United Nations Educational, Scientific and Cultural Organization

International Hydrological Programme

GOVERNMENT OF MONGOLIA

NATIONAL WATER COMMITTEE

Water Quality of the Kharaa River Basin, Mongolia

Pollution threats and hotspots assessment

with support of

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GEF project "Integrated Natural Resource Management in the Baikal Basin Transboundary Ecosystem" (Mongolia and Russia), 2011-2014

Technical report under Output 1.4 (pollution hotspot assessment)

Water Quality of the Kharaa River Basin, Mongolia: Pollution threats and hotspots assessment (2013)

International executing partner for Output 1.4 (pollution hotspot assessment)
United Nations Educational, Scientific and Cultural Organization - UNESCO

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UNDP-GEF project
"Integrated Natural Resource Management in the Baikal Basin Transboundary Ecosystem"

Water Quality of the Kharaa River Basin, Mongolia

Pollution threats and hotspots assessment

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with support of

Ulaanbaatar
2013

This report presents results of water quality assessment of the Selenge River Basin (Mongolia), with specific emphasis on assessment of pollution threats and pollution hotspots in the Kharaa River Basin.

The study was conducted in the framework of UNESCO-executed activities under the UNDP-GEF Project on “Integrated Natural Resources Management in the Baikal Basin Transboundary Ecosystem” (Mongolia and Russia). The project objective is to spearhead integrated natural resources management of Lake Baikal Basin, ensuring ecosystem resilience and reduced water quality threats in the context of sustainable economic development. The project is executed by UNOPS. UNESCO’s International Hydrological Programme (IHP) is an international executing partner for the project.

This study was carried out by UNESCO, in collaboration with the National Water Committee of Mongolia, Mongolia Water Forum-Uskhelts and a national team of experts. The study and report preparation was coordinated by Sarantuyaa Zandaryaa, Division of Water Sciences, UNESCO. The national team of experts was coordinated by Tsend Badrakh, National Water Committee of Mongolia, and comprised the following experts: Batimaa Punsalmaa, Mongolia Water Forum - Uskhelts; Erdenbayar Yadamsuren, Central Laboratory for Environment and Meteorology; Tumurstooj Dashdorj, Institute of Meteorology, Hydrology and Environment; Oyuntugs Tserendendev, National Water Committee of Mongolia; and Davaadalai Batnasan, Mongolia Water Forum-Uskhelts. Tserendolgor Munkhtsetseg, Mongolia Water Forum - Uskhelts, assisted in the preparation of the report for publishing.

Findings and recommendations of the study were discussed with relevant stakeholders at the National Workshop “Selenge – A River without Borders”, organized by UNESCO in collaboration with the National Water Committee and Ministry of Environment and Green Development of Mongolia, which took place in the State Palace in Ulaanbaatar on 04 June 2013. The workshop participants included representatives of the Ministry of Environment and Green Development, Ministry of Health, Ministry of Industry and Agriculture, River Basin Authorities, research institutions, universities, NGOs and the private sector. The key outcomes of the workshop discussions were incorporated in this final report. The report also benefited from discussions at the scoping meetings and workshops, organized by UNESCO in the framework of this study.

The publication of this report was made possible with the support of Sergey Kudelya, Project Manager (Ulan-Ude, Russia), and Tumurchudur Sodnom, Technical Director (Mongolia), of the GEF project “Integrated Natural Resource Management in the Baikal Basin Transboundary Eco-system”.

Foreword by Prime Minister of Mongolia

Throughout the human history, we, Mongolians, valued the water as the basis of all existence on the Earth and the unique treasure of the world. The Government of Mongolia attaches great importance to the protection and sustainable use of this precious resource and, in particular, to establishing an effective policy and legal framework for water resources management.

Water is a special resource that is not confined to a country's territory or political boundaries. Mongolia is located in the heart of Central Asia, where the headwaters of world's many large rivers are formed by runoff from numerous springs, snowmelt and glaciers of the Mongolian mountains. Mongolians have a long tradition of conserving the purity of water resources that originate in our country's territory and flow out to our neighboring countries. This tradition has been preserved from generation to generation and has been enshrined in the Mongolian government's policy on water resources management. Mongolia is fully engaged in international cooperation with our neighboring countries on fair, equitable and sustainable use of transboundary water resources. An example is our cooperation with the Russian Federation on the implementation of the "Agreement on the Protection and Use of Transboundary Waters", which was signed between the governments of our two countries in 1995.

Water resources are becoming scarcer due to climate change. In view of climate change impacts on water resources, international cooperation on fair and equitable use of transboundary water resources is essential. Furthermore, the support of international organizations is needed to strengthen cooperation to face up to new challenges and threats resulting from climate change impacts on water resources. I am pleased that the project on "Integrated Natural Resource Management in the Baikal Basin Transboundary Ecosystem", implemented by various UN organizations, responds to this need and to the goals that the Mongolian Government has prioritized for sustainable use and management of natural and water resources. I would like to warmly congratulate the organizers and participants of the National Workshop entitled "Selenge-A River without Borders" for providing a platform to discuss the results of the project studies presented in this report on water quality of the Kharaa River, which I consider an important contribution to maintain the Baikal Basin ecosystems that constitute the world's magnificent freshwater resource and heritage.

We share the same rivers. We live in the same river basin. We drink water from the same rivers. Therefore, our common goal must be to protect our precious water resources and to use them sustainably to enhance the country's development and improve the living standard of our people.

Norov Altankhuyag
Prime Minister of Mongolia
Chairman, National Water Committee

**This Foreword is based on the message of the Prime Minister of Mongolia to the National Workshop "Selenge-A River without Borders", organized by UNESCO, National Water Committee and Ministry of Environment and Green Development of Mongolia in Ulaanbaatar (State Palace) on 04 June 2013.*

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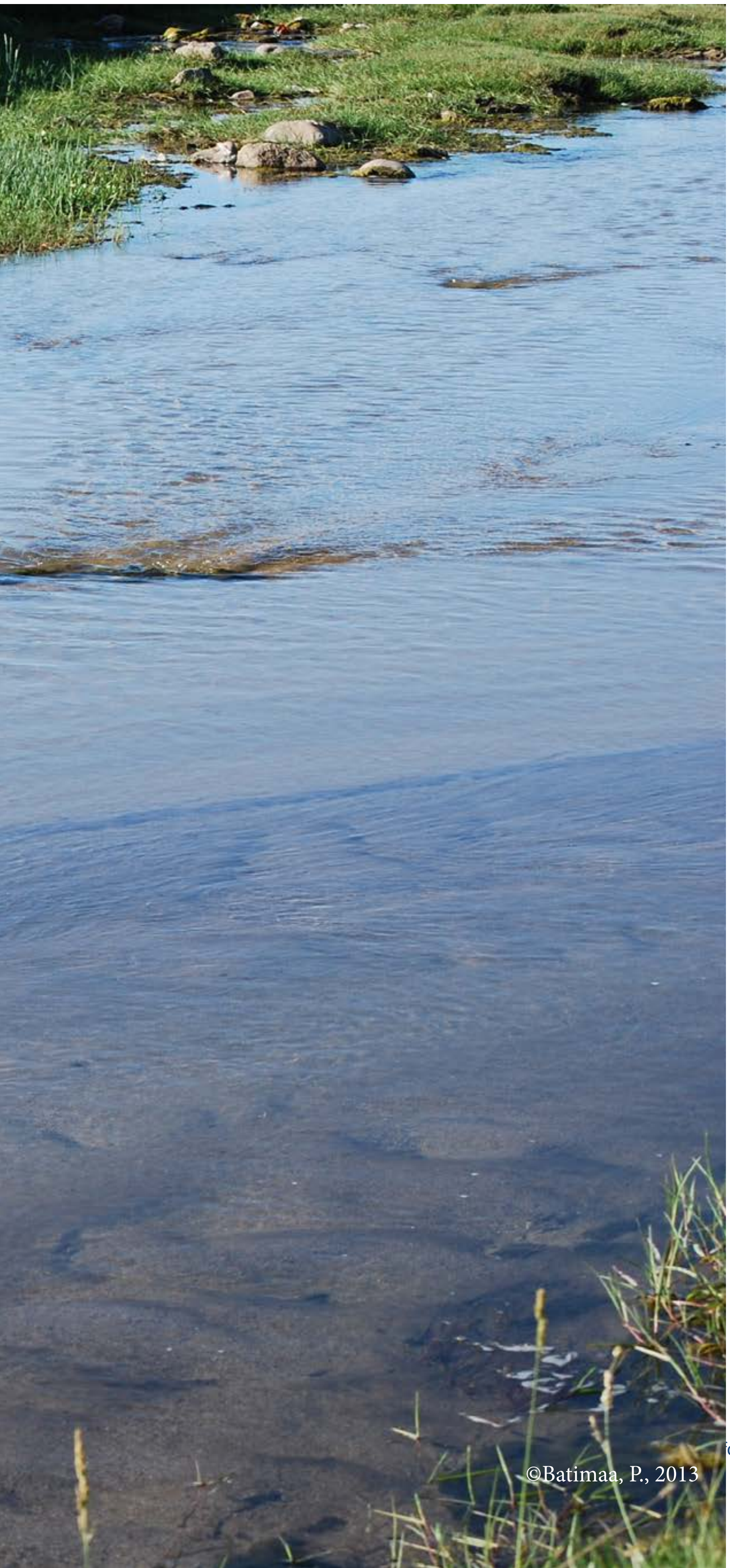
Acronyms

BOD	Biological oxygen demand
DO	Dissolved oxygen
EPT	Ephemeroptera, Plecoptera, Trichoptera
FAO	Food and Agriculture Organization
GEF	Global Environment Facility
IHP	International Hydrological Programme of UNESCO
MAC	Maximum Acceptable Concentrations
MNET	Ministry of Nature, Environment and Tourism of Mongolia
MNS	Mongolia National Standard
NSA	National Standard Agency of Mongolia
NSO	National Statistics Office of Mongolia
OCHA	Office for the Coordination of Humanitarian Affairs of the United Nations
TSS	Total suspended solids
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
USAG	Water Supply and Wastewater Company of Ulaanbaatar
WHO	World Health Organization
WQI	Water Quality Index
WWTP	Wastewater Treatment Plant

UNDP-GEF project
"Integrated Natural Resource Management in the Baikal Basin Transboundary Ecosystem"



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Executive summary

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Mongolia has many beautiful freshwater lakes and rivers. Some of the world's major rivers originate in Mongolia, including Selenge River, Yenisei and Irtysh. Most of Mongolia's rivers are spread across the northern part of the country, where the river system is also most extensive. The Selenge River is the largest river by volume of flow, which is a major transboundary river in the heart of Asia flowing to Lake Baikal, located in Russia. About two-thirds of the surface runoff leaves Mongolia. The largest lakes of Mongolia, including Khuvsgul, Uvs and Khar-Us, are located in the northern and western regions of the country. Mongolia has substantial groundwater resources, which are unevenly distributed over the country-abundant in the north and very scarce, or non-existent, in the south.

Driven by climate change, urbanization and rapid economic growth, Mongolia's water resources are under increasing pressure. Water resources of Mongolia are limited, with the annual water reserves of 34.6 cubic kilometers-which is relatively low compared to other countries. Yet, the per capita annual renewable water availability exceeds 10,000 cubic meters, which is more than in most other countries in the world. This seeming contradiction can be explained by the country's population density of only 1.8 persons per square kilometers, which is the lowest in the world1. Despite the huge amount of renewable water in the country, its availability is unevenly distributed in space and in time. Most of Mongolia's territory lies in arid and semi-arid regions, which makes its water resources particularly vulnerable to climatic and human pressures.

The Kharaa River Basin is one of the main tributaries of the Orkhon-Selenge River system. The Orkhon River originates in the Khangai Mountains in central Mongolia and flows northwards for 1,124 km before joining the Selenge River, which empties into Lake Baikal. The Orkhon River is the longest river in Mongolia and the valley along the river is an archaeologically-rich cultural landscape. The Orkhon Valley Cultural Landscape has been designated by UNESCO as a World Heritage Site.

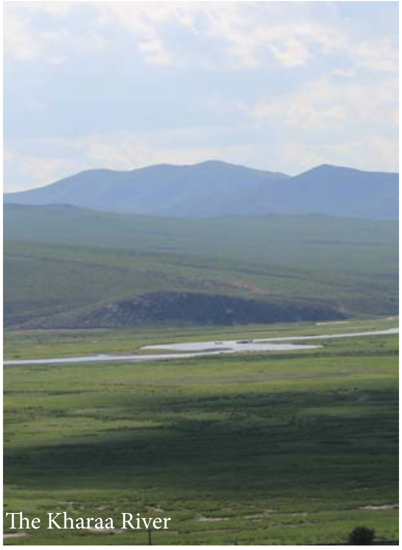
The pollution of the Kharaa River Basin is becoming a growing concern due to the high vulnerability of the basin to urban and industrial pollution from urban settlements and large industrial operations located in the basin. The Kharaa River Basin is shared among three administrative regions, called aimags (equivalent to provinces)-namely, Selenge aimag, Tuv aimag and Darkhan-Uul aimag. The basin also includes the rapidly-growing industrial city of Darkhan, which is thethird largest city with 74,738 inhabitants (as of 2010)2. The entire population of the Kharaa River Basin is about 133,000. The Kharaa River Basin is under increasing pressure from rapid urbanization, rising water demand and climate change. The upper basin is in a relatively pristine state and has experienced minimal anthropogenic impacts. The lower basin is characterized by diverse economic activities such as industry, agriculture and livestock breeding, which may potentially have significant impacts on the quantity and quality of water resources of the basin. Furthermore, the basin provides drinking water for the rapidly-growing city of Darkhan, which water supplies largely rely on alluvial aquifers containing shallow-depth groundwater, and the inhabitants of small human settlements in the basin. Hence, growing pressures from climate change and anthropogenic activities on the Kharaa River may become a matter of concern in securing future water supplies in the area.

The assessment of water quality and water pollution in the Selenge River Basin, undertaken by this study, focused on a case-study on pollution hotspots and pollution threats in the Kharaa River Basin, including urban water pollution in the city of Darkhan, Mongolia.

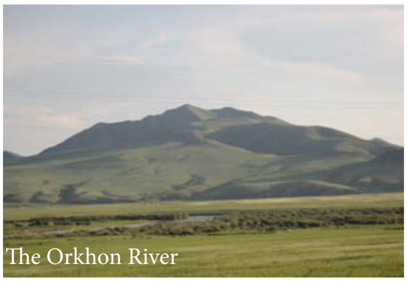
[1]Ministry of Environment and Green Development, 2012. Integrated Water Management Plan of Mongolia 2010-2021: A Brief Introduction, Ulaanbaatar, Mongolia, December 2012.

[2]Data from the National Statistical Office of Mongolia.

The main objectives of this study were to assess the current state of the water quality of the Kharaa River Basin, assess water pollution from diffuse and point sources, identify pollution hotspots in the basin, and determine the main pressures on the water quality of the Kharaa River, with a qualitative description of their impacts. The study focused on: the survey of water quality characteristics of the Kharaa River; the identification of anthropogenic impacts on the river's water quality; the identification of major threats to the water quality in the basin; and the development of recommendations on pollution prevention and control in the Kharaa River Basin.


The Kharaa River

The assessment of the water quality in the Kharaa River is based on both hydrochemical and hydrobiological parameters. The hydrochemical assessment is based on hydrochemical monitoring data collected by the Central Laboratory for Environment and Meteorology for the period from 1986 through 2011. The hydrobiological assessment is based on macroinvertebrates data collected by the Institute of Meteorology, Hydrology and Environment for the period from 2005 to 2010.

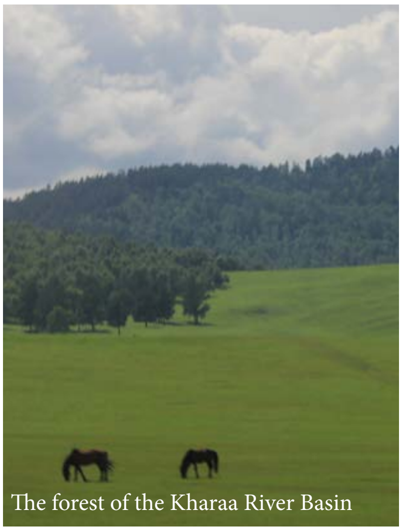

The Orkhon River

As part of the Mongolia's freshwater quality monitoring network, the Kharaa River water quality has been monitored at four sampling points at two monitoring stations since 1986. The upper monitoring station, which is the reference site of the study, is located near Zuunkharaa (a small urban settlement) and has two sampling points upstream and downstream from Zuunkharaa. The second monitoring station is located near to Darkhan city and has two sampling points too-upstream and downstream from the city.


The grassland of the Kharaa River Basin

The overall assessment of the chemical composition has shown good chemical conditions at the sampling sites on the Kharaa River. The monthly mean concentrations of total dissolved salts (the sum of Ca^{2+}, Na^{+}+K^{+}, Mg^{2+}, HCO_3-, SO_4^{2}- and Cl-), or mineralization, in the Kharaa River vary between 162.2-335.7 mg/l and show a tendency to increase towards downstream. The concentrations of total dissolved salts increase also during snow melting periods. In a vast majority of the cases, the order of abundance of cations is $Ca^{2+}>Na^{+}+K^{+}>Mg^{2+}$, and the order of abundance of anions is $HCO_3^{-}>SO_4^{2-}>Cl^{-}$.

The concentrations of the biological oxygen demand (BOD) are, in most of the cases, below the Maximum Acceptable Concentration of 5 mg/l-the standard set by the Mongolian National Standard for Water Quality of the Aquatic Environment: General Requirements MNS 4586-98 (NSA, 1998).


The forest of the Kharaa River Basin

This indicates that in general the river water is clean. However, it should be noted that the BOD concentrations occasionally exceed the Maximum Acceptable Concentrations (5 mg/l) at both sampling sites during summer. This may show that organic pollutants originating from urban and industrial areas and livestock wastes enter the river with surface washing during heavy rainfall events in summer.

Phosphorus and nitrogen concentrations show a decreasing trend near Zuunkharaa, while there is no trend near the city of Darkhan. The concentrations of NO3-N near Zuunkharaa have decreased since 1990s. Similarly, PO4-Pconcentrations have decreased near Zuunkharaa.

There are no observed data on metals, except total Fe and Cr^{6+} at the downstream sampling points of both monitoring stations. The monthly mean concentrations of Fe range between 0.08 and 0.15 mg/l and increases during rainy seasons. The Cr^{6+} concentrations are between 0 and 0.01 mg/l and also increase in rainy season.

The analysis of the macro-invertebrate communities at the two monitoring sites of the Kharaa River watershed indicates that the ecological condition of the river is good. The assessment of the fish communities has shown a good, or a very good, ecological status at the sites. A moderate status, detected at two sites in the watershed, is caused by the absence of ubiquistic species, showing no clear deficits in the ecological integrity of the fish fauna. Most of the fish species are known to occur in the Kharaa River Basin.

The major point source of pollution appears to be the wastewater treatment plants in the cities of Darkhan and Salkhit. The treatment rate of the Darkhan Wastewater Treatment Plant ranges between 80-98%. The BOD concentrations in the outlet wastewater range between 3.1-33.6 mg/land very rarely exceed the Maximum Acceptable Concentrations (20 mg/l), set by the Mongolian National Standard for Wastewater Treatment MNS 4943-2000.

More than 60 percent of the total area of the Kharaa River Basin is pasture. Accordingly, the livestock herding at the river bank is the major non-point source of pollution during warm seasons, leading to the fecal contamination and direct nutrient inputs to the river water by domestic waste, including animal manure.

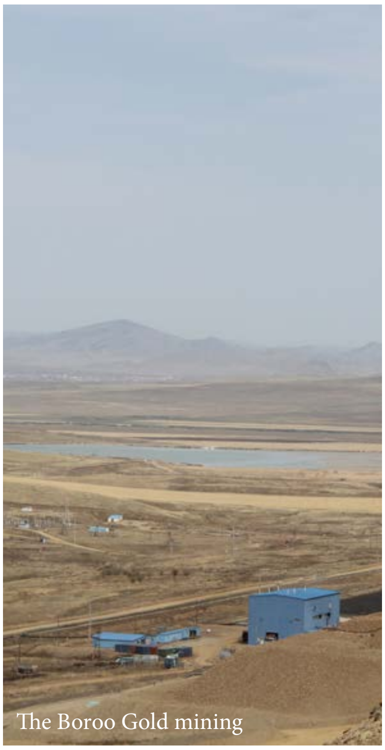
The second largest non-point source is open mining. Several large mining reserves are found in the Kharaa River Basin and occupy an area of about 16 percent of the total area of the basin. Some of the mines are not yet exploited, which means that exploration and development licenses of these reserves may have been issued to mining companies, with mining operations not having started. The mining area under operation represents 1.5 percent of the total area of the basin, which is about 9.3 percent of the total area for mining purposes (Figure 26). There are no systematically observed data to assess the pollution from mining activities in the area. Heavy metals such as mercury, arsenic, and cyanide are commonly used in gold mines, which may have potentially serious impacts not only on surface water quality but also on groundwater and soil. An incident of a possible mercury and cyanide contamination of groundwater caused by a tailings spill from a small mining operation in Khongor soum was recorded in 2007.

The results of the assessment indicate that the water quality in the Kharaa River Basin decreases occasionally to 'moderately-polluted' and 'very-polluted' near urban and industrial settlements, which may become a concern in the future. The main sources of water pollution in the basin are urban areas, agriculture and mining activities.

The assessment also shows that the self-purification rate in the Mongolian rivers is usually high with the distance of self-purification of 6-18 kilometers. The self-purification distance of the Kharaa River appears to be 10 kilometers downstream from the city of Darkhan. Consequently, the Kharaa River water becomes clean at its outlet at the confluence with the Orkhon quality of the Orkhon and Selenge rivers.

In overall, the results of the study show that the water quality of the Kharaa River Basin is clean and has good ecological conditions. The water quality of the Kharaa River decreases occasionally to 'moderately-polluted' and 'very-polluted' near urban and industrial areas, as well as during high water periods and snow melting times. This shows that moderate pollution occurs near urban areas and in snow melting periods, with no serious degradation in the water quality of the whole basin.

The main sources of water pollution in the basin are urban areas, agriculture and mining activities. Due to rapid urbanization and economic development, pollution from municipal wastewater and mining activities may become a concern in the future. Furthermore, the Kharaa River Basin is facing growing pressures from climate change and rising water demands. Hence, the sustainable use and management of water resources of the Kharaa River Basin is of crucial importance in securing future water supplies in the area.



The Boroo Gold mining

1. Introduction

Life on Earth originated from water. Water is essential for human life. We drink it, we produce food and other products with it, and we use water for many socio-cultural activities. Our health and well-being depend on it. It is essential for the sustainable development of society. Water a resource that must be sustained for future generations.

1.1. Background

With abundant water resources in some areas and shortages in others, Mongolia is facing a With abundant water resources in some areas and shortages in others, Mongolia is facing a challenge to use and manage its water resources for the country's sustainable development and the prosperity of its people, while protecting and maintaining them for future generations.

Mongolia has many beautiful freshwater lakes and rivers. Most of Mongolia's rivers are spread across the northern part of the country, where the river system is also most extensive. The largest and longest rivers in Mongolia are the Orkhon River (1,124 km), the Kherlen River (1,090 km), the Tuul River (704 km), Zavkhan River (670 km) and the Selenge River (539 km). The Selenge River is the largest river by volume of flow. Many rivers are used as sources of water for livestock and irrigation. Because of the mountainous terrain, there is a great concentration of potential hydropower in the north. Most of the rivers are unsuitable for navigation. The largest lakes of Mongolia, including Khuvsgul, Uvs and Khar-Us, are located in the northern and western regions of the country. Lake Khuvsgul, located in northern Mongolia, is Mongolia's largest freshwater lake and the 16th largest naturally formed lake in the world by water volume.
Lake Khuvsgul contains 60 percent of the surface freshwater resources of Mongolia and is a constant source of clean freshwater flowing to the Selenge River through its outflow the Eg River. It is one of the ancient lakes of Asia and a sister lake of Lake Baikal. Lake Uvs *(Uvs Nuur)* is the largest lake in Mongolia by surface area. The Uvs Nuur Basin has been designated by UNESCO as a World Heritage Site for its rich steppe biodiversity. Mongolia has substantial groundwater resources, which are unevenly distributed over the country-abundant in the north and very scarce, or non-existent, in the south.

Most of Mongolia's water resources belong to transboundary river basins of the Arctic Ocean and Pacific Ocean drainage. Some of the world's major rivers have their origin in Mongolia, including Selenge River, Yenisei and Irtysh. The Selenge River is a major transboundary river in the heart of Asia and the main tributary of Lake Baikal, located in Russia. The Selenge River Basin is shared by Mongolia and Russia (Figure 1). It forms the headwaters of the Yenisei-Angara river system. About two-thirds of the surface runoff leaves Mongolia.

Driven by climate change, urbanization and rapid economic growth, Mongolia's water resources are under increasing pressure. Water resources of Mongolia are limited, with the annual water reserves of 34.6 cubic kilometers- which is relatively low compared to other countries. Yet, the per capita annual renewable water availability exceeds 10,000 cubic meters, which is more than in most other countries in the world. This seeming contradiction can be explained by the country's population density of only 1.8 persons per square kilometers, which is the lowest in the world. Despite the huge amount of renewable water in the country, its availability is unevenly distributed in space and in time. Most of Mongolia's territory lies in arid and semi-arid regions, which makes its water resources particularly vulnerable to climatic and human pressures. Mongolia's water resources are faced with rapidly growing problems such as the impact of global climate change, overexploitation of water resources, wastewater discharge into rivers from point sources in urban and rural areas, and diffuse pollution from non-point sources like livestock and cropland (Batimaa et al, 2011).

Figure 1. Map of the Lake Baikal Basin, shared between Mongolia and Russia

The Kharaa River Basin is one of the main tributaries of Orkhon-Selenge River Basin (Figure 2). The Orkhon River originates in the Khangai Mountains in central Mongolia and flows northwards for 1,124 km before joining the Selenge River, which empties into Lake Baikal. The Orkhon River is the longest river in Mongolia and the valley along the river is an archaeologically-rich cultural landscape. The Orkhon Valley Cultural Landscape has been designated by UNESCO as a World Heritage Site. The pollution of Kharaa River Basin is becoming a growing concern due to the high vulnerability of the basin to urban and industrial pollution from urban settlements and large industrial operations located in the basin. The Kharaa River Basin is shared among three administrative regions, called aimags (equivalent to provinces)—namely, Selenge aimag, Tuv aimag and Darkhan-Uul aimag.

The basin also includes the rapidly-growing industrial city of Darkhan, which is the third largest city with 74,738 inhabitants (as of 2010). The entire population of the Kharaa River Basin is about 133,000. The Kharaa River Basin is under increasing pressure from rapid urbanization, rising water demand and climate change. The upper basin is in a relatively pristine state and has experienced minimal anthropogenic impacts. The lower basin is characterized by diverse economic activities such as industry, agriculture and livestock breeding, which may potentially have significant impacts on the quantity and quality of water resources of the basin.
Furthermore, the basin provides drinking water for the rapidly-growing Darkhan City, which water supplies largely rely on alluvial aquifers containing shallow-depth groundwater, and the inhabitants of small human settlements in the basin. Hence, growing pressures from climate change and anthropogenic activities on the Kharaa River may become a matter of concern in securing future water supplies in the area. Consequently, the assessment of water pollution in the Selenge River Basin focused on a case-study on pollution hotspots and pollution threats in the Kharaa River Basin, including urban water pollution in Darkhan, Mongolia.

1.2. Objectives of the study

River water systems bring a multitude of benefits, called “ecological goods and services”, to the society. Water resources for human uses and ecological services depend on good natural ecological conditions of rivers. Furthermore, the availability of valuable fish populations in rivers and lakes and the self-purification capacity of rivers directly depend on water quality. The protection and maintenance of water quality is, therefore, required to ensure the sustainability of water resources and ecosystem goods and services.

Climate change, rapid urbanization and expanding economic activities exert a wide range of pressures on the Selenge River Basin, particularly on the Kharaa River, which makes the Kharaa River Basin an ideal focus region of this study. There are growing concerns over the overexploitation of water resources and pollution from urban areas, agriculture and mining.

The assessment of water pollution in the Selenge River Basin focused on a case-study on pollution hotspots and pollution threats in Kharaa River Basin, including urban water pollution in Darkhan, Mongolia.

The main objectives of this study were to assess the current state of the water quality of the Kharaa River Basin, assess water pollution from diffuse and point sources, identify pollution hotspots in the basin, and determine the main pressures on the water quality of the Kharaa River, with a qualitative description of their impacts.

The water quality assessment focused on:

- the survey of water quality characteristics of the Kharaa River;
- the identification of anthropogenic impacts on the river’s water quality;
- the identification of major threats to the water quality in the basin; and
- the development of recommendations on pollution prevention and control in the Kharaa River Basin.

The scope of study includes:

- Human impacts on water quality in the basin;
- Major pollution threats to water quality;
- Pollution hotspots, including major pollution sources, types and levels of selected main pollutants;
- Urban pollution, including municipal wastewater, stormwater, and solid waste;
- Negative impacts of water pollution on the sustainability of water resources in the basin, as well as on human health and ecosystems.

The study is based on existing information and data that are available at national institutions.

1.3. Data and methodology

Mongolia has a surface water quality monitoring network, which consists of national sampling sites at various locations and frequencies throughout Mongolia's river network. The water quality monitoring aims to monitor the water quality of rivers and to provide an overview of the state of water quality of Mongolia's rivers in compliance with the Mongolian National Standard for Water Quality of the Aquatic Environment: General Requirements MNS 4586- 98 (NSA, 1998). Water quality monitoring measurements include physicochemical parameters such as temperature, pH, major ions, nutrients and metals. Since 1995, the surface water biomonitoring network has been recognized as an integral part of the long-term freshwater quality monitoring network. It incorporates biological information into traditional physicochemical water quality monitoring. Macro-invertebrate samples are collected for use in assessing the degradation of aquatic ecosystems.

The Selenge River is one of the most-extensively monitored rivers in Mongolia. As the study focuses on the Kharaa River Basin, data from selected water quality monitoring stations are used in the study. Monitoring stations and sampling sites selected for this study are described in the respective sections hereafter of the report.

1.3.1. Monitoring sites

As part of the Mongolia's freshwater quality monitoring network, the Kharaa River water quality has been monitored at two stations since 1986 (see Figure 6).

The upper monitoring station is located near Zuunkharaa-a small urban settlement. This station has been chosen as the reference site of the study. It has two sampling points: the first sampling point (Zuunkharaa-upper) is located upstream of Zuunkharaa; and the second sampling point (Zuunkharaa-down) is located downstream from Zuunkharaa in order to monitor the impact of the settlement on the quality of the Kharaa River water.

Figure 2. The Confluence of the Selenge and Orkhon rivers (29 June 2009)

The second monitoring station is located near to Darkhan city, and has two sampling points: Darkhan-upper and Darkhan-down, which are located upstream and downstream from the city.

1.3.2. Data

Water quality varies considerably throughout the year in relation to climatic conditions, runoff and human activities. In order to obtain a realistic view on surface water quality and to evaluate trends in the basin, monitoring data must be collected at different times of the year on same sampling sites. However, surface water sampling alone cannot characterize all the physical and biological conditions of surface water systems. In addition to surface water assessment, studies on sediments, habitats and biological diversity are also necessary to obtain a complete understanding of the state of water quality and ecological conditions of river basins and their changes.

The assessment of the water quality of the Kharaa River Basin included an assessment of changes in both hydrochemical and hydrobiological parameters. The hydrochemical monitoring data, collected by the Central Laboratory for Environment and Meteorology for the period from 1986 through 2011, are used for the hydro-chemical study. The macroinvertebrates data collected by the Institute of Meteorology, Hydrology and Environment for the period from 2005 to 2010 are used for the hydrobiological study.

Observed data on surface water quality

Within the Mongolian national environmental monitoring network, there are 64 sampling sites for surface water quality monitoring. These sampling sites are located on 19 rivers and one lake. There are also two sampling sites in the Selenge River Basin for the analysis of wastewater discharges from wastewater treatment plants. It should be noted that data from only selected sampling sites are assessed for this report, as the study focuses on the Kharaa River Basin. The Kharaa River water quality is monitored at four sampling points at two monitoring stations—near Zuunkharaa and the city of Darkhan.

The assessment of the water quality in the Kharaa River is based on both hydrochemical and hydrobiological parameters.

The hydrochemical assessment is based on hydrochemical monitoring data of the Kharaa River collected by the Central Laboratory for Environment and Meteorology for the period from 1986 through 2011.

The Kharaa River water quality is monitored at the Zuunkharaa monitoring stations with a monthly frequency during the months of April through November, whereas the monitoring is carried out once a month throughout the year at the Darkhan monitoring station. The water quality monitoring parameters at these stations are shown in Table 1.

The hydrobiological assessment is based on macroinvertebrates data collected by the Institute of Meteorology, Hydrology and Environment for the period from 2005 to 2010. Table 2 shows hydrobiological monitoring stations in the Selenge River Basin.

Table 1. Kharaa River monitoring stations and parameters

№	Stations	Chemistry								
		Ca^{2+}	Mg^{2+}	$Na^{+}+K^{+}$	HCO_3^{-}	SO_4^{--}	Cl^{-}	Hard-ness	pH	Suspended Solids
1	Zuunkharaa upper	+	+	+	+	+	+	+	+	+
2	Zuunkharaa down	+	+	+	+	+	+	+	+	+
3	Darkhan upper	+	+	+	+	+	+	+	+	+
4	Darkhan down	+	+	+	+	+	+	+	+	+

№	Stations			Nitrogen			Metals		
		O_2	BOD	NH_4-N	NO_3-N	PO_4-P	Fe	Cr	
1	Zuunkharaa upper			+	+	+			
2	Zuunkharaa down			+	+	+	+		+
3	Darkhan upper	+	+	+	+	+			
4	Darkhan down	+	+	+	+	+	+		+

Table 2. Hydrobiological monitoring stations

№	Rivers	Station	Location	
			Latitude	Longitude
1	Selenge	Khurag	$49^0$37′611	$102^0$85′056
2	Selenge	Khyalganat	49. ^{0}46′833	$104^0$37′944
3	Selenge	Sykhbaatar	$50^0$25′258	$106^0$13′786
4	Chuluut	Chuluut	$47^0$54′250	$100^0$24′722
5	Eg	Khantai	$49^0$55′000	$103^0$26′806
6	Orkhon	Orkhon	48^0.66′000	$103^0$56′778
7	Urdtamir	Tsetserleg	$47^0$44′722	$101^0$50′250
8	Achuut	Bulgan	$48^0$82′917	$103^0$50′306
9	Tuul	Ulaanbaatar	$47^0$88′333	$106^0$93′333
10	Tuul	Altanbulag	$47^0$68′333	$106^0$28′330
11	Tuul	Lun	$47^0$85′000	$105^0$18′333
12	Terelj	Terelj	$47^0$96′667	$107^0$46′667
13	Zuunturuu	Bulgan	$48^0$82′917	$103^0$54′583
14	Ulaistai	Uliastai	$48^0$04′130	$107^0$06′255
15	Selbe	Sanzai	$48^0$13′333	$106^0$88′333
16	Selbe	Dambadarjaa	$47^0$98′000	$106^0$92′000
17	Kharaa	Baruunkharaa	$48^0$91′089	$106^0$07′844
18	Kharaa	Darkhan	$49^0$59′142	$105^0$85′908
19	Ider	Tosontsengel	$48^0$74′111	$98^0$23′056
20	Sharyin gol	Jimsnii stants	$49^0$76′667	$106^0$16′667

Groundwater quality data

Groundwater quality monitoring is limited to only a number of locations for the period before 1990. Data on groundwater quality were recorded for shallow and deep wells and included data on mineral composition, pH, and sometimes nitrogen-based nutrients such as nitrite, ammonium, and nitrate. As mineralization of aquifers does not change significantly within a few decades, it was assumed that these data reflect roughly the current state of physico-chemical quality of groundwater. The available data are not sufficient to assess trends of groundwater quality in the Kharaa River Basin.

Reports, publications and other materials

Many other published reports were reviewed and used in this study in order to capture all available information on the water quality of the Kharaa Rver Basin. The study extensively used reports of the ongoing German-funded project on "Integrated Water Resources Management for Central Asia–MoMo" in the basin.

1.3.3. Methodology

In general, water quality is defined by the composition of its constituents, including: physical characteristics (such as temperature, suspended solids); chemical characteristics (such as major ions, nutrients, oxygen, organic compounds); and biological characteristics (such as macroinvertebrates). The assessment of the water quality monitoring data is based on the basic statistical analysis (arithmetic mean, max/min, trends, etc.) for each possible chemical parameter monitored at the sampling points in the Kharaa River as part of the national water quality monitoring network.

Water Quality Index

One of the key goals of implementing conservation practices is to maintain and improve water quality within a watershed. The overall state of water quality can serve as a simple first step tool in efforts of evaluating effects of the conservation practices in improving and/or sustaining the quality of water in the watershed. One of the methods to describe the overall state of water quality is Water Quality Index (WQI). It is based on information from a number of different sources and combines them into a single number that represents an overall state of the quality of the water at a particular time and location. Conventionally, WQI has been developed and used for evaluating water quality of water resources such as streams, rivers and lakes.

The Water Quality Index is used by the Central Laboratory for Environment and Meteorology of Mongolia for the purpose of assessing the ecological status of surface waters in Mongolia. Below is the description of the methodology for determining the WQI, used in this study. It is based on: surface water quality index; and biotic index.

Surface water quality index: The surface water quality index (W_{qi}) is defined as a simple expression of a more or less complex combination of a several parameters which serves as a measure for water quality (Bulgan, 2008). It is estimated by the following equation:

$$W_{qi} = \frac{\sum_i \left(\frac{C_i}{Pl_i}\right)}{n}$$

Table 3. Water quality classification

Water quality classification	Classification	Water Quality Index
I	Very clean	≤0.3
II	Clean	0.1-0.89
II	Moderately polluted	0.90-2.49
IV	Polluted	2.50-3.99
V	Highly polluted	4.00-5.99
VI	Extremely polluted	≥6.0

Where,
Ci is concentration of i^{th} pollutant, PI_i is the maximum permissible level of i^{th} pollutant in accordance with the MNS 4586- 98, and *n* is the total number of pollutants.

The water quality of rivers is then classified based on W_{qi} values, as shown in Table 3.

In determining the WQI, the water quality parameters should be chosen according to the importance of assessing water quality and the availability of monitoring data. The following parameters were used in the water quality assessment of the Kharaa River in the framework of this study:

- ammonium-nitrogen (NH4-N)
- nitrate-nitrogen (NO3-N)
- phosphate (PO4-P)
- permanganate value
- suspended solids.


The Boroo River dam

The dissolved oxygen (DO) and biological oxygen demand (BOD) are the most preferable parameters for the water quality assessment. However, the DO and BOD are monitored only at the two sampling points of the Darkhan monitoring station, whereas the Zuunkharaa monitoring station does not include these parameters, as shown in Table 1. Therefore, due to lack of data on DO and BOD at the Zuunkharaa monitoring station, these parameters were not taken into account the calculation of the Water Quality Index of the Kharaa River.

Biotic index: One of the methods that scale the water quality by the hydrobiology is the "Hilsenhoff Biotic Index" (Barbour et al, 1999). The Biotic Index is based on categorizing macroinvertebrates
into categories depending on their response to organic pollution (i.e., the tolerance of various levels of dissolved oxygen) and the pollution tolerance scores and expanded


The Bornuur irrigation channel

Table 4. Macroinvertebrates Biotic Index

Group name	Biotic index	Group name	Biotic index	Group name	Biotic index
Ephemeoptera		Lestidae	6	Dixidae	1
Ameletidae	0	Libellulidae	2	Emphididae	6
Baetidae	5	Macromiidae	2	Ephydridae	6
Baetiscidae	4	Trichoptera		Psychodidae	8
Caenidae	6	Brachycentridae	1	Simulidae	6
Ephemerellidae	1	Glossomatidae	1	Muscidae	6
Ephemeridae	3	Hydropsychidae	4	Syrphidae	10
Heptageniidae	3	Hydroptilidae	4	Tabanidae	5
Isonychiidae	1	Lepidostomatidae	1	Tipulidae	3
Leptophlebidae	3	Leptoceridae	4	Homoptera	
Metretopodidae	2	Limnephilidae	3	Corixidae	5
Oligoneyridae	2	Molannidae	6	Megaloptera	
Polymitarcyidae	2	Odontaceridae	0	Corydalidae	4
Potamanthidae	4	Phryganeidae	4	Sialidae	4
Siphlonuridae	4	Polycentropodidae	6	Lepidoptera	
Plecoptera		Psychomyiidae	2	Pyralidae	5
Capniidae	2	Rhaycophilidae	1	Pagurian	
Chloroperlidae	0	Battle		Gammaridae	6
Leuctridae	0	Elmidae	4	Asellidae	8
Nemouridae	2	Dytiscidae	5	Translingual	
Perlidae	2	Gyrinidae	4	Acariformes	4
Perlodidae	2	Haliplidae	5	Pulmonate	
Pteronarcyidae	0	Hydrophilidae	5	Lymnaeidae	6
Taeniopterygidae	2	Diptera		Physidae	8
Odonata		Athericidae	4	Planorbidae	7
Aeshnidae	3	Blepharoceridae	0	Sphaeridae	8
Calopterygidae	6	Ceratopogonidae	6	Clitellata	
Coenagrionidae	8	Chaoboridae	8	Oligochaeta	8
Cordulegastridae	3	RedChironomidae	8	Hirudinea	10
Corduliidae	2	Other Chironomidae	6	Turbellaria	4
Gomphidae	3	Culicidae	8		

The Macroinvertebrates Biotic Index, used for the assessment of the river water quality, is estimated by the following equation:

$$\text{Biotic Index} = \frac{\sum x_i t_i}{n}$$

Where,
x_i is *i-group* macroinvertebrates, t_i is macroinvertebrates index, and n is the total number of macroinvertebrates.

The water quality classification based on the Macroinvertebrates Biotic Index is given in Table 5 below.

Table 5. Water quality classification

Classification	Very clean	Clean	Slightlypolluted	Polluted	Very polluted
Biotic index	<4.18	4.18-5.09	5.10-5.91	5.92-7.05	>7.05

Source: Bulgan, 2008

The advantage of the Biotic Index is that it gives a possibility to assess the quality of water more precisely. But it requires that the analysis is done by specialized experts in a laboratory with special equipment.

Water Quality Index

The Mongolian National Standard for Water Quality of the Aquatic Environment: General Requirements MNS 4586-98, developed by the Centre of Standardization and Measure¬ments of Mongolia in 1998 (NSA, 1998) and still in force, provides a national standard for principal water quality parameters of the aquatic environment. This standard includes 27 parameters. The objective of this standard is control the quality of surface and groundwater in Mongolia.

There is, so far, no internationally-agreed stan-dard for physico-chemical and ecological wa¬ter quality of the aquatic environment and water resources as rivers, streams and lakes. Hence, the MNS 4586-98 has been applied for this study to evaluate the quality of the Kharaa River water.

Pollution hotspot assessment

There are a number of methodologies on pollution hotspot analysis (Vidon et. al., 2010), which are used worldwide. One of them is the methodology developed by UNIDO (2013) in the framework of the GEF-funded project on the Dnieper River Basin (2000-2005). The ap¬proach used in this methodology is to assess and prioritize the sources of industrial efflu¬ent discharges (hotspots) in a river basin. Only point source pollutions are considered under this methodology (http://www.unido.org/what- we-do/environment/). The following three steps are applied in this ap-proach:

1. Preliminary screening: The number of industries discharging their effluents into a river and its tributaries is significant. The goal of this step is to shortlist or reduce this number into a manageable number for the second step. The preliminary screening is based on available wastewater data such as biological oxygen de-mand (BOD5) or metal concentration.

2. Detailed evaluation: The objective of the evaluation is to gather information on the selected sites during the first step. Each hot spot is evaluated based on the impact of its discharges on the following issues: (i) pollution control, (ii) water quality and human health, (iii) biodiversity, and (iv) socio-economic.

3. Prioritization: Based on the data collected, each hot spot is scored. Higher score will be given to hot spot with higher negative impact. A rating is then established to classify the industrial hotspots based on their impact on the surface water.

The basic principles of the UNIDO's hotspot assessment methodology are applied in the pollution hotspot assessment of the Kharaa Riv¬er Basin due to the availability of data and the timeframe required for conducting a compre-hensive assessment.

Furthermore, there are only few point sources of pollution in the Kharaa River Basin, except two municipal wastewater treatment plants that discharge their treated wastewater into the Kharaa River. But there is no much informa¬tion of outflows of these wastewater treatment plants. Thus, the focus of the study was to ana¬lyze the Kharaa River water quality, as detailed as possible, using the available observed data on water quality monitoring.

UNDP-GEF project
"Integrated Natural Resource Management in the Baikal Basin Transboundary Ecosystem"

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2. Water Resources of the Selenge River Basin, Mongolia

UNOPS

The Selenge River Basin covers seven provinces, including Zavkhan, Khuvsgul, Bulgan, Arkhangai, Uvurkhangai, Tuv, and Selenge. Ulaanbaatar—the capital city of Mongolia—is located on the bank of the Tuul River, which is part of the Tuul-Orkhon-Selenge River system. Few other cities such as industrial cities of Darkhan (the second biggest city) and Erdenet (the third biggest city) are located in the Selenge River Basin.

Approximately 80 percent of the basin landscape is classified as high mountain plateau and mountainous taiga, 90 percent is forest steppe and, 15 percent is steppe zone. Due to the large area of the basin, the soil conditions and formation processes present differ significantly from region to region. Within the Khangai, Khentii, and Khuvsgul mountains, taiga, tundra, and mountain soils prevail, while drysteppe soil is dominant in the wide valley areas of the Orkhon and Selenge rivers (Dorjgotov, 2003).

The basin belongs to different geographical zones. The Selenge River Basin covers about 57.5 percent of the total Mongolian high mountain areas, 64.6 percent of the forest steppe, and 13.6 percent of the steppe zone area (National Atlas, 2009). The area of the Selenge River Basin does not have any desert, which indicates favorable ecological and climatic conditions of the area.

2.1. Hydrology

The water resources of the Selenge River Basin contain about 50 percent of total surface water resources of Mongolia (Myagmarjav and Davaa, 1999).

The Selenge River forms at the confluence of the Ider, Delgermuren and Bugsei rivers in the northern Mongolia. It is one of the biggest freshwater resources in Mongolia. Its drainage area is 282 154 square kilometers (Myagmarjav and Davaa, 1999). The Selenge River is a transboundary water system, located between latitudes 46 and 52°N and longitudes 96 and 109°E. The river flows northeastwards through Mongolia to Russia, emptying to Lake Baikal.

The Selenge River forms a large delta on the southeast shoreline of Lake Baikal. Average annual precipitation is 350-400 mm in the upper river reaches of the basin in the Khangai, Khentii and Khuvsgul mountains and 300-350 mm in the middle water way, while it is in the range of, or lower than, 250-300 mm in downstream valleys. About 70 percent of the total annual precipitation falls during the summer months from June to September (National Atlas, 2009).

The rivers directly flow into Selenge River are Orkhon, Eg and Khanui. The long-term average runoff data at the gauging stations on the Selenge River and its tributaries are given in Table 6 (Myagmarjav et al, 2012).

2.2. Hydrochemistry

In terms of chemical composition, the rivers in the Selenge River Basin are similar in that calcium (Ca^{2+}) and bicarbonate (HCO_3^-),are the dominant ions. About 90-100 percent of the all samples show the dominance of bicarbonate and 70-90 percent the dominance of calcium. During winter low-water periods and in years of drought, the Na^++K^+ appear to be dominant ions. The long-term mean of total dissolved salts, or mineralization of the main river, varies between 128-255 mg/l (Table 7).

Table 6. Hydrological parameters of rivers in the Selenge River and its tributaries

No	River-station	Period of observation	Area, km^2	Mean elevation, m	Discharge, m^3 /sec	Specific runoff, l/sec km^2	Runoff depth, mm
1	Selenge-Khutag	1945-2010	92300	1909	132.7	1.44	45.4
2	Selenge-Khyalgant	1982-2010	143500	1220	306.6	2.14	67.4
3	Selenge-Zuunburen	1975-2010	148000	1200	248.5	1.68	53.0
4	Ider-Zurkh	1960-2010	21300	2179	33.9	1.59	50.2
5	Delgermuren-Muren	1947-2010	18900	2023	36.1	1.91	60.3
7	Bugsei-Tumerbulag	1964-2010	2761	1980	1.57	0.57	17.9
11	Eg-Erdenebulgan	1973-2010	15300	1857	26.6	1.74	54.8
12	Eg-Khantai	1959-2010	41000	1708	99.2	2.42	76.4
13	Orkhon-Kharkhorin	1970-2010	6410	2241	13.3	2.08	65.5
14	Orkhon-Orkhon	1945-2010	36400	1900	41.6	1.14	36.1
16	Orkhon-Orkhon Tuul	1971-2010	96000	1880	81.1	0.84	26.7
17	Orkhon-Sukhbaatar	1950-2010	132000	1200	129.4	0.98	30.9

Source: Myagmarjav et al, 2012.

According to some studies (Myagmarjav et. al., 2012), the runoff of the Selenge River Basin has decreased in all seasons, except for winter for the period from 1945 through 2008.

Table 7. Long-term mean concentration of major ions in the Selenge Riverand its tributaries

Rivers	TDS	Ca^2+	Mg^2+	Na^++K^+	HCO_3-	SO_4--	Cl-
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Selenge	253.7	34.9	10.3	15.6	1578	18.6	5.9
Ider	162.2	25.2	6.8	14.0	104.6	14.1	7.9
Delgermuren	254.5	39.3	9.2	10.0	170.0	17.9	3.6
Eg	234.6	332	11.4	9.8	160.0	12.9	3.9
Orkhon	226.1	26.6	8.9	25.7	142.7	18.5	10.8
Eree	128.9	14.5	4.8	10.5	75.7	10.8	4.4

Data source:Central Laboratory for Environment and Meteorology

Table 8. Long-term mean concentrations of chemical pollutants in the Selenge and its tributaries

Rivers	NH4	NO_3	PO_4	Si	Permanganate Value	BOD	O_2	Hardness as Ca^{2+}+Mg^{2+}	pH
Selenge	0.190	0.265	0.037	5.9	3.2	2.1	9.6	2.4	7.8
Ider	0.170	0.280	0.015	4.1	3.2	1.5		1.9	7.5
Delgermuren	0.110	0.150	0.021	2.6	2.7	2.2	8.7	2.8	7.7
Eg	0.107	0.190	0.024	2.9	3.2	1.9		2.4	7.7
Orkhon	0.247	0.357	0.040	5.8	3.5	2.7	10.4	2.1	7.6
Eree	0.224	0.311	0.030	6.7	4.0	1.5	11.1	2.6	7.7

Data source: Central Laboratory for Environment and Meteorology

2.3. Water quality

The Selenge River's water quality is generally considered to be good. The long-term mean concentrations main water quality parameters (such as BOD and DO) and concentrations of chemical pollutants, ammonium-nitrogen, nitrate-nitrogen, orthophosphate and permanganate do not exceed the respective Maximum Acceptable Concentrations (Table 8).
The nutrient pollution in the Selenge River, which is generally the primary cause of water quality impairments in rivers and lakes, is very low. Low concentrations of orthophosphate, as shown in Table 8, indicate that there is no evident risk of water quality impairments caused by the presence of chemical fertilizers, polluted storm water run-off, and poorly treated sewage or leaking septic systems.

With respect to hydrobiology and ecological water quality, of the Selenge River and its tributaries are also considered to be in good conditions. The number of Ephemeroptera, Plecoptera, Trichoptera (EPT) individuals found in the Selenge River and its some tributaries are given in Table 9. The summary of macroinvertebrates is shown in Table 10.

Table 9. Ephemeroptera, Plecoptera, Trichoptera individuals found in the Selenge river and its tributaries

№	Stations	2005	2006	2007	2008	2009	2010
1	Selbe-Sanzai	4	6	8	6	13	0
2	Selenge-Khutag	2	4	5	16	6	0
3	Selenge-Sukhbaatar	3	22	11	5	4	77
4	Selenge-Khyalganat	7	11	13	11	25	0
5	Kharaa-Baruunkharaa	5	8	9	31	34	0
6	Kharaa-Darkhan	12	6	3	10	12	1
7	Achuut-Bulgan	4	6	5	3	6	0
8	Zuunturuu-Bulgan	5	4	2	4	5	0
9	Ider-Tosontsengel	6	2	11	10	2	0
10	Tuul-Lun	0	0	2	0	47	0
11	Tuul-Altanbulag	2	5	0	3	6	38
12	Tuul-Ulaanbaatar	12	20	8	4	40	66
13	Terelj-Terelj	5	11	3	18	5	1
14	Urdtamit-Tsetserleg	10	7	4	18	9	0
15	Chuluut-Chuluut	7	6	7	3	4	0
16	Shariyngol-Jibsnii stants	3	2	4	4	5	4
17	Eg-Khantai	5	6	17	18	5	0
	Total	112	140	124	168	294	276

Data source: Institute of Meteorology, Hydrology and Environment

In order to evaluate the quality of the Selenge River water flowing out of Mongolia at the Mongolia-Russia border, monitoring data at the outlet of the Sukhbaatar station on the Selenge River were assessed for the period of 2001-2010. The assessment is based on the Water Quality Index and parameters of five major chemical pollutants, described in section 1.3.3, using all observed/sampled data between 2001 and 2010 at the station. According to the WQI based on these parameters, the Selenge River water quality at the Sukhbaatar station appears from very clean to clean. The results are presented in Figure 3.

In addition, the water quality of the Selenge River has been assessed by the Biotic Index at three sites—namely, Khutag, Khyalganat and Sukhbaatar—for the period of 2005-2010. The results are presented in Figure 4. The water quality of the Selenge River at these sites appears to be also clean. Populations of pollutant sensitive insects were found at these sampling sites for the period of 2005 and 2010, indicating therefore that the good quality of the water conditions.

Table 10. Summary analysis of Aquatic Macroinvertebrate at different stations in the Selenge River and its tributaries (2005-2010)

№	Metric (by category)	Selenge River tributaries																
		Chuluut	Eg	Ider	Selenge-Khutag	Selenge-Khyalgana	Urdtamir	Achuut	Zuunturuu	Sharyingol	Kharaa-Baruunkha	Kharaa-Darkhan	Orkhonn	Terelj	Uliastai	Selbe	Tuul-UB	Tuul-lun
	Richness and Diversity																	
1	Total Taxa Richness	13	5	10	11	21	9	11	14	12	10	18	13	15	7	10	14	7
2	Taxa Richness of EPT	9	4	5	6	12	6	10	9	9	8	12	6	10	7	7	11	6
3	Simpson's Diversity Index	0.9	0.6	0.8	0.7	0.8	0.8	0.9	0.8	0.8	0.8	0.9	0.7	0.7	0.7	0.8	0.8	0.8
4	Simpson's Reciprocal Index	9.4	2.6	5.1	3	6	6.4	7.1	5.4	4.6	5.5	6.7	3.7	3	3.3	6.3	4.3	6
5	Total individuals of Taxa	54	343	46	276	178	60	115	196	200	79	233	146	88	113	51	144	13
6	Individuals of EPT Taxa	34	342	22	260	133	50	97	169	188	77	170	45	74	113	36	125	10
7	Individuals of Ephemeroptera	17	4	10	226	110	21	38	109	136	41	132	29	61	65	27	71	7
8	Individuals of Plecoptera	15	338	6	33	16	11	1	0	28	24	21	13	9	43	3	26	1
9	Individuals of Trichoptera	2	0	6	1	7	18	58	60	24	12	17	3	4	5	6	28	2
	Composition and Evenness																	
10	Dominant Taxon	18.5	53.1	37	43.5	33.1	26.7	18.3	32.1	38.5	31.6	25.8	48.6	56.8	41.6	31.4	43.1	38.5
11	EPT Taxa	69.2	80	50	54.5	57.1	66.7	90.9	64.3	75	80	66.7	46.2	66.7	100	70	78.6	85.7
12	EPT Individuals	63	99.7	47.8	94.2	74.7	83.3	84.3	86.2	94	97.5	73	30.8	84.1	100	70.6	86.8	76.9
13	Chironomidae	14.8	0	2.2	0	0.6	6.7	0	2.6	3	0	2.1	0	1.1	0	0	0	0
	Tolerance/Intolerance																	
14	Sensitive Organisms	45.3	100	67.5	96.3	61	78.4	96.4	54.3	62.1	48.5	71.1	84.6	83.2	68.2	72.4	63.8	37
15	Moderate-Sensitive Organisms	24.5	-	30	2.1	26.3	14.8	2.7	33.4	11.1	38	10.9	13.9	10.7	27.1	7.9	32.4	51.1
16	Tolerant Organisms	30.2	-	2.5	1.6	12.7	6.8	0.9	12.3	26.8	13.5	18	1.5	6.1	4.8	19.7	3.8	11.9

Data source: Institute of Meteorology, Hydrology and Environment

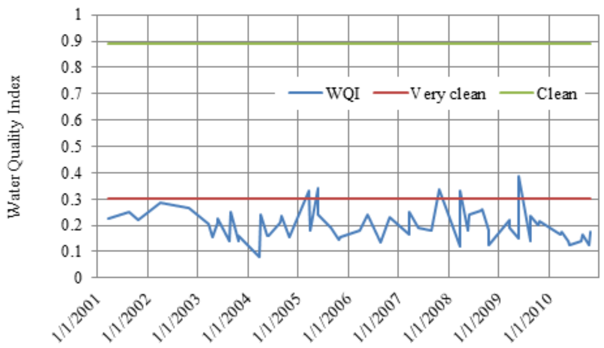


Figure 3. Water quality index at the Sukhbaatar of the Selenge River

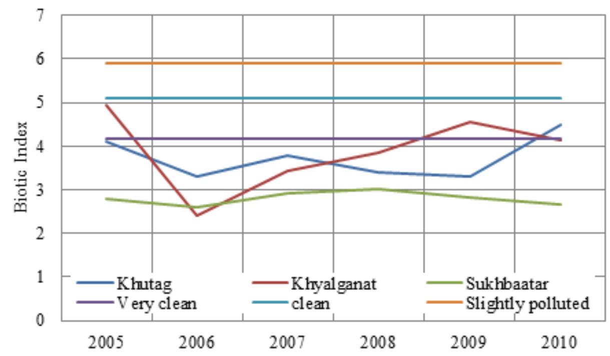
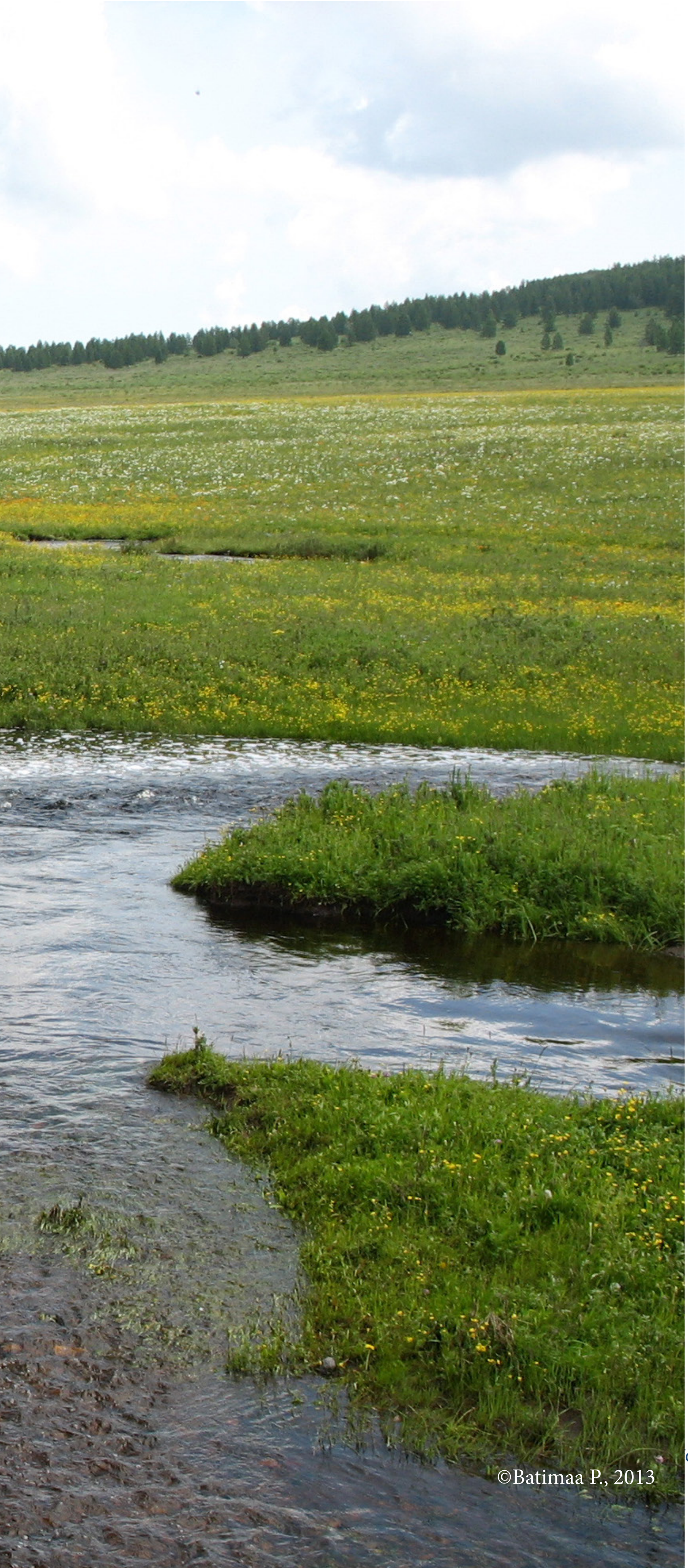


Figure 4. Biotic Index results at three sites of the Selenge River



3. Water Quality Assessment of the Kharaa River Basin

The Kharaa River Basin is shared among three administrative regions, called aimags (equivalent to provinces)—namely, Selenge aimag, Tuv aimag and Darkhan-Uul aimag. The basin also includes the rapidly-growing industrial city of Darkhan, which is the third largest city with 74,738 inhabitants as of 2010 (NSO, 2010).
The entire population of the Kharaa River Basin is about 133,000.

The Kharaa River Basin is under increasing pressure from rapid urbanization, rising water demand and climate change. The upper basin is in a relatively pristine state and has experienced minimal anthropogenic impacts. The lower basin is characterized by diverse economic activities such as industry, agriculture and livestock breeding, which may potentially have significant impacts on the quantity and quality of water resources of the basin. Furthermore, the basin provides drinking water for the rapidly-growing Darkhan City, which water supplies largely rely on alluvial aquifers containing shallow-depth groundwater, and the inhabitants of small human settlements in the basin.
Hence, growing pressures from climate change and anthropogenic activities on the Kharaa River (Figure 5) makes the basin an ideal example of river basins under a spectrum of climatic and anthropogenic pressures.

3.1. Hydrology and hydrogeology

3.1.1. Surface water

The Kharaa River Basin is located in northern Mongolia, not far away from the capital Ulaanbaatar, between latitudes 47°53′ and 49°38′N and longitudes 105°19′ and 107°22′E. The catchment area of the basin is about 15,050 square kilometers (Battsetseg, 2011). The lowest elevation is about 654 meters a.s.l. and is found near the outlet of the catchment, whereas the highest point is about 2668 meters a.s.l. and is located in the vicinity of the Asralt Khairhan (2799 meters a.s.l.)—the highest peak of the Khentii Mountains range and the area of the headwaters of some important Mongolian rivers. In around 60 percent of the basin area, the elevation ranges between 900 and 1300 meters a.s.l. The average altitude of the whole catchment is 1,167 meters (Figure 6).

At 291 km in length, the Kharaa River originates in the mountains north of Ulaanbaatar and passes through Selenge and Darkhan-Uul provinces in central northern Mongolia before emptying into the Orkhon River.

The annual mean discharge ranged from 3.84 to 26.3 m3/s between 1991 and 2010 (Battsetseg, 2011). Together with the Orkhon River, the Kharaa River discharges to the Selenge River Basin, which is the main catchment region of Lake Baikal.

The upper course of the Kharaa River is characterized by mid- to high mountain ranges of the Khentii Mountains, with steep valley slopes and rises. The summit region Asralt Khairhan, which peak altitude is 2799 meters a.s.l., is dominated by denudated, flattened and periglacially transformed mountains (MoMo, 2009). In the middle reaches, the relief is dominated by broad valleys with significant terrace levels and hilly uplands with gentle slopes, as well as remnants of denudated rocks.

Figure 5. The Kharaa River at Baruunkharaa hydrological gauging station (21 July 2012)

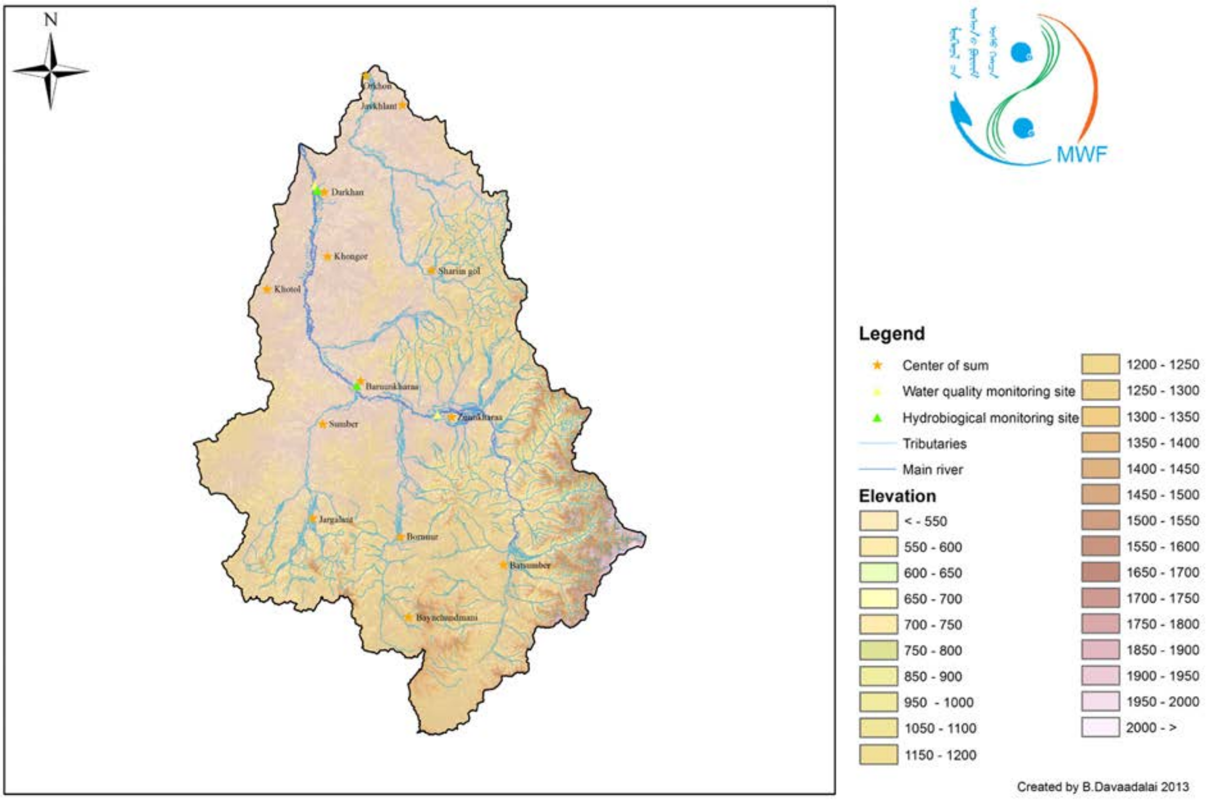


Figure 6. The Kharaa River Basin and water quality monitoring sites

In this river section, the Kharaa River flows through a wide floodplain and has a meandering channel of 10 to 25 meters wide and from 0.2 to 2 meters deep. Upstream of the city of Zuunkharaa, the river splits into several small and shallow branches. The lower reaches from the gauging station at Baruunkharaa to the confluence of the Kharaa River with the Orkhon River is an open steppe and lowland landscape. In the lowlands, the Kharaa River flows as a natural meandering river system with ancient cut-off meanders in some places.

Channelization was conducted only in some very limited river areas. Therefore, the floodplain meadow still serves its natural retention function, a situation which is important for nature conservation.

3.1.2. Groundwater

The Kharaa River Basin is mainly characterized by unconfined alluvial aquifers. The unconfined groundwater aquifers are characterized by alluvial sand and gravel with interlaced sandy loam (Batsukh, 2007). Due to the porous media, the conductivity of the aquifer is high, mainly from 10 to 100 m/day and partly up to 300m/day. The main water bearing stratum extends with a width of 10 to 20 kilometers along the Kharaa River, reaches near Darkhan a thickness of 70 m, and is divided up into different layers. The groundwater recharge from precipitation is very low in the Darkhan area.
The recharge depends on the inflow of groundwater from aquifers of the upper catchment area where the precipitation and groundwater infiltration are much higher.

The “exploitable groundwater resources” of the Kharaa River Basin has been estimated at 182 million cubic meters, as shown in Table 11 (Jadambaa, 2012).

Table 11. Exploitable groundwater resources of the Kharaa River Basin

No of aquifers	Area (sq.km.)	Resources per unit area, m^3/sec per sq.km.	Total resources per unit area, mln m^3/year per sq.km.
1	250	315000	79
3	3121	31500	98
7	46	5203	0.24
8	67	5203	0.35
11	4719	520	2
12	234	5203	1
13	9026	94.6	1
Total	17463		182

Data source: Jadambaa, 2012

3.2. Hydrochemistry

In general, concentrations of the chemical composition of the headwaters of the Kharaa River are near the natural background conditions and increase towards downstream along the river. Slightly higher concentrations were observed after snow melting and heavy rainy periods and dry years (Batimaa, 1998).

3.2.1. Major ions

The monthly mean concentrations of total dissolved salts, or mineralization, which is the sum of Ca^{2+}, Na^{+}+K^{+}, Mg^{2+}, HCO_3-, $SO_4^{\ 2-}$ and Clions, in the Kharaa River vary between 162.2 and 335.7 mg/l and increase in downstream are as along the river length (Table 12). The concentrations also increase during snow melting periods.

Table 12. Annual distribution of average concentrations of total dissolved salts, or mineralization

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Zuunkharaa (upper)	-	-	-	199.2	-	189.4	166.2	168.4	213.0	188.3	214.8	-
Zuunkharaa (down)	-	-	-	248.4	-	189.3	174.2	176.9	203.7	208.6	223.7	-
Darkhan (upper)	218.8	224.3	256.3	262.2	298.3	283.8	269.1	245.4	229.1	237.4	261.9	197.9
Darkhan (down)	264.7	290.6	268.6	275.5	335.7	294.8	273.6	284.4	270.1	270.1	300.6	253.7

Data source: Central Laboratory for Environment and Meteorology

In most of the cases, the calcium and bicarbonate are the dominant ions at all monitoring stations of the Kharaa River. According to the Piper diagram and classifications of O. A. Alekin, in a vast majority of the cases the order of abundance of cations is Ca^{2+}>Na^{+}+K^{+}>Mg^{2+} and the order of abundance of anions is HCO_3-> SO_4^{2-}>Cl^{-}. This order is clearer in upstream areas, as observed at the Zuunkharaa upper monitoring station on the Kharaa River (Figure 7). In the downstream from Darkhan city, the order of abundance of anions is the same as in the upstream station, while the order of abundance of anions becomes considerably unstable, as observed at the Darkhan down monitoring station on the river (Figure 8).

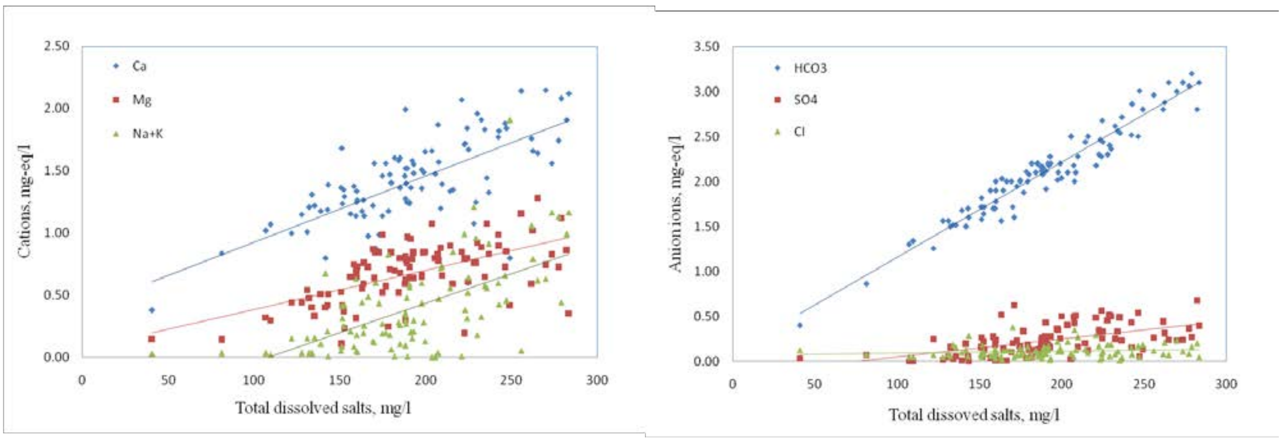


Figure 7. Relationship between total dissolved salts and cations and anions (Kharaa-Zuunkharaa (upper))

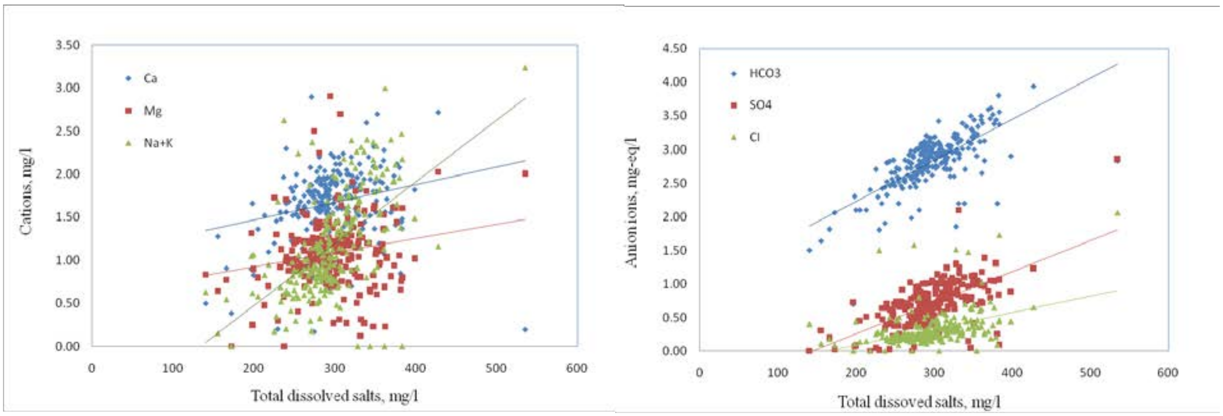


Figure 8. Relationship between total dissolved salts and cations and anions (Kharaa-Darkhan (down))

The overall assessment of the chemical composition has shown good chemical conditions at all sampling sites on the Kharaa River.

The Kharaa River water is moderately hard and its pH varies between 6.9 and 8.2. Chloride concentrations appear to be higher in downstream areas compared to in the upstream region near the Zuunkharaa upper sampling point. Higher levels of chloride may be indicative of possible water pollution.

Monthly mean concentrations of major ions, hardness and pH at all monitoring stations are given in Table 13.

The results of the MoMo (2009) study show very similar results of the chemical analysis of the Kharaa River water quality.

In general, the quality of surface waters in the mountainous region of the Kharaa River Basin is good with low nutrient concentrations, total solids concentrations ranging from 17 to 60 mg/l, very low chloride concentrations between 2 and 4 mg/l, and heavy metal concentrations almost below the detection limits. However, in the middle and lower reaches there are the nutrient concentrations tend to increase, whereas the total dissolved solids concentrations are as high as 100-340 mg/l and the chloride concentrations range between 10 to 17 mg/l.

3.2.2. Dissolved oxygen

Dissolved oxygen is absolutely essential for the survival of all aquatic organisms-not only fish, but also invertebrates such as crabs, clams, zooplankton, etc. Moreover, oxygen affects a vast number of other water quality indicators in terms of not only physical chemical and biological parameters of water quality, but also indicators of the esthetic quality of river's water like the odor, clarity and taste. Consequently, oxygen is perhaps the most well-established indicator of water quality. The level of dissolved oxygen is a much more important parameter to measure water quality than faecal coliform (Hunt et al, 2000).

The dissolved oxygen concentrations in the Kharaa River water are monitored only at the two sampling points of the Darkhan monitoring station: Darkhan upper and Darkhan down. The dissolved oxygen concentration is not measured at the Zuunkharaa monitoring station.

Table 13. Monthly mean concentrations of major ions of the Kharaa River

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Zuunkharaa upper												
Ca^{2+}	-	-	-	30.4	-	27.5	25.6	25.3	23.7	27.9	32.0	-
Mg^{2+}	-	-	-	9.4	-	9.2	7.3	7.0	6.0	8.4	8.9	-
$Na^{+} + K^{+}$	-	-	-	7.5	-	8.2	8.2	8.0	24.2	8.8	11.4	-
HCO_3^{-}	-	-	-	133.5	-	129.4	119.8	114.8	142.8	127.0	142.7	-
SO_4^{2-}	-	-	-	13.6	-	10.5	7.9	8.1	11.2	11.7	15.6	-
Cl^{-}	-	-	-	4.2	-	3.9	3.6	4.2	5.1	4.0	3.9	-
Hardness	-	-	-	2.3	-	2.1	1.9	1.8	1.7	2.1	2.3	-
pH	-	-	-	7.4	-	7.3	7.4	7.0	6.9	7.3	7.2	-
Zuunkharaa down												
Ca^{2+}	-	-	-	33.6	-	26.7	27.2	27.5	25.6	29.6	33.2	-
Mg^{2+}	-	-	-	11.1	-	7.9	6.1	8.0	6.5	9.8	8.6	-
$Na^{+} + K^{+}$	-	-	-	9.9	-	9.8	7.1	7.2	7.4	9.2	7.6	-
HCO_3^{-}	-	-	-	170.7	-	122.4	111.8	117.4	106.8	133.0	133.5	-
SO_4^{2-}	-	-	-	17.9	-	4.9	6.3	6.1	5.0	7.4	11.2	-
Cl^{-}	-	-	-	7.7	-	4.9	6.3	6.1	5.0	7.4	11.2	-
Hardness	-	-	-	2.6	-	2.0	1.8	2.1	1.8	2.3	2.4	-
pH	-	-	-	7.3	-	7.2	7.3	7.0	7.4	7.3	7.1	-
Darkhan Upper												
Ca^{2+}	33.5	32.3	33.4	31.8	31.2	30.5	32.4	29.8	31.1	31.0	32.5	31.9
Mg^{2+}	11.6	14.6	14.7	12.8	12.9	12.5	13.0	10.5	10.5	12.6	12.9	12.6
$Na^{+}+K^{+}$	27.7	30.1	24.7	23.9	27.2	28.2	23.3	25.6	24.9	26.4	29.4	25.7
HCO_3^{-}	182.2	190.8	166.8	164.0	169.8	157.1	160.3	162.1	159.7	161.4	182.7	170.2
SO_4^{2-}	35.5	28.6	34.6	31.9	35.7	30.4	34.9	28.8	32.8	35.5	31.4	26.2
Cl^{-}	8.2	9.2	8.8	7.5	9.6	8.2	11.5	9.3	6.5	14.0	9.4	7.7
Hardness	2.7	2.8	2.8	2.6	2.7	2.7	2.7	2.4	2.6	2.7	2.7	2.7
pH	8.1	7.8	8.1	8.0	8.0	8.1	8.0	8.1	8.0	8.1	8.2	8.2
Darkhan down												
Ca^{2+}	29.8	34.5	29.0	24.6	31.0	31.4	30.3	27.6	26.7	29.6	34.3	34.6
Mg^{2+}	11.4	12.1	11.9	9.6	12.3	12.1	12.8	11.1	10.0	13.2	12.4	13.4
$Na^{+}+K^{+}$	21.8	27.4	18.0	18.0	22.0	23.7	21.8	20.2	21.7	29.6	33.1	27.1
HCO_3^{-}	141.7	171.9	154.3	131.1	153.2	154.8	163.7	147.3	146.8	164.8	182.5	173.2
SO_4^{2-}	28.9	31.3	23.6	26.7	30.4	29.8	29.2	27.1	30.8	34.1	36.8	29.9
Cl^{-}	13.7	15.8	11.7	8.6	11.4	9.1	12.9	8.4	9.1	13.2	11.7	13.4
Hardness	2.4	2.7	2.3	2.0	2.3	2.6	2.4	2.1	2.1	2.7	2.7	2.8
pH	8.1	8.2	7.9	8.1	8.1	8.1	8.1	8.0	8.0	8.2	8.2	8.2

Data source: Central Laboratory for Environment and Meteorology

The dissolved oxygen concentrations at the Darkhan sampling points vary from 3.8 to 14.0 mg/l. The monthly mean, maximum and minimum concentrations of dissolved oxygen are given below in Table 14.

Table 14. Annual distribution of dissolved oxygen concentrations

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Darkhan upper												
Average	9.12	8.83	9.46	10.63	9.25	8.87	8.74	9.06	10.04	11.19	10.35	10.00
Max	12.16	12.10	12.00	18.80	14.00	11.60	11.20	12.40	13.60	13.40	13.60	12.09
Min	6.00	6.10	6.66	7.37	6.14	5.80	6.80	6.10	8.00	8.56	8.10	8.28
Darkhan down												
Average	8.47	9.89	9.89	9.43	8.82	8.93	8.21	8.87	9.50	10.96	9.91	9.59
Max	11.70	14.80	14.80	12.15	10.90	12.43	10.70	12.60	12.72	14.90	12.64	12.00
Min	6.33	7.80	7.80	4.03	6.00	6.40	6.10	1.20	5.40	5.44	5.21	5.80

Data source: Central Laboratory for Environment and Meteorology

The trend with regard to the river's water quality assessed for dissolved oxygen conditions over a twenty-five years period is shown in Figure 9. Between 1986 and 2011, there was no statistically significant trend in dissolved oxygen, based on the monthly spot measurements. On the other hand, the dissolved oxygen concentrations quite vary seasonally within a year, as shown in Table 14. No clear reason can be found for this seasonal change, while variations from year to year can be caused by a variety of factors, such as the weather conditions preced¬ing the sample collection, water temperature, other water quality parameters (e.g., nutrients), and the time of sample collection. In order to look assess any long-term changes in dissolved oxygen concentrations and their causes, a more continuous monitoring of dissolved oxygen is needed to understand the daily fluctuations and how it relates to weather conditions and the quality of the river's water.

The Mongolian National Standard for Water Quality of the Aquatic Environment MNS 4586- 98 sets the Maximum Acceptable Concentration of dissolved oxygen at 4-6 mg/l. According to the observed data, there were no cases when the dissolved oxygen concentrations fell below 4 mg/l in the upper stream of the Kharaa River. Slightly higher dissolved oxygen concentrations, but below the upper limit of 6 mg/l, were observed in very few cases downstream from Darkhan city (Figure 9).

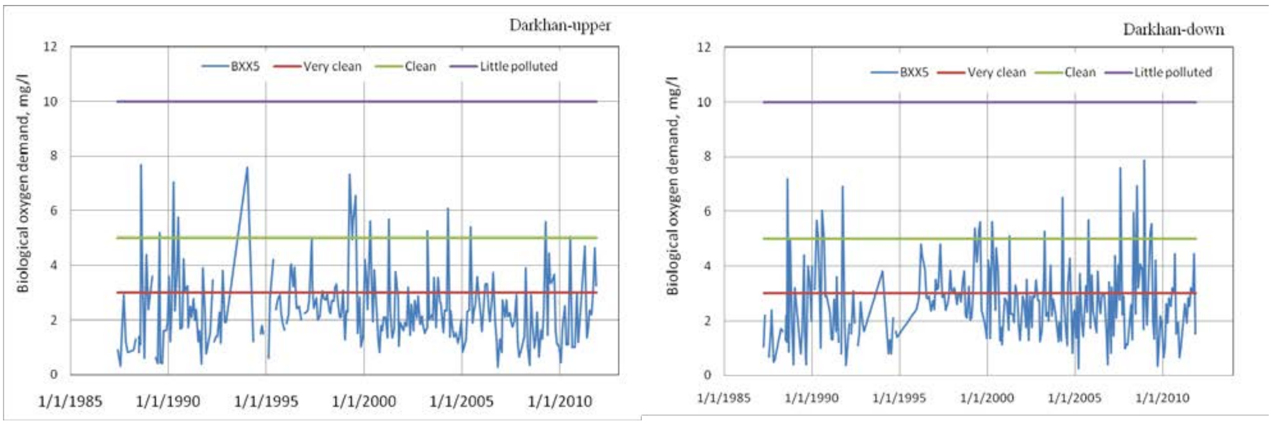


Figure 9. Dissolved Oxygen concentration trends of the Kharaa River for the period 1985-2010

3.2.3. Biological Oxygen Demand

The biological oxygen demand (BOD) is one of the chemical parameters that measure organic pollution in rivers and streams.

The BOD of the Kharaa River is monitored only at the two sampling points of the Darkhan monitoring station. The observed data for the period from 1985-2010 show that in most of the cases, the BOD concentrations were below the Maximum Acceptable Concentration of 5 mg/l (as set in the national water quality standard MNS 4586:98), indicating that the river water is clean. However, it should be noted that during summer the BOD concentrations occasionally exceeded the Maximum Acceptable Concentration in both sampling points (Figure 10). This may indicate that organic pollutants, originating from urban and industrial area of Darkhan city, and livestock wastes enter the river with surface washing during heavy rainfall events.

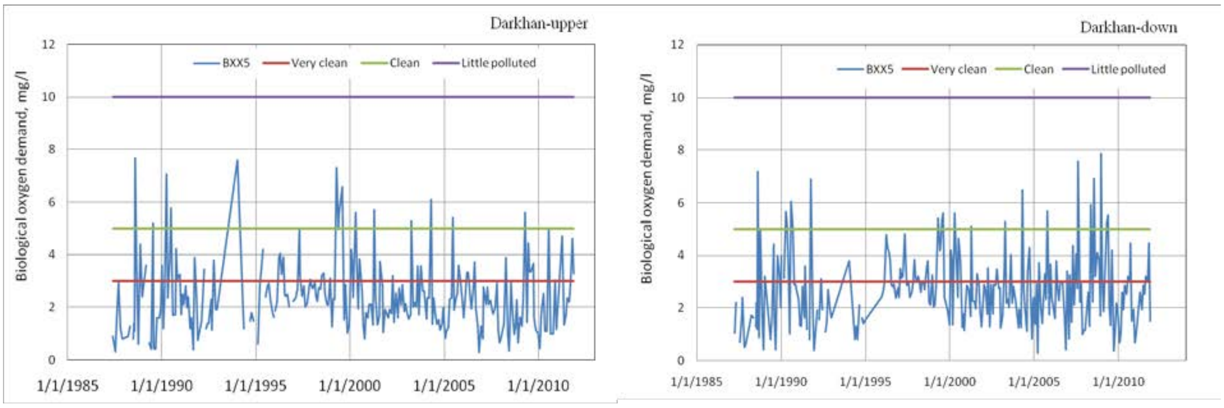


Figure 10. Biological oxygen demand concentration trend of the Kharaa River near Darkhan city for the period 1985-2010

As shown in Figure 10, there is no increasing, or decreasing, trends in BOD concentrations at both sampling points. However, the concentrations downstream from the city are noticeably higher than those upstream. This may be caused by the discharge of Darkhan Wastewater Treatment Plant effluents.

3.2.4. Nutrients

In Mongolia, the level of nutrients in rivers is generally influenced by natural factors such as catchment geology, rainfall and river flow patterns. The main source of nutrients in urban areas is municipal wastewater, whereas agricultural fertilizers and livestock manure are the major non-point sources of nitrogen and phosphorus in rural areas. Usually nutrients concentrations increase during high water periods due to snowmelting and heavy rainfalls. This is mainly due to Mongolia's pastoral livestock herding practices, as herders live along a river bank. Traditionally, rivers and streams are used as sources of livestock water. This leads to fecal contamination and direct nutrient inputs to the river water in warm seasons because animal manure is washed into rivers with showmelt and rainfall runoff (Batimaa, 1998).

Monthly mean concentrations of ammonium-nitrogen (NH4-N) range between 0.09 and 0.38 mg/, while the concentrations of nitrate-nitro¬gen (NO3-N) vary from 0.01 to 0.84 mg/l for the period from 1985 to 2010. The concentrations of phosphate (PO4-P) are in the range from 0.01 to 0.21 mg/l. The phosphate concentrations in the Kharaa River were much lower than the ni¬trogen concentrations.

The nutrient concentrations in the Kharaa River water usually increased during spring and summer time (Table 15) and sometimes exceeded the Maximum Acceptable Concentrations by the order of 2 to 3 times. However, the number of cases, in which the nutrient concentrations exceeded the MAC levels represents less than 5 percent of all samples.

Table 15. Monthly mean concentrations of ammonium of the Kharaa River

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NH_4-N, *(MAC is 0.5 mg/l)*												
Zuunkharaa (upper)	-	-	-	0.32	-	0.20	0.14	0.28	0.34	0.11	0.19	-
Zuunkharaa (upper)	-	-	-	0.38	-	0.32	0.21	0.20	0.13	0.26	0.17	-
Darkhan (upper)	0.09	0.10	0.10	0.25	0.39	0.24	0.22	0.17	0.15	0.12	0.12	0.06
Darkhan (down)	0.13	0.09	0.09	0.45	0.29	0.18	0.22	0.20	0.11	0.15	0.18	0.12
NO_3-N, *(MAC is 10 mg/l)*												
Zuunkharaa (upper)	-	-	-	0.35	-	0.47	0.35	0.75	0.15	0.37	0.26	-
Zuunkharaa (upper)	-	-	-	0.25	-	0.28	0.84	0.67	0.56	0.24	0.59	-
Darkhan (upper)	0.17	0.01	0.15	0.19	0.17	0.25	0.24	0.14	0.10	0.13	0.17	0.24
Darkhan (down)	0.50	0.01	0.56	0.35	0.34	0.49	0.80	0.26	0.21	0.34	0.36	0.76
PO_4-P, *(MAC is 0.1 mg/l)*												
Zuunkharaa (upper)	-	-	-	0.05	-	0.06	0.03	0.04	0.06	0.02	0.03	-
Zuunkharaa (upper)	-	-	-	0.07	-	0.03	0.06	0.04	0.10	0.10	0.04	-
Darkhan (upper)	0.04	0.04	0.04	0.06	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.03
Darkhan (down)	0.01	0.04	0.04	0.09	0.07	0.04	0.06	0.04	0.05	0.05	0.21	0.06

Data source: Central Laboratory for Environment and Meteorology

Most domestic and industrial wastewaters have much higher concentrations of ammonia, nitrate, and phosphate than the river water does. The Darkhan Wastewater Treatment Plant, which is located in the study area, is a major source of nutrient pollution in the Kharaa River (see Section 4.1.1). Thus, higher concentrations of NH4-N,NO3-N and PO4-P observed in the downstream of Darkhan city with respect to other sampling points indicate that munici¬pal wastewater discharges into streams of the basin increase the nutrient concentrations in the Kharaa River water.

Results of the trend analyses of nutrient concentrations since 1990 are illustrated in Figures11 through 13. As shown in Figure 11, there are no increasing, or decreasing, trends in NH4-N concentrations in both monitoring stations. The concentrations of NO3-N near Zuunkharaa have decreased since 1990, while data from the Darkhan monitoring station show no trend (Figure 12). Similarly, PO4-P concentrations have decreased near Zuunkharaa, while there is no trend near Darkhan city (Figure 13).

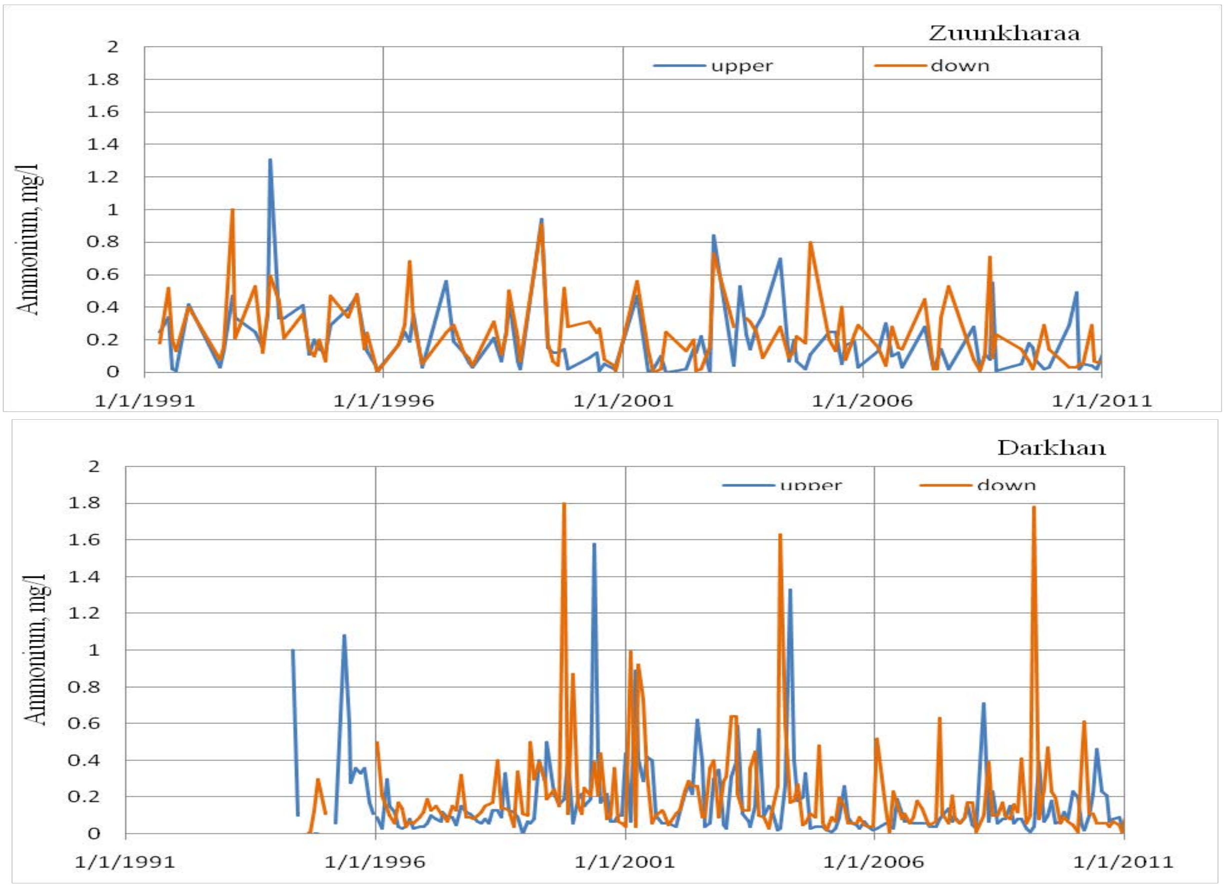


Figure 11. Trends in NH4-N concentrations at Zuunkharaa and Darkhan monitoring stations

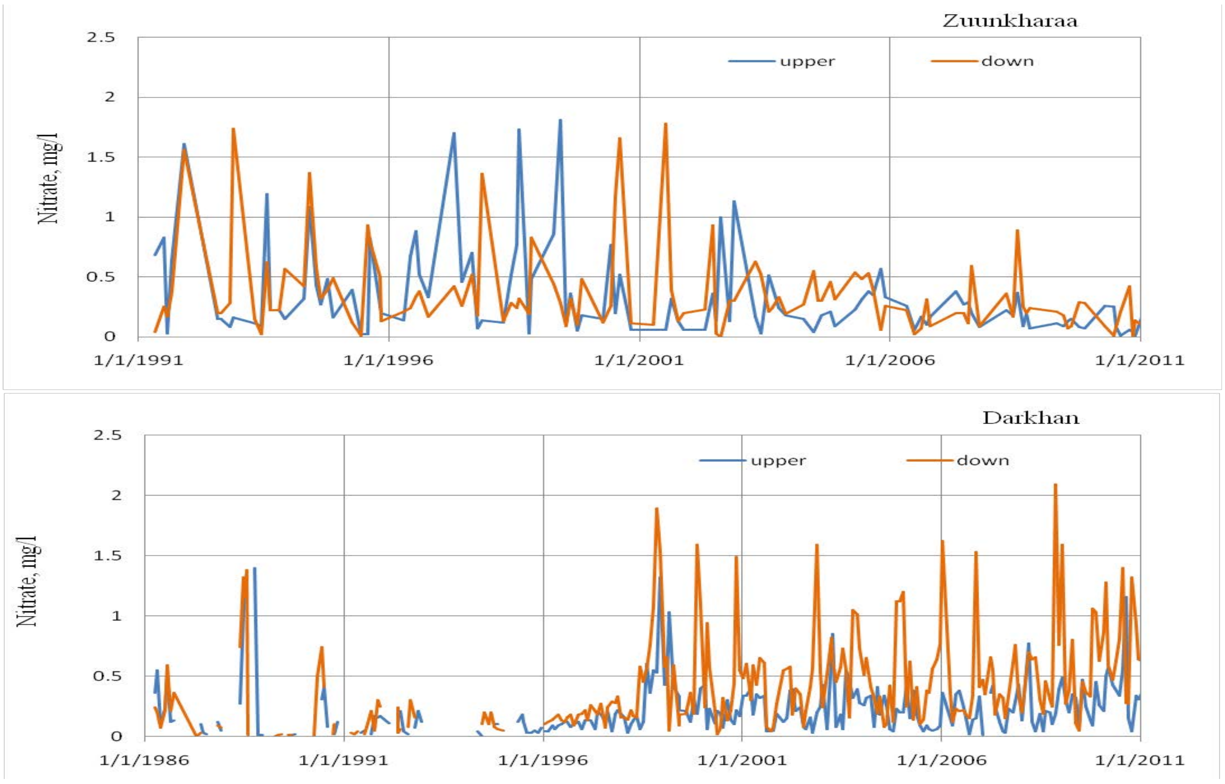


Figure 12. Trends in NO3-N concentrations at Zuunkharaa and Darkhan monitoring stations

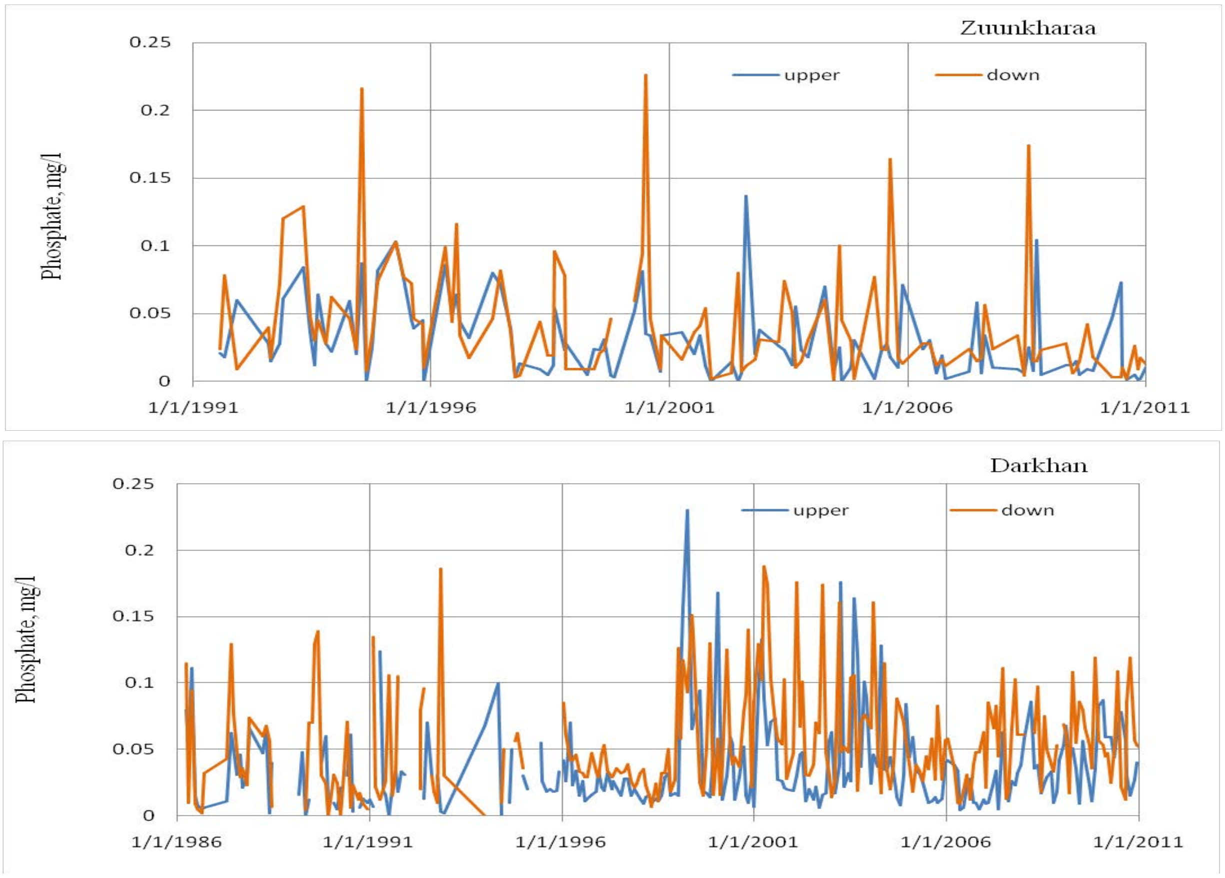


Figure 13. Trends in PO4-P concentrations at Zuunkharaa and Darkhan monitoring stations

3.2.5. Metals

There are very limited observed data on metals, except for iron (Fe) and chromium (Cr^{6+}) ions. The total Fe and Cr^{6+} ions are measured at the downstream sampling points of both monitoring stations in Zuunkharaa and Darkhan. The monthly mean concentrations of Fe vary between 0.08 and 0.15 mg/l with concentrations increasing during rainy seasons. The Cr^{6+} concentrations range from below the de-tection level to 0.01 mg/l and also increase in rainy seasons (Table 16).

Table 16.Concentrations of metals in the Kharaa Riverstations

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Fe, *(MAC is 0.5 mg/l)*						
Zuunkharaa (upper)	-	-	-	0.08	-	0.12	0.11	0.18	0.16	0.17	0.12	-
Darkhan (down)	0.09	0.09	0.09	0.15	0.12	0.12	0.08	0.08	0.16	0.08	0.09	0.11
						Cr^{6+}, *(MAC is 0.01 mg/l)*						
Zuunkharaa (down)	-	-	-	0.01	-	0.01	0.01	0.00	0.00	0.01	0.01	-
Darkhan (down)	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01

Data source: Central Laboratory for Environment and Meteorology

In terms of trends over time, the total Fe concentrations have decreased in both stations since 1990. The concentrations of Cr^{6+} have increased near Zuunkharaa, while decreasing at the Darkhan station (Figure 14).

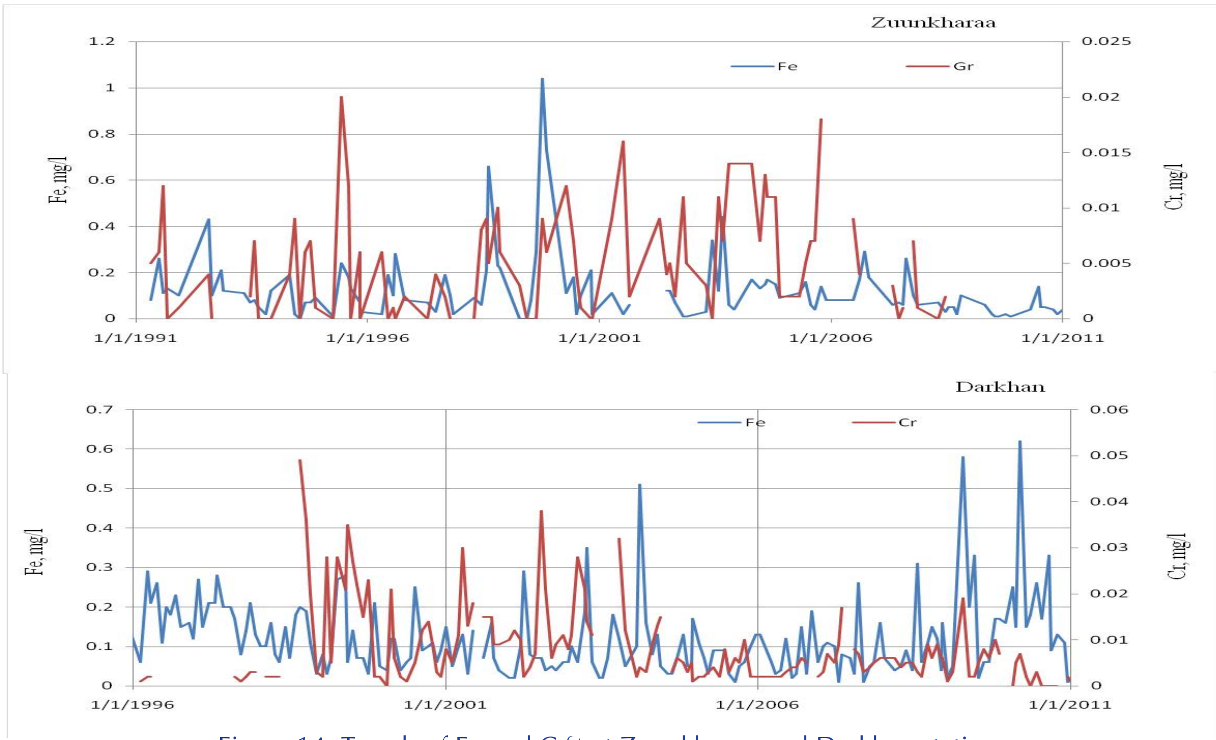


Figure 14. Trends of Fe and Cr^{6+} at Zuunkharaa and Darkhan stations

As part of the MoMo project, measurements of other metals and a number of heavy metals, such as arsenic (As), lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), mer¬cury (Hg), zinc (Zn), iron (Fe) and manganese (Mn), were conducted on the Kharaa River at the Darkhan monitoring station and the outlet of the basin near Burentolgoi during the period from September 2006 to 2008 (Table 17).

Table 17. Heavy metalsconcentrations in the Kharaa River, mg/l

Sampling site	As	Pb	Cd	Cr	Cu	Ni	Hg	Zn	Fe	Mn
Kharaa-Darkhan	0.0021	n.d.	n.d.	0.0025	0.0127	0.004	n.d.	0.013	0.95	0.091
Kharaa-Burentolgoi (river basin outlet)	0.0025	n.d.	n.d.	0.009	0.013	0.011	n.d.	0.026	1.645	0.158

Data source: Central Laboratory for Environment and Meteorology

The results of these measurements (MoMo, 2009) indicate that the heavy metal concentrations show increased levels, although most of them being lower or near to the allowed maximum concentration. Concentrations of dissolved heavy metals in the upper and middle reaches are often below detection limit (e.g. cadmium and lead). Natural background concentrations in suspended solids are low. Concentrations of arsenic, primarily originating from human activities, increase downstream and show increasing values in Darkhan. Elevated concentrations of heavy metals were detected especially in the Boroo River and downstream of the city of Darkhan.

3.2.6. Suspended solids

The concentration of total suspended solids (TSS) is important for ecological and water quality. Suspended solids in most freshwater systems originate from watershed sources, pollutant point sources and sediments.

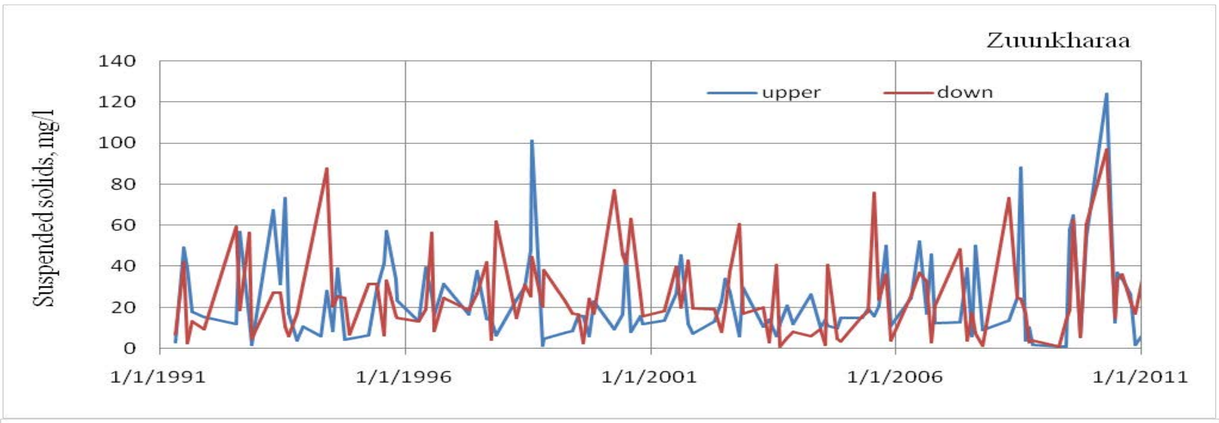
In Mongolia, total suspended solids appear to be more strongly related to surface deposits (such as river bank erosion) than to land use and to increase from headwater down along a river (Batimaa, 1998).

The results of suspended solids monitoring data at Zuunkharaa and Darkhan stations show a similar characteristic, as the concentrations increase during snowmelt and rainfall runoff. In general, suspended solids concentrations were highest in the spring-summer and lowest in the winter (Table 18). The increase during the spring-summer can be attributed to higher flows, surface washing and the associated increase in runoff and transport. The trend of suspended solids is shown in Figure 15.

Table 18. Monthly mean concentrations of suspended solids in the Kharaa River

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Zuunkharaa (upper)	-	-	-	39.4	-	28.4	31.4	37.7	28.1	14.5	12.5	-
Zuunkharaa (down)	-	-	-	31.7	-	75.6	25.8	54.9	11.7	18.4	18.1	-
Darkhan (upper)	20.6	25.0	24.9	37.0	62.9	65.5	81.7	51.5	64.6	25.6	24.9	28.1
Darkhan (down)	25.4	25.0	25.0	62.2	101.4	60.7	82.3	60.8	74.9	32.1	28.9	29.4

Data source: Central Laboratory for Environment and Meteorology



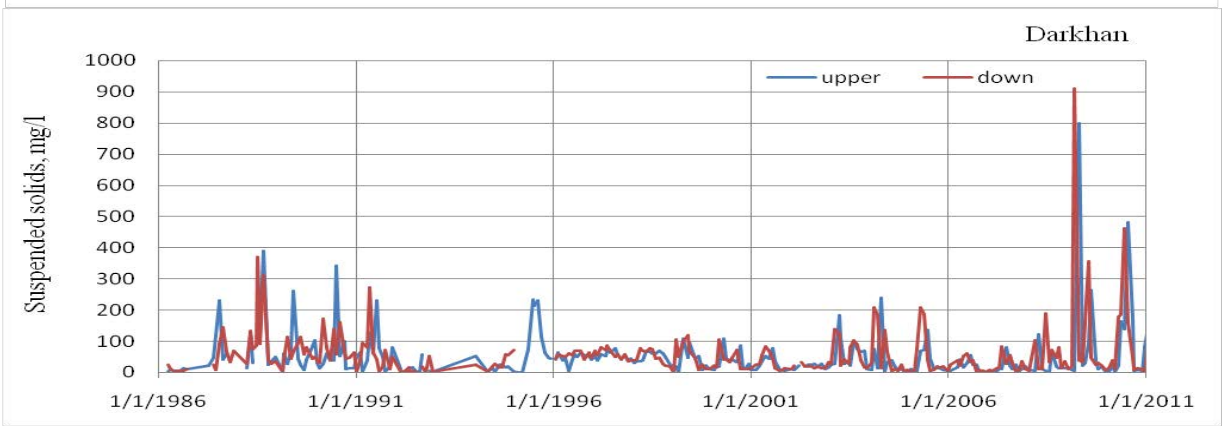


Figure 15. Trends of suspended solidsat Zuunkharaa and Darkhan stations

3.3. The Kharaa River water quality

The Kharaa River water quality was assessed using the Water Quality Index, described in Section 1.3.3. In order to analyze trends in water quality, all observed data for the period from 1991to 2011 were used, and the results are presented in Figure 16.

At the upper reaches of the river near the Zuunkharaa monitoring station, the quality of the Kharaa River water can be classified as 'very clean' to 'clean', except for few cases. The river water quality decreased in lower reaches of the river near the city of Darkhan. More than 95 percent of the all samples show that the river's water quality can be classified as 'clean'. A slight decline in the river's water quality to the *'slightly-polluted'* level is observed during highwater periods of snowmelt in April to May, as well as in low-water periods in June.

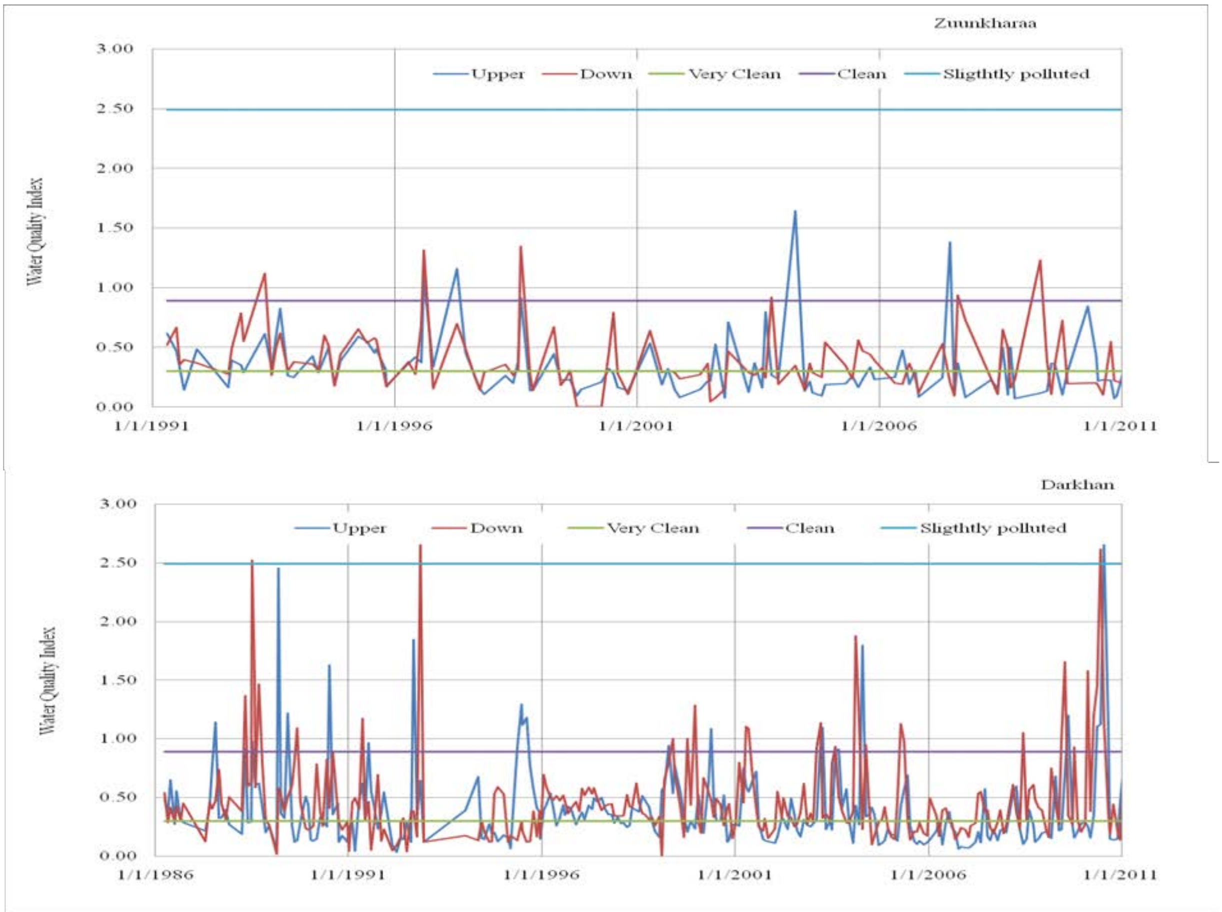


Figure 16. Water quality of the Kharaa river at Zuunkharaa and Darkhan stations

3.4. Aquatic ecology

The potential impacts of human activities on the ecological functions and services of the Kharaa River ecosystems and their interactions have not been fully studied, or understood. According to the studies MoMo project (2009), monitoring programs for the ecological status of rivers and the trends of relevant impact factors are rare and not locally adapted in the basin.

As macroinvertebrates are emerging as promising ecological indicators of water quality and ecological health. The evaluation of the ecological status of the Kharaa River is based on aquatic macroinvertebrate communities data monitored at two sites in the Kharaa River Basin for the period from 2005 to 2010.

The number of total individuals of Taxa, and Ephemeroptera, **P**lecoptera, **T**richoptera **(EPT)** individuals found in the Kharaa River are shown in Figure 17.

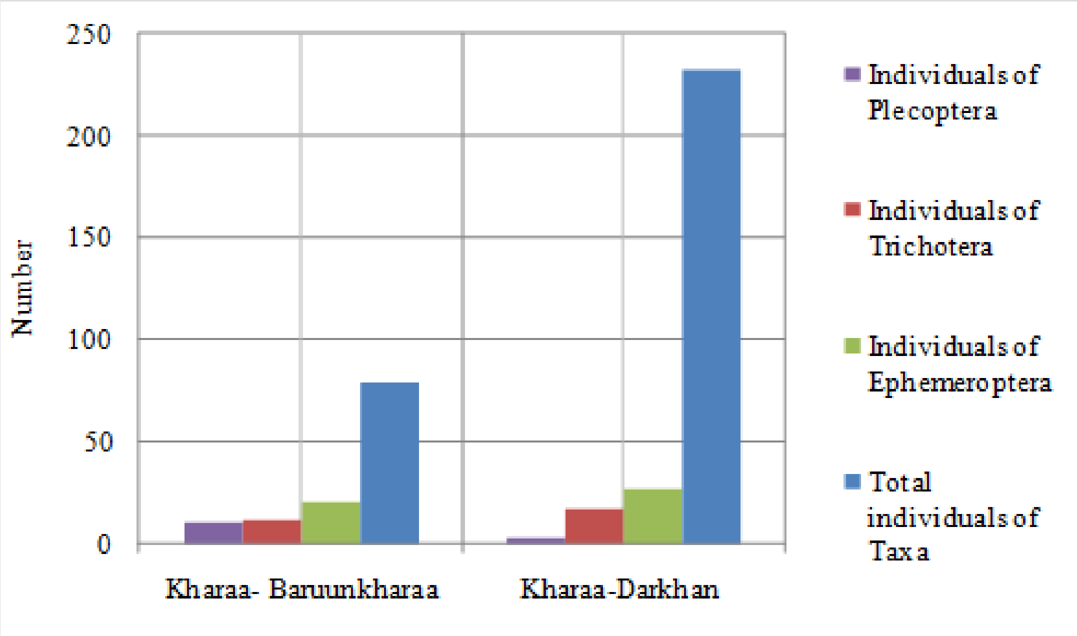


Figure 17. Number of total individuals of Taxa and EPT

The analysis of the macroinvertebrate communities at two sites of the Kharaa River Basin indicates good ecological conditions of the river. The number of total individuals of Taxa is almost three times higher at the Darkhan monitoring site than at the Baruunkharaa site. However, the number of highly pollution-sensitive individuals of EPT is almost the same.

The Kharaa River water quality has been also been assessed using the Biotic Index at the two monitoring sites. The water quality of the Kharaa River meets the 'clean' level of the water quality classification at both sites in Baruunkharaa and Darkhan, although the water quality slightly decreases near Darkhan (Figure 18). However, the water quality of the Kharaa River at the reach near Baruunkharaa has decreased since 2005 and has reached the same levels as those near the city of Darkhan in 2009 and 2010. This shows that the quality of the river's water at the Baruunkharaa monitoring site has been continuously declining for the last six years, while it stays stable near the city of Darkhan.

In terms of the annual distribution, water quality is lower during spring and autumn and gets better in summer (Figure 19).

The results of the two sites are similar to that results of integrated ecological assessment that based on benthic invertebrates produced by MoMo project by mean value (Figure 20). As there was no data between these sites it was not possible to compare results.

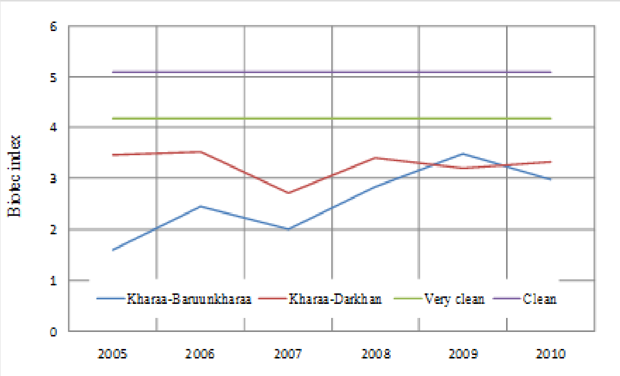


Figure 18. The Kharaa river water quality assessed by Biotic index

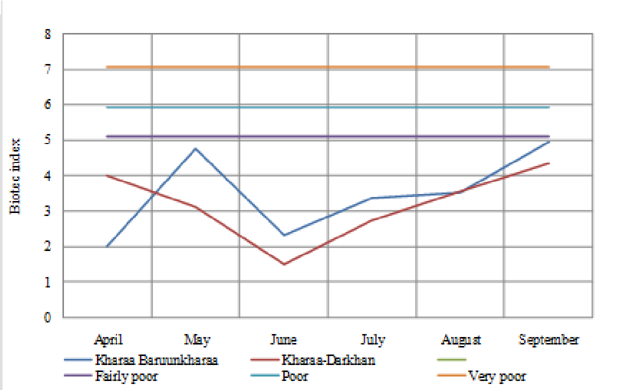


Figure 19. Annual variation of the Kharaa river water quality assessed by Biotic index

Due to lack of data, the assessment of the ecological water quality of the Kharaa River is mainly based on the available data. As part of the first-phase of the MoMo project (MoMo, 2009), the ecology of the Kharaa River was assessed based on monitoring of fish communities and macroinvertebrate communities. The monitoring was conducted at 10 sites between 2006 and 2009. The results of this MoMo project monitoring are summarized below.

The analyses of fish community and of the chemical and physic-chemical components were based on the results of all conducted expeditions, where an overall amount of 54,789 fish were caught and released. Since the analysis of the macroinvertebrate samples is much more time consuming due to the (un)availability of laboratory facilities, the results of only two expeditions could be used to assess the ecological status. However, two different seasons were included and the assessment was based on the analysis of more than 106,000 individuals. Criteria for the selection of sampling points were: 1) to include upper, middle and downstream reaches of the basin; 2) to study the influences of larger settlements in the basin such as Zuunkharaa, Baruunkharaa and Darkhan; and 3) to study a typical range of anthropogenic impacts like land use and mining.

The assessment of the fish communities has shown (MoMo, 2009) a 'good' or 'very good' ecological status at most of the monitoring sites. A 'moderate' status, detected at two sites in the watershed, is caused by the absence of ubiquistic species, showing no clear deficits in the ecological integrity of the fish fauna. Most of the fish species known to occur in the Kharaa River Basin (Dulmaa, 1999) were detected; however, some species seem to be very rare such as taimen *(Hucho taimen)*, lenok *(Brachymystax lenok)* and arctic grayling *(Thymallus arcticus)*. Even in biocoenotic regions, where they find optimal conditions, the average sum of adult fish of these species is very low, ranging from 0.5 to 7.7 individuals caught during one hour of sampling.

The analysis of the macroinvertebrate communities along the Kharaa River basin has also indicated good ecological conditions at most of the monitoring sites. However, at many sites of the main channel, i.e. in the lower part of the middle region and the transition to the down region, and also in its tributaries, deficits in benthic communities could be shown. These are mainly caused by the absence of the EPT individuals (Ephemeroptera, Plecoptera, Trichoptera) in the community composition, the absence of so-called indicator organisms, especially of the order Plecoptera, and an abnormal increased percentage of fine sediment colonisers.

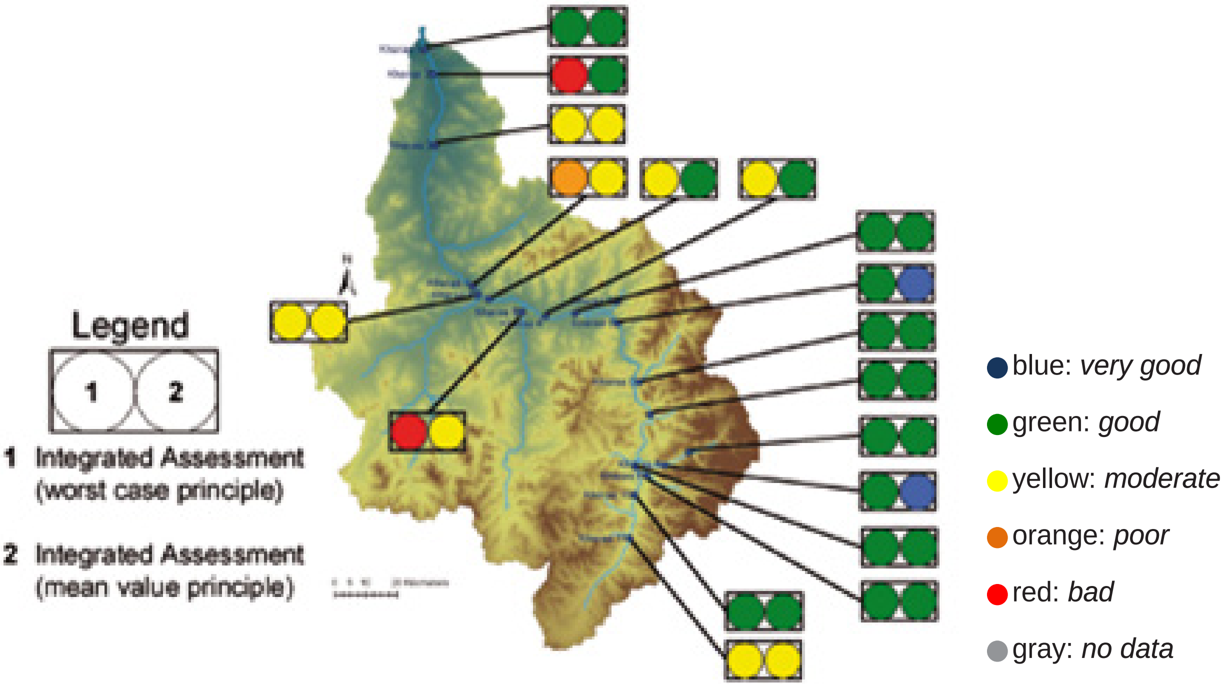


Figure 20. Ecological assessment of the Kharaa River Basin (MoMo, 2009)

The analysis of the water quality conditions based on benthic invertebrates (MoMo, 2009) showed ecological deficits in the Kharaa River near the city of Baruunkharaa and city of Khongor, as sensitive groups (EPT) had low numbers in these areas. Figure 20 shows the integrated ecological assessment based on a five class category from *'very good' to 'bad'*. As shown in the figure, the ecological water quality ranked *'very good'* and *'good'* by mean value in all parts of the river. By the worst values, the upper reaches of the river ranked *'clean'*, whereas in the river section between Baruunkharaa and Darkhan ranked from *'moderate'* to *'bad'* and improved to *'clean'* at the river outlet.

The above assessment shows that the water quality of the Kharaa River Basin decreases occasionally to *'moderately-polluted'* and *'very-polluted'* near urban settlements such as Darkhan, Baruunkharaa and Zuunkharaa. This indicates that the Kharaa River water quality is highly vulnerable to pollution, in particular in areas close to point sources of pollution, such as urban areas, and in source areas of diffuse pollution, such as agriculture and mining.

On the other hand, the self-purification rate in the Mongolian rivers is usually high, with their self-purification distances ranging between 6 and 18 kilometers. The self-purification distance of the Kharaa River is estimated 10 kilometers.

That explains why the water quality of the Kharaa River improved to *'clean'* status at its outlet, having no negative impact on the Orkhon River water quality.

3.5. Groundwater quality in the Kharaa River Basin

The groundwater quality is the most important for the drinking water quality, as groundwater is the main drinking water source in the Kharaa River Basin. Presently, there is no groundwater quality monitoring network in the basin. Only a few groundwater wells are used for drinking water extraction. Hence, groundwater quality data is very scares.

The only available data on groundwater quality was a single chemical analysis of groundwater at various locations in the Kharaa River Basin, reported in an unpublished technical report on "The groundwater quality overview" (Jadambaa, 2000). The results of this analysis are presented in Table 19.

Table 19. Groundwater quality parameters

Lon	Lat	TDS	Ca	Mg	NaK	HCO_3	SO_4	Cl	Hard-ness	pH	NH_4	NO_2	NO_3	Fe
					mg/l				mg-eqv/l			mg/l		
106.21	48.92	691	40.6	13.4	151.	262.3	143	81	3.15	8.0	0.00	0.00	10.0	0.00
105.92	49.49	611	40.5	14.7	110	366.0	45.0	35	3.84	7.2	0.00	0.03	8.0	0.00
105.98	49.43	527	40.1	25.5	80	231.8	114	36	4.10	7.5	0.10	0.50	0.0	0.20
106.75	48.64	504	40.1	11.5	77.9	335.6	34.5	4.3	2.95	7.0	0.10	0.00	0.0	0.00
105.93	49.3	413	32.1	15.8	65.8	213.5	18.1	68	2.90	7.2	0.20	0.00	0.0	0.20
106.63	48.85	351	22.1	12.2	57	213.5	25.0	21	2.10	6.7	0.30	0.01	0.0	0.30
106.27	48.82	509	58.1	22.5	56.3	286.7	62.5	23	4.75	7.9	0.20	0.00	1.0	0.00
105.92	49.5	478	44.1	25.5	55.6	305.1	15.6	32	4.30	7.0	0.00	0.00	0.0	0.00
106.48	48.85	417	52.1	17.0	44.6	244.0	45.2	14	4.00	7.9	0.30	0.01	1.0	0.00
106.08	48.91	426	54.1	15.7	38.9	237.9	65.8	14	4.00	7.8	0.20	0.00	2.0	0.00
106.78	48.82	330	43.1	12.2	28.1	189.1	47.1	10	3.15	7.1	0.10	0.00	0.0	0.30
106.48	48.81	291	36.1	14.6	26.2	164.7	34.6	15	3.00	7.9	0.10	0.00	1.0	0.00
106.52	48.8	243	32.1	10.9	16.1	140.3	34.6	8.9	2.50	7.5	0.40	0.00	1.0	0.00
106.26	49.49	233	27.1	13.4	15.6	143.4	25.0	8.9	2.45	7.0	0.00	0.00	0.7	0.00
106.76	48.64	340	50.1	26.1	4.65	213.6	34.5	11	4.65	7.0	0.40	0.05	2.0	0.00

Data source: Jadambaa, 2000

The chemical composition of groundwater is almost the same as in the Kharaa River water. The mineralization of groundwater is in the range between 233 and 691 mg/l. Similar to the Kharaa River water, the calcium and bicarbonate are the dominant ions in groundwater at all sampled points. The order of abundance of cations is Ca^{2+}>Na^{+}+K^{+}>Mg^{2+}, and the order of abundance of anions is HCO_3^{-}>SO_4^{2-}>Cl^{-}.
According to nitrogen (N) concentrations, the nutrient level in groundwater in aquifers in the Kharaa River Basin is very low, indicating that groundwater is clean.

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4. Assessment of pollution hotspots in the Kharaa River Basin

An assessment of water pollution hotspots in the Kharaa River Basin was conducted as part of the water quality assessment of the basin. This included the identification of potential pollution hotspots and their effects on the water quality of the basin, as well as the identification of possible threats to the environment and human health.

In general, a water pollution hotspot is an area where the concentration of a pollutant exceeds the standards. Pollution hotspots are characterized by both a high concentration, or loading, of a pollutant and a high risk that the pollutant enters adjacent water bodies such as rivers, lakes, groundwater aquifers, causing water pollution. The pollution hotspots assessment is useful in identifying areas with most serious pollution risks, thus allowing the decision-makers to target compliance efforts on the problem sites.

The water quality assessment of the Kharaa River Basin, described in the previous section, shows that there are no potentially-serious water quality problems in the basin, except for the localized and seasonal water quality degradation due to the impacts of municipal wastewater effluents on the river water quality downstream of urban areas and a potential risk of bacteriological contamination by livestock waste. However, the basin is becoming more sensitive to pollution, as there are growing pressures from population growth, urbanization, industrial development, and increasing farming and tourism activities that are likely to generate more pollution.

The assessment focused on both point and diffuse pollution sources in the Kharaa River Basin in order to have a comprehensive overview of existing, or potential, pollution hotspots.

4.1. Pollution from urban areas

The Kharaa River Basin includes several large and small urban areas. The largest urban area in the basin is the industrial city of Darkhan—the second biggest city of Mongolia with a population of about 75,000. Moreover, a total of 24 soums (an administrative unit equivalent to small towns) are located in the basin. The basin is shared by three provinces: Selenge, Tuv and Darkhan Uul aimags (Figure 21).

The entire population of the Kharaa River Basin is about 133,000, which is approximately 5 percent of the total population of Mongolia. The basin has the highest population density in Mongolia, which is about 9.2 persons per sq.km. The Darkhan city has the highest population density of about 300 people per sq.km.

In addition to being an industrial city, Darkhan is the second largest educational center in Mongolia too, with 10 universities and higher education institutions, 25 secondary schools and 14 pre-school establishments and kindergartens. In addition, several research institutions are located in the city of Darkhan, including: the Institute of Management and Development; Regional Business Development Center; and Horticultural and Agricultural Research and Training Institute. Every year, hundreds of students come Darkhan from other parts of Mongolia to study.

4.1.1. Municipal wastewater

Municipal wastewater and runoff from urban areas are, in general, the largest point source of water quality impairments.

The discharge of inadequately-treated municipal wastewater to surface water resources is a major water quality concern in the Kharaa River Basin.

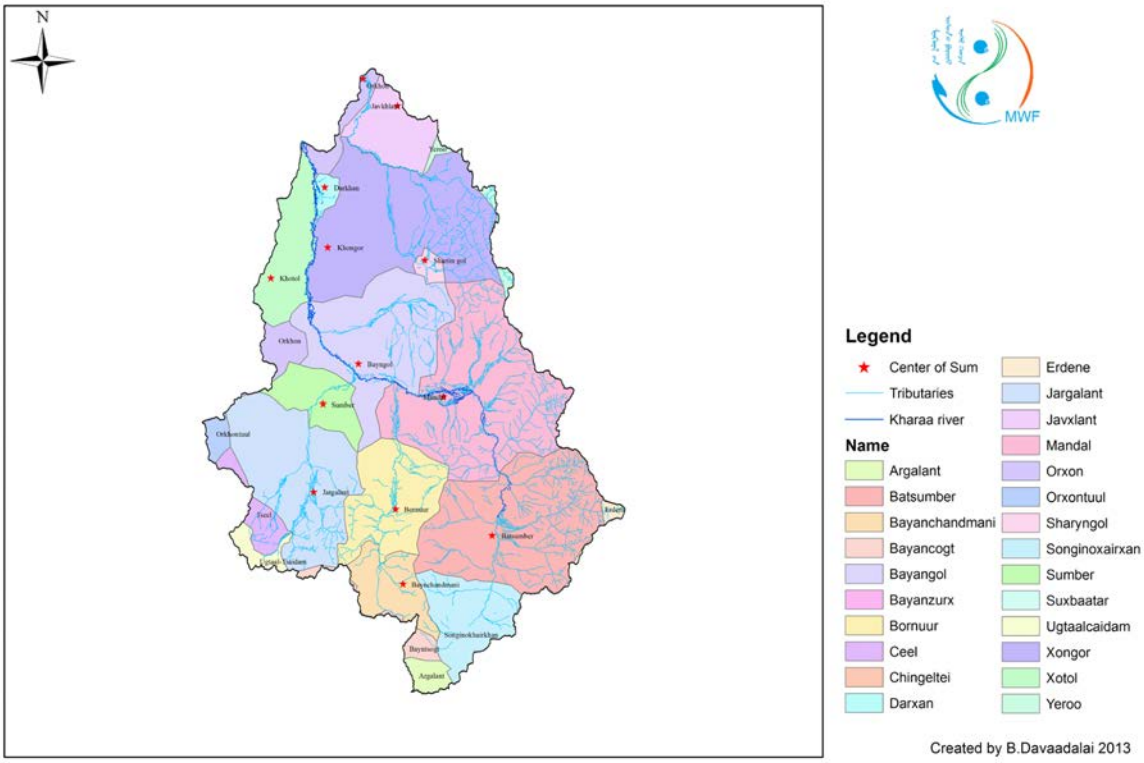

Figure 21. The administrative units in the Kharaa River Basin

There are five Wastewater Treatment Plants (WWTPs) in the Kharaa River Basin, two of which discharge their treated wastewater directly into the Kharaa River. The other three plants have no direct outlet to the Kharaa River. Most soums (small towns) do not have wastewater treatment facilities and infrastructure. A majority of households in soums use simple traditional pit latrines in their compounds.

The Wastewater Treatment Plant in the Darkhan city treats both municipal and industrial wastewater and discharges its effluents directly to the Kharaa River. The Wastewater Treatment Plant in Salkhit (a railway station town) has mechanical and primary biological treatment processes and discharges its effluents directly to the Kharaa River, too.

The WWTPs in Zuunkharaa, Baruunkharaa and Khongor soums, which are located in the upstream reaches of the basin, are smaller and have no direct outlet to the Kharaa River. These WWTPs have mechanical and primary biological treatment processes. The treated wastewater of these plants is discharged to infiltration ponds and the sludge is disposed of in sludge fields close to the Kharaa River. Consequently, there is a potential risk of pollution of groundwater, soil and river water by leakage from the sludge ponds.

Darkhan Wastewater Treatment Plant

The Darkhan Wastewater Treatment Plant is biggest in the Kharaa River Basin (Figure 22). It was commissioned in 1968.

The plant treats both municipal and industrial wastewater. It has mechanical, biological and chemical treatment processes. Some biological processes are affected by the cold weather and slow down, or cease, at lower temperatures during winter. Due to the cold climate, the polishing ponds cannot be used in winter time.

The plant has no denitrification system. Raw wastewater entering the plant is initially passes through mechanical screens and then treated biologically in primary and secondary sedimentation tanks. The plant has a chlorination unit for the disinfection of treated wastewater before its discharge to the river. However, the chlorination system is temporarily out of order.

The Darkhan Wastewater Treatment Plant has a laboratory for the chemical analyses of wastewater. The total capacity of the Darkhan Wastewater Treatment Plant is 50,000 m3/ day. However, the plant is operating at one third of its design capacity, treating from 15,000 to 17,000 m3/ day wastewater. Only wastewater from apartment buildings and administrative and services areas, which are connected to the sewage system of the city, is treated at the plant.

The Darkhan Thermal Power Plant (DTPP) is the largest user of water in the city. It has its own wastewater tratment facility. The wastewater of the plant is discharged into the Kharaa River through 12 oxidation ponds and a bioaquifer system. However, the DTPP wastewater treatment facility often encounters technical problems, and untreated industrial wastewater is discharged into the area outside the plant.

This area is largely residential, and close to the 'ger' district (a district of traditional Mongolian housing and small houses).

The 'ger' districts and small villages are not connected to the sewage system of the city. The wastewater from these areas is discharged into simple traditional pit latrines or soak pits. Many of these latrines are inadequately maintained, and overflowing latrines are often a major source of pollution in 'ger' areas of the city, especially during heavy rainfalls.

The Darkhan Water Supply and Wastewater Company (Darkhan USAG) is responsible for water supply and wastewater collection treatment in the city.

In order to evaluate the efficiency and rate of wastewater treatment of the Darkhan Wastewater Treatment Plant, data of the chemical analyses of treated wastewater at the plant outlet have been analyzed for the period from 2002 to 2012. The wastewater treatment rate of the plantvariesbetween 76.8 and 98.1 percent (Figure 23). However, in most of the time, the treatment rate is below 90 percent, which means to a certain extent that polluted water is discharged into the Kharaa River.

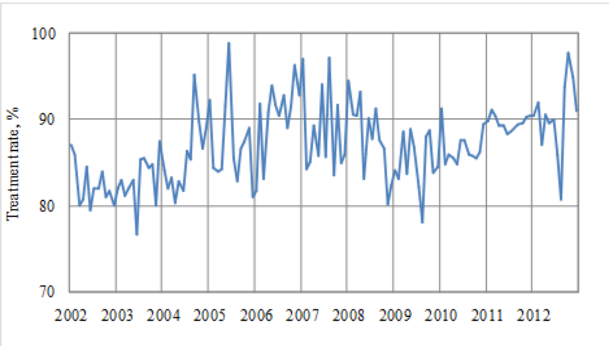

Figure 23. Wastewater treatment rate of the Darkhan WWTP

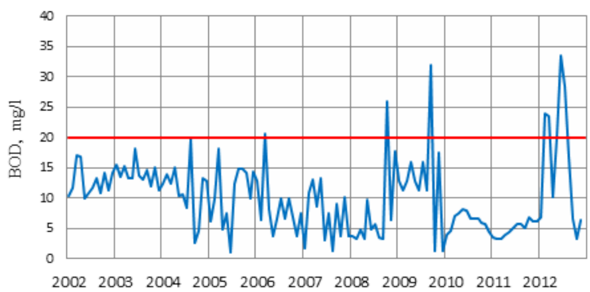

Figure 24. BOD concentrations of treatedwastewater of the Darkhan WWTP

Thus, concentrations of BOD and suspended solids of the treated wastewater have been analyzed to determine how much polluted water is discharged into the Kharaa River.

The results are presented in Figure 24and 25, respectively.

The wastewater BOD concentrations at the outlet of the plant range between 3.1 and 33.6 mg/l and rarely exceed the Maximum Acceptable Concentration of 20 mg/l, set by the Mongolian National Standard for Discharge of Treated Wastewater into the Environment MNS:4943-2011 (NSA, 2011). This shows that even though the treatment rate of the plant is not high enough, the treated wastewater discharged into the Kharaa River has no significant organic pollutant in most of the cases.

Figure 22. The Darkhan Wastewater Treatment Plant

On the other hand, the concentrations of suspended solids of treated wastewater are quite high and regularly exceed the Maximum Acceptable Concentration of 50 mg/l, as per MNS:4943-2011 (NSA, 2011). In general, the concentrations of suspended solids in wastewater are similar to those of the Kharaa River water.

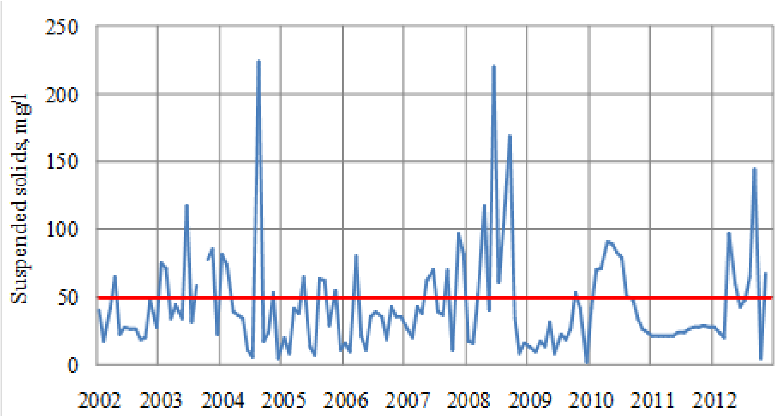

Figure 25. Suspended solids concentrations in treated wastewater of the Darkhan WWTP

The Darkhan Wastewater Treatment Plant requires substantial technical upgrading and construction maintenance. Most treatment process units of the plant are outdated, with rather mediocre treatment efficiencies. The construction of a new wastewater treatment plant may be needed.

The MoMo project (2009) developed a simulation modeling of the Darkhan Wastewater Treatment Plant to improve and optimize the treatment processes of the plant, in terms of both the quality and quantity of treated wastewater, as well as with regard to the energy consumption of the plant for the aeration of the biological tanks. In the framework of the follow up the MoMo project first-stage, researchers of the Helmholtz Centre for Environmental Research of Germany have developed an integrated concept for decentralized wastewater treatment and have built a pilot plant to test it in local Mongolian conditions. In May 2012, the decentralized wastewater pilot plant with integrated wood production was commissioned and handed

over to the College of Polytechnics in Darkhan of the Mongolian University of Science and Technology. This innovative concept was developed through the cooperation of Mongolian and German researchers with the aim to contribute to solving problems such as the lack of access to appropriate sanitation; increasing water scarcity and deforestation, caused by a high demand of wood for heating (www.ufz.de).

In addition to municipal wastewater, wastewater from various industries and tanneries is combined with the municipal wastewater of Darkhan without any pre-treatment, which may cause serious environmental and health problems. A wide variety of industries are located in Darkhan, including slaughter houses, wool factories, bakeries and confectioneries, pharmaceutical companies, hospitals, power stations, printing houses, vehicle repair shops, etc.

4.1.2. Solid waste

At the national level, the amount of municipal solid waste is growing rapidly, while the composition of solid waste is becoming more and more diversified with increasing volumes of non-biodegradable waste such as plastics. In general, solid waste management is inadequate throughout the country and the absence of a proper waste disposal system creates significant environmental and health concerns. In early 1990s, outdoor burning of household garbage was commonly practiced as a method of waste disposal throughout the country to reduce household waste quantities and also to separate recyclable material from waste. Concerns about the impact of this practice on air quality led to its banning nationwide. However, no new solutions for waste management have been introduced thus far, and open burning continues to be practiced in some places. Only a small portion of solid waste is recycled despite a potential market for recycled waste materials such as plastics, glass bottles, and scrap metals. In 2012, the Parliament of Mongolia adopted a new "Law on Solid Waste". This new law replaces the previously existing Law on Household and Industrial Waste and Law on Hazardous and Toxic Chemicals. It has introduced 3R '*reduce, recycle,* and *reuse*' principles.

Over the past years, solid waste management is becoming an increasingly significant problem the Kharaa River Basin, mainly due to the concentration of the population in urban areas, changes in economic structure, growing consumption and changing lifestyles, as in any other parts of Mongolia. There are growing concerns about inappropriate solid waste management and increasing litter. Municipal solid waste, including garbage from larger cities and small towns, account for the biggest share of solid waste generated and disposed of in the region. However, there are no systematic and comprehensive data to quantify the amount of solid waste generated in the Kharaa River Basin as a whole. While, in larger cities, municipal solid waste is collected and disposed of in landfills or dumpsites, most small towns do not have proper solid waste management systems.

Solid waste management in Darkhan

The city of Darkhan–the largest urban centre in the Kharaa River Basin–accounts for the biggest share of the municipal solid waste generated in the basin.

A feasibility assessment of solid waste management in the city of Darkhan was conducted by the Ministry of Nature, Environment and Tourism of Mongolia, in cooperation with the Korea Environment Cooperation, in 2011 (MNET, 2011). Based on this assessment, the city's solid waste generation has increased nine times during the past decade. The amount of municipal solid wastes collected and disposed of in the Darkhan area is summarized in Table 20. As shown in the table, total waste generation in the Darkhan city was approximately 49,640 tons in 2010, with a per capita waste generation of about 1,8 kg per day (MNET, 2011).

Table 20.Quantities and composition of solid waste generated in Darkhan by source category, 2010 (tons/year, wet weight)

Source	Apartment building area	'Ger' district area	Office buildings and service areas	Streets and public space	Total
Paper	1057.3	744.6	2283.4	297.8	4383.2
Cardboard	2730.2	282.9	2591.2	620.5	6224.9
Glass	1588.6	819.1	2874.2	397.1	5678.8
Metal	1022.6	1027.6	357.4	248.2	2655.7
Plastic	953.1	794.2	1360.1	-	3107.5
Wood/green waste	1444.5	1384.9	1747.3	248.2	4825.0
Animal remains	680.1	868.7	1653.0	1092.1	4293.9
Other organic	585.8	1310.5	1002.7	-	2899.0
Other inorganic	1007.7	2874.2	412.0	516.3	4810.1
HHW	238.3	387.2	665.2	-	1290.6
Mixed waste	610.6	794.2	511.3	496.4	2412.5
Total	12613.5	16832.9	16277.0	3916.6	49640.0

Data source: MNET, 2011

In apartment buildings, the solid waste is deposited in a room on the ground floor and collected by waste management companies. In areas with lower buildings and individual houses, community bins are available for each block. Residents of *'ger'* districts are required to deposit their household wastes in designated areas.

The city's solid waste is disposed of at the Baraat central waste disposal site and other five unofficial disposal sites. The Baraat waste disposal site is located at the northern edge of the city in 15 kilometers from Darkha. The site covers an area of 15.02 hectares. The disposal site does not have a waste sorting facility. The Public Utility Services Department of the Municipality of Darkhan is responsible for overseeing the collection and transportation of municipal solid waste from the apartment buildings area, *'ger'* districts, office buildings, service areas such as hotels, restaurants and shopping centers, as well as for street and public space cleaning. Waste collection trucks pick up mixed solid wastes. All solid wastes are transported to the disposal sites without presorting. There is no system for waste separation at source. The city has no official recycling program in place as of yet.

In 2007, the city of Darkhan developed and implemented a project on rehabilitation of the Baraat central solid waste disposal site. The project was financed by the Ministry of Nature, Environment and Tourism. At the request of the Ministry, the Institute of Geo-ecology of the Mongolian Academy of Sciences developed general guidelines for a landfill facility in Mongolia. In 2008, the solid waste at the Baraat disposal site was removed to a smaller disposal area in order to reduce the site area, through the financial support from the Ministry of Nature, Environment and Tourism, as part of the project. Rehabilitation works and tree planting works were implemented, as well.

In 2010, the Municipality of Darkhan developed a programme "Darkhan – a clean city", adopted by the Darkhan City Council of Representatives.

The programme will be implemented for the period from 2010 to 2014.

This programme has three main objectives, as follows:

Objective 1: Establish an efficient and suitable system for waste separation at source:

- Develop a methodology to determine the amount, types and composition of solid wastes from apartment buildings, 'ger' districts, enterprises and industrial plants, and conduct relevant studies on waste generation;

• Develop a database on solid waste generation in the Darkhan-Uul aimag (province), with an inventory system for solid wastes from households, business areas and industries;
• Implement pilot projects of waste separation in selected districts and select optimal alternatives for waste separation in apartment building areas, 'ger districts', and business and service areas;
• Establish a specific site for the collection of recycled waste materials in order to support the voluntary collection and sale of recyclable waste materials by individuals and residents;
• Increase the involvement of enterprises in waste separation by providing waste separation containers to shops, supermarkets, service providers and in the streets.

Objective 2: Establish a waste sorting and recycling plant and implement projects on reuse and recycling of household and industrial wastes and waste materials
• Adopt economic tools to motivate to produce less waste and use the resources more efficiently in production, services and other sectors at the local level;
• Operate a regular site for the exchange and sale of used materials (such as books, clothing, newspapers, journals, home furniture, etc.), as well as for sharing information and advertisements of enterprises that collect/purchase secondary raw materials (recyclable waste materials), in order to support waste separation, recycling and reuse with increased participation of residents and individuals;
• Conduct a study on the quantity, types and composition of secondary raw materials (recyclable waste materials) and on technical and economic feasibility of waste recycling, and build a waste recycling and sorting plant;
• Implement projects on waste recycling/reprocessing and sorting, based on the composition of wastes from different sources, including projects to separate and process organic wastes from households and restaurants to produce compost for use as a fertilizer;
• Support enterprises operating storage, collection and transportation of secondary raw materials.

Objectives 3. Improve the collection, transportation and disposal of solid wastes.
• Transport all solid wastes from enterprises, public organizations and households;
• Modernize waste disposal systems of enterprises;
• Improve waste collection, storage and transportation services;
• Select waste collection and storage sites taking into account of specific conditions of different areas such as service and business areas, public areas, apartment building areas, and 'ger' districts, respectively;
• Increase public awareness by disseminating information handouts and training pamphlets about more efficient management of solid wastes;
• Develop new routines and schedules for cleaning streets and public spaces, and waste collection from enterprises, apartments buildings and 'ger' districts;
• Estimate costs of waste removal and the reclamation of land used by enterprises and individuals for the purposes such as unfinished construction and garages, and collect these costs from them;
• Support public officers, administrators of local communities and public organizations, apartment co-ownership associations, enterprises and individuals for their accomplishments and efforts made in improving waste management in their communities;
• Organize a "Organization with No Waste" competition amongst local communities, public organizations, apartment co-ownership associations, enterprises and industries with no open-waste disposal sites;
• Implement technologies for solid waste disposal in landfills.

Consequently, the solid waste management in the Darkhan city is expected to improve over the coming years, as a result of the "Darkhan – a clean city" programme.

4.2. Industrial pollution

The city of Darkhan, which is located in the Kharaa River Basin, is one of the largest industrial centres in Mongolia. It is home to most of country's large industries, including steel production, construction and building material manufacturing, textile and leather factories, and food processing. Many other industries are located in Darkhan, including food processing, vehicle repair, and the production of woolen textiles, carpets,dressed sheepskins, and clothing. Lime quarrying and metal foundries have also experienced a large growth, becoming important contributors to the local economy. There has been a significant growth in the dairy industry and milk production too. The Darkhan Thermal Power Plant (a coal power plant) supplies electricity for the city, as well as to other larger cities.


The Darkhan city

The size of these enterprises varies greatly. In general, most enterprises are quite small. The construction industry, which once was the biggest employer, has been declining over the past years and now employs only six percent of the labor force of the city. In the last few years, the economy has begun to diversify with investments in transportation, storage and communications owing to good road and rail links to other large cities such as Ulaanbaatar and Erdenet.


The Darkhan city

The steel production and processing industry has experienced the greatest growth in the past few years. The Darkhan Metallurgical Plant, located in the city of Darkhan, is the only steel and iron processing plant in Mongolia. The plant was established in 1994 and employs 500 staff. It produces 100,000 tons of steel per year from iron ore and scrap.

Environmental impact assessments have not been conducted for most of small enterprises.

Critical concentrations of toxic heavy metals were reported at a sampling site one kilometer downstream of the city of Darkhan (MNET, 2011).The concentration of mercury at the sampling site was 0,5 μg/l. Increased concentrations of chromium were also detected, which can be caused by pollution from leather industries in the city.


The Darkhan city

4.3. Mining

Open mining is one of the major sources of pollution in the study area. Several mining reserves are found in the Kharaa River Basin and occupy an area of about 16 percent of the total area of the basin.

Some of the mines are not yet exploited, which means that exploration and development licenses of these reserves may have been issued to mining companies, with mining operations not having started. The mining area under operation represents 1.5 percent of the total area of the basin, which is about 9.3 percent of the total area for mining purposes (Figure 26).

One of the most productive gold mining sites of Mongolia, the Boroo Gold Mine, is located in the Boroo River Basin, which is one of the tributary of the Kharaa River. The Sharyn Gol Coal Mines-the second largest coal mining company in Mongolia, which produces over 1.000.000 tons of coal per year—is also located in the Kharaa River Basin.

There are no systematically observed data to assess the pollution from mining activities in the basin, which may have serious negative impacts not only on surface water quality, but also on groundwater and soil. Heavy metals (such as mercury and cyanide) were commonly used in small-scale gold mines mines until the use of mercury mercury for mining and extract minerals was banned in 2008.

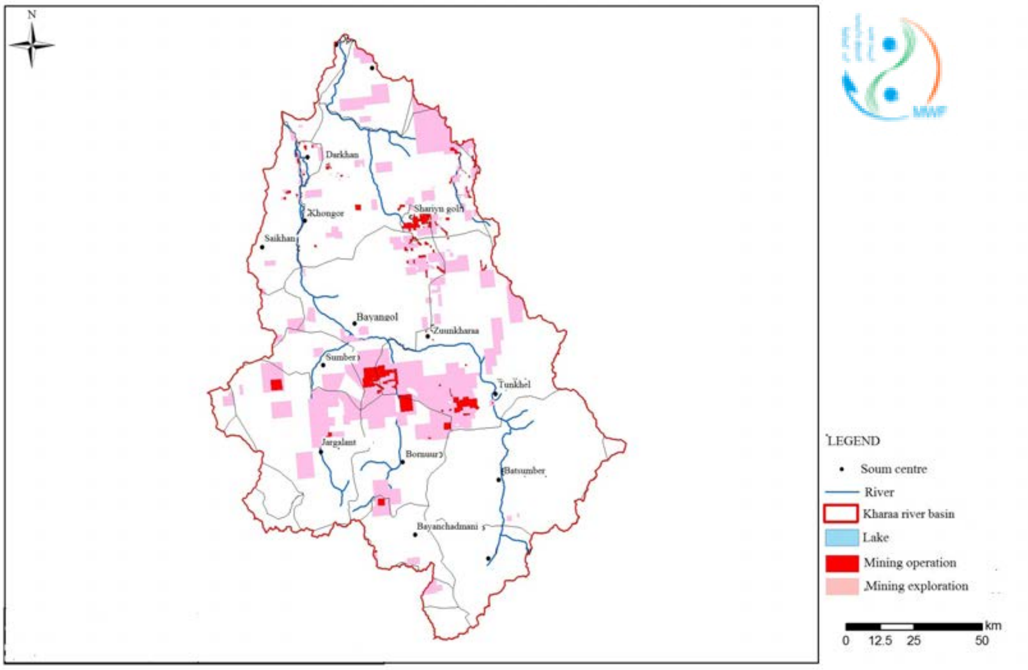

Figure 26. Mining areas of the Kharaa River Basin

An incident of a possible mercury and cyanide contamination of groundwater caused by a tailings spill from a small mining operation in Khongor soum was recorded in 2007.

As part of the MoMo project (2009), concentrations of heavy metals in surface waters and the river sediment were measured. The study indicated that the concentrations heavy metals in the river water and sediment had a correlation to mining activities and tended to increase in areas downstream from mining sites. In the Boroo River, for example, concentrations of arsenic in the surface water were above the threshold level for drinking water of 10 μg/l, and elevated concentrations of arsenic, lead, chromium, mercury and nickel were found in the sediment.

Boroo Gold Mine

The Boroo Gold Mine (Figure 27) is located in 110 kilometers to the northwest of the capital city of Ulaanbaatar and about 230 kilometers to the south of the international boundary with Russia, at 48°45′ North and 106°10′ East.

The Boroo Mine was the first hard-rock gold mine established in Mongolia and the largest foreign investment in the country at the time it began production. The Boroo Gold Mine is owned by the Canadian mining company, Centerra Gold Inc. It began commercial production in March 2004 and produced more than 46 tons of gold through the end of 2010 (www.boroogold.mn). The Boroo project consists of a suspended open-pit mine, an inactive heap leach processing facility, an operating processing plant, a tailings facility, ore and waste rock stockpiles, and other surface infrastructure normally associated with an open pit mining operation. Wastewater and sludge from the mining operation of the Boroo Gold Mine is stored in a tailings facility (a reservoir behind a dam).

Figure 27. The Boroo Gold mining site

Figure 28. The tailing facility of the Boroo mining

Table 21. Results of chemical analysis of the monitoring wells

Elements	Averages of 2012 samples (January -October)								
	Monitoring wells								
	MAC levels (MNS 6148:2010)	MW#4	MW#7	MW#8	MW#9	MW#14	MW#4A	MW#3	MW#1
K	na	1.93	8.34	1.66	2.34	2.7	2.76	2.7	2.19
Na	na	112.8	284	129.4	65.5	139.4	113.6	83.2	96
Cl	3	0.34	0.32	0.3	0.3	0.34	0.32	0.37	0.45
SO4	350	97	324	98.7	80.8	112	110	82.8	61.5
NO2	500	242.3	1042	212.7	196.5	251.7	315.8	420	120.2
NO3	1	0.14	0.14	0.02	0.05	0.02	0.15	0.02	0.02
pH	50	2.79	8.36	2.9	2	2.18	5.2	5.3	5.7
CN total	6.5-8.5	7	6.88	7.0	7.1	7.1	7.0	7	6.9
CN free	0.1	<0.002	<0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CN WAD	0.005	<0.002	<0.002	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cr	na	<0.05	<0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Al	0.07	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mn	0.5	<0.015	<0.015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mo	0.1	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ba	0.04	<0.03	<0.03	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zn	2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	5	<0.01	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Co	0.1	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ag	na	<0.05	<0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
U	0.02	0.016	0.016	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fe	0.3	0.02	0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
As	0.01	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cd	0.003	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu	1	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pb	0.05	<0.01	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hg	0.002	<0.001	<0.001	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Se	0.04	<0.05	<0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Data source: Boroo Gold Mine, 2013

The average depth of these monitoring wells is 50-65 meters, the groundwater table is 38.2 to 44.62 meters and yield is 0.02 to 0.9 l/s.

According to the average values of the water quality parameters of 2012 of these eight monitoring wells (Table 21), the concentrations of most pollutants were below the Maximum Acceptable Concentrations in most of the monitoring wells, set in the Mongolian National Standard on Water Quality: Permissible Levels for Groundwater Pollutants MNS 6148:2010 (NSA, 2010).

In only one case, the concentration of a pollutant exceeded the MAC level, where the concentration of sulfates (SO4) in the Monitoring Well No.7 was twice higher than the Maximum Acceptable Concentration value. Also, it was not clear whether concentrations of selected pollutants and some heavy metals such as cyanide (CN), cadmium (Cd), selenium (Se), cobalt (Co), arsenic (As) and mercury (Hg) in some wells exceeded the MAC values. The concentrations of these pollutants were reported as less than certain levels, without indicating their exact values.

However, it still should be noted that in case of a leakage, the tailings from the mine may cause heavy metals contamination in the Boroo River (a tributary of the Kharaa River) and consequently will have potentially serious impacts on both surface water and groundwater resources of the Kharaa River Basin.

4.4. Agriculture

Mongolia's most productive agricultural lands are found in the Kharaa River Basin and the surrounding region. The region's soil and natural climatic conditions are favorable for the cultivation of cereals and vegetables, especially potatoes. There are 35 agricultural producers and agricultural cooperatives in the Kharaa River Basin.

The cropland in the valleys along the Kharaa River and its tributaries is used mainly for growing wheat and basic vegetables and occupies 11.9 percent of the total area of the Kharaa River Basin. This area contains 30 thousand hectares of soil suitable for arable crops and 1,287.8 thousand hectares for vegetable production.

Despite the expansion of the urban economy, livestock farming is still the main activity and major means of sustaining livelihoods and food security of the rural population. There are approximately 130,000 heads of livestock in the Darkhan-Uul aimag (NSO, 2010).

Figure 29. Cropland area on the Kharaa River bank

Figure 30. Bornuur cropland farming near the Boroo River bank

In Mongolia, the use of chemical fertilizers in agriculture is insignificant. Traditionally, fertilizer is not used for cereals production. Currently, natural fertilizer such as animal manure is the most widely used fertilizer for vegetables. According to the information provided by the officials[3] of the Ministry of Food and Agriculture, the total fertilizer use is about 1,200 tons per year in Mongolia. Consequently, the impact of fertilizer use in agriculture on the water quality of the Kharaa River Basin is insignificant, given the insignificant amount of fertilizer used in crop production.

However, some of the cropland is located close to, or directly on, the banks of the Kharaa River (Figures 29 and 30). The proximity of the cropland to surface waters may have potential impacts on water quality and sedimentation of the river systems of the basin.

According to data of land use and land cover studies (Hudelmer, 2006), more than 60 percent of the total area of the Kharaa River Basin is used as pasture land for livestock grazing. Hence, the livestock grazing is the major non-point source of pollution to surface waters, leading to fecal contamination and direct nutrient inputs to the river water during warm seasons.

4.5. Pollution hotspots mapping

Based on the identification of major pollution sources in the Kharaa River Basin, a pollution hotspots mapping was carried out. The areas of concern, or potential pollution hotspot, have been identified with regard to potential impacts on the quality of surface waters and groundwater resources in the Kharaa River Basin.

The overview of the areas of concern in the Kharaa River Basin is shown in Figure 31. The pollution hotspots mapping has shown similar results as the major points of concern identified by the MoMo project (2009).

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[3]*Statement of Mr. Sh. Baranchuluun, Senior officer at Ministry of Industry and Agriculture, during the National Workshop conducted in the framework of this study in Ulaanbaatar, Mongolia, on 04 June 2013*

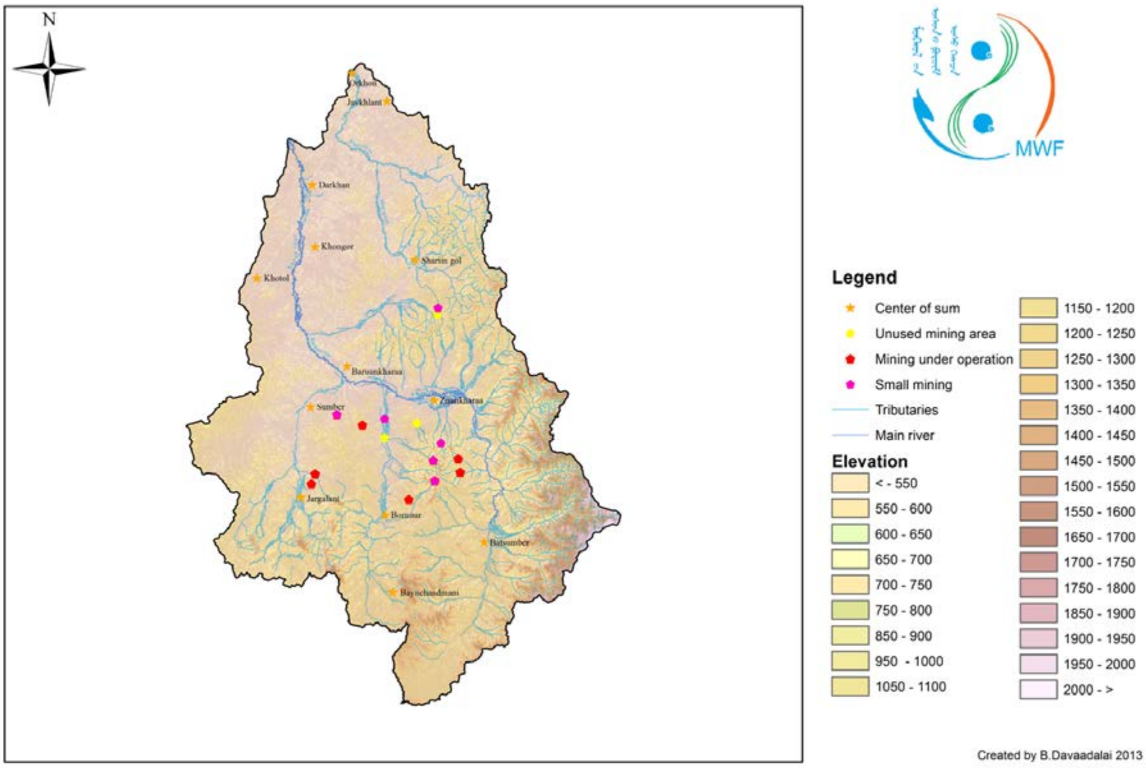


Figure 31. Map of areas of concern (potential pollution hotspots) in the Kharaa River Basin

4.6. Environmental and health impacts

The Kharaa River Basin became a Mongolia's major industrial and agricultural region in the late 1950's and early 1960's with the establishment of the industrial city of Darkhan (on 17 October 1961) and an agro-industrial farming complex to change the country's economic base from traditional livestock production into modern industrial and agricultural economies. The political and economic changes from the socialist regime to a democratic system and a market economy in 1990-1991 resulted in the collapse of agricultural production. Currently, the agricultural sector is rebounding with increasing wheat production over the past several years.

The industrial and agricultural development of the region, hence, has become the main driver of environmental change in the Kharaa River Basin. The discharge of poorly treated municipal and industrial wastewater due to outdated wastewater plants has led to increasing loadings of pollutants to surface waters and groundwater systems across the basin. Other environmental factors such as deforestation, over-grazing, and land use changes resulting from the extensive tillage for cereal and crop production have become increasingly apparent, too. As a result of these environmental impacts of industrial and agricultural activities, the lower and middle reaches of the basin have shown degradation of the pristine natural environment.

The water demand in the basin is increasing year after year due to population growth, industrialization, mining development, growth of irrigated agriculture and lifestyle changes. Furthermore, climate change impacts are becoming more evident. The current and future climate changes and their impacts, coupled with enhanced climate variability, will likely increase water scarcity in the Kharaa River Basin, as well as in Mongolia as a whole (Batimaa et al, 2005 and 2011).

Hence, the impact of climate change on water resources' and water availability is seen as an equally important concern for the future water supplies of the country.

Since the 1990 transition, mining activities have grown significantly in the region and gold mining is playing an increasingly important part in the country's economy. With the expansion of the mining industry, concerns over environmental and health impacts of mining activities are becoming increasing important, especially because the Boroo Gold Mine (one of the most productive gold mines in Mongolia) is located in the Kharaa River Basin.

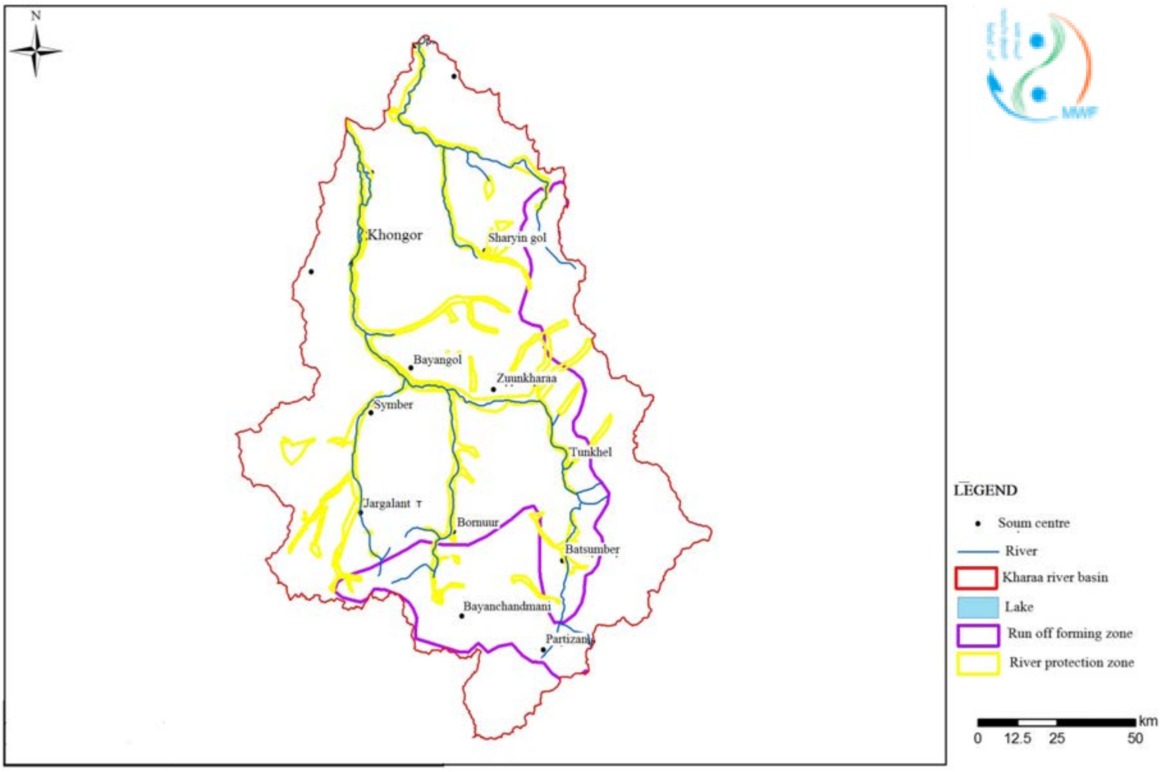


Figure 32. Map of areas of concern (potential pollution hotspots) in the Kharaa River Basin

Several incidents of releases of hazardous and highly toxic substances such as mercury and cyanide into the environment were caused by lack of compliance with environmental and health safety regulations for the management and disposal of tailings from mining activities. The most serious incident occurred in Khongor soum in April 2007 and was caused by the release of large quantities of mercury and cyanide into the soil and groundwater from a smallscale mining operation. The Khongor incident has raised a serious concern over among the local population over environmental and health effects which might result from this environmental contamination. The initial investigations were conducted jointly by the World Health Organization, the joint UNEP/OCHA Environment Unit, and the Mongolian authorities and highlighted the need to conduct a health risk assessment for the population at risk. Upon request of the Mongolian Government, a Joint UN mission consisting of international experts from the World Health Organization (WHO), the United Nations Environmental Programme (UNEP) and the Food and Agriculture Organization (FAO), took place in February-March 2008 to assess the situation with regards to effects of mercury and cyanide contamination on human health, food production, animal health, and the environment. The results of neurological and medical examinations conducted by WHO among the local population at risk did not suggest any health effects which could be attributed to mercury exposure or acute cyanide poisoning. To address growing concerns over environmental and health impacts of the miningindustry, the Parliament of Mongolia adopted the Law on Prohibition of Mineral Exploration and Mining Activities in areas in the Headwaters of Rivers, River Protection Zones and Forested Areas (2009). This law prohibits any economic activity in areas of the headwaters of rivers, streams, and creeks and in a distance of 200 meters and more in the riparian zone of a river. Consequently, the former Water Authority has identified river protection zones in all rivers in Mongolia. The Institute of Meteorology and Hydrology has defined also the headwaters areas of all river basins of Mongolia. The map of the river protection zones and headwaters areas of the Kharaa River Basin is shown in Figure 32.


The Orkhon River Valley


A Hayland

5. Conclusions and Recommendations

5.1. Conclusions

The Kharaa River Basin is one of the main tributaries of the Orkhon-Selenge River system, which ultimately drains to Lake Baikal. The Orkhon River is the longest river in Mongolia and the valley along the river is an archaeologically-rich cultural landscape. The Orkhon Valley Cultural Landscape has been designated by UNESCO as a World Heritage Site. The Selenge River is the largest river by volume of flow. The upper basin is in a relatively pristine state and has experienced minimal anthropogenic impacts. The lower basin is characterized by diverse economic activities such as industry, agriculture and livestock breeding, which may potentially have significant impacts on the quantity and quality of water resources of the basin. Furthermore, the basin provides drinking water for the rapidly-growing Darkhan City, which water supplies largely rely on alluvial aquifers containing shallow-depth groundwater, and the inhabitants of small human settlements in the basin.

Driven by climate change, urbanization and rapid economic growth, Mongolia's water resources are under increasing pressure. The Kharaa River Basin is facing relatively high anthropogenic pressures on both water quality and water quantity from rapid urbanization, rising water demand and climate change. The pollution of the Kharaa River Basin is becoming a growing concern due to the high vulnerability of the basin to urban and industrial pollution. The assessment of water quality and water pollution in the Selenge River Basin, undertaken by this study, focused on a case-study on pollution hotspots and pollution threats in the Kharaa River Basin, including urban water pollution in the city of Darkhan, Mongolia.

The main objectives of this study were to assess the current state of the water quality of the Kharaa River Basin, assess water pollution from diffuse and point sources, identify pollution hotspots in the basin, and determine the main pressures on the water quality of the Kharaa River, with a qualitative description of their impacts. The study focused on: the survey of water quality characteristics of the Kharaa River; the identification of anthropogenic impacts on the river's water quality; the identification of major threats to the water quality in the basin; and the development of recommendations on pollution prevention and control in the Kharaa River Basin.

The assessment of the water quality in the Kharaa River is based on both hydrochemical and hydrobiological parameters. The hydrochemical assessment is based on hydrochemical monitoring data collected by the Central Laboratory for Environment and Meteorology for the period from 1986 through 2011. The hydrobiological assessment is based on macroinvertebrates data collected by the Institute of Meteorology, Hydrology and Environment for the period from 2005 to 2010. As part of the Mongolia's freshwater quality monitoring network, the Kharaa River water quality has been monitored at four sampling points at two monitoring stations since 1986. The upper monitoring station, which is the reference site of the study, is located near Zuunkharaa (a small urban settlement) and has two sampling points upstream and downstream from Zuunkharaa. The second monitoring station is located near to Darkhan city and has two sampling points too-upstream and downstream from the city. The overall assessment of the chemical composition has shown good chemical conditions at all sampling sites on the Kharaa River. The Kharaa River water is moderately mineralized and moderately hard. The monthly mean concentrations of total dissolved salts (the sum of Ca^{2+}, $Na^{+}+K^{+}$, Mg^{2+}, HCO_3^-, SO_4^{2-} and Cl^-), or mineralization, in the Kharaa River vary between 162.2-335.7 mg/l and show a tendency to increase towards downstream. The concentrations of total dissolved salts increase also during snow melting periods.

In a vast majority of the cases, the order of abundance of cations is $Ca^{2+}>Na^{+}+K^{+}>Mg^{2+}$, and the order of abundance of anions is $HCO_3^{-}>SO_4^{2-}>Cl^{-}$. The pH values range between 6.5 and 8.5, which is within the standard range for river waters.

The dissolved oxygen concentration of the Kharaa River range from 3.8 to 14.0 mg/l. The concentrations biological oxygen demand (BOD) varies between 0.3 mg/l and 7.8 mg/l. In most of the cases, the BOD concentrations are below the Maximum Acceptable Concentration of 5 mg/l, the standard set by the Mongolian National Standard for Water Quality of the Aquatic Environment: General Requirements MNS 4586-98. This indicates that in general the river water is clean. However, it should be noted that the BOD concentrations occasionally exceed the Maximum Acceptable Concentrations (5 mg/l) at both sampling sites during summer. This may show that organic pollutants originating from urban and industrial areas and livestock wastes enter the river with surface washing during heavy rainfall events in summer.

Monthly mean concentrations of ammonium-nitrogen (NH4-N) range between 0.09 and 0.38 mg/, while the concentrations of nitrate-nitrogen (NO3-N) vary from 0.01 to 0.84 mg/l for the period from 1985 to 2010. The concentrations of phosphate (PO4-P) are in the range from 0.01 to 0.21 mg/l. The phosphate concentrations in the Kharaa River were much lower than the nitrogen concentrations. Both phosphate and nitrogen concentrations show a decreasing trend near Zuunkharaa, while there is no trend near the city of Darkhan. The concentrations of NO3-N near Zuunkharaa have decreased since 1990s. Similarly, PO4-P concentrations have decreased near Zuunkharaa.

The nutrient concentrations in the Kharaa River water usually increased during spring and summer time and sometimes exceeded the Maximum Acceptable Concentrations by the order of 2 to 3 times. However, the number of cases, in which the nutrient concentrations exceeded the MAC levels represents less than 5 percent of all samples.

There are very limited observed data on metals, except for iron (Fe) and chromium (Cr^{6+}) ions, which are measured at the downstream sampling points of both monitoring sites. The monthly mean concentrations of Fe vary between 0.08 and 0.15 mg/l with concentrations increasing during rainy seasons. The Cr^{6+} concentrations range below the detection level to 0.01 mg/l and also increase in rainy seasons.


Water crown


The Selenge River


Bayangol crop area


Horses under a tree

At the upper reaches of the river near the Zuunkharaa monitoring station, the quality of the Kharaa River water can be classified as *'very clean'* to *'clean'*, except for few cases. The river water quality decreases in lower reaches of the river near the city of Darkhan. However, more than 95 percent of the all samples show that the river's water quality can be classified as *'clean'*. A slight deterioration in the river's water quality to the *'slightly-polluted'* level is observed during high-water periods of snowmelt in April to May, as well as in low-water periods in June.

The analysis of the macro-invertebrate communities at the two monitoring sites of the Kharaa River watershed indicates that the ecological condition of the river is good. The assessment of the fish communities has shown a good, or a very good, ecological status at the sites. A moderate status, detected at two sites in the watershed, is caused by the absence of ubiquistic species, showing no clear deficits in the ecological integrity of the fish fauna. Most of the fish species are known to occur in the Kharaa River Basin. According to the Biotic Index and **EPT** criteria, the water quality of the Kharaa River can be classified as 'clean' at both monitoring sites.

However, the water quality of the Kharaa River has been decreasing at the reach near Baruunkharaa since 2005, while it stays stable at Darkhan. This shows that the quality of the river's water at the reach near Baruunkharaa has been continuously declining for the last six years.

In general, the water quality of the Kharaa River is lower in spring and improves in summer.

The groundwater of the Kharaa River Basin has a similar chemical composition as the Kharaa River water. In general, the calcium and bicarbonate are the dominant ions at all groundwater sampling points. The order of abundance of cations is $Ca^{2+}>Na^{+}+K^{+}>Mg^{2+}$, whereasthe order of abundance of anions is $HCO_3^{-}>SO_4^{2-}>Cl^{-}$. The nutrient level in groundwater in aquifers in the Kharaa River Basin is very low, indicating that groundwater is clean.

The major point source of pollution appears to be the wastewater treatment plants in urban areas. There are five wastewater treatment plants in the Kharaa River Basin, two of which discharge their treated wastewater directly into the Kharaa River.

The other three plants have no direct outlet to the Kharaa River. Most soums (small towns) do not have wastewater treatment facilities and infrastructure. A majority of households in *soums* use simple traditional pit latrines in their compounds. The Darkhan WWTP is biggest in the basin and discharges its treated wastewater directly into the Kharaa River. The wastewater treatment rate of the plant varies between 76.8 and 98.1 percent.

However, in most of the time, the treatment rate is below 90 percent, which means to a certain extent that polluted water is discharged into the Kharaa River. The WWTPs in Zuunkharaa, Baruunkharaa and Khongor soums, which are located in the upstream reaches of the basin, are smaller and have no direct outlet to the Kharaa River. On the other hand, the treated wastewater of these plants is discharged to infiltration ponds and the sludge is disposed of in sludge fields close to the Kharaa River. The sludge field of the Zuunkharaa WWTP is located particularly close to the river bank and therefore, there is a potential risk of pollution of groundwater, soil and river water by leakage from the sludge ponds.

During high water periods, especially in snow melting times, the water quality of the Kharaa River deteriorates to *'moderately-polluted'* and *'very-polluted'* near urban settlements such as Darkhan, Baruunkharaa and Zuunkharaa. This indicates that the Kharaa River water quality is highly vulnerable to pollution; in particular, in areas close to point sources of pollution, such as urban areas, and in source areas of diffuse pollution, such as agriculture and mining.

Open mining is one of the major sources of pollution in the study area.

Several large mining reserves are located in the Kharaa River Basin and occupy an area of about 16 percent of the total area of the basin. Some of the mines are not yet exploited. The Boroo Gold Mine, which is one of the most productive gold mines of Mongolia, is located in the basin. There are no systematically observed data to assess the pollution from mining activities in the basin, which may have serious negative impacts not only on surface water quality, but also on groundwater and soil. Heavy metals (such as mercury and cyanide) were commonly used in small-scale gold mines until the use of mercury for mining and extract minerals was banned in 2008. Elevated concentrations of heavy metals, but not exceeding the MAC levels, were detected in groundwater in monitoring wells near the tailings facility of the Boroo Gold Mine. An incident of a possible mercury and cyanide contamination of groundwater caused by a tailings spill from a small mining operation in Khongor soum was recorded in 2007.

Mongolia's most productive agricultural areas are found in the Kharaa River Basin and the surrounding region. The region's soil and natural climatic conditions are favorable for the cultivation of cereals and vegetables, especially potatoes. The use of chemical fertilizers in agriculture is insignificant. Traditionally, fertilizer is not used for cereals production. Natural fertilizer such as animal manure is the most widely used fertilizer for vegetables. According to the information provided by the officials of the Ministry of Food and Agriculture, the total fertilizer use is about 1,200 tons per year in Mongolia. Consequently, the impact of fertilizer use in agriculture on the water quality of the Kharaa River Basin is insignificant, given the insignificant amount of fertilizer used in crop production. However, some of the cropland is located close to, or directly on, the banks of the Kharaa River. The proximity of the cropland to surface waters may have potential impacts on water quality and sedimentation of the river systems of the basin.

More than 60 percent of the total area of the Kharaa River Basin is used as pasture land for livestock grazing. Hence, the livestock grazing is the major non-point source of pollution to surface waters, leading to fecal contamination and direct nutrient inputs to the river water during warm seasons.

The assessment also shows that the self purification rate in the Mongolian rivers is usually high with the distance of self purification of 6 to 18 kilometers. The self purification distance of the Kharaa River appears to be 10 kilometers downstream from the city of Darkhan. Consequently, the Kharaa River water becomes clean at its outlet at the confluence with the Orkhon River, with no adverse impacts on the water quality of the Orkhon and Selenge rivers.

In overall, the results of the study show that the water quality of the Kharaa River Basin is clean and has good ecological conditions, although The water quality of the Kharaa River decreases occasionally to 'moderately-polluted' and 'very-polluted' near urban and industrial areas, as well as during high water periods and snow melting times. This shows that moderate pollution occurs near urban areas and in snow melting periods, with no serious degradation in the water quality of the whole basin. The main sources of water pollution in the basin are urban areas, agriculture and mining activities. Due to rapid urbanization and economic development, pollution from municipal wastewater and mining activities may become a concern in the future. Furthermore, the Kharaa River Basin is facing growing pressures from climate change and rising water demands.

Hence, the sustainable use and management of water resources of the Kharaa River Basin is of crucial importance in securing future water supplies in the area.

5.2. Recommendations

Based on the results of the water quality assessment of the Kharaa River Basin, the following observations are made and recommendations for future improvements in key areas are outlined below.

Water quality monitoring

• The monitoring and analysis of key water quality parameters such as dissolved oxygen, biological oxygen demand, and heavy metals is limited to only the Darkhan monitoring station. It is recommended to modify the monitoring programme and include all these parameters in all sampling points of all monitoring stations in order to identify more reliably the sources of pollution.

• The water quality monitoring does not hydrological parameters such as the river water discharge. It is recommended to measure the river streamflow at the time of water sampling.

• The Kharaa River water quality monitoring is carried out once a month during the months from April through November at the Zuunkharaa (upstream) monitoring station, and once a month throughout the year at the Darkhan monitoring station. Samples are collected mostly in the second half of each month. It is recommended to increase the sampling/ monitoring intervals and carry out sampling according to hydrological conditions (for example, snowmelt, summer baseflow, heavy rain events, etc.) in addition to the routine sampling intervals.

• The monitoring carries out the chemical analysis only of the river water, but not of bottom sediments and particulate matters in the river water. It is recommended to analysis particulate matters in the river water. Particulate matters and bottom deposits are an important factor in the study of water quality in that it yields valuable information about the source of settle able particulate solids, the effect of the sediments on the quality of the overlying water and the biological system that will predominate.

• There is no regular groundwater quality monitoring in the Kharaa River Basin. The existing groundwater monitoring wells do not monitor the quality of groundwater. It is recommended to establish a groundwater monitoring network in the basin to monitor both the water level and quality of groundwater.

• The sampling sites for chemical and biological monitoring are located in different parts of the basin. It is recommended to conduct biological, and chemical monitoring at the same sites, if possible.

Wastewater management

• The wastewater treatment plants are the main source of pollution. The wastewater treatment plants in the basin are outdated, poorly maintained and based on obsolete technology. There is a need to make substantial investment to upgrade existing wastewater treatment plants and build new ones.

• The Darkhan Wastewater Treatment Plant, which is the biggest in the basin, is not able to fully treat raw sewage before discharging the treated wastewater directly into the Kharaa River. Its wastewater treatment rate is mostly below 90 percent. The Salkhit Wastewater Treatment Plant also discharges its treated wastewater directly into the Kharaa River after only primary mechanical and biological treatment. It is recommended to rehabilitate urgently the Darkhan and Salkhit Wastewater Treatment Plants, which discharge their effluents directly into the Kharaa River.

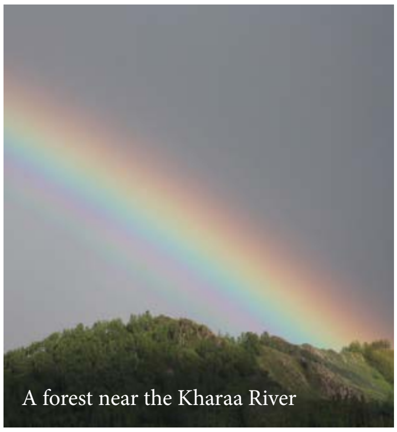
• The wastewater treatment facilities in the small cities and villages in the Kharaa River Basin are mostly out of operation. Most of these facilities discharge their treated wastewater in infiltration ponds. The sludge from these plants is disposed of in sludge fields located close to the Kharaa River. This raises a concern over groundwater nutrients and heavy metal contamination by leakage from sludge fields. It is recommended to reconstruct the wastewater treatment plants in Zuunkharaa, Baruunkharaa, and Khongor soums and rehabilitate infiltration ponds and sludge fields of these facilities.


A groundwater well

Agricultural pollution

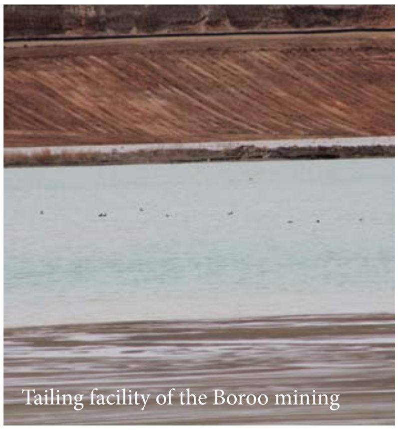
• The river banks of the Kharaa River Basin—especially, the Boroo River bank near Bornuur—are heavily used for cropland, leading to soil and river bank erosion. This, in turn, causes increased suspended solids in the river water. It is recommended to limit the use of river banks for cultivation and implement soil conservation tillage measures.

• The use of chemical fertilizers in agriculture is insignificant. Currently, natural fertilizer such as animal manure is the most widely used fertilizer for vegetables. The impact of fertilizer use in agriculture on the water quality of the Kharaa River Basin is insignificant, given the insignificant amount of fertilizer used in crop production. It is encouraged to avoid and/or restrict the use of chemical fertilizers in the future.


A forest near the Kharaa River

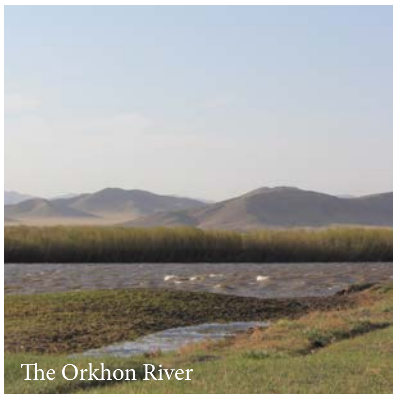
Mining pollution

• Open mining is one of the major sources of pollution in the study area. There are no systematically observed data to assess the pollution from mining activities in the basin. The water use and waste management is controlled in the most of the mining sites. However, the amounts of toxic waste containing heavy metals particularly mercury and cyanide are unknown. A more systematic monitoring and reporting of compliance with environmental regulations needs to be developed for all mining operations.


Tailing facility of the Boroo mining

• Heavy metals (such as mercury and cyanide) were commonly used in small-scale gold mines until the use of mercury for mining and extract minerals was banned in 2008. There is a need to implement measures to clean up residual mercury in the environment.

• An incident of a possible mercury and cyanide contamination of groundwater caused by a tailings spill from a small mining operation in Khongor soum was recorded in 2007. Such cases may have potentially serious impacts on the


The Orkhon River

environment and human health and should be avoided in the future. There is an urgent need to implement "responsible mining" practices and closely monitor the environmental safety of mining operations in the basin.

Mining pollution

• Although the water quality of the Kharaa River Basin is clean and has good ecological conditions, the water quality of the Kharaa River decreases occasionally near urban and industrial areas. It is recommended to take necessary measures to enhance and protect the water quality of the Kharaa River from urban and industrial pollution.

• Climate change is likely to increase the river bank erosion in addition to the impact of agricultural activities near the river banks. In order to reduce the river bank erosion, it is recommended to introduce river bank prevention measures, such as planting trees along the river bank.

• The Kharaa River water at its confluence to the Orkhon River is still clean. It is, however, needed to make efforts to preserve the water quality of the river in order to maintain the integrity of the basin and its ecosystems.

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Annex

1. Mongolian National Standard for Water Quality of the Aquatic Environment: General Requirements. MNS 4586-98. Ulaanbaatar. (in Mongolian)

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Data analyses

1. **The Kharaa River Water Hydro-biological Data Analysis for the period 2005-2010**

A data analysis report prepared based on data provided by the Institute of Meteorology, Hydrology and Environment of Mongolia. The report was prepared in the framework of this study by Tumertsooj D. *(in Mongolian language)*

2. **The Kharaa River Water Hydro-chemical Data Analysis for the period 1986-2011**

A data analysis report prepared based on data provided by the Central Laboratory for Environment and Meteorology of Mongolia. The report was prepared in the framework of this study by Erdenebayar Y. *(in Mongolian language)*