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Hygienic assessment of surface, ground and drinking water in The Kharaa River Basin

Bachelor Thesis

by

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Statutory Declaration

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List of Abbreviations

EC	Electrical conductivity
E.coli	Escherichia coli
FC	Fecal Coliform
IWRM	Integrated Water Resources Management
KRB	The Kharaa river basin
MPN	Most Probable Number
MF	Membrane Filter
MTF	Multiple Tube Fermentation
MUG	4-methyl-umbelliferyl- β -D-glucuronide
ONPG	Ortho nitrophenyl- β -D-galactopyranoside
TC	Total Coliform
USUG	Water Supply and Sewage Authority
WASH	Water sanitation and hygiene
WWTP	Wastewater treatment plant
WHO	World Health Organization

Abstract

The Kharaa river basin is ranked in the 5th of 29 river basins in terms of the economic importance and industrial production in Mongolia. However, this river basin has one of the smallest total area basins which is 26th of 29 river basins (1). As several research studies, there have been resulted that the Kharaa River Basin (KRB) is one of the highest populated river basins in Mongolia because of agricultural and industrial activities. Most drinking water source of inhabitants is provided by groundwater which is fed by KRB and livestock is mostly using surface water (2). Until recently, data on the hygienic quality of water resources in the KRB was limited and it was hardly found openly.

In the study, there was used a test method that conforms to international standards for the microbiological assessment of drinking water or environmental waters. It is the Idexx Colilert® system, which is not only most commonly used methods for the enumeration of indicator bacteria in drinking water in many countries of the world, but also has the advantage of less risk for sampling from contamination (a major benefit when working under field conditions in Mongolia). In order to assess the hygienic quality of surface, ground, drinking and wastewater, samples were collected during two campaigns in May 2017 and April 2018, and were found respectively for 3410.1 and 13873.9 of mean concentrations of total coliforms, 491 and 4621 E. coli bacteria and 414.3 and 4685.2 fecal coliforms per 100ml (MPN) . During both periods, samples collected from tap water and water kiosks were normally found to be free of bacteria.

Keywords:

Hygiene ▪ coliform bacteria ▪ surface water ▪ groundwater ▪ drinking water

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1 Introduction

1.1 Background

The Kharaa River Basin was chosen under the “Research for Sustainability” Program of the German Ministry of Education and Research since 2006 and as a model region for the development and implementation of an Integrated Water Resources Management (IWRM) in Mongolia (3).

This project has been implemented in 3 phases among the years from 2006 to 2018. During the projects have been identified important water management related issues in the river basin such as the impact on climate change, groundwater reduction, and pollution, land management, material fluxes in receiving surface waters, ecology, drinking water supply and wastewater disposal in settlements along the river. The goal was to offer innovative solutions to the wide range of comparable river basins of Mongolia and Central Asia (4).

The first phase had been implemented with the aim of the comprehensive analysis of catchment characteristics and future development scenarios and had been adapted technological concepts in Mongolia, between 2006 and 2009.

During 2010-2013, this project was moved into the scientific understanding of IWRM's regional prerequisites and to use experimental measures for the development of multi-level capacity for selected issues. Furthermore, a more detailed analysis of water governance structures that support IWRM implementation.

The current focus of the ongoing phase (2015-2018) focused on the implementation and transfer of results. This will include the development of advisory services and capabilities in the river basin management process, improvement of the project geodesy database, transferring to Mongolian partners and multiplying and replicating the technical solutions developed by the project (Fig 1-1) (3).

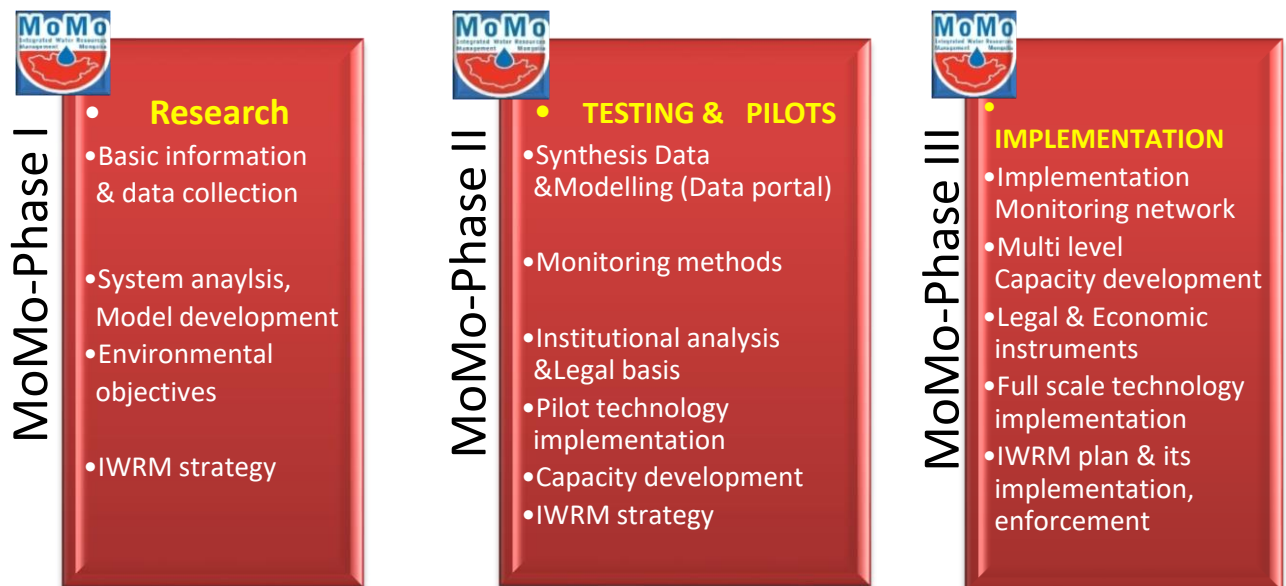


Figure 1-1 MoMo agenda during 3 project phases in 12 years¹

Ongoing MoMo project III is structured in three thematic modules and one cross-sectional module (Fig 1-2). For the river basin management, MoMo project is working for development and implementation according to fulfill four main tasks and measures should be implemented from 2018 to 2021.

- 1) to assess the status of each specific river catchment
- 2) to prevent potential water scarcity
- 3) to protect water resources against pollution
- 4) to allocate and use water resources in the most efficient way.

Environmental monitoring has been considering using innovative remote sensing methods, water quality monitoring using the automatic monitoring stations, and hygienic monitoring has been conducted (3).

¹ Source: Project Profile IWRM MoMo project, 2018

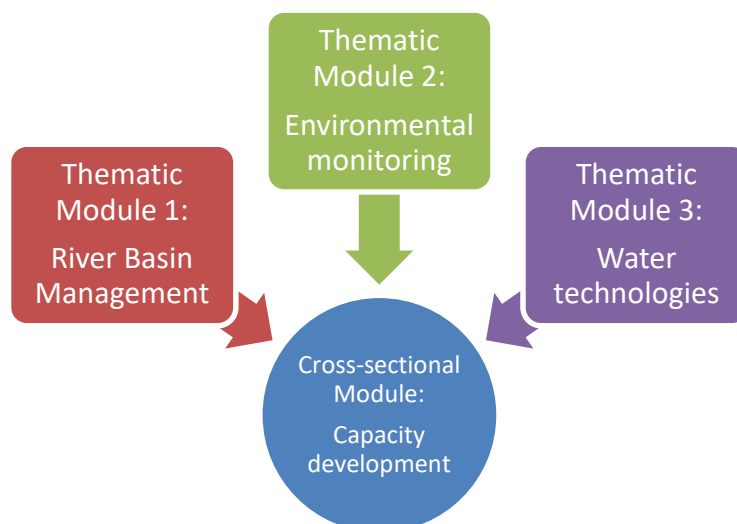


Figure 1-2 Structure of IWRM MoMo III project²

There is currently physical-chemical water quality has been investigated, however no research related to the hygiene of water had been done and almost nothing is known about surface and groundwater hygiene in the Kharaa river basin (2&4) .

This thesis study is focused on to understanding the current state of knowledge on water and hygiene of surface and groundwater sources in the Kharaa River Basin by using data from May 2017 and April 2018. Data from 2017 had been collected by the previous researcher Prof.Dr.Daniel Karthe and Ms.Katja Westphal(2). This thesis study will contribute to module 2 "Environmental monitoring" of the MoMo project and the results are also relevant for modules 1 and 3.

The thesis consists of six chapters. In the first chapter begins with a background, objectives and research questions and hypothesizes. In the second chapter presents a state of the knowledge, which including a review of the previous water hygiene studies in worldwide and in Mongolia, continued by reviewing indicator bacteria studies, their commonly used methods description of the study area. Chapter three is a methodology part. It contains sample collection methods, materials, and data analysis. Last chapters present the result of the study and their discussion and conclusion.

² Source: *Project Profile IWRM MoMo project, 2018*

1.2 Objective of the study

The objective of the thesis is focused on assessing hygiene of drinking water quality from surface and groundwater sources in the Kharaa river basin by enumerating indicator bacteria and to understand the current situation. According to the objective, there were the following questions through into hypothesizes.

Questions

- Is there any fecal contamination in ground and surface water?
- Are the drinking water sources suitable for human consumption in KRB?

Hypothesis

- To detect and quantify indicator microorganisms which express pathogen of waterborne at target point that after the surface snow melted and when it goes to the river their might occurs higher contamination.
- To analyze data using point pollution sources such as wastewater effluent can increase the river contamination

2 State of knowledge

2.1 Water and hygiene

According to the WHO data in 2015 that only 5.2 billion people of the global population (71%) use water from safely managed water supply system and 6.5 billion people of the total population (89%) use drinking water from basic drinking-water service. A basic drinking-water service means an improved source that can be collected around 30 minutes of the trip.

Totally, around 2 billion people are provided with drinking water sources, which is contaminated with feces (5). Diseases such as diarrhea, cholera, dysentery, hepatitis A, typhoid, and polio can be transmitted by contaminated water sources. Every year about 842 000 people are estimated to die from diarrhea as a result of contaminated drinking water, sanitation, and hygiene. For solving unsafe drinking water problems, the deaths of 360 000 children aged under 5 years could be avoided each year (6).

One of the most important sources of gastro enteric diseases worldwide is drinking water, mainly cause of the fecal contamination of raw water, failure in the water treatment process or decontamination of drinking water at source and point of use. About two-thirds of drinking water consumed from various surface water sources such as lakes, rivers, and open walls. Therefore, it can be easily polluted by microbiological pollution like sewage discharges or fecal loading by domestic or wild animals (4).

Safety of drinking water requires to the public and environmental health, which means that drinking water sources must be free of pathogenic bacteria. Among the pathogens diffuse in water sources, enteric pathogens are the ones most frequently exist. As a consequence, sources of fecal contamination in waters should be strictly controlled before using it for human activity (7).

2.2 Studies in Mongolia

Mongolia is the second largest landlocked country in the world. The country is facing the problem with abundant water resources in some areas and also 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(8).

WHO reported in 2018, Water resources of Mongolia are differently distributed. In mountainous regions have sufficient water resources. However, in the Southern part such as Gobi desert area, about 80% of total water consumption from underground sources. Mongolia's 76-90% people of the total population using at least basic drinking water services (Fig 2-1). About 30% of the population has access to the water supply system and about 25% of the population receives water from the water transportation, around 35% get water from water supply points and less than 10% use water from surface water such as springs, rivers, and snow water(5).

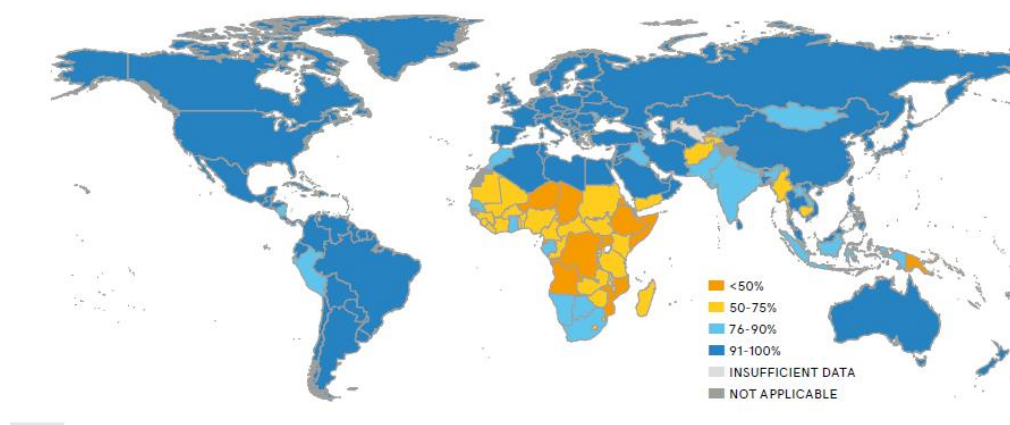


Figure 2-1 Proportion of population using at least basic drinking water services, 2015³

In the capital city Ulaanbaatar, Water Supply and Sewage Authority (USUG) is a charge for provides water and sanitation services to industrial users and apartment area (500000 residents) and ger area residents (600000 residents) with drinking water through water kiosks that are truck-fed or connected to the centralized water supply(9). Before drinking water enters to centralized water supply, mostly from water source facilities tests for indicator bacteria. Smaller cities such as Darkhan have their own water supply facilities and carries out tests for indicator bacteria in the drinking water. In smaller towns, the reason of the limitation for drinking water monitoring is lack of the laboratory staff or long distances to the nearest water laboratory. In the past only a few scientific studies on the hygienic quality of the different type of drinking water sources have been performed in Mongolia and quality-assured data on water hygiene is very limited (2).

³ Source: *Progress on Drinking Water, Sanitation and Hygiene, 2017*, WHO

2.3 Coliform bacteria

Since the early 1900s, scientific knowledge about nature and the causes of the diseases have been increased promptly and the major focus was on public health. At that time, techniques to identify and enumerate the indicator microbial were developed. An indicator of microbial water quality is a general thing, that has entered the water at the same time as feces but is easier to measure than the full range of microorganisms which pose the health risk (10).

There are several potentials that are desirable for a useful water quality indicator. The use of the coliform group for microbiological water quality is based on the evidence that coliforms are present in high concentration in the feces of humans and all warm-blooded animals if fecal pollution has entered drinking water, it is possible that these bacteria will be present, even after significant dilution because millions is excreted by body waste.

Several exceptions indicate that the coliform does not consider itself as a health risk, but their occurrence shows that the potential for fecal contamination may be pathogenic. The coliform group of bacteria, is a functionally-related group which all belong to Enterobacteriaceae and includes many genera and species (11).

2.3.1 Total coliform

Total coliforms have been the microbial indicator of water treatment efficiency decades. Enteric bacteria of the total coliform group are present in the environment in larger numbers than pathogens such as Salmonella and Shigella. If drinking water was free of coliforms, it was presumed there would be no health risk to the consumer.

However, total coliforms not associated with disease-causing enteric microorganisms are also present in the environment. It is widely accepted that the total coliform group of bacteria is diverse and they can be considered normal inhabitants of many soil and water environments which have not been impacted by fecal pollution. Even though the presence of *E. coli* is considered an appropriate and specific indicator of fecal pollution, uncertainty surrounds the use of total coliforms as a health indicator (10).

Total coliforms are organisms that can grow and grow. They are therefore not effective in fecal pathogens but can be used to identify the assessment, the cleanliness and integrity of distribution systems. However, for these purposes, there are better indicators. Total coliform has been purposed as a disinfection indicator. Nevertheless, the test for total coliforms is far slower and less reliable than direct measurement of disinfectant residual. In addition, total coliforms are much more sensitive to disinfection than are enteric viruses and protozoa. Therefore, the use of TC a microbiological indicator of water quality in developing countries is not appropriate (12).

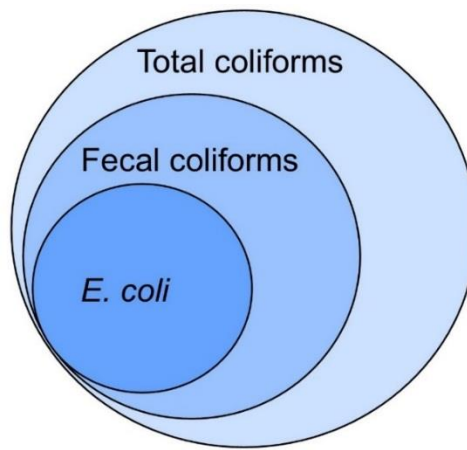


Figure 2-2 Classification of coliforms⁴

Total coliform bacteria include a wide range of aerobic and facultative anaerobic, Gram-negative, non-spore-forming bacilli capable of growing in the presence of relatively high concentrations of bile salts with the fermentation of lactose and production of acid or aldehyde within 24 hours at 35–37 °C (13).

2.3.2 Escherichia coli

Edberg reported and concluded with an unambiguous statement that *E. coli* should be the indicator of choice. These researchers provided strong historical evidence that *E. coli* were always the target organism because *E. coli* makes up > 95% of the intestinal coliform flora but that inadequate detection technology resulted in the creation of more easily performed *E. coli* surrogates such as total and fecal coliform (14).

E. coli is able to survive long distances underground and is for that reason also a useful indicator of fecal contamination of groundwater(15). Verification of the microbial quality of drinking-water typically includes testing for *Escherichia coli* as an indicator of fecal pollution. In practice, analyzing for thermotolerant coliform bacteria can be an acceptable alternative in many situation.

Although *E. coli* is useful, it has limitations. Enteric viruses and protozoa are more resistant to disinfection, consequently, the absence of *E. coli* will not necessarily indicate freedom from these organisms. Under certain circumstances, the inclusion of more resistant indicators, such as bacteriophages and/or bacterial spores, should be considered.

⁴ Source: <https://www.maine.gov/dhhs/mecdc/environmental-health/dwp/pws/totalColiform.shtml>

2.3.3 Fecal coliform

Fecal coliforms are a subdivision of a greater group of organisms known as coliform bacteria. The term “fecal coliform” has been used in water microbiology to represent coliform organisms which can grow at 44 or 44.5°C and ferment lactose to produce gas and acid. In practice, some organisms with these characteristics may not be of fecal origin and the term “thermotolerant coliform” is, therefore, more correct and is becoming more commonly used. Nevertheless, the presence of thermotolerant coliforms nearly always indicates fecal contamination. Usually, more than 95 per cent of thermotolerant coliforms isolated from water are the gut organism *Escherichia coli*, the presence of which is definitive proof of fecal contamination. As a result, it is often unnecessary to undertake further testing to confirm the specific presence of *E. coli* (12).

2.4 Enumeration methods for coliform bacteria

Several methods are commonly used for detection of coliform bacteria. Multiple tube fermentation (MTF), membrane filtration (MF) and Colilert (IDEXX Laboratories) are laboratory methods used to qualify or quantify the level of bacteria in drinking water samples. The multiple tube fermentation and membrane filtration tests measure total coliforms and *E. coli* and are standard methods for water quality assessments. Both tests assess the number of bacteria based on lactose fermentation with production of sheen colonies, gas, or acid and gas (16).

2.4.1 Multiple fermentation tube technique

Over 90 years multiple-tube fermentation has been used for the technique of enumerating coliforms as a water quality monitoring method.

The technique consists of inoculating a series of tubes with appropriate decimal dilutions of the water sample. Production of gas, acid formation or abundant growth in the test tubes after 48 hours of incubation at 35 °C constitutes a positive presumptive reaction. The formation of gas in a brilliant green lactose bile broth fermentation tube at any time within 48 h at 35 °C constitutes a positive confirmation test. The fecal coliform test can be applied to determine TC that are FC the production of gas after 24 h of incubation at 44.5 °C in an

EC broth medium is considered as a positive result. The results of the MTF technique are expressed in terms of the most probable number (MPN) of microorganisms present. This number is a statistical estimate of the mean number of coliforms in the sample. As a consequence, this technique offers a semi-quantitative enumeration of coliforms. Nevertheless, the precision of the estimation is low and depends on the number of tubes used for the analysis: for example, if only 1 ml is examined in a sample containing 1 coliform/ml, about 37% of 1-ml tubes may be expected to yield negative results because of the random distribution of the bacteria in the sample. But, if five tubes, each with 1 ml sample, are used, a negative result may be expected less than 1% of the time. MTF is easy to implement and can be performed by a technician with basic microbiological training, but the method can become very tedious and labor-intensive since many dilutions have to be processed for each water sample.

However, it is also relatively inexpensive, as it requires unsophisticated laboratory equipment. Nevertheless, this method requires 48 hours for presumptive results, which is extremely time consume and necessitates a subculture stage for confirmation which could take up to a further 48 h (17).

Table 2-1 Advantages and disadvantages of Multiple fermentation tube technique

Advantages	Disadvantages
More Sensitive	Requires more time than MF (48 hours for positive)
Applicable to all types of water	Requiring greater expenditure on labor
	Not suitable for field use

2.4.2 Membrane filter technique

The membrane filter technique is fully accepted and approved as a procedure for monitoring drinking water microbial quality in many countries. This technique consists of filtering a water sample on a sterilized filter with a 0.45-mm pore size which holds bacteria, incubating this filter on a selective medium and enumerating typical colonies on the filter. Many incubation conditions and agar media for the membrane filter method has been tested for optimal recovery of coliforms from water samples (18).

Today, the membrane filter technique is the method used most widely used for the enumeration of coliforms in drinking water. This technique, simple to perform and cheap, requires at least an overnight incubation period and a confirmation test after the initial typical colony investigation. Moreover, when standard agar media are used with this technique is not possible to recover stressed or injured coliforms.

Specially developed media and the addition of specific compounds improve the recovery rate of these stressed or injured cells. Moreover, a long response time, the length of which depends on the biochemical test used for the confirmation step, are still limiting factors. The important challenges for the development of new coliform detection methods are to improve the specificity of the method, which could eliminate the time-consuming confirmation step, to take into account stressed and injured cells and to reduce the analysis time (13).

The membrane filter technique can be used to test relatively large numbers of samples and yields results more rapidly than the multiple fermentation tube technique. It was originally designed for use in the laboratory but portable equipment is now available that permits use of the technique in the field.

The membrane filter method shows a direct count of total coliforms and fecal coliforms present in a given sample of water. A measured volume of water is filtered, under vacuum, through a cellulose acetate membrane of uniform pore diameter, usually 0.45 μm . Bacteria are retained

on the surface of the membrane which is placed on a suitable selective medium in a sterile container and incubated at an appropriate temperature. If coliforms and/or fecal coliforms are present in the water sample, characteristic colonies form that can be counted directly.

Table 2-2 Advantages and disadvantages of Membrane filter technique

Advantages	Disadvantages
More quickly (18 hours for positive)	Not applicable for turbid waters
Need less culture medium	Cost of consumables is high
Need less glassware	Less sensitive

The technique is not suitable for natural waters containing very high levels of suspended solids, sludge, and sediments, all of which could block the filter before an adequate volume of water has passed through. When small quantities of sample such as of sewage effluent or of grossly polluted surface water are to be tested, it is necessary to dilute a portion of the sample in sterile diluent to ensure that there is sufficient volume to filter across the entire surface of the membrane(12).

2.4.3 Colilert system

The Colilert system is defined substrate technology and international approved standard technique for the microbiological investigation of both drinking and surface water. Test results are not much affected by the microbial background flora, and while underestimations are possible such as with most other microbiological techniques, Colilert is in suitable for the enumeration of coliforms in different water bodies (13).

Moreover, Colilert and QuantiTray systems have approved by US Environmental Protection Agency for the detection of wastewater bacteria. Colilert⁵ is a defined substrate technology that drives the metabolism of total coliforms and *E. coli* toward the indicator nutrients ortho nitrophenyl- β -D-galactopyranoside (ONPG) and 4-methyl-umbel liferyl- β -D-glucuronide (MUG), respectively. The coliform group of bacteria produces the enzyme β -galactosidase, which metabolizes ONPG by cleaving the bond between the nutrient portion (galactopyranoside) and the indicator portion (ortho-nitrophenyl). Ortho-nitrophenyl remains free in solution, which turns yellow. Any other heterotrophic bacteria capable of metabolizing

⁵ <https://www.idexx.com/en/water/water-products-services/colilert/>

ONPG are chemically suppressed during the 24-hour incubation period and, therefore, do not interfere with the specific identification and confirmation of the presence of total coliforms.

There is a similar positive reaction for *E. coli* using the Colilert system. *Escherichia coli* possesses an additional unique enzyme, glucuronidase, which will cleave the MUG molecule into the glucuronide nutrient and the indicator portion, methylumbelliferone. When free in solution, methylumbelliferone fluoresces blue under 365-nm wavelength UV light. Therefore, two separate but simultaneous and specific microbial assays are carried out in the sample (18).

Table 2-3 Advantages and disadvantages of Colilert system

Advantages	Disadvantages
Less sample contamination	Not applicable for turbid waters
More rapid (18 hours)	Cost of consumables is high
Need less glassware	Less sensitive

2.4.4 Most probable number

The method that used to enumerate the concentration of possible organisms in a sample is most probable number⁶, by means of imitating liquid broth growth in ten times dilutions. Water to be tested is diluted experiments and to grow lactose salts and to drink in water is able to produce acid and gas in the lactose environment. The dimensions are characterized by color alterations, and the bubbles in the gas are represented by gas bubbles that react to the atmosphere of the Durham tube. A total number of coliforms are counted by the number of tubes that show the positive reaction between color change and gas production and have standardized tables comparing the positive results pattern.

⁶ <https://microbeonline.com/probable-number-mpn-test-principle-procedure-results/>

2.5 Description of study area

2.5.1 The Kharaa River Basin

The Kharaa River basin covers a total area of 14500 km^2 in between latitudes 47°53' and 49°38' N and longitudes 105°19' and 107°22' E and with its headwaters lying in the Khentii Mountains, about 100 km northern of the capital city Ulaanbaatar (Fig 3-1) (4).

The Kharaa River begins in the Khentii Mountains and flows north to north-west into the Orkhon River and the length of the river is 291km (8), hence its one on the part of the Selenge River basin, which is the main source tributaries of Baikal Lake. About 60% of the catchment area the elevation ranges between 900 and 1300 m as, and the average altitude of the whole basin is 1167 m (19).



Figure 2-3 The Kharaa river basin

The Kharaa river basin covers land of 4 provinces (Darkhan-Uul, Khentii, Selenge and Tov) and has population of about 133000. Darkhan is the 3rd largest city in Mongolia and most

populated area in KRB. A half of the population (43.7%) is living in a ger area which means those area has not connected to the centralized water supply facilities. For that reason population in ger area consumes water from their own wells (typically 2-4 m depth) and lying near to the pit latrine (15-20 m), which makes it unimproved sources, contaminating the soil and ground water resources. It has become a major negative factor influencing health and poverty of the population (4).

2.5.2 Climate and Hydrology

The Kharaa River Basin is a harsh, cold, dry winter camp with extreme continental climate and is characterized by a short, hot summer. Therefore, the average January temperature is between minus 20 and minus 25°C (minimum temperature drops to 40°C). Due to harsh winter conditions, the Kharaa River freezes from November to March, most of the basin is a semi-arid zone in semi-humid and cold zones in the summit region of the Khentii Mountains only. The average annual rainfall in the Kharaa range ranges from 250 to 350 mm. In summer, evaporation is high, 85% to 95% of precipitation is mainly evaporated (20).

2.5.3 Land use

In the Kharaa river basin land-cover consists of about 60% grazing, 26% of forest and 11% of farmland. Livestock grazing and farming are the most important land use activities in the river basin. Next important land use activities are open pit mining (mainly gold) and forest use (legal and partially illegal timber extraction), is followed by urbanization (mainly in Darkhan).

Land-use dynamics have a significant impact on all land-use activities that depend on many environmental and socio-economic factors. In recent years, major land-use changes have led to increased numbers of animals, decrease in agricultural activity, logging, reducing forest cover, mining activities, industrialization and urbanization (mainly Darkhan). Currently, the cultivated land area is approximately 59,000 ha, of which approximately 6,000 ha is suitable for irrigation, an average of 93,000 ha. The transition from the socialist system to agricultural-oriented agriculture has dramatically reduced the intensity and space of agricultural use during the period of 1990-2006. Since the late 1980's, the decline in harvest has been observed. The fluctuation of the average annual average yield indicates high evolution and vulnerability in food supply systems. The planned trend is replaced by a national land use policy for conversion of additional 50,000 hectares of crop cultivation till 2010 and most of the land is located in Kharaa and neighboring basins. At the same time, the water demand for irrigation will increase due to the intensity of the water supply. The first simulation illustrates that the irrigation of irrigation can reduce water availability(4).

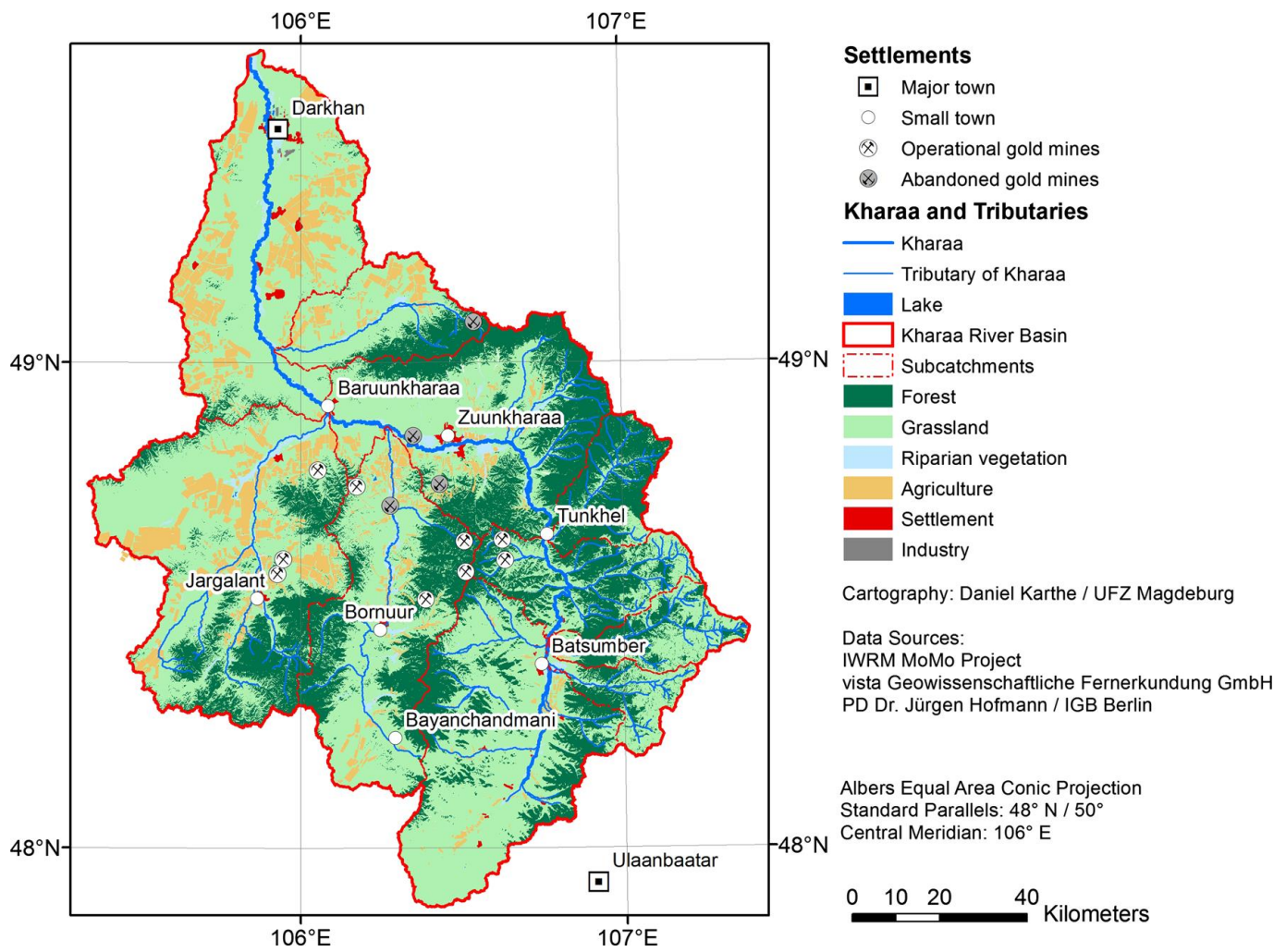


Figure 2-4 Land use and mining in The Kharaa River Basin

3 Methodology

3.1 Sample collection

Total of 43 samples in May 2017 and total of 32 samples in April 2018 were collected from Darkhan, Baruunkharaa, Zuunkharaa, Tunkhel, Sugnugur and Batsumber from upstream to downstream of Kharaa river by using grab sampling method (Fig 3-3). All sampling sites were selected randomly by researchers Ms.Katja Westphal and Prof.Dr.Daniel Karthe who did the sampling in 2017. For the drinking water wells, they made sure that the points were located in the lowlands of the nearby river so that there was some sort of connection between groundwater and river. When it comes to the surface river water the main purpose was to cover the complete river continuum. In case of smaller tributaries we tried to measure the impact of settlements by choosing sites up- and downstream of a settlement. They were aware from the beginning that this could only be a snapshot sampling and that it does not cover the full truth. But the overall objective was to get an overview and very first impression of the hygienic situation of water kiosks, wells and surface water in the catchment.

Water sampling types were divided into two different main sources. First, the main source was from surface water, which is included river and polluted river (Annex 1 a-d). River samples were collected mainly from up and downstream of settlements that located nearby the Kharaa River. Polluted river sample was collected from the river after wastewater effluent entering before the river. The second main source was groundwater, which is included common well, private well, water kiosk and tap water (Annex 1 e-i).

Common well is mainly used by several families, which are mostly located far from the other possible sources such as water kiosks. Private well is mainly used by the family who lives in ger area district and has not connected to the centralized water supply. The groundwater level is only 2 to 4 m below the surface, which is the reason why most families use private wells on their properties as an additional water source (4).

Apartment area residents use tap water which is connected with centralized water supply. Darkhan's centralized drinking water supply system became operational in the 1960s and relies entirely on groundwater abstractions from 18 wells located along the Kharaa up to 8 km upstream from the city and the drinking water is not purified or chemically treated. Water kiosks are supplied by truck. Additionally, wastewater effluent has been sampled.

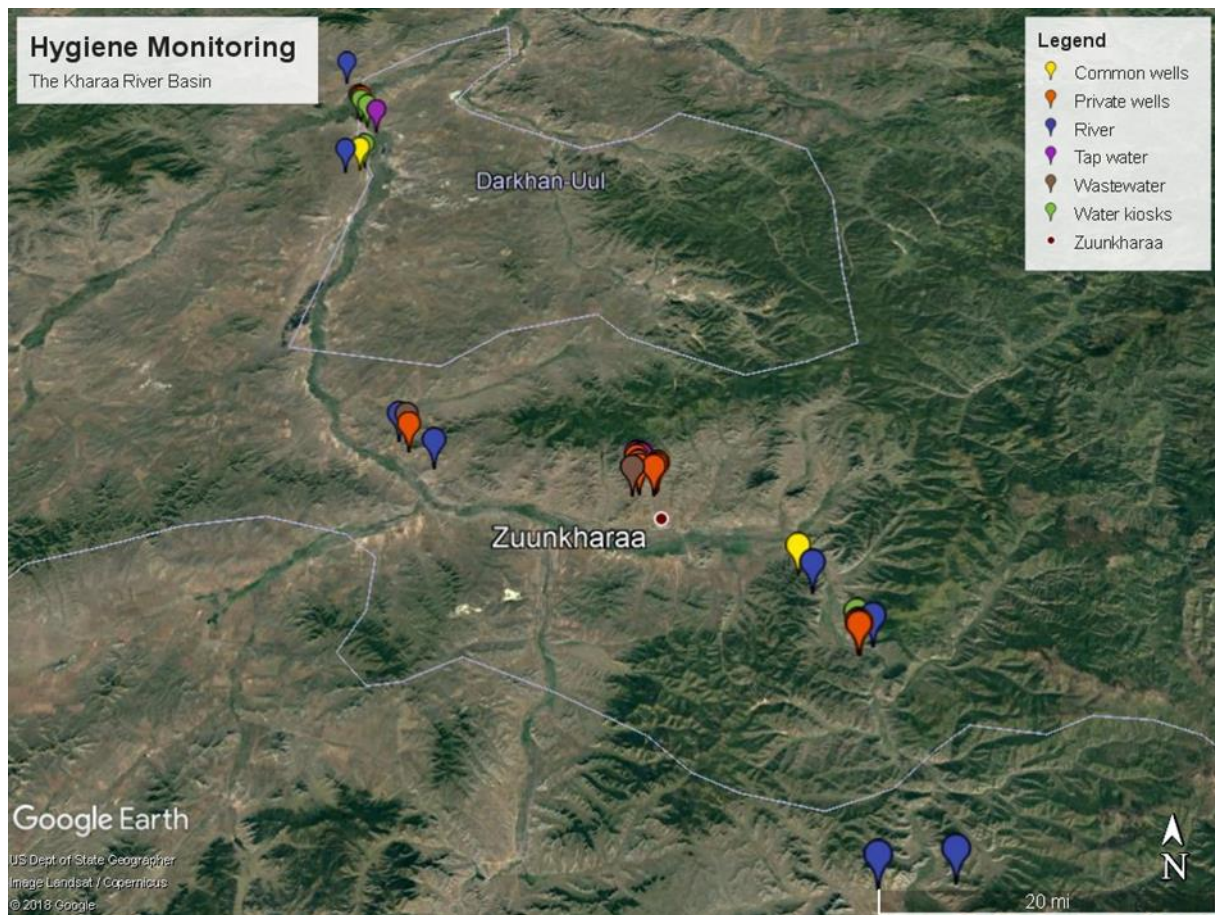


Figure 3-1 Map depicting the sampling locations

From Tunkhel, 3 rivers, 5 private well, 1 water kiosk total 9 samples were collected and in 2018 2 private well, 2 rivers, 1 water total 5 samples were collected. From Batsumber to Sugnugur both years one river samples were collected. In Table 3-1, there were more detailed information with coordinates.

Both periods of time sampling was grab sampling which means all of the sampling material is collected at one time. As such, a grab sample imitates performance only at the point in time that the sample was collected, and then only if the sample was properly collected.

Each sample was collected in sterile single-use plastic bottles two times. One is for detection of total coliform and E.coli and another one is for Fecal coliforms. For the reason that is they had been incubated at a different temperature.

Firstly, In April 2017, From Darkhan 4 private well, 1 common well, 1 tap water, 3 water kiosk, 1 wastewater effluent, 3 river samples totally 13 sample were collected and In May

2018, 2 private wells (2 wells were frozen), 1 common well, 1 tap water, 3 water kiosks, 1 wastewater effluent, 3 river samples 11 samples were collected.

From Baruunkharaa in 2017, 1 private well, 1 wastewater effluent, 2 river samples totally 4 samples were collected and in 2018 also the same amount of samples were collected.

From Zuunkharaa in 2017 8 private well, 5 tap water, 1 wastewater effluent total 14 samples were collected and in 2018 4 private wells (Some of them were frozen or no family was there), 4 tap water, 1 WW effluent total 9 samples were collected.

The transport time to the mobile laboratory did not exceed 4 hours. Additionally, Dissolved oxygen, electrical conductivity, temperature and pH of all samples were measured in the field at the time of sampling by using Multiparameter HI9829 Hanna equipment(Annex 2 b). Table 3-1 shows the description of the sampling sites.

Table 3-1 Description of sampling sites

HYG_ID	Coordinates		Description of sampling sites
	North	East	
1	49.592389	105.860423	Kharaa at Buren Tolgoi
2	49.508700	105.903198	Treated wastewater outlet below central WWTP Darkhan
3	49.511319	105.898802	Downstream section of small channel receiving treated wastewater, just before entering Kharaa
4	49.389937	105.897264	Kharaa upstream of Darkhan (Deed Gur Bridge)
5	48.389258	106.755339	Kharaa at Batsumber, downstream of bridge
6	48.394083	106.854158	Sugnugur River just downstream of bridge
7	48.634156	106.766663	Tunkhel river just upstream of bridge
8	49.511142	105.901886	Private well in Bag 3, Ajilchinii 15, Darkhan (wooden, with wooden cover, bucket style)
9	49.393475	105.924465	Common well used by several families south of Darkhan (near train line)
10	49.400492	105.932286	Water kiosk south of Darkhan, near small railway settlement; supplied by 24 m deep well
11	49.511670	105.899280	Private well in Northern Darkhan, no cover - only tire around well, close to small channel with treated wastewater effluent
12	49.511654	105.900453	8m deep private well in Northern Darkhan, with electric pump
13	49.489772	105.920593	Water kiosk No. 1-2, Darkhan (NW of train station)
14	49.508620	105.906440	Private well in Northern Darkhan, Ajilchnii 13 House 5, with hand pump, 11 m deep
15	49.501496	105.906030	Water kiosk in Northern Darkhan
16	49.477520	105.941150	Tap water at MBM Hotel Darkhan
17	48.895701	106.093609	Private well (concrete walls but no cover) in Baruunkharaa, between Kharaa and railway line, 2.5 m deep

HYG_ID	Coordinates		Description of sampling sites
	North	East	
18	48.911160	106.075628	Kharaa downstream of Baruunkharaa
19	48.909891	106.087923	Outlet of wastewater treatment plant, Baruunkharaa
20	48.871898	106.136977	Kharaa upstream of Baruunkharaa (Kh 5)
21	49.854980	106.456250	Tap water at Hotel Narnii Urtuu Plaza
22	48.849665	106.454270	Private well in Zuunkharaa, with wooden cover with holes, electric, 12 m deep; cows, pigs and chicken around
23	48.841483	106.456770	Private well with cover, Zuunkharaa, Naran 98, with cover, about 3,20m deep to water surface. Very clean khashaa, no livestock
24	48.842172	106.457413	Private well in Zuunkharaa, Naran 90, about 3 m deep. Open Well with wooden cover, some holes, very clean khashaa, latrine >25m away, no livestock at this time
25	48.836615	106.458456	Electric well with good cover, about 3 m deep, Naran 119, Zuunkharaa, latrine >25m, no livestock
26	48.834461	106.447968	Polishing pond of WWTP Zuunkharaa
27	48.854050	106.453850	Tap in the kitchen of Solongo Hotel
28	48.851870	106.460749	Hospital Zuunkharaa, kitchen. Supplied by own well
29	48.852501	106.462006	Elementary school no 3. Tap water, from well of alcohol factory
30	48.852501	106.462006	Drinking water dispenser (Winix filtration system) -- Same location as 29
31	48.841140	106.486559	Tap water in wooden house, Shirkhentseg 80, Zuunkharaa. From 6 m deep well, 26 m to latrine, very clean khashaa and good well sealing.
32	48.838434	106.483639	Private well in front of ger in Zuunkharaa, good sealing, 1,50 m deep, 1m water depth.
33	48.838187	106.484099	Drinking water well of same family as [32], good sealing, 1,80 m deep
34	48.835518	106.480813	Shirkhentseg 140, Zuunkharaa, private well in wooden and orange metal sealing, 2m deep
35	48.729461	106.691844	Herders' well near Tunkhel
36	48.707930	106.710575	Kharaa near Noyon Uul ger camp
37	48.642496	106.788629	Tunkhel river upstream settlement
38	48.635527	106.767029	Well behind small shop in Tunkhel, built up in spring 2016. Sulfur smell in 2017. Electric, 4m depth.

HYG_ID	Coordinates		Description of sampling sites
	North	East	
39	48.632281	106.767332	Private well on khashaa in Tunkhel, nearby animal feces, good sealing, 8m deep.
40	48.633024	106.767034	Private electric well near [39] in Tunkhel, good sealing, animal feces around well, 6m deep, many cattle around
41	48.632496	106.766584	Private electric well near [40], 10 m deep, much cleaner and only a few chicken on compound.
42	48.633191	106.769108	Private well in Tunkhel, bucket and rope, near [41], khashaa without house, 5m deep
43	48.647001	106.766130	Water kiosk in Tunkhel, filter not working in May 2017 (sampling time), well 30 m deep, kiosk was built by Boroo Gold

3.1.1 Field data recording

All sample's data were recorded and written on paper. The information included the location of the sample, type of the water, date of the sampling and time, electrical conductivity, dissolved oxygen % and temperature. In 2018 pH were recorded. Additionally, during the sampling of private wells and water kiosk, contact number of the family had been recorded and the depth of the well, the distance between latrine well had been recorded.

3.1.2 Analysis Method

During the field trip, a mobile laboratory has been installed in Darkhan and Zuunkharaa. This laboratory had been equipped with mobile equipment such as two incubators, Quanti-Tray sealer and 6 watts 365 nm UV light equipment (Annex II b) and analyzing method were followed by Colilert Quantitray/2000 instruction (Annex I).

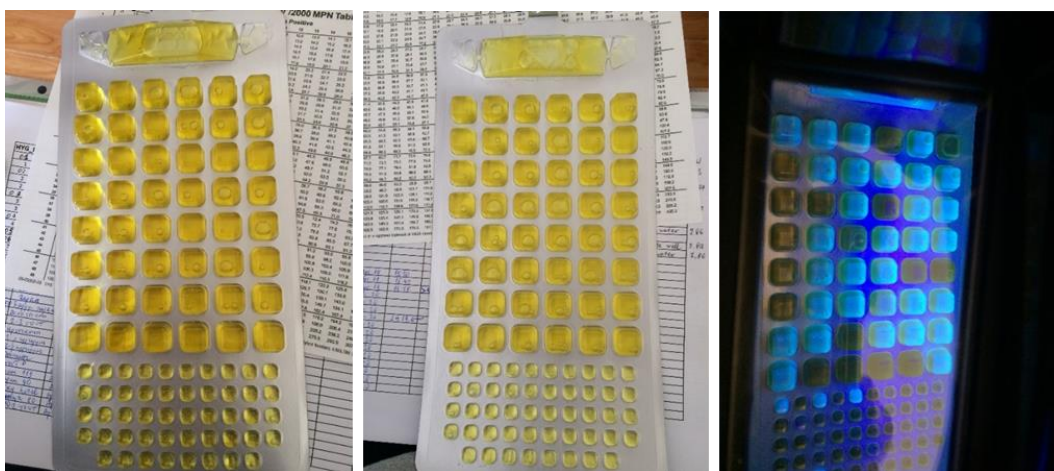


Figure 3-2 Example of the sample after incubation. Color has been shown. Before counting the small and big wells.

In the mobile laboratory, necessary high polluted samples were diluted with distilled water 1:10 or 1:100 such as wastewater and polluted river samples.

All samples mixed with the culture substrates and then poured into the QuantiTray containers, which is showing in Figure 3-2. Samples were incubated for 18-20 hours at $35\pm 0.5^{\circ}\text{C}$ (for total coliforms and *E. coli*) and $44.5\pm 0.2^{\circ}\text{C}$ for fecal coliforms. Subsequently, the most probable number for each sample were calculated using interpretation tables provided by the manufacturer and the IDEXX MPN Quantitray/2000 table (Annex IV).

For counting coliforms⁷ β -galactosidase (ONPG) has used to metabolize and make it colorless into yellow (Fig 3-2). For *e.coli* has used β -glucuronidase (MUG) to metabolize and create blue-fluorescence color under the 365-nm wavelength UV light.

⁷ <https://www.idexx.com/en/water/water-products-services/colilert/>

4 Results

4.1 Overview of the result

During two campaign of sampling results in May 2017 and April 2018 mean concentration of coliforms including all water bodies were found respectively for 3410.1 and 13873.9 of mean concentrations of total coliforms, 491 and 4621 E. coli bacteria and 414.3 and 4685.2 fecal coliforms per 100ml (MPN), which means in 2018 coliforms found out higher than in 2017. (Figure 4-1) is showing difference between two years result by concentration of coliforms with logarithmic mean value (y-axis) and type of coliforms bacteria (x-axis).

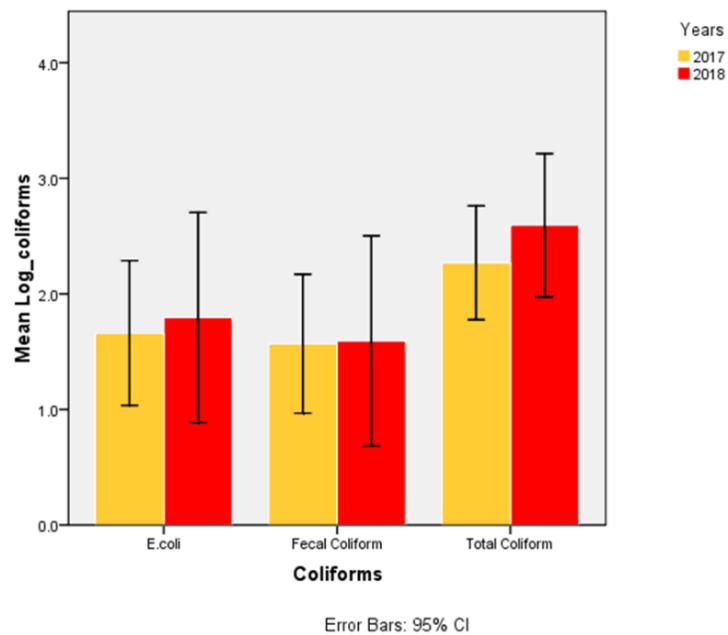


Figure 4-1 Total coliform, E. coli, Fecal coliform in 2017 and 2018

In Table 4-1 shows results of different water bodies in two years. Most contamination of total coliform, E.coli, fecal coliform were found in Wastewater effluent in both period of time. During the analysis test even wastewater samples were diluted 100 times with distilled water, we didn't get the exact number cause of the limitation of enumeration method.

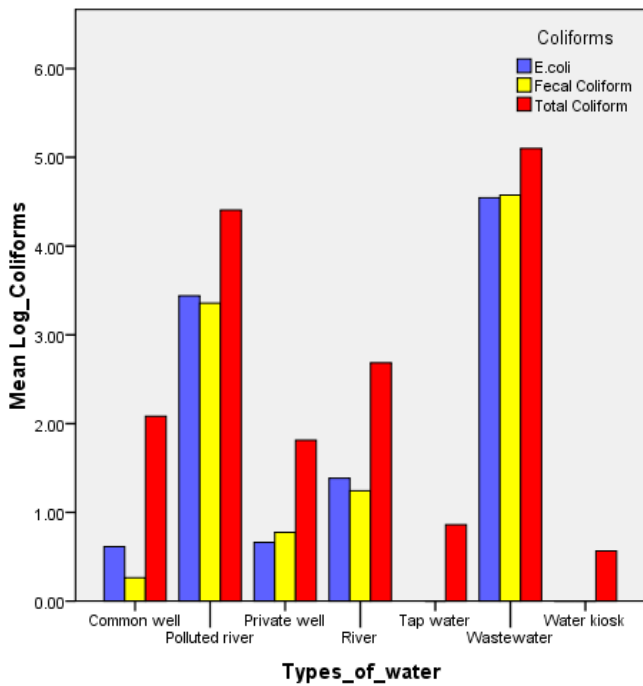
Table 4-1 Coliform concentrations in different types of water samples as most probable numbers/100 ml

Type of water		2017			2018		
		Total coliform	E.coli	Fecal coliform	Total coliform	E.coli	Fecal coliform
River	Mean	354	29.3	34.25	1052	33.6	28.4
	Minimum	53.1	6.9	6.3	313	4.1	3.1
	Maximum	579.4	>200.5	116	2419.6	66.3	62.7
Polluted stream (wastewater recipient)	Mean	26202.3	1953.2	1501.2	24196.0	3873.0	3448.0
	Minimum	17850	1460.0	655.0	24196.0	3873.0	3448.0
	Maximum	32492.5	3125.0	2010.0	24196.0	3873.0	3448.0
Wastewater	Mean	46935	8623.8	7053.3	84404.0	69550.0	70780.0
	Minimum	32550	520.0	860.0	141360.0	34480.0	43520.0
	Maximum	>241960	>241960	>241960	>241960	>241960	>241960
Private well	Mean	879.6	38.3	80.7	89.7	0.2	0.3
	Minimum	0.0	0.0	0.0	0.0	0.0	0.0
	Maximum	5794.0	660	1350.0	461.1	1.0	1.0
Tap water	Mean	0.2	0.0	0.2	38.1	.0	.0
	Minimum	0.0	0.0	0.0	0.0	0.0	0.0
	Maximum	2.0	0.0	1.0	190.4	0.0	0.0
Common well	Mean	234.5	5.4	11.5	162.7	3.6	1.0
	Minimum	124.1	4.1	0.0	34.5	2.0	1.0
	Maximum	344.8	6.7	22.5	290.9	5.2	1.0
Water kiosk	Mean	0.1	0.0	0.0	3.4	0.3	0.3
	Minimum	0.0	0.0	0.0	0.0	0.0	0.0
	Maximum	1.0	0.0	0.0	13.5	1.0	1.0

Table 4-2 Mean physico-chemical parameters in different type of water samples

Type	2017	2018	2017	2018	2017	2018
Parameters	Tem °C	Tem °C	EC µS/cm	EC µS/cm	DO%	DO%
River	11.3	8.5	226.7	191.8	109.7	93.2
Private well	3.0	3.7	498.4	372.4	50.1	54.6
Common well	3.3	3.5	417.5	320.0	36.9	49.9
Tap water	13.5	13.0	471.2	422.8	72.3	74.9
Water kiosk	6.2	7.3	543.0	390.8	75.4	72.1
Waste water	11.4	15.3	1078.5	972.0	102.8	19.3
Polluted river	13.3	17.3	1093.5	1563.0	150.2	61.2

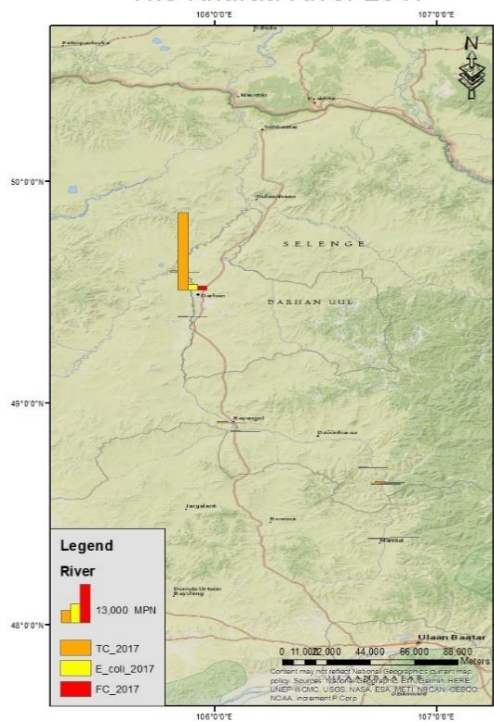
Figure 4-2 Coliforms concentrations on different types of water samples



Y-axis shows their concentration by mean logarithm scale. Most contaminated water types are Wastewater effluent and polluted river. From drinking water source, private well ,common well even river show high number. Only tap water, water kiosk are free from E.coli.

Figure 4-3 River samples result in both years

The Kharaa River 2017



The Kharaa River 2018

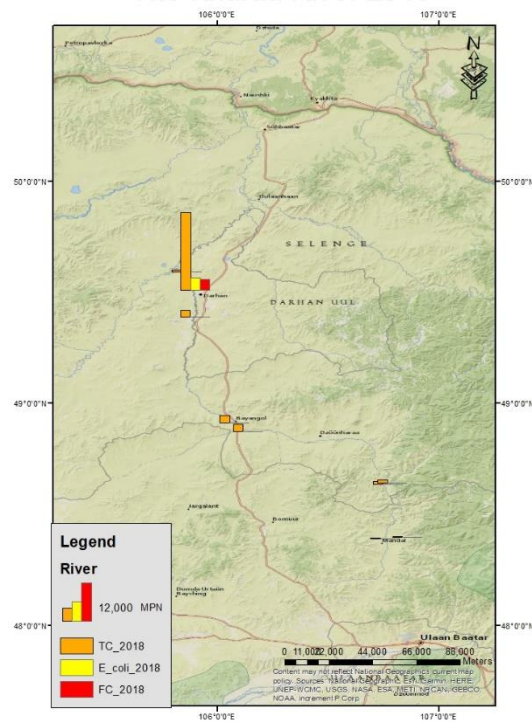
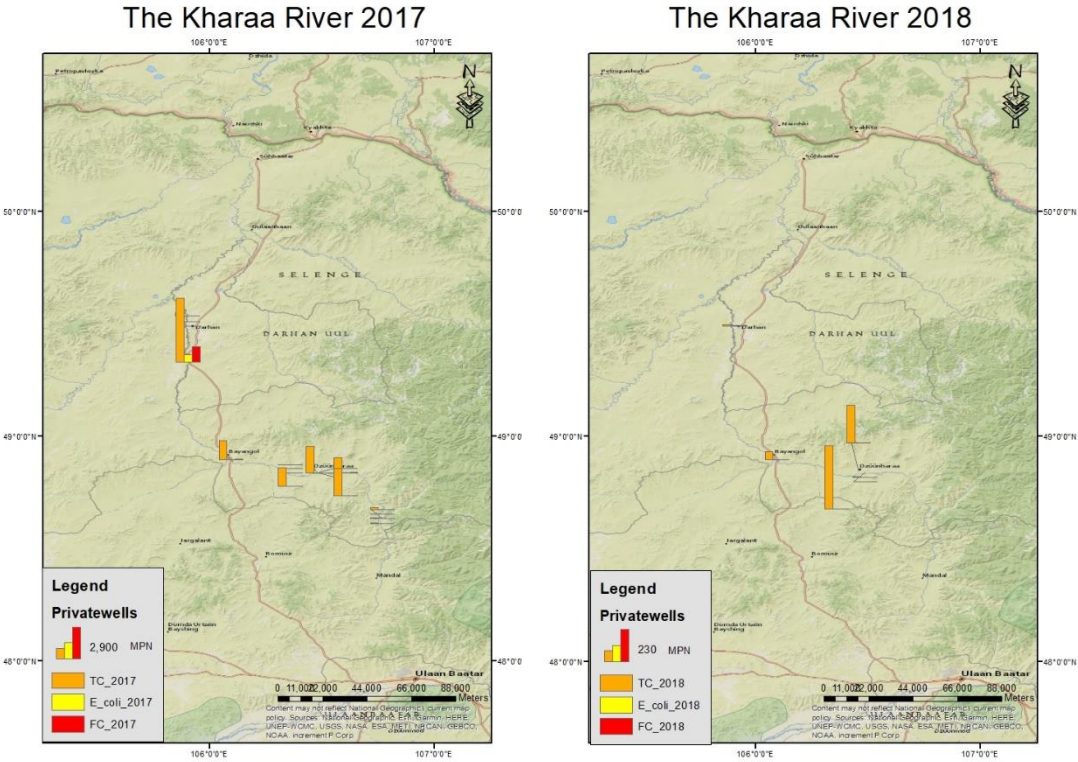


Table 4-1 is showing in 2018 river mean total coliform concentration was 1052, mean concentration of E.coli 33.6 and mean fecal coliform was 28.4 MPN/100mL. The result of 2017 was found 354 of mean TC, 29.3 of mean E.coli and 34.25 of FC MPN/100mL.

In 2018 highest TC contamination was in downstream of Baruunkharaa with >2419 MPN/100mL. However, the highest E.coli and FC contamination were found out in Buren Tolgoi 66.3 and 62.7 MPN/100mL, which is the last point of river sampling. In 2017 Buran Tolgoi was recorded with the highest contamination (Annex III).

The lowest contaminated area was subbasin outlet at Sugnugur in May 2017 and in April 2018 the lowest contaminated was in Kharaa at Batsumber bridge.

Figure 4-4 Private wells result in both years



In April 2017, 88% of the all private well samples have been found out at least 1MPN/100mL of coliforms. 28% of those sample shows more than 1000 MPN/100mL (Figure 4-4). The highest number was 5794 MPN/100mL in Darkhan and 3465 MPN/100mL in Zuunkharaa.

In 2017 only 2 samples founded free of bacteria in Zuunkharaa and Tunkhel.

However, in 2017 the highest mean concentration of total coliform was in Darkhan and Baruunkharaa with 1536.5 and 1733 MPN/100mL and highest E.coli and FC found out from Darkhan with mean concentration of 167.5 and 337.5 MPN/100mL.

About 2018, Zuunkharaa was found with the highest TC mean concentration. It was 185MPN/mL. Nevertheless, E.coli and FC almost didn't find out from private wells. Except for only 3 wells in Darkhan, Baruunkharaa and Zuunkharaa were with 1 MPN/100mL.

Figure 4-5 Private wells coliforms concentration

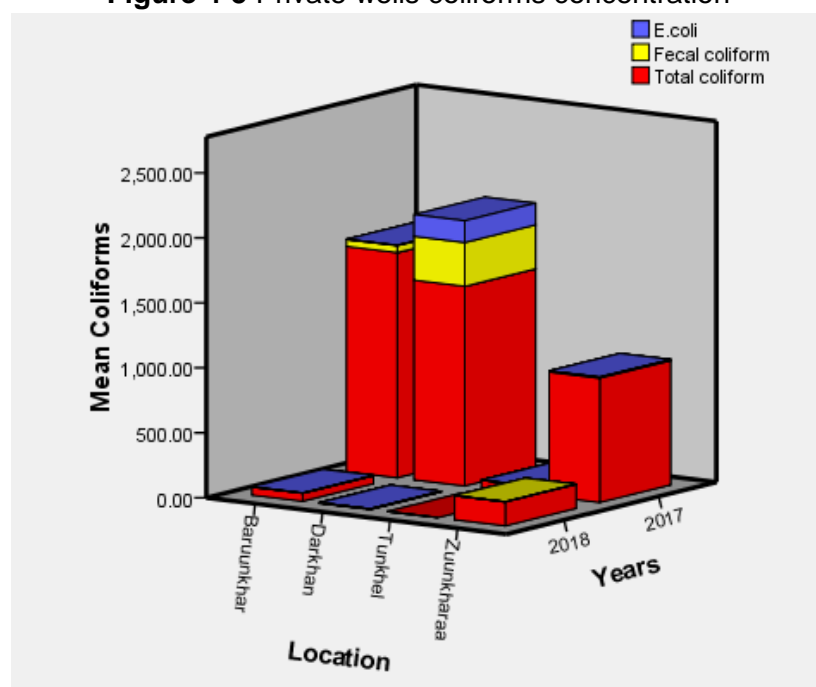
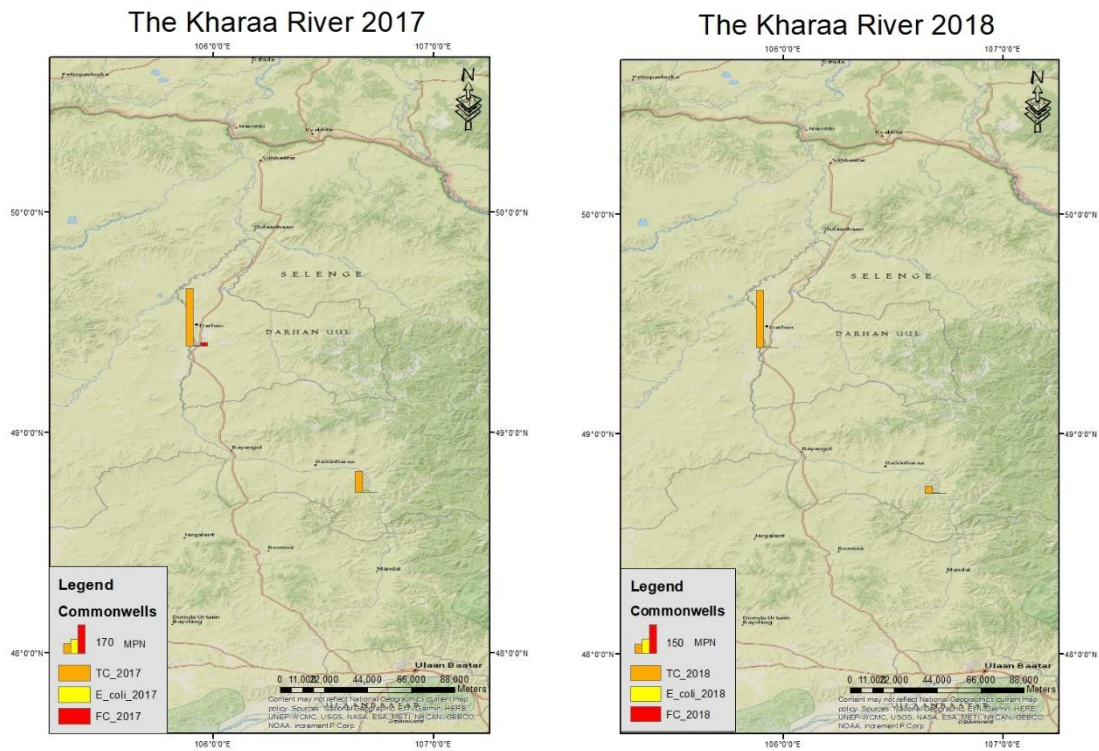
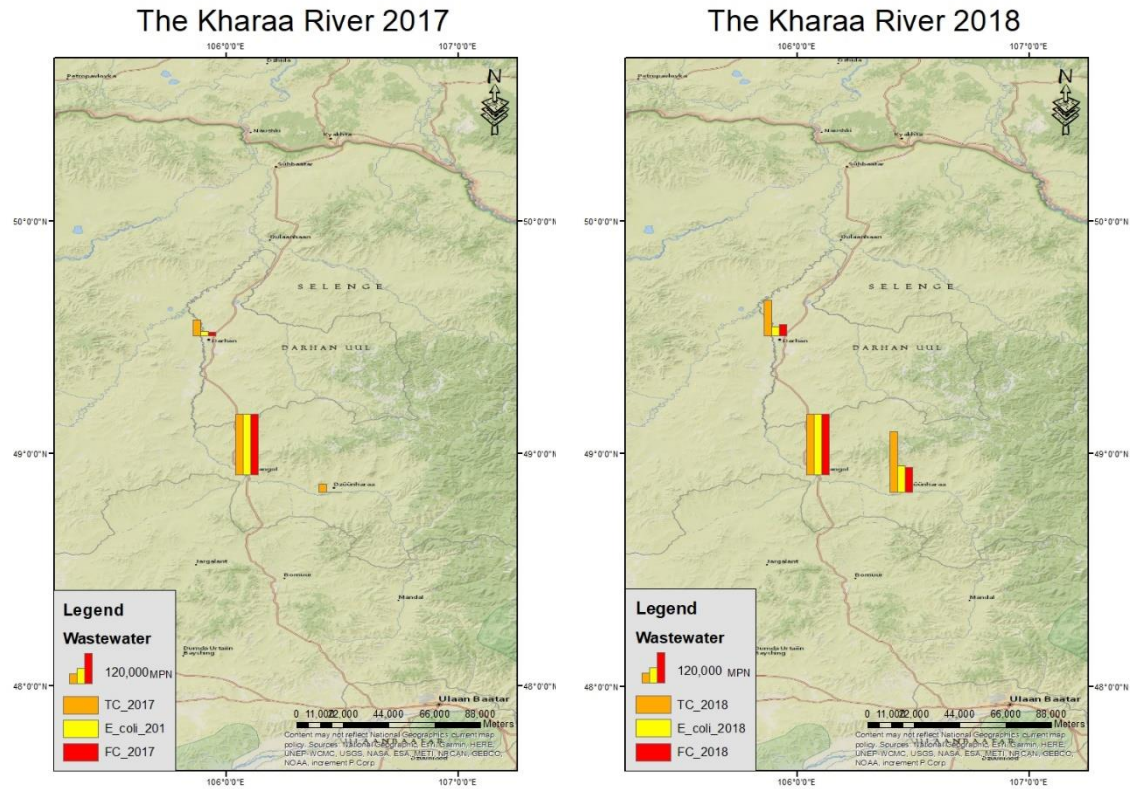


Figure 4-6 Common wells result in both years



Common wells are founded contaminated by all tree type of bacteria. In 2017 mean total coliform was 224.2 , E.coli 8.75 , fecal coliform 11.75 MPN/100mL and in 2018 mean total coliform was 162.7, E.coli 3.6 and fecal coliform 1MPN/100mL.

Figure 4-7 Wastewater effluent result in both years



From the wastewater effluent samples, highest concentration found out from Baruunkharaa in both campaigns. The result of all tree type of bacteria above the limited value even they diluted a hundred times. In 2017, Mean concentration of total coliform has found 46935, mean concentration of E.coli 8623.8 and fecal coliform 7053.3MPN/100mL. In 2018 mean total coliform was 84404, mean E.coli 69550 and mean concentration of fecal coliform was found out 70780 MPN/100mL.

Figure 4-8 Tap water result in both years

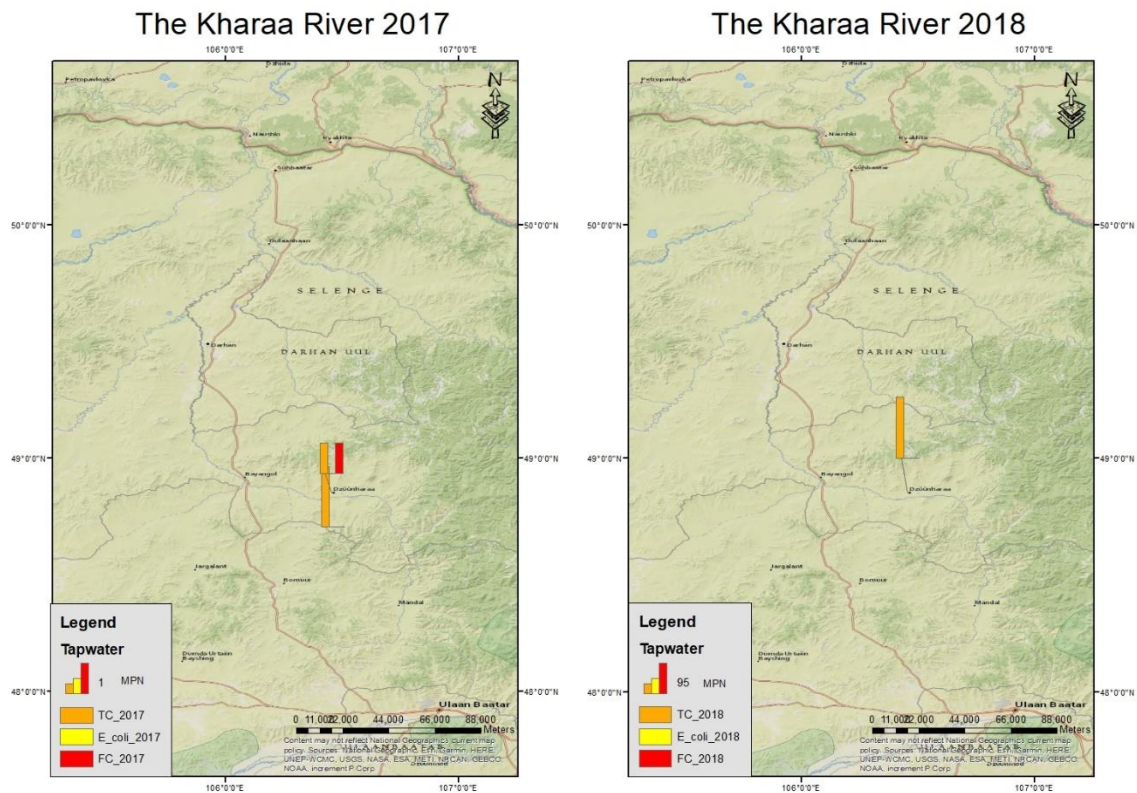
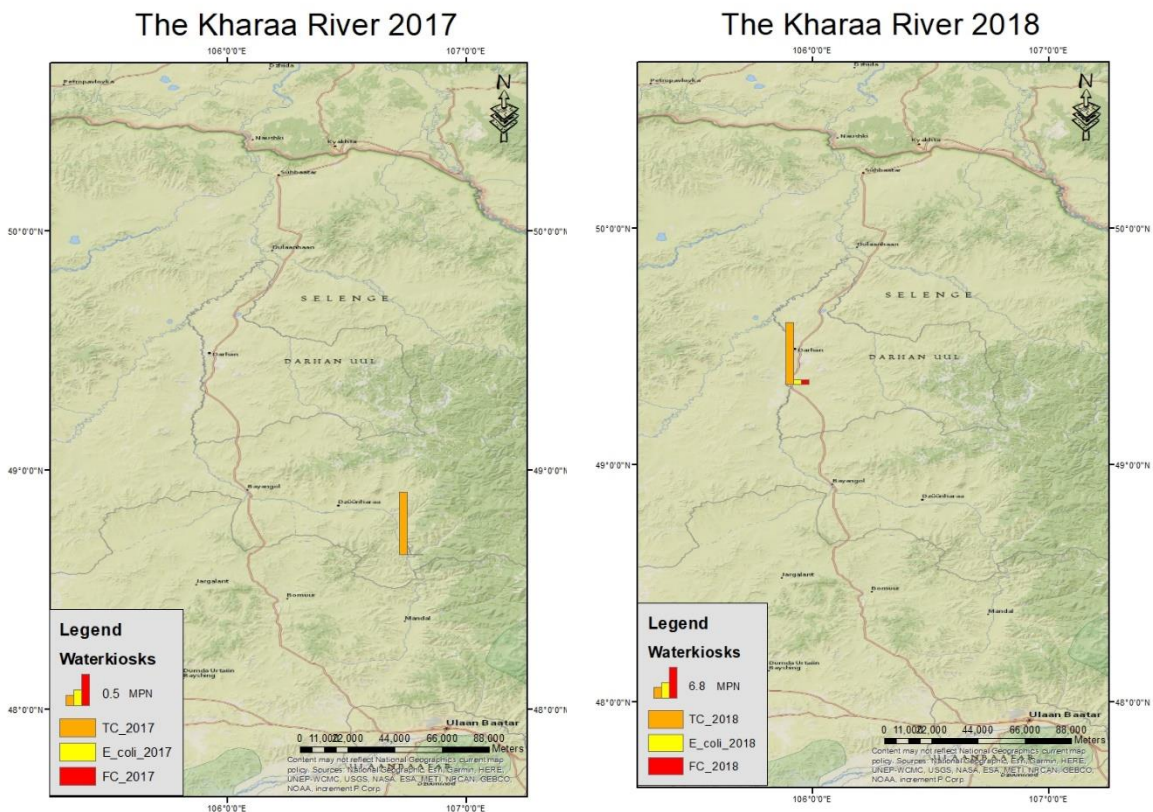


Figure 4-10 Water kiosks result in both years



During both campaigns, most of the tap water and water kiosks are founded free of bacteria. However, In 2017, 70% of the sample founded free of bacteria and another 30% of them founded with 1 or 2 MPN/100mL of total coliform. In 2018, Water kiosks from Darkhan which is located near to the railway have found 13.5 MPN/100mL of total coliform and 1MPN/100mL of E.coli and fecal coliform. Furthermore, in Zuunkharaa, Tap water from Solongo hotel found out with 190.4 MPN/100mL of total coliform. Temperature of the water sample was out of the limit which is 30.5 (Table 4-3).

Dissolved oxygen, electrical conductivity, temperature and pH of all samples were under the limitation shown in Table 4-3.

Table 4-3 Water quality standards

Parameter	MNS stardard 0900:2005(drinking water) 4943:2011(WW effluent)	International standard (EPA,WHO 2011)
pH	6.5-8.5 (drinking water) 6-9 (WW effluent)	8.2-8.8
Temperature	20°C	20°C
EC		2500 μ S cm ⁻¹ at 20°C ⁸
Total coliform	100 /100mL	Absent(drinking water) <400/100mL (WW effluent) ⁹
E.coli	Absent	Absent <200/100mL (WW effluent)
Dissolved oxygen		90-110 % ¹⁰

⁸ EPA standard

⁹ EPA 2002

¹⁰ http://www.who.int/water_sanitation_health/resourcesquality/wpcchap2.pdf

5 Discussion

Comparison between 2017 and 2018 river sample, in April 2018 enumerated more concentration of coliform bacteria. One of the hypothesis of the thesis study was indicator microorganisms which express pathogen of waterborne at target point that after the surface snow melted and when it goes to the river their might occurs higher contamination.

Climate condition in April is normally colder than May. However, during the field sampling, the river was observed highly polluted with a sediment. Due to the snow melting, rainfall it is possible that coliform bacteria can enter the stream by surface run-off (20). This type of contamination can be occurred by non-point pollution such as livestock that live near to the river basin or after winter small amount of river stream contained more of these bacteria. Correlation between river discharge and contamination level might show a reliable result. However, During the thesis study, it wasn't able to get those data from monitoring stations from the Kharaa river.

The Second hypothesis of the study was that point pollution sources such as wastewater effluent can increase the river contamination. According to the Mongolian and International standards (Tab 4-2), wastewater effluent has required limits before entering the environment.

All of the wastewater effluent results show that there occurs high concentration of microbiological contamination. It matches to some researchers report that mentioned dilution of the poorly treated wastewater can be a reason for the high concentration of coliform bacteria in the river stream(20).

Other drinking water sources such as common wells and private wells showed unsuitable results. According to the drinking water standard of Mongolia total coliform's maximum limit is 100MPN/100mL. However, Other international standards say those type of bacteria has to be absent in drinking water.

In 2017 most of the private well showed a high amount of contamination. Due to the result, each family was informed about their well contamination results. From the result of 2018 private wells contamination level has decreased a lot (Fig 4-6).

During the sampling private well, some family had changed their well location. They avoided to drill it near to the latrine and according to the result of 2017 some family increased their depth of the well.

6 Conclusion and Recommendation

Aim of thesis study was considered to understand the current situation of water hygiene from different water sources in the Kharaa river basin. Even though, the river basin highly populated by people and livestock providing them with the safe and improved water supply is necessary. As a result of the study, all types of water bodies have contaminated by indicator microorganisms which mean there is a potential to occur pathogenic organism that leads to several disease.

In the future, correlate the water hygiene monitoring with the public health problems is necessary. Moreover, doing monitoring in monthly or if possible doing it more frequently is needed for understanding contamination factors from river stream begins until it freeze again.

Positive attitude has been observed during the sampling was some families who had detected with contaminated wells during last year monitoring had taken action and reinstalled their wells or has been forbade to use those contaminated wells.

Improving knowledge of local people and informing people with the current knowledge and existing result can lead to prevention of waterborne related disease.

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How to use Colilert

Presence/Absence Test Procedure

1



Carefully separate one snap pack from the strip, taking care not to accidentally open adjacent pack.

2



Open one pack by snapping back the top at the scoreline as shown.
Caution: Do not touch the opening of pack.
Add the reagent to a 100 mL water sample in a sterile, transparent, non-fluorescent vessel.

3



Aseptically cap and seal the vessel and then shake until dissolved.

4



Incubate for 24 hours at $35^{\circ} \pm 0.5^{\circ}\text{C}$.




5



Read the results at 24 hours. Compare each result against the comparator dispensed into an identical vessel.

- If no yellow color is observed, the sample is negative for total coliforms and *E. coli*.
- If the sample has a yellow color, the presence of total coliforms is confirmed. If color is not uniform, mix by inversion, then recheck.
- If the sample is yellow, but not fluorescent, the sample is coliform positive, the color will intensify. If it does not intensify, the sample is negative.
- If yellow is observed, check vessel for fluorescence. If fluorescence is observed, the presence of *E. coli* is confirmed. Use a 6 watt 365 nm UV light within five inches of the sample in a dark environment. Be sure the light is facing away from your eyes and towards the vessel.

these test reactions should be seen in Colilert and Colilert-18:

		
COLORLESS	YELLOW	FLUORESCENT*
Negative for total coliforms and <i>E. coli</i> .	Positive for total coliforms.	Positive for <i>E. coli</i> . <small>*Use 365nm UV lamp</small>

Quanti-Tray[®]/2000

Introduction

IDEXX Quanti-Tray/2000 is designed to give quantitated bacterial counts of 100 ml samples using IDEXX Defined Substrate Technology* reagent products. Add the reagent/sample mixture to a Quanti-Tray/2000, seal it in a Quanti-Tray Sealer and incubate per the reagent directions. Then count the number of positive large and small wells and use the MPN table attached to determine the Most Probable Number (MPN).

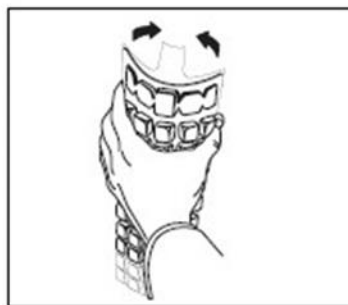
Contents

This package contains 100 sterile Quanti-Tray/2000s.

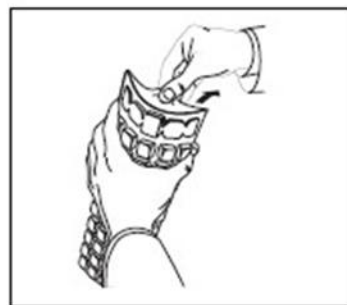
User Instructions



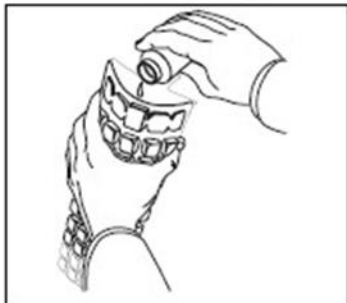
1. Use one hand to hold a Quanti-Tray upright with the well side facing the palm.



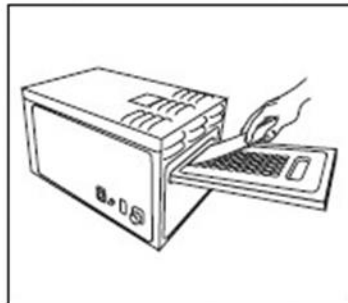
2. Squeeze the upper part of the Quanti-Tray so that the Quanti-Tray bends towards the palm.



3. Gently pull foil tab to separate the foil from the tray. Avoid touching the inside of the foil or tray.



4. Pour the reagent/sample mixture directly into the Quanti-Tray avoiding contact with the foil tab. Tap the small wells 2-3 times to release any air bubbles. Allow foam to settle.



5. Place the sample-filled Quanti-Tray onto the Quanti-Tray/2000 rubber insert of the Quanti-Tray Sealer with the well side (plastic) of the Quanti-Tray facing down.

6. Seal according to Sealer instructions.
7. Incubate according to reagent directions.
8. Count large and small positive wells and refer to the Quanti-Tray/2000 MPN table to find the Most Probable Number (MPN).
9. Dispose of media in accordance with Good Laboratory Practices.

For Technical Assistance, visit www.idexx.com/water,
or in the U.S. and Canada, call 1-800-321-0207 or 1-207-856-0496.

IDEXX Laboratories, Inc. One IDEXX Drive, Westbrook, Maine 04092 USA

*Quanti-Tray and Defined Substrate Technology are either trademarks or registered trademarks of IDEXX Laboratories, Inc. in the United States and/or other countries. Covered by U.S. Patent Numbers 4,925,789 ; 5,429,933 ; 5,518,892. Other patents pending.

IDEXX

Annex III Equipment used for analysis a) Incubators b) Multiparameter equipment c) Idexx sealer d) UV light



Annex IV All sampling data 2017 and 2018

		2017		2018		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2018	
HYG_ID		Date	Time	Date	Time	TC MPN	TC MPN	E coli MPN	E coli MPN	FC MPN	FC MPN	EC	EC	DO%	DO%	Temp	Temp	pH	Type
1	Kharaa at Buren Tolgoi	5-May-17	12:20	18-Apr	15:34	514.8	686.7	29.3	66.3	44.6	62.7	400	227	98.1	92	7.9	14.5	8.3	River
2	WWTP outlet Darkhan	5 May 2017	16:20	18-Apr	17:48	61320	141360	16727.5	34480	13246.7	43520	1632.5	1224	21.2	4.3	7.2	17.3	7.86	Wastewater
3	Before entering Kharaa WW Darkhan	5 May 2017	16:51	18-Apr	16:58	26808.3333	24196	1953.225	3873	1507.15	3448	1093.5	1563	150.2	61.2	13.3	17.3	7.94	Polluted River
4	Kharaa upstream Darkhan	5 May 2017	17:46	19-Apr	15:58	140.3	1986.3	6.9	40.2	2.55	43.2	375	171	102.6	93.6	14.0	9.3	8.09	River
5	Downstream of bridge Batsumber	6 May 2017	11:51	21-Apr	19:32	>200,5	313	>200,5	41	88.5	27.9	155	80	102.5	92.1	11.5	8.4	7	River
6	Downstream of bridge Sugnugur	6 May 2017	12:35	21-Apr	19:19	53.1	325.5	11.1	10.8	8.7	6.3	59	35	115.4	92.9	9.6	2.5	8.14	River
7	Upstream of bridge Tunkhel	6 May 2017	14:47	21-Apr	17:00	461.1	816.4	119.45	8.4	115.9	6.2	143.5	61	103.9	95.4	13.4	7.5	8.02	River
8	Bag 3 Ajilchnii 15 Darkhan	9-May-17	13:36	18-Apr	17:30	5794	0	660.1	0	1350	0	402	316	56.0	28.6	4.3	6.4	7.87	Private well
9	Used by several families Darkhan	9 May 2017	18:15	19-Apr	15:42	344.8	290.9	4.1	5.2	22.5	1	460	349	16.5	35.8	2.5	2.3	7.66	Common well
10	Near railway settlement Darkhan	9 May 2017	19:00	19-Apr	15:30	0	13.5	0	1	0	1	869	580	88.6	73.4	7.7	6.7	7.82	Water kiosk
11	Northern Darkhan	10 May 2017	12:00	x	x	231	x	10	x	0	x	1528	x	24.3	x	0.9		x	Private well
12	Northern Darkhan	10 May 2017	12:25	x	x	118.2	x	0	x	0	x	464	x	47.3	x	3.6		x	Private well
13	№1-2 Darkhan	10 May 2017	14:16	19-Apr	14:51	0	0	0	0	0	0	356	250	85.2	81.4	5.0	6.4	8.05	Water kiosk
14	Ajilchin 13 house 5 Darkhan	10 May 2017	15:30	18-Apr	18:22	3	6.3	0	1	0	1	800	792	48.0	59	4.9	4.9	7.84	Private well
15	№3-1 Darkhan	10 May 2017	16:14	19-Apr	14:37	0	0	0	0	0	0	349	244	84.3	90.4	6.8	9.6	8.21	Water kiosk
16	MBM, Sky Hotel Darkhan	10 May 2017	18:20	18-Apr	19:44	0	0	0	0	0	0	348	358	38.5	63	18.5	18.8	7.86	Tap water
17	№2-3 Darkhan	11 May 2017	17:55	20-Apr	15:55	1732.9	61.3	2	1	53.9	1	314	361	33.8	46	1.6	2.4	7.66	Private well
18	Kharaa downstream Baruunkharaa	11 May 2017	18:45	20-Apr	15:35	579.4	>2419.6	12	42.6	5.2	44.8	297	741	129.7	92.8	11.9	9.0	7.98	River
19	WWTP outlet Baruunkharaa	11 May 2017	19:22	20-Apr	15:10	>241960	>241960	>241960	>241960	>241960	>241960	755	849	42.1	48.7	6.4	10.8	8.26	Wastewater
20	Kharaa upstream Baruunkharaa	11 May 2017	19:56	20-Apr	16:15	410.6	2419.6	12.1	55.6	23.1	32.7	275	146	115.8	91.6	10.5	9.0	7.99	River

HYG_ID		2017		2018		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	Type
		Date	Time	Date	Time	TC MPN	TC MPN	E coli MPN	E coli MPN	FC MPN	FC MPN	EC	EC	DO%	DO%	Temp	Temp	pH		
21	Hotel Narnii Urtuu Plaza	11 May 2017	23:40	x	x	0	x	0	x	0	x	521	x	64.2	x	8.3	x	x	Tap water	
22	Zuunkharaa	12 May 2017	10:30	x	x	2	x	0	x	2	x	892	x	30.2	x	6.3	x	x	Private well	
23	Naran 98 Zuunkharaa	12 May 2017	11:25	x	x	1732.8	x	0	x	0	x	515	x	37.0	x	2.5	x	x	Private well	
24	Naran 90 Zuunkharaa	12 May 2017	11:51	20-Apr	19:00	40.5	272.3	0	0	1	0	545	415	58.9	72.5	2.3	2.1	7.51	Private well	
25	Naran 119 Zuunkharaa	12 May 2017	12:23	20-Apr	18:47	3.1	461.1	0	0	0	0	363	355	19.4	25	3.4	3.8	7.27	Private well	
26	WWTP polishing pond Zuunkharaa	12 May 2017	12:45	20-Apr	18:18	32550	241960	520	104620	860	98040	848	843	245.0	5	20.5	17.8	8.08	Wastewater	
27	Solongo Hotel Zuunkharaa	12 May 2017	13:50	20-Apr	19:50	1	190.4	0	0	1	0	490	331	109.1	95.9	30.4	19.7	7.48	Tap water	
28	Hospital Zuunkharaa	12 May 2017	16:32	20-Apr	17:48	2	0	0	0	0	0	522	513	71.4	69.1	4.7	8.4	7.55	Tap water	
29	Elementary school №3 Zuunkharaa	12 May 2017	16:45	20-Apr	17:29	0	0	0	0	0	0	475	457	74.9	82.4	10.1	10.3	7.6	Tap water	
30	Dispenser Elementary school №3 Zuunkharaa	12 May 2017	17:00	20-Apr	17:30	0	0	0	0	0	0	471	455	75.4	64.1	9.1	7.8	7.57	Tap water	
31	Shirkhentseg 80 Zuunkharaa	12 May 2017	17:47	21-Apr	10:31	1	1	0	0	0	0	488	361	55.5	68.2	2.3	4.7	8.1	Private well	
32	Zuunkharaa	12 May 2017	18:21	x	x	3465.8	x	0	x	8.2	x	399	x	35.1	x	2.2	x	x	Private well	
33	Shirkhentseg 102 Zuunkharaa	12 May 2017	18:40	21-Apr	10:54	0	5.2	0	0	10.4	1	411	261	46.4	52	1.5	3.9	8.05	Private well	
34	Shirkhentseg 140 Zuunkharaa	12 May 2017	19:07	x	x	2406.6	x	15	x	26.8	x	276	x	35.1	x	1.5		x	Private well	
35	Herder's well Tunkhel	13 May 2017	12:35	21-Apr	15:52	124.1	34.5	6.7	2	0.5	1	375	291	57.3	63.9	4.0	4.6	7.75	Common well	
36	Noyon uul ger camp	13 May 2017	12:58	x	x	410.6	x	23.1	x	6.3	x	194	x	107.4	x	11.9		x	River	
37	Upstream settlement Tunkhel	13 May 2017	13:52	21-Apr	16:50	261.3	816.4	20.3	4.1	13.4	3.1	142	73	111.8	94.8	11.2	7.9	8.13	River	
38	Tunkhel	13 May 2017	15:22	x	x	146.4	x	1	x	0	x	206	x	29.2	x	4.4		x	Private well	
39	Bulgiin 2-23 Tunkhel	13 May 2017	15:48	21-Apr	17:19	17.3	0	0	0	0	0	362	276	92.0	70.6	3.4	2.2	7.4	Private well	
40	Bulgiin 34 Tunkhel	13 May 2017	16:20	21-Apr	17:32	44.25	0	0	0	0	0	295	215	87.2	69.7	4.1	2.5	7.44	Private well	
41	Tunkhel	13 May 2017	16:35	x	x	0	x	0	x	0	x	383	x	85.9	x	2.2		x	Private well	
42	Tunkhel	13 May 2017	16:56	x	x	93.5	x	1	x	1	x	328	x	79.8	x	2.2		x	Private well	
43	Kiosk Tunkhel	13 May 2017	17:33	21-Apr	16:27	1	0	0	0	0	0	598	489	43.5	43.1	5.3	6.3	7.21	Water kiosk	

Annex V Quantitray 2000 MPN table

# Large Wells Positive	(per 100ml)																								
	# Small Wells Positive																								
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	<1	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.1	15.1	16.1	17.1	18.1	19.1	20.2	21.2	22.2	23.3	24.3
1	1.0	2.0	3.0	4.0	5.0	6.0	7.1	8.1	9.1	10.1	11.1	12.1	13.2	14.2	15.2	16.2	17.3	18.3	19.3	20.4	21.4	22.4	23.5	24.5	25.6
2	2.0	3.0	4.1	5.1	6.1	7.1	8.1	9.2	10.2	11.2	12.2	13.3	14.3	15.4	16.4	17.4	18.5	19.5	20.6	21.6	22.7	23.7	24.8	25.8	26.9
3	3.1	4.1	5.1	6.1	7.2	8.2	9.2	10.3	11.3	12.4	13.4	14.5	15.5	16.5	17.6	18.6	19.7	20.8	21.8	22.9	23.9	25.0	26.1	27.1	28.2
4	4.1	5.2	6.2	7.2	8.3	9.3	10.4	11.4	12.5	13.5	14.6	15.6	16.7	17.8	18.8	19.9	21.0	22.0	23.1	24.2	25.3	26.3	27.4	28.5	29.6
5	5.2	6.3	7.3	8.4	9.4	10.5	11.5	12.6	13.7	14.7	15.8	16.9	17.9	19.0	20.1	21.2	22.2	23.3	24.4	25.5	26.6	27.7	28.8	29.9	31.0
6	6.3	7.4	8.4	9.5	10.6	11.6	12.7	13.8	14.9	16.0	17.0	18.1	19.2	20.3	21.4	22.5	23.6	24.7	25.8	26.9	28.0	29.1	30.2	31.3	32.4
7	7.5	8.5	9.6	10.7	11.8	12.8	13.9	15.0	16.1	17.2	18.3	19.4	20.5	21.6	22.7	23.8	24.9	26.0	27.1	28.3	29.4	30.5	31.6	32.8	33.9
8	8.6	9.7	10.8	11.9	13.0	14.1	15.2	16.3	17.4	18.5	19.6	20.7	21.8	22.9	24.1	25.2	26.3	27.4	28.6	29.7	30.8	32.0	33.1	34.3	35.4
9	9.8	10.9	12.0	13.1	14.2	15.3	16.4	17.6	18.7	19.8	20.9	22.0	23.2	24.3	25.4	26.6	27.7	28.9	30.0	31.2	32.3	33.5	34.6	35.8	37.0
10	11.0	12.1	13.2	14.4	15.5	16.6	17.7	18.9	20.0	21.1	22.3	23.4	24.6	25.7	26.9	28.0	29.2	30.3	31.5	32.7	33.8	35.0	36.2	37.4	38.6
11	12.2	13.4	14.5	15.6	16.8	17.9	19.1	20.2	21.4	22.5	23.7	24.8	26.0	27.2	28.3	29.5	30.7	31.9	33.0	34.2	35.4	36.6	37.8	39.0	40.2
12	13.5	14.6	15.8	16.9	18.1	19.3	20.4	21.6	22.8	23.9	25.1	26.3	27.5	28.6	29.8	31.0	32.2	33.4	34.6	35.8	37.0	38.2	39.5	40.7	41.9
13	14.8	16.0	17.1	18.3	19.5	20.6	21.8	23.0	24.2	25.4	26.6	27.8	29.0	30.2	31.4	32.6	33.8	35.0	36.2	37.5	38.7	39.9	41.2	42.4	43.6
14	16.1	17.3	18.5	19.7	20.9	22.1	23.3	24.5	25.7	26.9	28.1	29.3	30.5	31.7	33.0	34.2	35.4	36.7	37.9	39.1	40.4	41.6	42.9	44.2	45.4
15	17.5	18.7	19.9	21.1	22.3	23.5	24.7	25.9	27.2	28.4	29.6	30.9	32.1	33.3	34.6	35.8	37.1	38.4	39.6	40.9	42.2	43.4	44.7	46.0	47.3
16	18.9	20.1	21.3	22.6	23.8	25.0	26.2	27.5	28.7	30.0	31.2	32.5	33.7	35.0	36.3	37.5	38.8	40.1	41.4	42.7	44.0	45.3	46.6	47.9	49.2
17	20.3	21.6	22.8	24.1	25.3	26.6	27.8	29.1	30.3	31.6	32.9	34.1	35.4	36.7	38.0	39.3	40.6	41.9	43.2	44.5	45.9	47.2	48.5	49.8	51.2
18	21.8	23.1	24.3	25.6	26.9	28.1	29.4	30.7	32.0	33.3	34.6	35.9	37.2	38.5	39.8	41.1	42.4	43.8	45.1	46.5	47.8	49.2	50.5	51.9	53.2

19	23.3	24.6	25.9	27.2	28.5	29.8	31.1	32.4	33.7	35.0	36.3	37.6	39.0	40.3	41.6	43.0	44.3	45.7	47.1	48.4	49.8	51.2	52.6	54.0	55.4
20	24.9	26.2	27.5	28.8	30.1	31.5	32.8	34.1	35.4	36.8	38.1	39.5	40.8	42.2	43.6	44.9	46.3	47.7	49.1	50.5	51.9	53.3	54.7	56.1	57.6
21	26.5	27.9	29.2	30.5	31.8	33.2	34.5	35.9	37.3	38.6	40.0	41.4	42.8	44.1	45.5	46.9	48.4	49.8	51.2	52.6	54.1	55.5	56.9	58.4	59.9
22	28.2	29.5	30.9	32.3	33.6	35.0	36.4	37.7	39.1	40.5	41.9	43.3	44.8	46.2	47.6	49.0	50.5	51.9	53.4	54.8	56.3	57.8	59.3	60.8	62.3
23	29.9	31.3	32.7	34.1	35.5	36.8	38.3	39.7	41.1	42.5	43.9	45.4	46.8	48.3	49.7	51.2	52.7	54.2	55.6	57.1	58.6	60.2	61.7	63.2	64.7
24	31.7	33.1	34.5	35.9	37.3	38.8	40.2	41.7	43.1	44.6	46.0	47.5	49.0	50.5	52.0	53.5	55.0	56.5	58.0	59.5	61.1	62.6	64.2	65.8	67.3
25	33.6	35.0	36.4	37.9	39.3	40.8	42.2	43.7	45.2	46.7	48.2	49.7	51.2	52.7	54.3	55.8	57.3	58.9	60.5	62.0	63.6	65.2	66.8	68.4	70.0
26	35.5	36.9	38.4	39.9	41.4	42.8	44.3	45.9	47.4	48.9	50.4	52.0	53.5	55.1	56.7	58.2	59.8	61.4	63.0	64.7	66.3	67.9	69.6	71.2	72.9
27	37.4	38.9	40.4	42.0	43.5	45.0	46.5	48.1	49.6	51.2	52.8	54.4	56.0	57.6	59.2	60.8	62.4	64.1	65.7	67.4	69.1	70.8	72.5	74.2	75.9
28	39.5	41.0	42.6	44.1	45.7	47.3	48.8	50.4	52.0	53.6	55.2	56.9	58.5	60.2	61.8	63.5	65.2	66.9	68.6	70.3	72.0	73.7	75.5	77.3	79.0
29	41.7	43.2	44.8	46.4	48.0	49.6	51.2	52.8	54.5	56.1	57.8	59.5	61.2	62.9	64.6	66.3	68.0	69.8	71.5	73.3	75.1	76.9	78.7	80.5	82.4
30	43.9	45.5	47.1	48.7	50.4	52.0	53.7	55.4	57.1	58.8	60.5	62.2	64.0	65.7	67.5	69.3	71.0	72.9	74.7	76.5	78.3	80.2	82.1	84.0	85.9
31	46.2	47.9	49.5	51.2	52.9	54.6	56.3	58.1	59.8	61.6	63.3	65.1	66.9	68.7	70.5	72.4	74.2	76.1	78.0	79.9	81.8	83.7	85.7	87.6	89.6
32	48.7	50.4	52.1	53.8	55.6	57.3	59.1	60.9	62.7	64.5	66.3	68.2	70.0	71.9	73.8	75.7	77.6	79.5	81.5	83.5	85.4	87.5	89.5	91.5	93.6
33	51.2	53.0	54.8	56.5	58.3	60.2	62.0	63.8	65.7	67.6	69.5	71.4	73.3	75.2	77.2	79.2	81.2	83.2	85.2	87.3	89.3	91.4	93.6	95.7	97.8
34	53.9	55.7	57.6	59.4	61.3	63.1	65.0	67.0	68.9	70.8	72.8	74.8	76.8	78.8	80.8	82.9	85.0	87.1	89.2	91.4	93.5	95.7	97.9	100.2	102.4
35	56.8	58.6	60.5	62.4	64.4	66.3	68.3	70.3	72.3	74.3	76.3	78.4	80.5	82.6	84.7	86.9	89.1	91.3	93.5	95.7	98.0	100.3	102.6	105.0	107.3
36	59.8	61.7	63.7	65.7	67.7	69.7	71.7	73.8	75.9	78.0	80.1	82.3	84.5	86.7	88.9	91.2	93.5	95.8	98.1	100.5	102.9	105.3	107.7	110.2	112.7
37	62.9	65.0	67.0	69.1	71.2	73.3	75.4	77.6	79.8	82.0	84.2	86.5	88.8	91.1	93.4	95.8	98.2	100.6	103.1	105.6	108.1	110.7	113.3	115.9	118.6
38	66.3	68.4	70.6	72.7	74.9	77.1	79.4	81.6	83.9	86.2	88.6	91.0	93.4	95.8	98.3	100.8	103.4	105.9	108.6	111.2	113.9	116.6	119.4	122.2	125.0
39	70.0	72.2	74.4	76.7	78.9	81.3	83.6	86.0	88.4	90.9	93.4	95.9	98.4	101.0	103.6	106.3	109.0	111.8	114.6	117.4	120.3	123.2	126.1	129.2	132.2
40	73.8	76.2	78.5	80.9	83.3	85.7	88.2	90.8	93.3	95.9	98.5	101.2	103.9	106.7	109.5	112.4	115.3	118.2	121.2	124.3	127.4	130.5	133.7	137.0	140.3
41	78.0	80.5	83.0	85.5	88.0	90.6	93.3	95.9	98.7	101.4	104.3	107.1	110.0	113.0	116.0	119.1	122.2	125.4	128.7	132.0	135.4	138.8	142.3	145.9	149.5
42	82.6	85.2	87.8	90.5	93.2	96.0	98.8	101.7	104.6	107.6	110.6	113.7	116.9	120.1	123.4	126.7	130.1	133.6	137.2	140.8	144.5	148.3	152.2	156.1	160.2
43	87.6	90.4	93.2	96.0	99.0	101.9	105.0	108.1	111.2	114.5	117.8	121.1	124.6	128.1	131.7	135.4	139.1	143.0	147.0	151.0	155.2	159.4	163.8	168.2	172.8

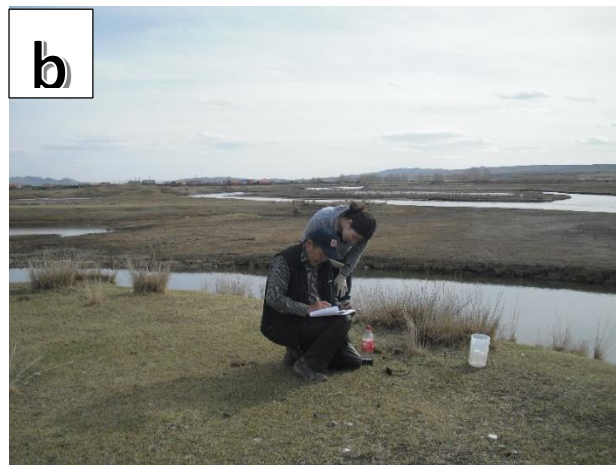
44	93.1	96.1	99.1	102.2	105.4	108.6	111.9	115.3	118.7	122.3	125.9	129.6	133.4	137.4	141.4	145.5	149.7	154.1	158.5	163.1	167.9	172.7	177.7	182.9	188.2
45	99.3	102.5	105.8	109.2	112.6	116.2	119.8	123.6	127.4	131.4	135.4	139.6	143.9	148.3	152.9	157.6	162.4	167.4	172.6	178.0	183.5	189.2	195.1	201.2	207.5
46	106.3	109.8	113.4	117.2	121.0	125.0	129.1	133.3	137.6	142.1	146.7	151.5	156.5	161.6	167.0	172.5	178.2	184.2	190.4	196.8	203.5	210.5	217.8	225.4	233.3
47	114.3	118.3	122.4	126.6	130.9	135.4	140.1	145.0	150.0	155.3	160.7	166.4	172.3	178.5	185.0	191.8	198.9	206.4	214.2	222.4	231.0	240.0	249.5	259.5	270.0
48	123.9	128.4	133.1	137.9	143.0	148.3	153.9	159.7	165.8	172.2	178.9	186.0	193.5	201.4	209.8	218.7	228.2	238.2	248.9	260.3	272.3	285.1	298.7	313.0	328.2
49	135.5	140.8	146.4	152.3	158.5	165.0	172.0	179.3	187.2	195.6	204.6	214.3	224.7	235.9	248.1	261.3	275.5	290.9	307.6	325.5	344.8	365.4	387.3	410.6	435.2

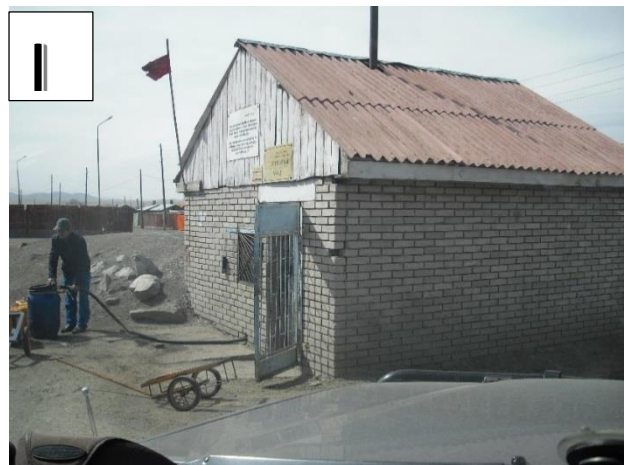
# Large Wells Positive	<i>(per 100ml)</i>																							
	# Small Wells Positive																							
	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
0	25.3	26.4	27.4	28.4	29.5	30.5	31.5	32.6	33.6	34.7	35.7	36.8	37.8	38.9	40.0	41.0	42.1	43.1	44.2	45.3	46.3	47.4	48.5	49.5
1	26.6	27.7	28.7	29.8	30.8	31.9	32.9	34.0	35.0	36.1	37.2	38.2	39.3	40.4	41.4	42.5	43.6	44.7	45.7	46.8	47.9	49.0	50.1	51.2
2	27.9	29.0	30.0	31.1	32.2	33.2	34.3	35.4	36.5	37.5	38.6	39.7	40.8	41.9	43.0	44.0	45.1	46.2	47.3	48.4	49.5	50.6	51.7	52.8
3	29.3	30.4	31.4	32.5	33.6	34.7	35.8	36.8	37.9	39.0	40.1	41.2	42.3	43.4	44.5	45.6	46.7	47.8	48.9	50.0	51.2	52.3	53.4	54.5
4	30.7	31.8	32.8	33.9	35.0	36.1	37.2	38.3	39.4	40.5	41.6	42.8	43.9	45.0	46.1	47.2	48.3	49.5	50.6	51.7	52.9	54.0	55.1	56.3
5	32.1	33.2	34.3	35.4	36.5	37.6	38.7	39.9	41.0	42.1	43.2	44.4	45.5	46.6	47.7	48.9	50.0	51.2	52.3	53.5	54.6	55.8	56.9	58.1

6	33.5	34.7	35.8	36.9	38.0	39.2	40.3	41.4	42.6	43.7	44.8	46.0	47.1	48.3	49.4	50.6	51.7	52.9	54.1	55.2	56.4	57.6	58.7	59.9
7	35.0	36.2	37.3	38.4	39.6	40.7	41.9	43.0	44.2	45.3	46.5	47.7	48.8	50.0	51.2	52.3	53.5	54.7	55.9	57.1	58.3	59.4	60.6	61.8
8	36.6	37.7	38.9	40.0	41.2	42.3	43.5	44.7	45.9	47.0	48.2	49.4	50.6	51.8	53.0	54.1	55.3	56.5	57.7	59.0	60.2	61.4	62.6	63.8
9	38.1	39.3	40.5	41.6	42.8	44.0	45.2	46.4	47.6	48.8	50.0	51.2	52.4	53.6	54.8	56.0	57.2	58.4	59.7	60.9	62.1	63.4	64.6	65.8
10	39.7	40.9	42.1	43.3	44.5	45.7	46.9	48.1	49.3	50.6	51.8	53.0	54.2	55.5	56.7	57.9	59.2	60.4	61.7	62.9	64.2	65.4	66.7	67.9
11	41.4	42.6	43.8	45.0	46.3	47.5	48.7	49.9	51.2	52.4	53.7	54.9	56.1	57.4	58.6	59.9	61.2	62.4	63.7	65.0	66.3	67.5	68.8	70.1
12	43.1	44.3	45.6	46.8	48.1	49.3	50.6	51.8	53.1	54.3	55.6	56.8	58.1	59.4	60.7	62.0	63.2	64.5	65.8	67.1	68.4	69.7	71.0	72.4
13	44.9	46.1	47.4	48.6	49.9	51.2	52.5	53.7	55.0	56.3	57.6	58.9	60.2	61.5	62.8	64.1	65.4	66.7	68.0	69.3	70.7	72.0	73.3	74.7
14	46.7	48.0	49.3	50.5	51.8	53.1	54.4	55.7	57.0	58.3	59.6	60.9	62.3	63.6	64.9	66.3	67.6	68.9	70.3	71.6	73.0	74.4	75.7	77.1
15	48.6	49.9	51.2	52.5	53.8	55.1	56.4	57.8	59.1	60.4	61.8	63.1	64.5	65.8	67.2	68.5	69.9	71.3	72.6	74.0	75.4	76.8	78.2	79.6
16	50.5	51.8	53.2	54.5	55.8	57.2	58.5	59.9	61.2	62.6	64.0	65.3	66.7	68.1	69.5	70.9	72.3	73.7	75.1	76.5	77.9	79.3	80.8	82.2
17	52.5	53.9	55.2	56.6	58.0	59.3	60.7	62.1	63.5	64.9	66.3	67.7	69.1	70.5	71.9	73.3	74.8	76.2	77.6	79.1	80.5	82.0	83.5	84.9
18	54.6	56.0	57.4	58.8	60.2	61.6	63.0	64.4	65.8	67.2	68.6	70.1	71.5	73.0	74.4	75.9	77.3	78.8	80.3	81.8	83.3	84.8	86.3	87.8
19	56.8	58.2	59.6	61.0	62.4	63.9	65.3	66.8	68.2	69.7	71.1	72.6	74.1	75.5	77.0	78.5	80.0	81.5	83.1	84.6	86.1	87.6	89.2	90.7
20	59.0	60.4	61.9	63.3	64.8	66.3	67.7	69.2	70.7	72.2	73.7	75.2	76.7	78.2	79.8	81.3	82.8	84.4	85.9	87.5	89.1	90.7	92.2	93.8
21	61.3	62.8	64.3	65.8	67.3	68.8	70.3	71.8	73.3	74.9	76.4	77.9	79.5	81.1	82.6	84.2	85.8	87.4	89.0	90.6	92.2	93.8	95.4	97.1
22	63.8	65.3	66.8	68.3	69.8	71.4	72.9	74.5	76.1	77.6	79.2	80.8	82.4	84.0	85.6	87.2	88.9	90.5	92.1	93.8	95.5	97.1	98.8	100.5
23	66.3	67.8	69.4	71.0	72.5	74.1	75.7	77.3	78.9	80.5	82.2	83.8	85.4	87.1	88.7	90.4	92.1	93.8	95.5	97.2	98.9	100.6	102.4	104.1
24	68.9	70.5	72.1	73.7	75.3	77.0	78.6	80.3	81.9	83.6	85.2	86.9	88.6	90.3	92.0	93.8	95.5	97.2	99.0	100.7	102.5	104.3	106.1	107.9
25	71.7	73.3	75.0	76.6	78.3	80.0	81.7	83.3	85.1	86.8	88.5	90.2	92.0	93.7	95.5	97.3	99.1	100.9	102.7	104.5	106.3	108.2	110.0	111.9
26	74.6	76.3	78.0	79.7	81.4	83.1	84.8	86.6	88.4	90.1	91.9	93.7	95.5	97.3	99.2	101.0	102.9	104.7	106.6	108.5	110.4	112.3	114.2	116.2
27	77.6	79.4	81.1	82.9	84.6	86.4	88.2	90.0	91.9	93.7	95.5	97.4	99.3	101.2	103.1	105.0	106.9	108.8	110.8	112.7	114.7	116.7	118.7	120.7
28	80.8	82.6	84.4	86.3	88.1	89.9	91.8	93.7	95.6	97.5	99.4	101.3	103.3	105.2	107.2	109.2	111.2	113.2	115.2	117.3	119.3	121.4	123.5	125.6
29	84.2	86.1	87.9	89.8	91.7	93.7	95.6	97.5	99.5	101.5	103.5	105.5	107.5	109.5	111.6	113.7	115.7	117.8	120.0	122.1	124.2	126.4	128.6	130.8
30	87.8	89.7	91.7	93.6	95.6	97.6	99.6	101.6	103.7	105.7	107.8	109.9	112.0	114.2	116.3	118.5	120.6	122.8	125.1	127.3	129.5	131.8	134.1	136.4

31	91.6	93.6	95.6	97.7	99.7	101.8	103.9	106.0	108.2	110.3	112.5	114.7	116.9	119.1	121.4	123.6	125.9	128.2	130.5	132.9	135.3	137.7	140.1	142.5
32	95.7	97.8	99.9	102.0	104.2	106.3	108.5	110.7	113.0	115.2	117.5	119.8	122.1	124.5	126.8	129.2	131.6	134.0	136.5	139.0	141.5	144.0	146.6	149.1
33	100.0	102.2	104.4	106.6	108.9	111.2	113.5	115.8	118.2	120.5	122.9	125.4	127.8	130.3	132.8	135.3	137.8	140.4	143.0	145.6	148.3	150.9	153.7	156.4
34	104.7	107.0	109.3	111.7	114.0	116.4	118.9	121.3	123.8	126.3	128.8	131.4	134.0	136.6	139.2	141.9	144.6	147.4	150.1	152.9	155.7	158.6	161.5	164.4
35	109.7	112.2	114.6	117.1	119.6	122.2	124.7	127.3	129.9	132.6	135.3	138.0	140.8	143.6	146.4	149.2	152.1	155.0	158.0	161.0	164.0	167.1	170.2	173.3
36	115.2	117.8	120.4	123.0	125.7	128.4	131.1	133.9	136.7	139.5	142.4	145.3	148.3	151.3	154.3	157.3	160.5	163.6	166.8	170.0	173.3	176.6	179.9	183.3
37	121.3	124.0	126.8	129.6	132.4	135.3	138.2	141.2	144.2	147.3	150.3	153.5	156.7	159.9	163.1	166.5	169.8	173.2	176.7	180.2	183.7	187.3	191.0	194.7
38	127.9	130.8	133.8	136.8	139.9	143.0	146.2	149.4	152.6	155.9	159.2	162.6	166.1	169.6	173.2	176.8	180.4	184.2	188.0	191.8	195.7	199.7	203.7	207.7
39	135.3	138.5	141.7	145.0	148.3	151.7	155.1	158.6	162.1	165.7	169.4	173.1	176.9	180.7	184.7	188.7	192.7	196.8	201.0	205.3	209.6	214.0	218.5	223.0
40	143.7	147.1	150.6	154.2	157.8	161.5	165.3	169.1	173.0	177.0	181.1	185.2	189.4	193.7	198.1	202.5	207.1	211.7	216.4	221.1	226.0	231.0	236.0	241.1
41	153.2	157.0	160.9	164.8	168.9	173.0	177.2	181.5	185.8	190.3	194.8	199.5	204.2	209.1	214.0	219.1	224.2	229.4	234.8	240.2	245.8	251.5	257.2	263.1
42	164.3	168.6	172.9	177.3	181.9	186.5	191.3	196.1	201.1	206.2	211.4	216.7	222.2	227.7	233.4	239.2	245.2	251.3	257.5	263.8	270.3	276.9	283.6	290.5
43	177.5	182.3	187.3	192.4	197.6	202.9	208.4	214.0	219.8	225.8	231.8	238.1	244.5	251.0	257.7	264.6	271.7	278.9	286.3	293.8	301.5	309.4	317.4	325.7
44	193.6	199.3	205.1	211.0	217.2	223.5	230.0	236.7	243.6	250.8	258.1	265.6	273.3	281.2	289.4	297.8	306.3	315.1	324.1	333.3	342.8	352.4	362.3	372.4
45	214.1	220.9	227.9	235.2	242.7	250.4	258.4	266.7	275.3	284.1	293.3	302.6	312.3	322.3	332.5	343.0	353.8	364.9	376.2	387.9	399.8	412.0	424.5	437.4
46	241.5	250.0	258.9	268.2	277.8	287.8	298.1	308.8	319.9	331.4	343.3	355.5	368.1	381.1	394.5	408.3	422.5	437.1	452.0	467.4	483.3	499.6	516.3	533.5
47	280.9	292.4	304.4	316.9	330.0	343.6	357.8	372.5	387.7	403.4	419.8	436.6	454.1	472.1	490.7	509.9	529.8	550.4	571.7	593.8	616.7	640.5	665.3	691.0
48	344.1	360.9	378.4	396.8	416.0	436.0	456.9	478.6	501.2	524.7	549.3	574.8	601.5	629.4	658.6	689.3	721.5	755.6	791.5	829.7	870.4	913.9	960.6	1011.2
49	461.1	488.4	517.2	547.5	579.4	613.1	648.8	686.7	727.0	770.1	816.4	866.4	920.8	980.4	1046.2	1119.9	1203.3	1299.7	1413.6	1553.1	1732.9	1986.3	2419.6	>2419.6

Annex VI. Types of water samples a-b) Kharaa river in Burentolgoi Darkhan downstream c) Kharaa river in Tunkhel upstream d) Kharaa river in Deed gur Darkhan upstream e-h) Typical private wells in Darkhan i-j) Wastewater effluent k-m) Water kiosks





m



n



o



p

