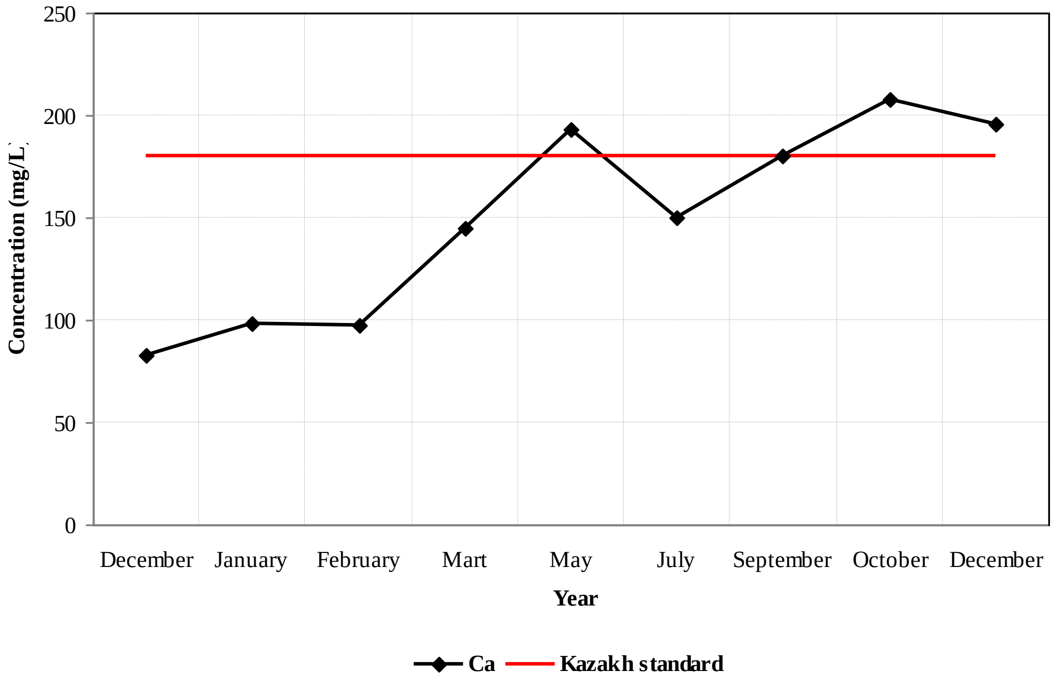

Figure 5.3 Ca concentrations in Mirgalimsai mine in 2003

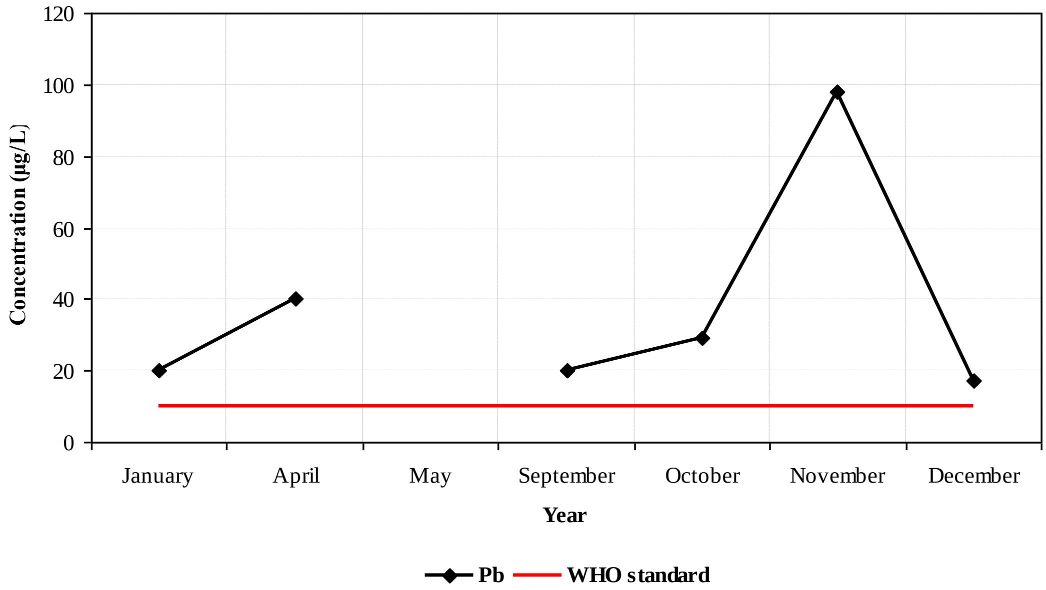

Figure 5.4 Pb concentrations in Mirgalimsai mine in 2004

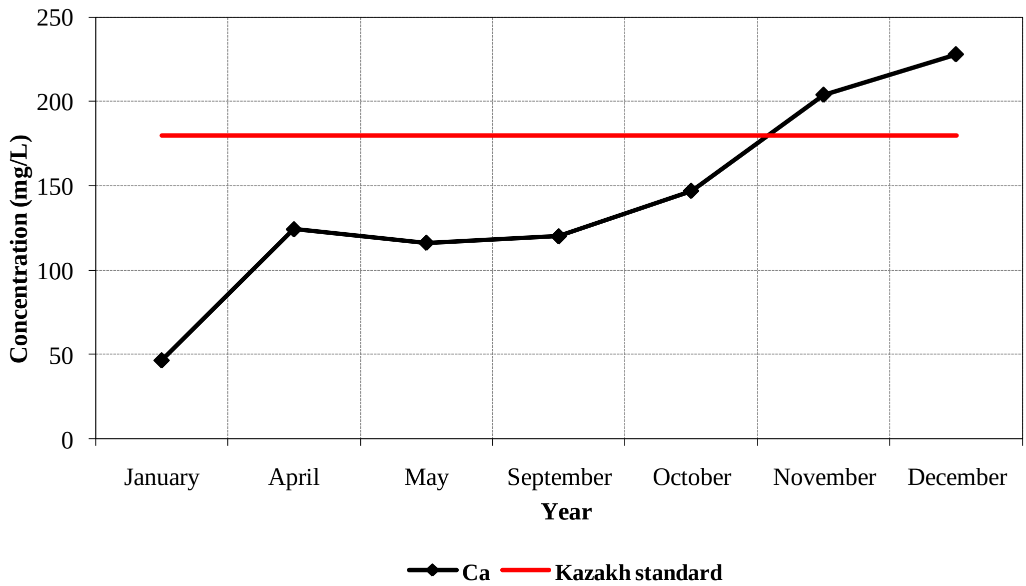

Figure 5.5 Ca concentrations in Mirgalimsai mine in 2004

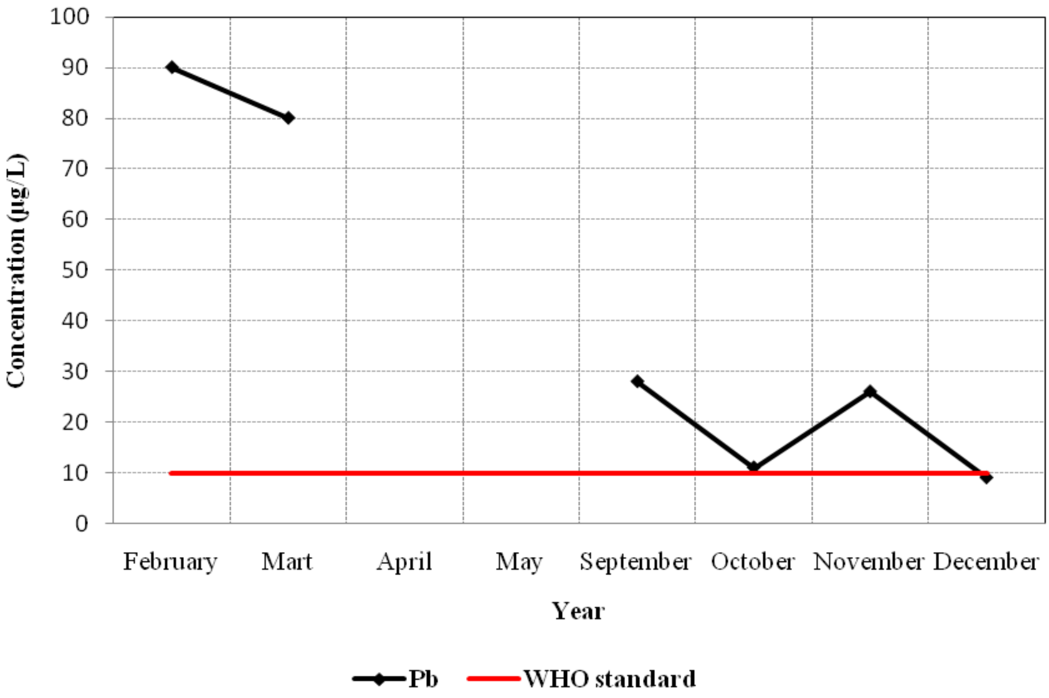

Figure 5.6 Pb concentrations in Mirgalimsai mine in 2005.

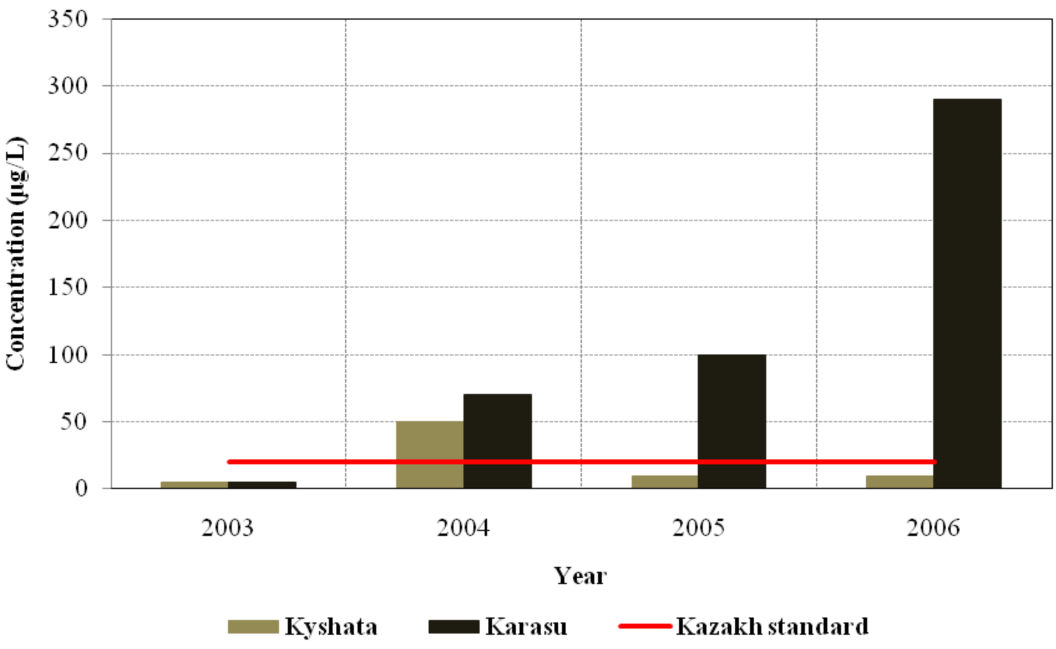

Figure 5.7 Ni concentrations in Kushata and Karasu region in 2004.

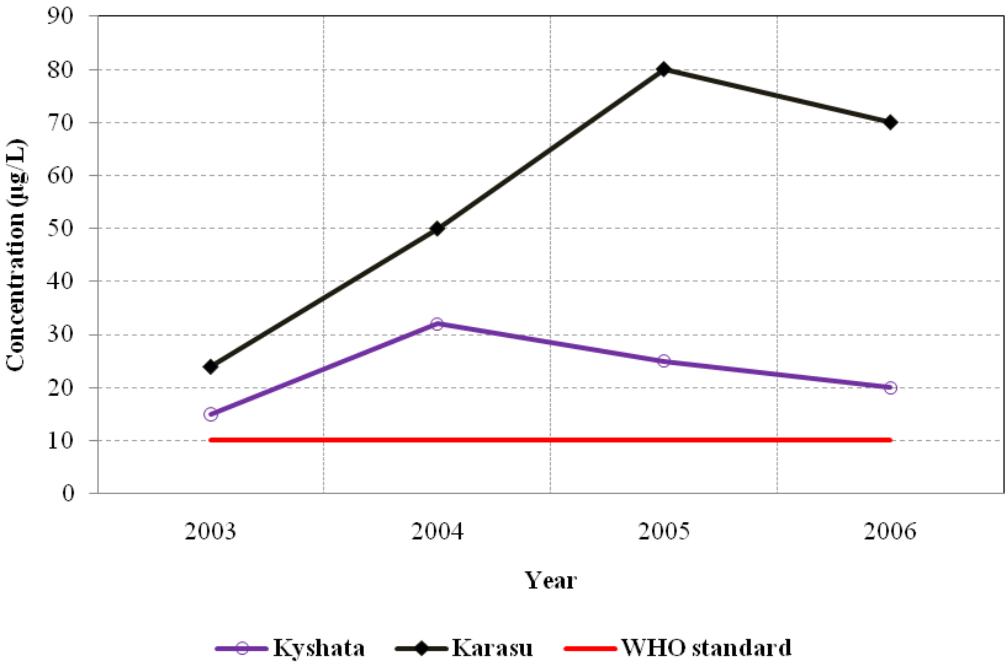

Figure 5.8 Pb concentrations in Kushata and Karasu region in 2004

5.2 Turkestan City

The Turkestan City is also located in South Kazakhstan province. The city covers an area of 24000 km^2 area or 6.3% of the entire territory of South Kazakhstan Province. Turkestan city borders with Otyrar city in the east, in north Kentau and Suzak cities while, in west borders with Zhanakurgan region (Kyzyl Orda province) (Figure 5.9). Nowadays, Turkestan is considered to be a large industrial, educational and cultural center of the province. In the region, there are 13 major industrial enterprises, most of which are cotton processing plants.

In the region, the climate is continental with an average winter temperature of -15°C and an average summer temperature of about +37°C. The annual precipitation ranges between 150 – 550 mm.

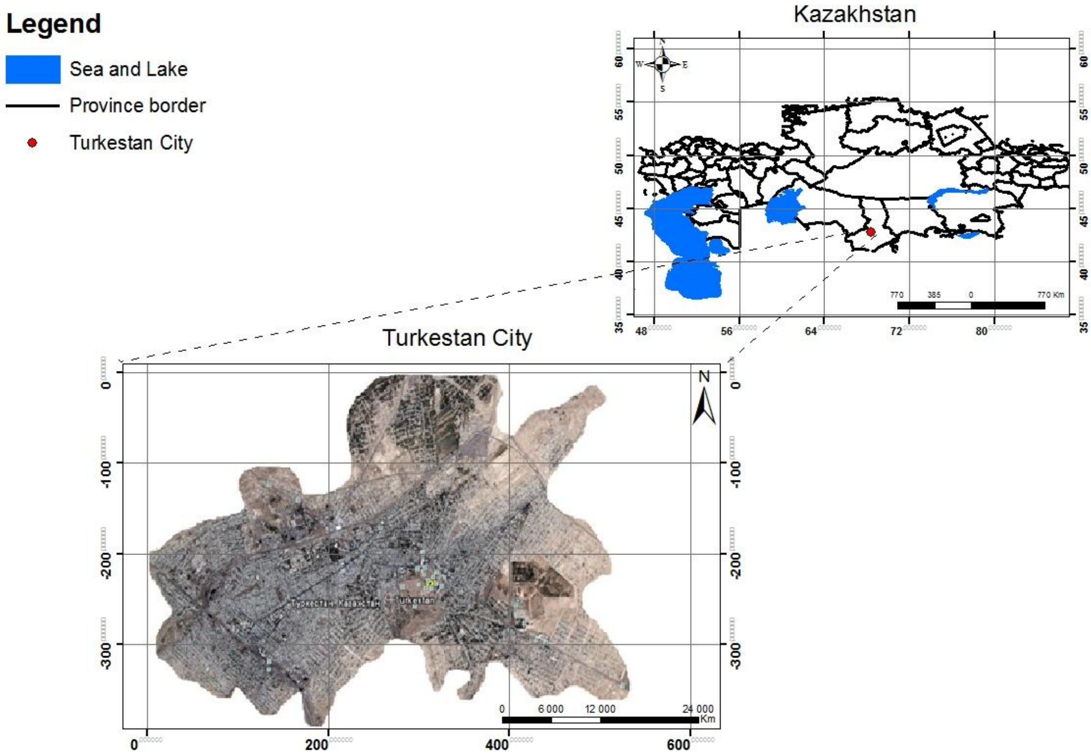

Figure 5.9 Turkestan City

The city is mostly dependent on groundwater for domestic, agricultural and industrial water supply. The basic sources of drinking water supply in Turkestan region is Karashyk, Bayaldir and Hantagy-Biresek aquifers, which are fed from infiltration of atmospheric precipitation and from influx from Birsek and Kantagy rivers. The average groundwater depth in the area is about 6 m from the surface. The maximal charges of ground waters are usually marked in summer season as the major part of the resource is consumed for agricultural irrigation. Water supply in the city is provided by 21 artesian wells with a total capacity 2,247,000 m^3/year.

In the city, particularly on the territory of Central Water-Reservoir area, 6 operational wells (№1,2,3,4,5,6) are in service, which are situated 120 m apart and are drilled to a depth of 40 m Furthermore, in the territory of Telman Water Reservoir area, 2 wells (№2 and 3) are in service which are drilled to depths of about 36 m. Finally, in the territories of Vodokanal, Novostroika, Raybolnisa and Neftebaza, several wells are in service, which are drilled to depths of about 30-34 m.

The groundwater characteristics of Turkestan region is presented in the Table 5.5 and Table 5.7 by the time periods. Some parameters are found to be above the Kazakh and WHO drinking water quality standards. For instance, in Communism well, the SO_4 concentration reaches to 750 mg/L in 2003-2004. In 2005-2006, the water supply point of Sattarhanov, Samal and Communism were high in SO_4 levels and the concentration ranged from 500 to 1534 mg/L, which is about 3-4 folds higher than standard value of 500 mg/L (Figure 5.10 and 5.11). Additionally, in 2005-2007s the Pb concentration was found above the standard in the territory of Masloprom, Akimat, Well №6, Xlopzabod, MKTU, Malbazar and Samal (Figure 5.15 and Figure 5.16). As seen from the Figure 5.16, the Pb concentration in Vodokonal region contributed to about 70 µg/L, which is about 7 folds higher than identified drinking water quality standards. During the same year and in the same stations, the Mg concentrations are also above the established Drinking Water standards (Figure 5.12 and 5.14).

Table 5.5 Subsurface water quality of Turkestan city in 2003-2004 (Kentau University Laboratory).

Water source	Data Sample	pH	HCO3- mg/L	CL mg/L	SO_4 mg/L	H_4SiO_4 mg/L	Ca mg/L	Mg mg/L	Na+K mg/L	Cu µg/L	Fe µg/L	Zn µg/L
Zhukovski	09.04.03	6	305	47.9	408.2		174	56.2	35.7	4		5
Well №6	09.04.03	6	359.9	72.6	256		124	53.6	61.6	3		38
Well №6	29.05.03	7.4	341.6	74.7	271		128	51.2	63.5	2	140	14
MKTU, depth 815 m	09.09.03	7.5	225.7	27.8	48.5	9.6	42	17	45.8	16		35
MKTU, depth 815 m	11.09.03	7.6	225	24.3	51	13.2	40	18.2	44.6	4	57	76
Samal	14.10.03	7.4	274.5	31.3	269.5	21.8	114	15.9	92	16	70	
Vodozabor, depth 30m	10.11.03	7.5	274.5	30.4	249.2	18.6	110	41.9	37.9	10	80	
Well №4	11.11.03	7.5	268.4	27.8	109.7	18	105	32.8	10.8	6	60	
Telman	17.11.03	7.4	250.1	29.5	434.7	20.5	166	63.5	11.3	16	57	
Bazar	19.11.03	7.5	298.9	53	285	20.5	138	48.8	33		52	
Vodozabor	28.11.03	7.5	286.7	37	252	16	115	31.6	60.7	3	83	1
Zhelezno Dorozhny Park.	01.12.03	7.3	298.9	88	224.1	24	129	32.8	66.7	6		
Rektorat	05.01.04	7.7	216.5	10	43.5	25	46.4	13.9	25.9	7		
Remzavod, region.	08.01.04	7.5	616.1	220.3	560	33.2	110	212.9	112.9	12	405	
Selgman	15.01.04	7.4	366	82.1	272.4	21.9	132	63.4	50.4	28	50	
Communism	28.01.04	7.4	231.8	25	752.4	23.7	272	66	27.2	4	155	263
WHO		6.5-9.5		250	500				200	2000	1000	2000
EPA		6.5-8.5		250	250					1000	300	1000
Kazakh		6-9		350	500		180	40		1000	200	2000
Turkish		6.5-9.5		250	250				200	2000	300	1000

Table 5.6 Subsurface Water quality Turkistan City in 2005-2006 (Kentau University Laboratory).

Water source	Data Sample	pH	HCO_3- mg/L	SO_4 mg/L	CL mg/L	H_4SiO_4 mg/L	Ca mg/L	Mg mg/L	Na+K mg/L	Cu µg/L	Pb µg/L	Fe µg/L	Zn µg/L
Pharab №1	29.03.05	7.5	237.9	284	48.1	22.9	90.2	42.6	97.3	13	11	20	35
Sattarhanov	29.03.05	7.5	323.3	900	226.9	30.7	244.5	210.4	64.8	5	10	130	
MKTU, depth 750 m	14.04.05	7.7	225.7	69.8	10.3	23	40.1	12.2	64.7	9	5		
MKTU, depth 50 m	14.04.05	7.7	292.8	435	25.8	33.3	176.4	68.1	18.6	5	31		
MKTU, depth 15 m	19.04.05	7.3	189.1	433	30.9	10.2	88.2	41.3	121	7	24	4070	
Ishtihad	19.04.05	7.5	335.5	341.6	56.7	25.6	112.2	63.2	92.6	8	9	910	
Samal	23.05.05	7.6	268.4	490	32.7	21.1	92.2	38.9	180.6	3	26	8	1
Jenis	12.05.05	7.5	231.8	65.8	16.4	26.2	42.1	13.4	58.7	11	6	40	
Communism	07.12.05	6.8	231.8	1533.6	2957.2	28.1	390.8	104.6	2105.4		49	2070	
Sattarhanov №2	04.01.06	6.9	231.8	71.8	17.2	18	46.1	14.6	52.6		22	20	
Pharab №2	13.03.06	6.9	231.8	179.7	51.7	16.6	94.2	36.5	30.2	3	7	937	96
WHO		6.5-9.5		500	250				200	2000	10	1000	2000
EPA		6.5-8.5		250	250					1000	15	300	1000
Kazakh		6-9		500	350		180	40		1000	30	200	2000
Turkish		6.5-9.5		250	250				200	2000	10	300	1000

Table 5.7 Subsurface Water quality in Turkistan City in 2007 (Kentau University Laboratory).

Water source	Data Sample	pH	HCO_3- mg/L	SO_4 mg/L	Cl- mg/L	H_4SiO_4 mg/L	Ca mg/L	Mg mg/L	Na+K mg/L	Cu µg/L	Pb µg/L	Zn µg/L
Telman	10.04.07	7.7	247.1	404.5	36.3	18.3	144.3	56.4	48.7	4		
Masloprom	10.04.07	7.3	274.5	258.8	51.9	20.1	112.2	46.2	56.1	4	25	
Selgman	10.04.07	7.4	338.6	277.9	73.2	21.6	134.3	49.8	84.4	10	11	
Akimat	10.04.07	7.5	262.3	632.6	50.9	18.4	186.4	74.2	91.6	7	7	
Novostroika	10.04.07	7.5	298.9	316.3	46	18.4	126.3	49.9	64.8	1	7	
Scientist center	10.04.07	6.9	286.7	376.7	29.3	24.2	164.3	44.5	40	2		
Xlopzavod	15.04.07	6.9	320.3	318.2	43.9	21.9	42.1	13.4	45.4	20	29	
Vodokanal	10.04.07	7.3	320.3	318.2	43.9	18.8	122.2	57.6	60.4	5	70	
Novostroika	10.04.07	7.1	463.6	421.7	121.3	36.5	130.3	113.1	141.1	2	4	
Well № 6	23.04.07	7.3	329.4	290.4	73.9	22.3	128.3	27.5	93.2	33	28	
Depot well, 8 m	23.04.07	7.2	503.3	412.2	132.5	48.3	148.3	102.1	169.5	48		
Jenis	15.04.07	7.5	286.7	268.7	35	17.9	96.2	46.2	69.4	8	17	
Malbazar	15.04.07	7.7	269	263.6	34.2	19.5	98.2	43.8	61.9	9	10	19
Neftebaza	15.04.07	7.7	262.3	249.2	30.7	18.9	96.2	35.3	67.7	6	12	20
Remzavod	16.04.07	7.7	384.3	421.7	126.9	27.5	157.5	91.7	103.3	3	11	148
WHO		6.5-9.5		500	250				200	2000	10	2000
EPA		6.5-8.5		250	250					1000	15	1000
Kazakh		6-9		500	350		180	40		1000	30	2000
Turkish		6.5-9.5		250	250				200	2000	10	1000

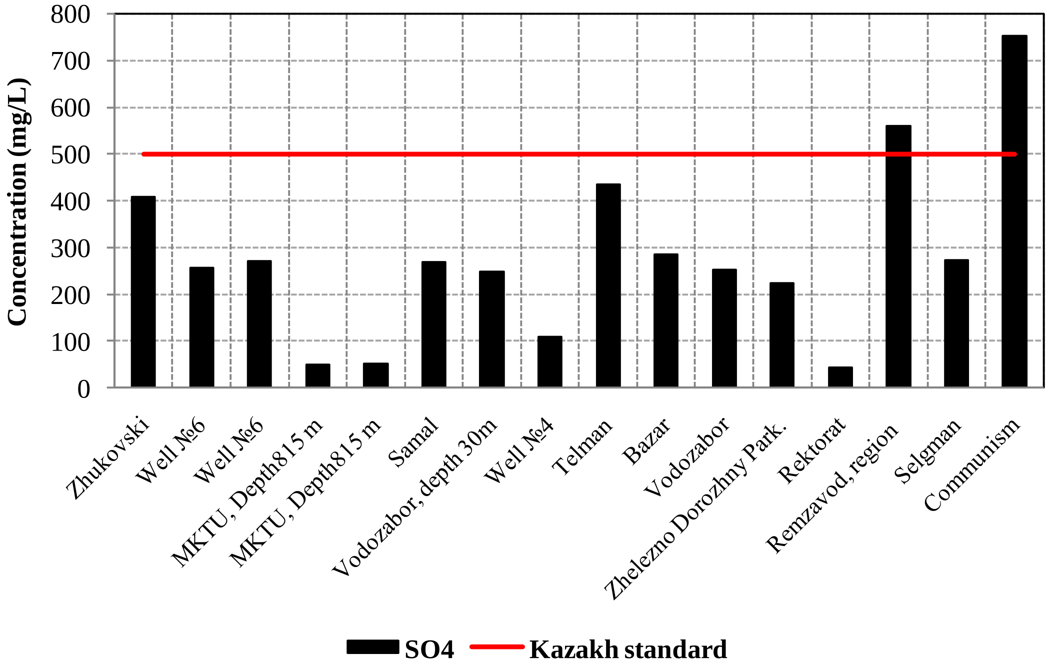

Figure 5.10 SO_4 concentrations in groundwater of Turkestan city in 2003-2004

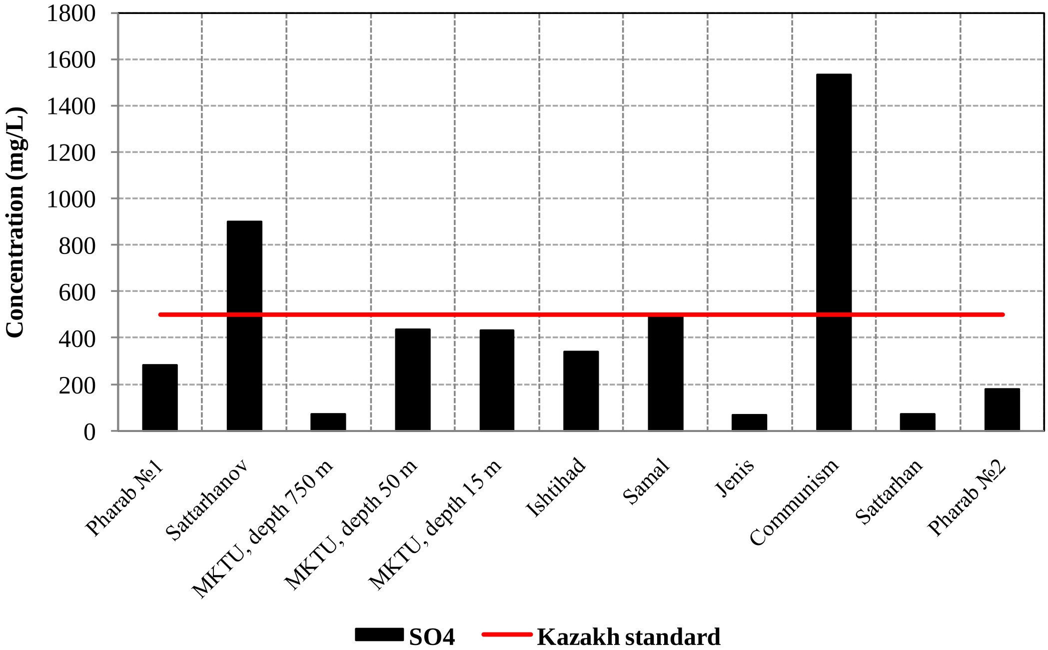

Figure 5.11 SO_4 concentrations in groundwater of Turkestan city in 2005-2006

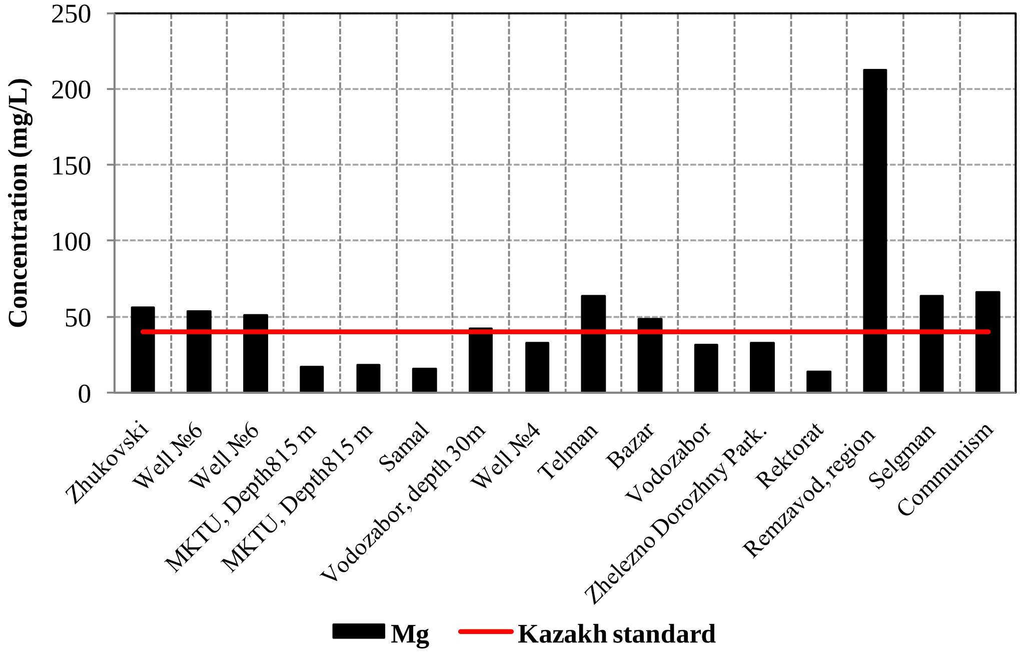

Figure 5.12 Mg concentration in groundwater of Turkestan city in 2003-2004

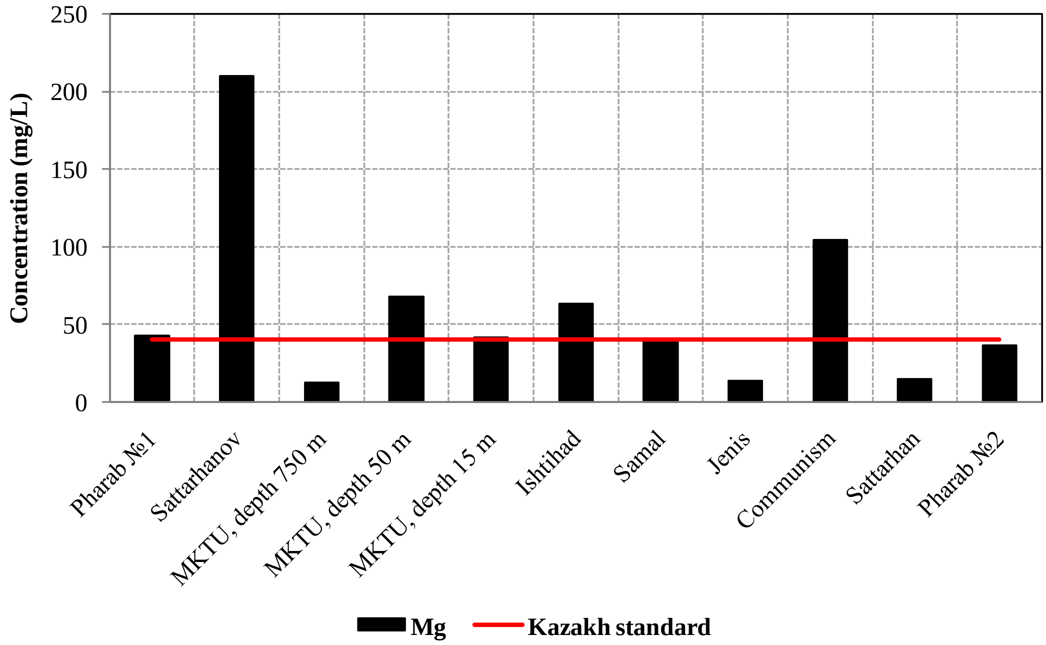

Figure 5.13 Mg concentration in groundwater of Turkestan city in 2005-2006

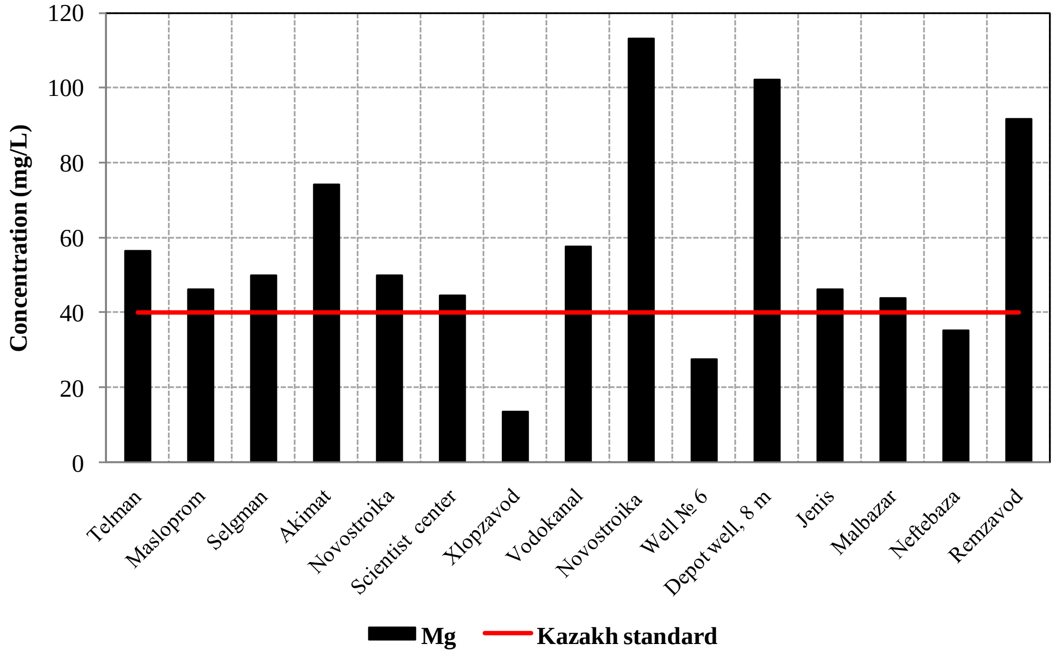

Figure 5.14 Mg concentration in groundwater of Turkestan city in 2007

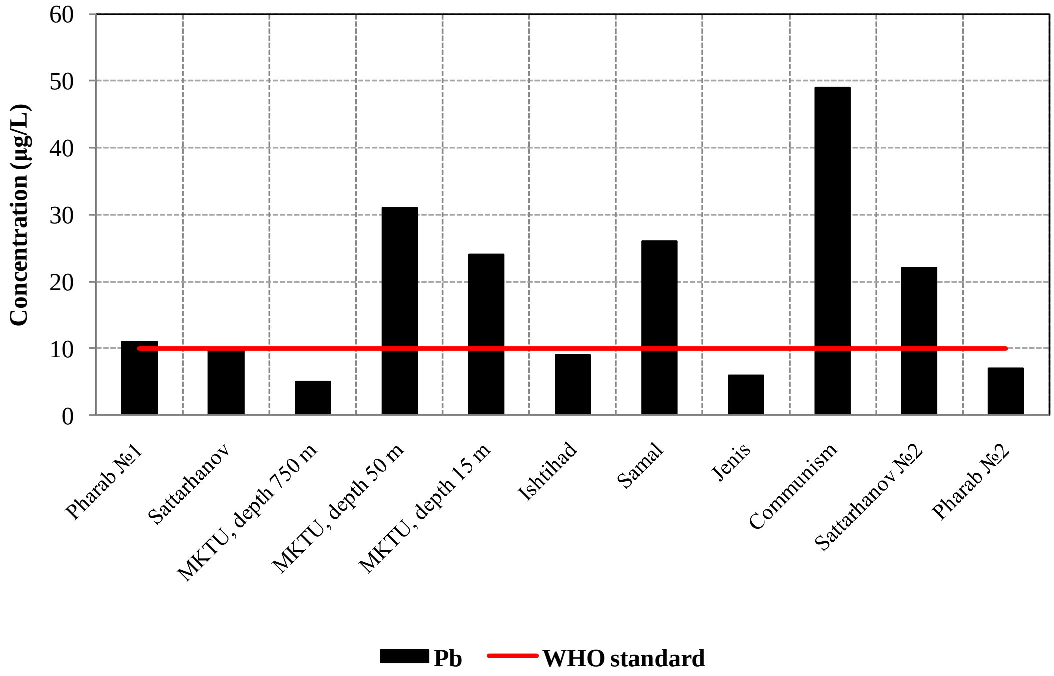

Figure 5.15 Pb concentrations in groundwater of Turkestan city in 2005-2006

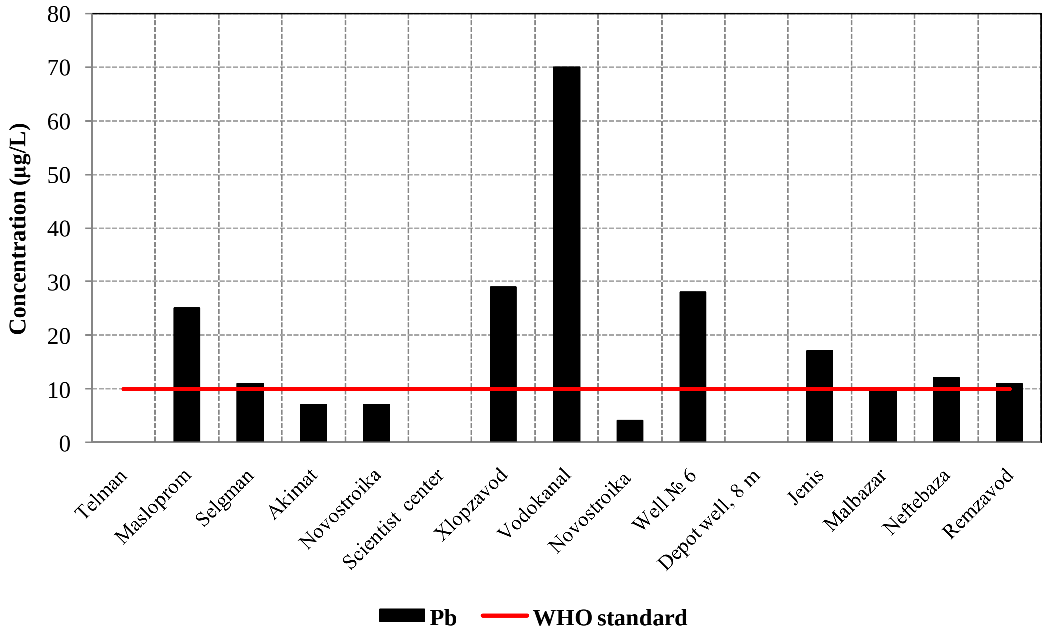

Figure 5.16 Pb concentrations in groundwater of Turkestan city in 2007

CHAPTER SIX
GENERAL ASSESSMENT

6.1 Surface water

In terms of water availability, Kazakhstan is one of the most water scarce countries on the Eurasian continent. In a average year, water quantity of the Republic is estimated to be 100.5 km^3 and about half of this quantity (44 km^3) is formed outside the country. The amount of water available for economic use only amounts to 43 km^3 that corresponds to about 43% of the grand total. Moreover, available water is not uniformly distributed within the Republic. Generally, Kazakhstan is located at the most downstream parts of all large transboundary waterways. Thus, inadequate water quality and quantity directly influences the everyday life in the country and creates conflicts with neighbouring countries.

In Central Asia, surface water resources such as Aral Sea, Syr Darya River and Balkhash Lake are international waters that are under the jurisdiction of more than one country. Under the Soviet Regime, the water management system was highly centralized. However, with independence, water issues like many others rapidly became a national rather than a regional concern. Conseuqnetly, the water quality and quantity problems have changed drastically since 1991, when independent states were established in Central Asia.

In the area, numerous bilateral and trilateral agreements were signed and several intergovernmental organizations were established to solve water related conflicts. Among these, the Basin Water Organizations (BWOs), Interstate Coordination Water Commission (ICWC), Interstate Council on the Aral Sea Basin (ICAS), Executive Committee of ICAS (EC-ICAS), International Fund for the Aral Sea (IFAS) and the Sustainable Development Commission (SDC) could be named as the most influential ones. Active participation from international partners for the implementation of concrete programs and projects are of primary importance to improve the ecological situation of surface water resources of the region. Despite these efforts, there are numerous unresolved problems and questions related to water quality and quantity.

In Southern Kazakhstan region, surface water resources are typically used for irrigation and drinking purposes. Degradation of river water quality influences for agricultural productivity with regards to the amount and quality of the products. Therefore, water quality is playing a significant role in social and economical life of the region. The Syr Darya is one of the major rivers discharging into the Aral Sea. The River is divided between four former Soviet States; Kyrgyzstan (Naryn, Dzhalalabadsky and Osh regions), Tajikistan (Sogdijsky area), Uzbekistan (Andizhan, Namangan, Fergana, Tashkent, Dzhizak and Syr Darya areas) and Kazakhstan (South Kazakhstan and Kyzyl Orda provinces). According to the data of Aral-Syr Darya Department that provides information on water quantity of the river between 1941 and 2010, it is seen that the water quantity of the river is drastically decreased to 10% of the pre 1960 amounts during 1970 and 1980. During the same period, the water withdrawal from the Syr Darya is significantly increased and contributed to about 90% of the pre 1960 amounts, primarily as a result of agricultural irrigation projects. Comparing the change in decades, one could see that the greatest reduction has occurred between 1970 and 1980s.

According to the data of Aral-Syr Darya Department, the river is mostly contaminated by chemical substances such as nitrate, sulphate and heavy metals. The water quality of the river is investigated in the 7 water quality monitoring stations (Zhanakurgan, Kyzyl Orda, Kazaly, Aralsk, Amanotkel, Aklak and Ust Syr Darya). In general, the chemical concentrations had the lowest values at the most upstream stations and gradually increased as river flows downstream due to anthropogenic influences. Consequently, the levels of most substances were in the order of the water quality standard value up to Aralsk station. After this point, concentrations considerably increased to about 4-10 folds above the standard values. It is believed that these high values are related to uncontrolled industrial discharges and agricultural return flows.

Being the final discharge point, the Aral Sea is directly influenced from changes in water quality and quantity in Syr Darya and Amu Darya rivers. The Aral Sea basin is located in the heart of the Asian continent and covers the territory of present Tajikistan, Turkmenistan, Uzbekistan, Afghanistan, Iran, Kyrgyz Republic and the Southern parts of Kazakhstan. Nowadays, the Aral Sea is considered one of the most critical environmental zones in the world. Inefficient irrigation systems and mismanagement of irrigation water diversions have resulted in not only the loss of Aral Sea but also created elevated water and soil salinity levels, widespread environmental degradation and diminished agricultural productivity.

The Aral Sea Basin receives majority of its waters from two major rivers of the region, the Amu Darya and Syr Darya. The average annual river flow in to the Aral Sea during 1927-1960 periods was stable. However, since 1960s, the inflow to the Sea has begun to decline. Hence, it could be said that the degradation of the Aral Sea is mostly related to the degradation in these rivers. Between 1960 and 1975, the Syr Darya River inflow to the Aral Sea has decreased drastically from 15.6 km^3 to 0.9 km^3. During the same period, the Amu Darya River inflow to the sea has also declined from 37.9 km^3 to 10 km^3. As a consequence of such reductions in river flows, the level of the Sea has fell at an average rate of 20 cm per year from 1961 to 1970. This reduction in water levels has resulted in a drastic decline in surface area and the volume of the sea, which corresponded to about 75% and 90%, respectively. As a consequence of such reductions, the Aral Sea has separated into two parts which are now known as the Small Aral Sea and the Large Aral Sea.

From a water quality point of view, the Aral Sea is mostly contaminated with heavy metals such as chromium, lead, cadmium nickel and cobalt. The number of pollutants in the Sea is high compared with the standard values, which is commonly associated with the pollutants entering into the sea via Amu Darya and Syr Darya rivers. As a result, particularly in Small Aral Sea, the heavy metal concentrations were excessively higher than the water quality standards during 2004-2007 periods. However, since 2007, all substances are considerably decreased.

Being another important surface water resource of the Central Asia, the Balkhash Lake is the largest moderately saline lake in the continent. The inflows to the Balkhash Lake originate from Tien Shan Mountains. The Lake is divided with a narrow strait into two parts: western Balkhash Lake and eastern Balkhash Lake that has with different characteristics with regards to water quality.

Similar to Aral Sea, the surface area of the lake has also gradually decreased since 1970s, due to the reductions of river discharges into the lake as a result of increased irrigational water demands as well as the storage effect of Kapchagay reservoir. On the average, the rate of water level decline of the lake is approximately 15 cm/year since 1970. Currently, the volume of the Lake is about 22.5 km^3. The water quality in the lake is noticeably influenced from high levels of Cl, Mg, Na, SO_4 and TDS. All of these parameters have been found to be 4-6 folds above the standard values.

6.2 Subsurface water

Subsurface water resources are non-uniformly distributed on the territory of the Republic. Basically more than 50% of subsurface water resources are concentrated in the Southern Kazakhstan Region along the foothill plains of Dzhungarskogo, Zailinskogo, the Kyrgyz Ala-Tau and Karatau Mountains. The subsurface water in this part of the country makes about 56% of the entire subsurface potential of the Republic.

One of the industrial centers of the Southern Kazakhstan Region is the Kentau city, which was formed in 1955 at the foothills of the Karatau Mountains in the South Kazakhstan Province. The water quality status of the subsurface waters near Kentau city is influenced from the Mirgalimsai mine and high levels of Pb, Ca and SO_4 were reported to be above the standard levels. Furthermore, between 2003 and 2006, the groundwater quality of Kushata and Karasu regions were also investigated and it was found out that the groundwater in these regions is mostly contaminated by Pb and Ni.

The Turkestan city is another residential area located in the South Kazakhstan Province, which provides its waters mostly from groundwater resources. The basic source of drinking water supply in the region is Karashykski, Bayaldirski and Hantagy-Biresekski subsurface waster aquifers. In Turkestan territory, numerous wells were drilled to extract the required water. According to the data of Kentau Ahmet Yassavi University Laboratory, the groundwater quality of the city is significantly contaminated by the Pb, Ca and SO_4. It is interesting to note that the pollutants which were found in groundwater of Kentau city were also found to be high in the groundwater of Turkestan city. Wells situated at Telman, Remzona and Communism wells are mostly contaminated by Pb, Mg and SO_4, which are found to be above the standards. Thus, in the Region the groundwater resource is not suitable for drinking purposes.

CHAPTER SEVEN
CONCLUSIONS AND RECOMMENDATIONS

This study is conducted to assess the surface and subsurface water quality in Southern Kazakhstan Region. In order to ascertain the surface water quality in the region, three case studies were assessed: Syr Darya River, Aral Sea and Balkhash Lake. Moreover, the subsurface water quality has been reviewed by focusing on Kentau and Turkestan cities. Based on this general review, the following conclusions were reached:

- The status of surface and subsurface waters of Southern Kazakhstan Region were reviewed from a quantity and quality point of view. In Southern Kazakhstan Region, surface water resources are typically used for irrigation and drinking purposes. Degradation of water quality of the Syr Darya River influences agricultural productivity with regards to the amount and quality of the products. The degradation of water quality in surface water sources (i.e., Aral Sea, Syr Darya River and Balkhash Lake) is mostly associated with anthropogenic activities.

- The water quantity of Syr Darya River within Kazakhstan territory is monitored in 8 stations: Kokbulak, Shardara, Koktobe, Tomenarik, Kyzyl Orda, Zhusaly, Kazaly and Karateren. As a result, in the Kyzyl Orda station the river discharge has decreased from 679.3 m^3/s (between 1942 and 1959) to 252.5 m^3/s (between 1960 and 1980). When the change in decades is compared, it is seen that the greatest reduction in water quantity in the region was observed between 1970 and 1980.

- The Syr Darya River is mostly used in supplying irrigational water demands, which approximately corresponded to more than 90% of the total water use in this region. The reduction in water levels in the river has reduced the productivity of the agricultural production in the region.

- In essence, the Syr Darya River is highly contaminated. Along the river, 7 water quality monitoring stations (i.e., Zhanakurgan, Kyzyl Orda, Kazaly, Aralsk, Amanotkel, Aklak and Ust Syr Darya) are situated that collects water quality data. According to the data of Aral-Syr Darya Department, the river is mostly contaminated by chemical substances such as nitrate, sulphate and heavy metals. For instance, the heavy metal concentrations tend to be below the standard levels up to Aralsk station and dramatically increased thereafter. In Ust Syt Darya station, where the river meets the Aral Lake, for instance, the chromium concentrations are detected to be seven times higher than the Kazakh standard value of 50 μg/L.

- Along the River, 140 collectors are present and these collectors totally discharge about 5-6 km^3/year wastewater into the river. In essence, the chemical concentrations had the lowest values at the most upstream station and gradually increased as river flows downstream due to anthropogenic influences such as collector discharges.

- One of the largest water resources in the Southern Kazakhstan Region is the Aral Sea. Aral Sea has shrunk due to excessive consumption of the two inflowing rivers: Amu Darya and Syr Darya.

- In 1960s, the area of Aral Sea was 68320 km^2 and the volume was 1066 km^3. In 2009, on the other hand, the remaining surface area of the sea was reduced to 8112 km^2, which is only 11% from the original sizes. Correspondingly, the volume decreased to about 30% of its original size. During the 1970 and 1980 periods, the water deficiency of the sea contributed to about 33 km^3/year.

- Irrigated areas in the Aral Sea basin grew rapidly from 4,510,000 ha in 1960 to about 8,000,000 ha in 2000. During 1970 and 1980s, the water intake for irrigation also increased about 90% as a result of the enlarging irrigated lands.

- According to the data, the sea is commonly contaminated by heavy metals. For instance, the Pb concentration ranged between 65 μg/L to 93 μg/L, which has exceeded the water quality standard value to about 5-7 folds. Other parameters such as Co, Cr and Cd were also above the standard levels until 2007-2008. Since 2007, considerable decreases in heavy metal concentrations were observed.

- About 3.5 million people live along the sea, about 1.5 million of which are children. The population around Aral Sea generally suffers from poor health. The deaths caused by diseases of the circulatory system are 24%, malignant neoplasms are 72%.

- It has been estimated that at least 73 km^3/year of water would have to be discharged into the Aral Sea for at least 20 years in order to recover the 1960 water level.

- Balkhash Lake has been selected as the third case study and its water quantity and quality were investigated. The water quantity of the lake has considerably decreased since 1970s. The rate of decline in water level of the lake is about 15 cm/year.

- Since 1970, the Lake is morphologically divided with a narrow strait into two parts: western Balkhash and eastern Balkhash that has with different characteristics.

- The construction of reservoirs on rivers discharging into the lake had significantly influenced to the ecosystems of the lake. Consequently, the hydrochemistry of the lake has changed. The water quality in western part of the lake was found to be more polluted compared to eastern part and parameters were found to exceed the standards.

- About 60% (71 km^3/year) of the entire surface water resources of Kazakhstan is found in the Southern Kazakhstan Region. Similarly, 55% (25.6 million m^3/day) of the entire subsurface water resources of the country is found in Southern Kazakhstan Region.

- Kentau and Turkestan cities were selected as two case studies to represent the quality status of subsurface waters. Although some of the industrial establishments are now closed, Kentau city is considered to be one of the industrial centers of the province. One such establishment is the Mirgalimsai mine, which is believed to influence the subsurface quality in the region. High levels of Pb, Ni and Ca were reported in Kentau city groundwaters.

- The Turkestan city is a city located 30 km downstream the Kentau city. Thus, it was believed that if contaminated the groundwater of Kentau would also influence the groundwater in Turkestan city. The groundwater of the Turkestan city was found to be contaminated by Pb, SO_4 and Mg, all of which were found to be above the drinking water quality standards.

Based on these findings, the following recommendations were listed to improve the quality and quantity status of Southern Kazakhstan Region water resources:

- It is important to construct multiple reservoirs to control and regulate river flows and to prevent the annual flooding.

- The water resources should be monitored on a regular basin. Continuous monitoring of hydrological and hydrochemical parameters of surface and subsurface waters is deemed crucial for proper management of these water resources.

- Allocation of water between different countries should be based on sound hydrological (flow rates, precipitation and evaporation totals, agricultural withdrawals, etc.) data. Countries should respect the rights of neighboring states and allocations among the countries should be made in an equitable and reasonable manner.

- Well-defined and achievable limits should be set on water withdrawal from the surface and subsurface water resources, taking into account ecologically viable volumes of water in river systems.

- In the Southern Kazakhstan region, almost about 80-90% of total water withdrawal from the river is used for agricultural irrigation purposes. Thus, the water efficient irrigation systems should be implemented and existing agricultural lands should not be extended without prior assessment of current and future status of water resources.

- Wastewaters discharged to rivers via collector system should be treated and water reuse measures should be implemented to reduce the burden on exsting fresh water resources.

- The organizations that control and allocate water resources could set reasonable fees for excess water use. The accumulated money could then be used in development of joint water saving projects and activities within the basin.

- There would also be a need to change agriculture policies in a more sustainable direction than what was originally introduced during the Soviet era.

- Uncontrolled wastewater discharge into rivers should be prevented to sustain the general quality pattern in river systems.

- Priority should be given to educate local people on the merits of efficient water use.

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