

The present work was submitted to the Faculty of Engineering

**INFLUENCE OF PIT LATRINES ON PRIVATE WELLS' WATER QUALITY IN
GER SETTLEMENT AREA (NALAIKH DISTRICT, ULAANBAATAR)**

Bachelor Thesis

by

Munkhzorig Nyamkhuu

First supervisor: **Dr. Ariuntuya.Ts, GMIT**

Second supervisor: **Enkhjargal.S, GMIT**

Ulaanbaatar/Nalaikh, 2022, May 16

STATUTORY DECLARATION

Nyamkhuu Munkhzorig
Last Name, First Name

15011476969557
Student ID Number

I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis

Influence of pit latrines on private wells' water quality in ger settlement area (Nalaikh district, Ulaanbaatar)

I did not use any sources other than those stated. In case that the work is additionally submitted on a data medium, I declare that the written and the electronic form are completely identical. The work was not submitted in the same or similar form to any examination authority.

Ulaanbaatar, Mongolia
Place, Date


Signature

TABLE OF CONTENTS

STATUTORY DECLARATION.....	2
LIST OF FIGURES	5
LIST OF TABLES	6
ABSTRACT	7
1. INTRODUCTION	9
1.1 STATEMENT OF THE PROBLEM.....	9
1.2 STUDY AIMS AND OBJECTIVES.....	12
2. STATE OF ART	13
2.1 GROUND WATER RESOURCE IN NALAIKH.....	13
2.2 PIT LATRINE COVERAGE IN NALAIKH	14
2.3 GROUNDWATER AND SOIL CONTAMINATION FROM PIT LATRINES.....	16
2.4 COLIFORM BACTERIA	17
2.4.1 TOTAL COLIFORM	18
2.4.2 FECAL COLIFORM	18
2.4.3 ESCHERICHIA COLI	18
2.5 CHEMICAL CONTAMINANTS	19
2.5.1 NITRATES	19
2.5.2 AMMONIA	19
2.5.3 CHLORIDE	19
2.6 HEAVY METALS.....	21
3 STUDY AREA.....	22
4 METHODOLOGY	24
4.1 SAMPLE COLLECTION	24
4.1.1 WELL WATER SAMPLING	24
4.1.2 SOIL SAMPLING	25
4.2 ANALYSIS METHOD.....	28

4.2.1	COLIFORM BACTERIA	28
4.2.2	CHEMICAL PARAMETERS.....	29
4.2.3	HEAVY METALS IN SOIL AND CALCULATION.....	30
4.2.4	SOIL TEXTURE	31
4.2.5	SOIL PH.....	32
5.	RESULTS & DISCUSSION	33
5.1	RESULT OF THE WATER SAMPLES.....	33
5.2	RESULT OF THE SOIL SAMPLES	36
6.	CONCLUSION AND RECOMMENDATION	40
	REFERENCES.....	41
	APPENDICES.....	43
	ANNEX 1 INSTRUCTION OF COLILERT QUANTI-TRAY, 51 WELLS.....	43
	ANNEX 2 IDEXX 51-WELL QUANTI-TRAY MPN TABLE	44
	ANNEX 3 SOIL INORGANIC (HEAVY METAL) CONTAMINANTS MAXIMUM PERMISSIBLE LEVEL (MG / KG).....	45
	ANNEX 4 SOIL SAMPLES TEXTURE ANALYSIS BY SOIL TEXTURE TRIANGLE .	46
	ANNEX 5 EQUIPMENT USED FOR WATER SAMPLE ANALYSIS.....	47
	ANNEX 6 DRINKING WATER QUALITY AND SAFETY MONITORING INDICATORS	
	48	
	ANNEX 7 WATER AND SOIL SAMPLING SITES	49
	ANNEX 8 MAPS OF 1 ST SUB-DISTRICT GENERATED BY ARCGIS.....	50

LIST OF FIGURES

Figure 1 Population using pit latrines for sanitation	11
Figure 2 Population using groundwater for drinking	11
Figure 3 Ger settlement area by districts.....	15
Figure 4 Pit latrines in 1st sub-district, Nalaikh.....	15
Figure 5 Groundwater and soil contamination from ger settlement area	16
Figure 6 Soil sampling points in Ulaanbaatar ger settlement area	17
Figure 7 Coliform bacteria	17
Figure 8 Population of subdistricts, Nalaikh district	22
Figure 9 1st sub-district, Nalaikh	22
Figure 10 Landscape profile of 1st sub-district, Nalaikh	23
Figure 11 Map illustrating water sampling points.....	24
Figure 12 Soil profile of sampling area	25
Figure 13 Soil sampling points, 1st sub-district	27
Figure 14 Soil sampling points with the illustration of lowest point	27
Figure 15 Samples in Quanti-Tray after incubation	28
Figure 16 Colilert-18 Working Principle	29
Figure 17 Measurement of nitrite concentration using NitriVer reagent.....	29
Figure 18 Measurement of iron concentration using FerroVer	30
Figure 19 Soil sample preparation for XRF analysis	30
Figure 20 Dry sieving method.....	32
Figure 21 pH measurement process	32
Figure 22 Coliform concentrations of water samples.....	34
Figure 23 Soil texture triangle, (Source: United States Department of Agriculture website).....	37

LIST OF TABLES

Table 1 Types of well.....	14
Table 2 Major chemical contaminants in drinking water	20
Table 3 Global chemical contamination.....	20
Table 4 Deep well information (1st subdistrict).....	23
Table 5 Well water sampling point.....	25
Table 6 Coordinates of soil sample points.....	26
Table 7 Water sampling data.....	33
Table 8 Coliform bacteria analysis data in each sample.....	35
Table 9 Chemical parameters in each sample	35
Table 10 Measurements of physical characteristics of soil samples	36
Table 11 The measured concentration of heavy metals (mg/kg) by mobile XRF (X-ray fluorescence)	38
Table 12 Calculation of geo-accumulation index in soil samples.....	38
Table 13 Geo-accumulation index proposed by Muller (1979)	39
Table 14 Calculation of Pollution Load Index for each heavy metals	39

ABSTRACT

This bachelor thesis focuses on the impacts of pit latrines on groundwater quality. Impacts of pit latrines on groundwater quality associated with microbiological and chemical contamination of groundwater are the main concerns. Apart from this, those contaminants could be transported by runoff to surface water because of the geographic condition of the land area of the 1st sub-district. Therefore, there is important to study for assessing the current situation.

Ger settlement area in Nalaikh district is not connected to the central water supply system. In that case, sanitation facilities and drinking water quality in ger area are important concerns. Most households in the ger area are using pit latrines for their sanitation besides there are some households and industries that have their own wells for drinking water. The main research area is 1st sub-district of the Nalaikh district where a number of households, organizations, and industries have more private wells than the other sub-district. Feces contamination from pit latrine could potentially leach into the ground and might be polluting soil through well water.

In this study, water from three wells, including a private well, a flowing artesian well, and tap water from Khos-Uyanga secondary school, were collected from the 1st sub-district of Nalaikh district once a month between January and April. Moreover, a total of 14 soil samples were collected from the 1st sub-district ger settlement area. During this thesis work, the analysis of coliform bacteria in well water samples and heavy metal concentration in soil samples were conducted. The highest bacterial contamination was detected in the secondary school tap water, which was 200.5 MPN per 100ml of the total coliform concentration and 13.7 MPN per 100 ml of E. coli as well as Fecal coliform compared to MNS 4943:2015.

A total of 13 heavy metals concentrations were recorded and compared with the standard of MNS 5850:2008. The exceeded concentration of metals cobalt, copper, zinc, and arsenic was determined. However, at some sample points, the heavy metal concentration was found the limit detection by XRF. In order to more accurately determine soil contamination, calculations were made on the geo-accumulation index the contamination factor, and the pollution load index.

ACKNOWLEDGEMENT

Foremost, I would like to express my sincere gratitude to my supervisors Dr. Ariuntuya Tserendorj and Mrs. Enkhjargal Sodnomdarjaa for the continuous support of my bachelor thesis, their guidance helped me in all the time of research and writing of this thesis.

I am thankful that Dr. Ariuntuya Tserendorj helped and guided me through the whole process of working in the environmental laboratory and was always ready to ask me for help.

My sincere thanks also go to Mrs. Enkhjargal Sodnomdarjaa for suggesting this thesis topic and for supervising me during the soil sampling experiment.

I would also like to thank Mr. Baasandorj Myagmarsuren and Ms. Narangarav Terbish, for providing me with the opportunity to work in the Process Laboratory.

In addition, I would like to thank the family in the 1st sub-district who provided the water samples, the staff of Khos-Uyanga Secondary School, and my family members and friends who helped transport the water and soil samples to the laboratory.

Last but not the least, I would like to wish to extend my special thanks to the teachers, staff and friends who have always supported and provided valuable advice during my years at the German Mongolian Institute for Resources and Technology.

1. INTRODUCTION

1.1 STATEMENT OF THE PROBLEM

In Mongolia, due to unexpected urbanization, the Ger settlement area has become a major cause of concern in Ulaanbaatar city. Apart from electricity, there are significant disparities in access to heat, water, sanitation, and disposal between the Ger area and the apartment. Ger settlement area that is not connected to the central water supply and sewerage system. All environmental pollution of Ulaanbaatar, air, soil, and water is directly related to the Ger settlement area. For instance, the heating process in winter and pit latrines in summer from the ger area significantly increase air pollution, and soil and water contamination respectively.

In such a situation, the drinking water supply and sanitation facilities in ger settlement areas are critical issues to solve step by step. My thesis topic is going to study pit latrines' impact on the drinking water system. The majority of households in the ger area utilize pit latrines for their sanitation. Some households and industries in ger settlement areas where have their own well for drinking water. The main problem associated with pit latrines is that feces contamination from pit latrine could potentially leach into the ground and the flow of pollution from latrines might be infiltrating through the soil and polluting deep well water. On a daily basis, 2.1 billion kilograms of urine and 0.6 billion kilograms of feces are retained in pit latrines across the world. As well that 2 billion people rely on groundwater as their primary source of drinking water in areas where pit latrines are common including Mongolia. Nearly 1.77 billion people adopt pit latrines as their major source of sanitation around the world, according to studies. Whereas, it is estimated that 48% of those who use pit latrines do so in improved facilities, while the rest use shared or unimproved ones. [1]

According to the Mongolian technical requirement for pit latrines and flush holes, pit latrines should be located as far away from gers and houses as possible, 15 meters from apartments, and service areas, 20 meters from water kiosks, 150 to 250 meters from mines, and drilled deep wells, and at least 200-250 meters from river banks. [2] In Mongolia, 61-80 percent of population uses groundwater for drinking and similarly, 61-80 percent of the population uses pit latrines for sanitation.[3]

Due to the increasing use of groundwater resources and pit latrines in Mongolia, there are concerns that pit latrines could have human and ecological health implications associated with microbiological and chemical pollution of groundwater. Most of the pit latrines in Mongolia generally have no physical barriers such as isolation between the latrine and the ground soil, such as concrete. It can be to make contaminants from pit latrine excrement into the percolation of groundwater, thereby endangering human health by contaminating well water. Since pit latrines are being used more often in low-income countries, there is significant concern that pit latrines may have adverse human and ecological health consequences as a result of groundwater pollution by microbiological and chemical contaminants.

From the previous study in Africa, microbes (usually coliforms) and chemicals (e.g., nitrate (NO_3^-), phosphate (PO_4^{3-}), chloride (Cl^-), and ammonia (NH_3)) have been correlated to pit latrine use in soil and local water sources in studies. Microbes and chemicals transported less than 15 meters from latrines on average, however other investigations found contamination up to 25 meters distant. Viruses were found 50 meters away from pit latrines. However, even for the same site, different research has obtained significantly varied outcomes, indicating a confounding range of experimental approaches. The majority of recorded groundwater pollution occurred downstream of pit latrines. [4]

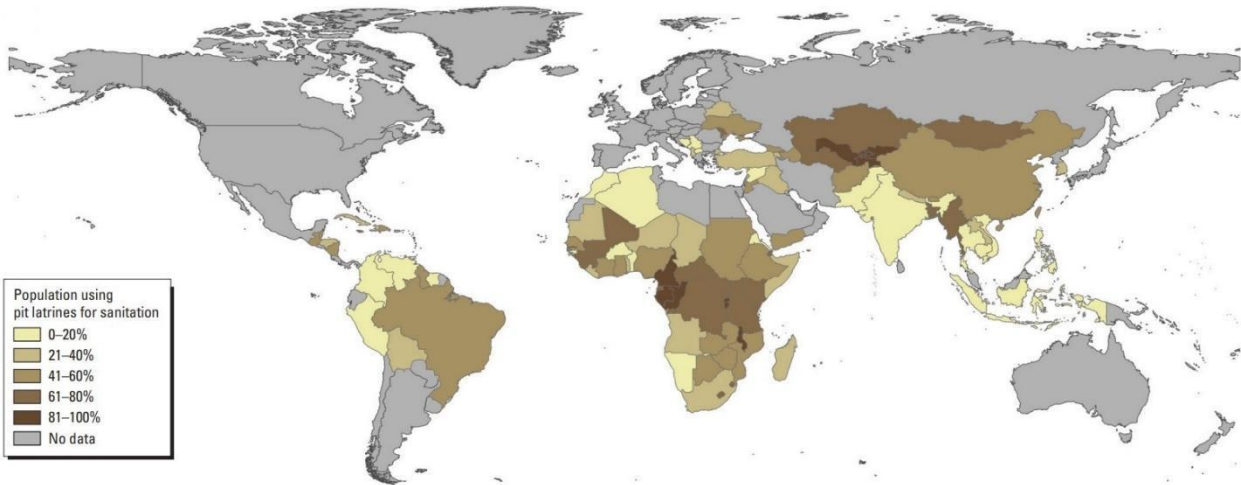


Figure 1 Population using pit latrines for sanitation

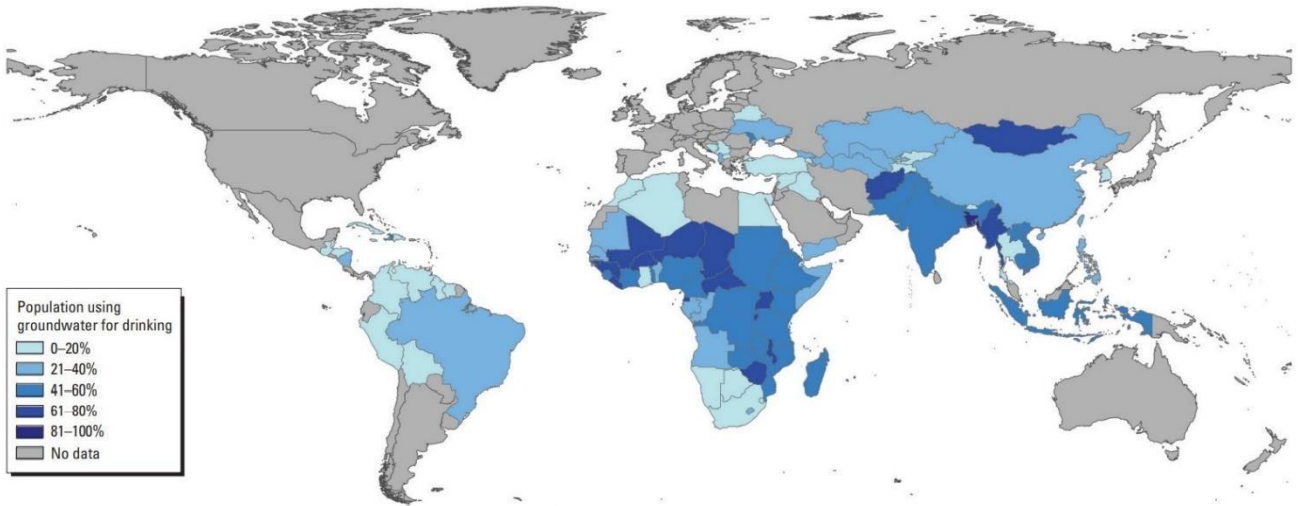


Figure 2 Population using groundwater for drinking

1.2 STUDY AIMS AND OBJECTIVES

The main objective of this bachelor thesis is to determine the impacts of pit latrines on the quality and composition of groundwater and soil in the 1st sub-district, Nalaikh district. To achieve this purpose, collecting microbiological and chemical, and heavy metals data in well water, as well as the soil, are going to analyze. Apart from this, the result could be assessed the geographic condition of the land area of the 1st sub-district and the recommendations on a comprehensive assessment of water and soil quality will be provided in the next implementation.

Questions:

- Is the quality of the water and soil sample to meet the Mongolian standards?
- Are pit latrines influencing the water quality in wells?

Objectives following the main objective:

- Determining what number of pit latrines in 1st sub-district and Nalaikh district
- Defining the existing water consumption of the 1st sub-district households and its supply system
- Making watershed analysis of 1st sub-district, Nalaikh district
- Defining quality of soil and well water and with statistical analysis
- Assessing the impact from pit latrine through public health.

2. STATE OF ART

2.1 GROUND WATER RESOURCE IN NALAIKH

Rivers, lakes, and groundwater are Mongolia's primary sources of water. Lakes are very abundant, accounting for 84 percent of all water resources. Many of the country's lakes are found in the northwestern mountains, while others can be found throughout the country. Only about 5% of all lakes have a surface area of more than 5 km². Mongolia's rainfall evaporates 70-90 percent of the time, with the rest replenishing rivers and groundwater. Mongolia has 500 km³ of annual water resources from lakes, 62.9 km³ from glaciers, 34.6 km³ from surface water, and 10.8 km³ from groundwater. Surface water contributes for 63.5 percent of these resources, while groundwater provides for 36.5 percent. Surface water resources contribute around 20% of Mongolia's water use, with the balance coming from groundwater. Classification in water consumption is followed by 18.1 percent is used for drinking and domestic uses, 39.3 percent is used for industry, 24.0 percent is used for animal husbandry, 17.4 percent is used for irrigation, and 1.2 percent is used for other purposes. [5]

Most groundwater resources are located in the Khangai region, mainly in large river valleys. For example, in Ulaanbaatar, the main source of centralized water supply exists large groundwater deposits along the Tuul river basin, which can be replenished. The Tuul flows for 704 kilometers from its source in the Khentii Mountains' Gorkhi-Terelj National Park, with a river basin comprising 49.84 square kilometers. It drains into the Selenge River, which discharges into Lake Baikal, after connecting with the Orkhon River. Around 150 wells have been built along the Tuul River to depths of 30-70 meters below ground level, supplying 170,000 m³ of groundwater per day to households.[6] According to a report conducted by the National Statistics Office of Mongolia in 2013, there are 256 deep wells in Nalaikh district. Of these, 37 of them are owned by households and 219 of them are owned by companies and organizations. The majority of the deep wells in Nalaikh district are drilled well.

Table 1 Types of well

Types of well	Definition
Dug well	A dug well usually consists of a large diameter hole that is usually over 2 feet wide, and it can be constructed by hand or using excavation equipment
Bored well	Bored wells are constructed using a boring machine and they usually have an average depth of about 15 m or 50 ft., although some wells are 30m or 100 ft. deep.
Driven point well	The sand-point or driven-point wells are constructed using assembled lengths of pipe that are driven into the ground. These wells are usually small in diameter- about 2 inches or less, and they are less than 50 feet in depth.
Drilled well	Drilled wells often refer to all the other types of wells, and this includes those that are constructed using a combination of driving and jetting. Drilled wells for farm use are usually 4 to 8 inches in diameter and they pose a low risk of contamination when properly constructed. Drilled wells can get water from bedrock aquifers and overburden.

2.2 PIT LATRINE COVERAGE IN NALAIKH

A soil contamination and ecological risk assessment from ger settlement area pit latrines in Ulaanbaatar committed on behalf of the Ulaanbaatar Mayor's Office by the Mongolian Academy of Sciences' Institute of Geography-Geoecology identified 144,992 pit latrines in seven districts of Ulaanbaatar city including Bayanzurkh, Bayangol, Chingeltei, Khan-Uul, Nalaikh, Sukhbaatar, and Songinokhairkhan. The purpose of this work was that determine the number and location of pit latrines in the ger district of the capital city, create a database (GIS), assess the environmental and human health impacts of pit latrines, and prohibit the use of pit latrines in the restricted area. [7]

In the Mongolian situation, the capital city of Ulaanbaatar is home to 1.4 million people (414,292 households), half of the country's population. Of these, 208049 households live in ger settlement areas, and 206243 households live in the apartment area. In contrast, 206248 households, who live in ger area, are heated on a simple stove in both traditional Mongolian gers and small homes. [8]

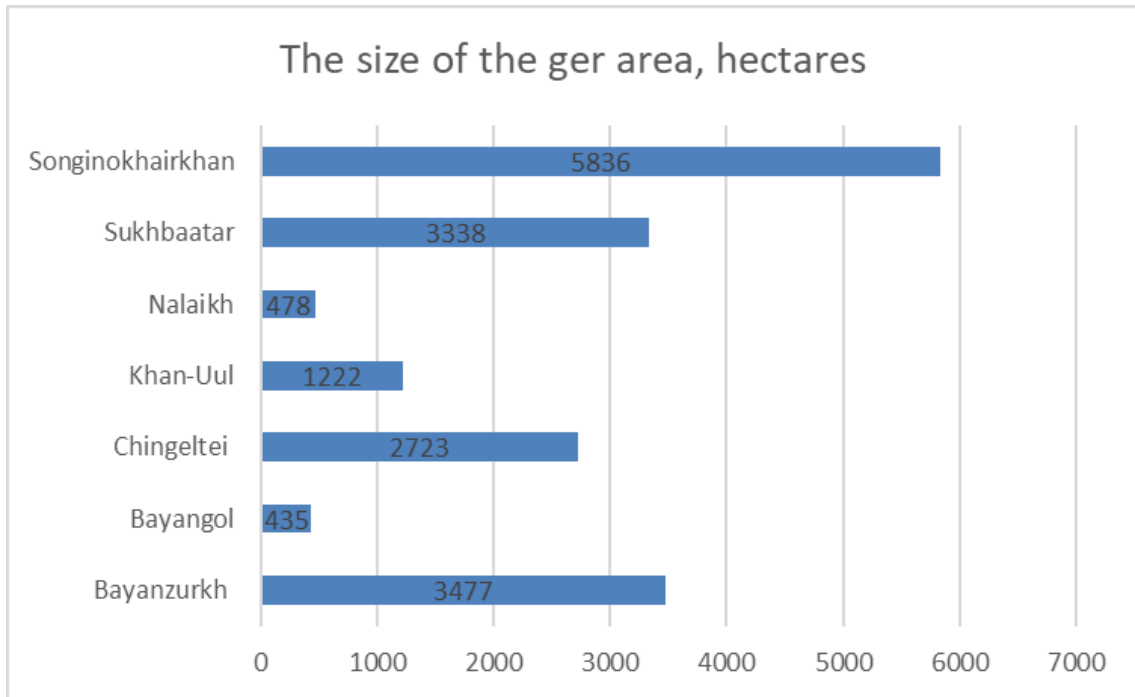


Figure 3 Ger settlement area by districts

There are 10,388 households in Nalaikh district, of which 2582 live in the apartment area and 7806 live in the ger settlement areas. So, it was assumed that there are such pit latrines based on the population of ger settlement area in Nalaikh district. [8]

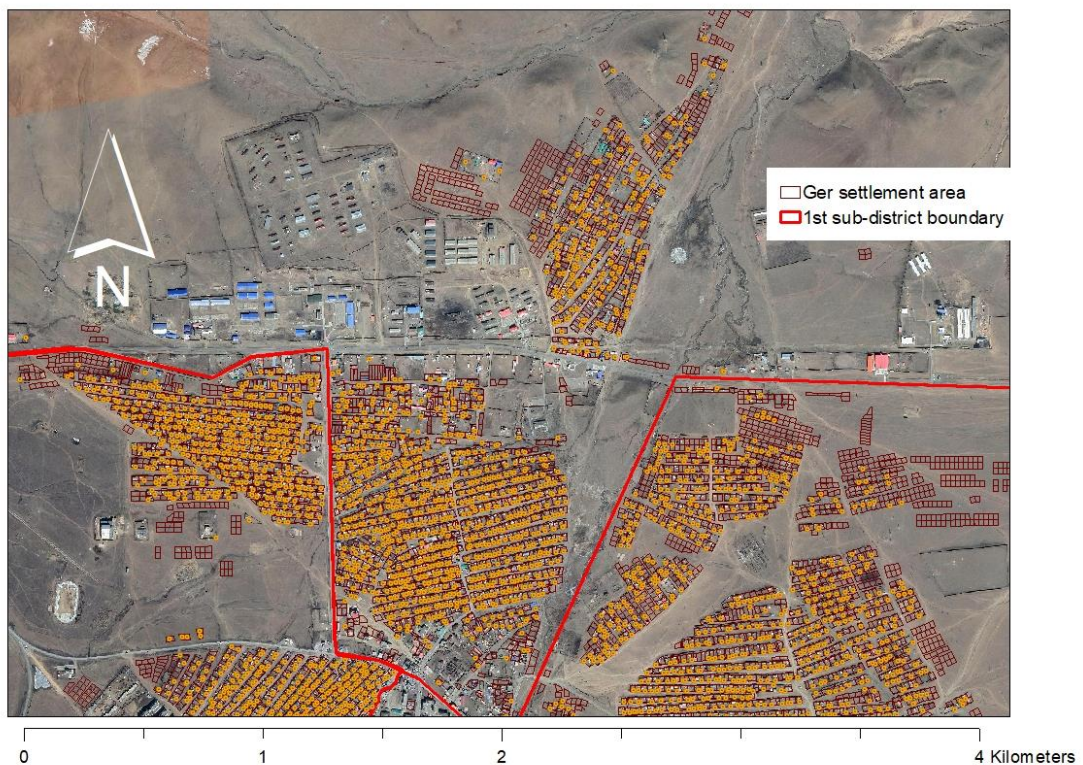


Figure 4 Pit latrines in 1st sub-district, Nalaikh

In this risk assessment from Mongolian Academy of Sciences' Institute of Geography-Geo-ecology, the principles of pollution index PI (Hakanson 1980) and pollution load index PLI (Tomlinson 1980) were used to assess the negative impact of pit latrines. Pit latrines in Ulaanbaatar's ger settlement areas will be assessed for each of the multiple spatial criteria as a pollution assessment or PI of 1-5, and the total pollution assessment will be calculated as a sum of n for a total pollution assessment (PLI) of 1-5. [7]

$$KLI = \frac{(PI1 + PI2 + PI3 + \dots \dots PIn)1}{n}$$

n - Number of indicators

KI - negative impact index

2.3 GROUNDWATER AND SOIL CONTAMINATION FROM PIT LATRINES

In Ulaanbaatar's ger settlement areas, the average depth of maximum microbiological contamination is 2.8 meters. At this level, soil bacterial contamination is mainly prevalent in the ger settlement area, which is 1.5-3.0 meters deep. The deepest part of bacterial contamination in soil is 6.3 meters on average. There is considerable potential for groundwater pollution in the long term, as well as the spreading of intestinal diseases among the population. At a depth of 47 meters, E.Coli was identified in the water. The water in wells 1.5 meters deep at the surface is severely polluted with E.Coli and Proteus bacteria. [7]



Figure 5 Groundwater and soil contamination from ger settlement area

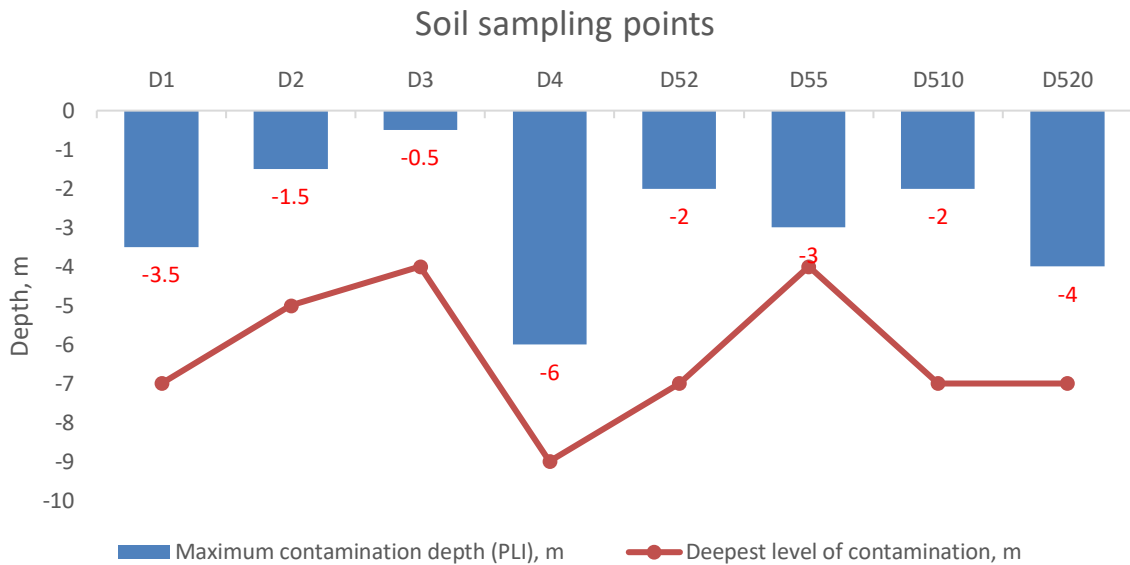


Figure 6 Soil sampling points in Ulaanbaatar ger settlement area

2.4 COLIFORM BACTERIA

In the late nineteenth and early twentieth centuries, hygienic procedures for the processing and disposal of sewage were created in the United States. A number of researchers and state organizations have been recording national statistics on aquatic illness outbreaks caused by bacteria, chemicals, or unknown etiologies since 1920.

Drinking water should ideally be absent of pathogenic (disease-causing) microorganisms as well as pathogens associated with feces contamination. In practice, the detection of thermotolerant (fecal) coliform bacteria is an acceptable alternative to the detection of *Escherichia coli*, which gives definitive evidence of fecal contamination. [9]

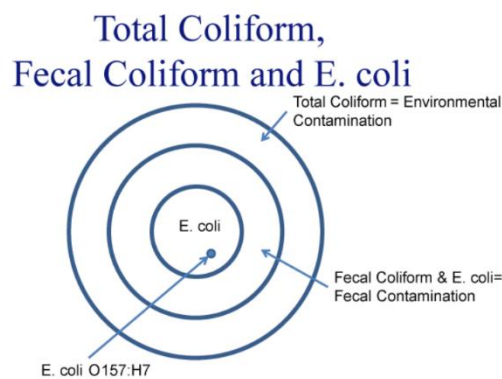


Figure 7 Coliform bacteria

2.4.1 TOTAL COLIFORM

Bacteria are common in the environment (soil or vegetation) and are generally harmless. Total coliform bacteria in drinking water typically doesn't have a health risk associated with it and if water testing only detects it, the source is probably environmental and not fecal contamination. Total coliform bacteria are often considered an indicator there may be something more serious contaminating a drinking water system, specifically E. coli bacteria. Total coliform bacteria are colorless, odorless, and tasteless and the only way they can be detected in drinking water is through submitting a sample for laboratory testing.[9]

2.4.2 FECAL COLIFORM

Bacteria are a subgroup of total coliform bacteria. They exist in the intestines and feces of people and animals. The fecal coliform group includes all of the rod-shaped bacteria that are non-spore-forming, Gram-Negative, lactose-fermenting in 24 hours at 44.5 °C, and which can grow with or without oxygen. [9]

Fecal coliform by themselves is usually not pathogenic; they are indicator organisms, which means they may indicate the presence of other pathogenic bacteria. Pathogens are typically present in such small amounts that it is impractical to monitor them directly.

2.4.3 ESCHERICHIA COLI

E. coli is a subgroup of the fecal coliform group. Most E. coli bacteria are harmless and exist in the intestines of people and warm-blooded animals. But some strains can cause illness. The presence of E. coli in a drinking water sample typically implies fecal contamination that occurred recently. This indicates that pathogens are more likely to be present. [9]

2.5 CHEMICAL CONTAMINANTS

Drinking water sources near pit latrines are likely to contain various chemical contaminants, with nitrates, ammonia, chloride and arsenic being the main chemical contaminants. Otherwise, ground and surface water can be contaminated by wastewater discharges, agricultural runoff, uncontrolled discharges or leaks from industrial operations or landfill sites, and chemical catastrophes and disasters. One of the biggest concerns about water quality and public health is the potential long-term impacts of chronic exposure to chemicals found in drinking water, even at low quantities. [10] In addition, nitrite, sulfate, phosphate and arsenic contamination from pit latrines can be observed in groundwater, even if it is below than the standard level. The following chemical contaminants are the main determinants of drinking water from sources close to the pit latrines.

2.5.1 NITRATES

Nitrate has been the most thoroughly observed chemical pollutant caused from pit latrines due to high nitrogen concentrations in human excreta, its negative health effects, and its usage as a fecal contamination indicator. Methemoglobinemia is reported to be caused by excessive nitrate levels in drinking water, and correlations with cancer in people have been reported, but not regularly. Latrines, plant waste, animal feces, rubbish dumps, soil, and fertilizers are all possible sources of nitrate in urban and rural areas. [1] Nitrate in drinking water should not exceed 50 mg/L, according to World Health Organization guidelines.

2.5.2 AMMONIA

From the previous studies, ammonia has not been observed to accumulate noticeably in groundwater near latrines, either directly from latrine waste or as a result of denitrification of nitrate discharged by latrines. Under anaerobic circumstances, ammonia tends to concentrate and persevere, and significant quantities are anticipated when the water table contacts the base of the latrine pit. [1]

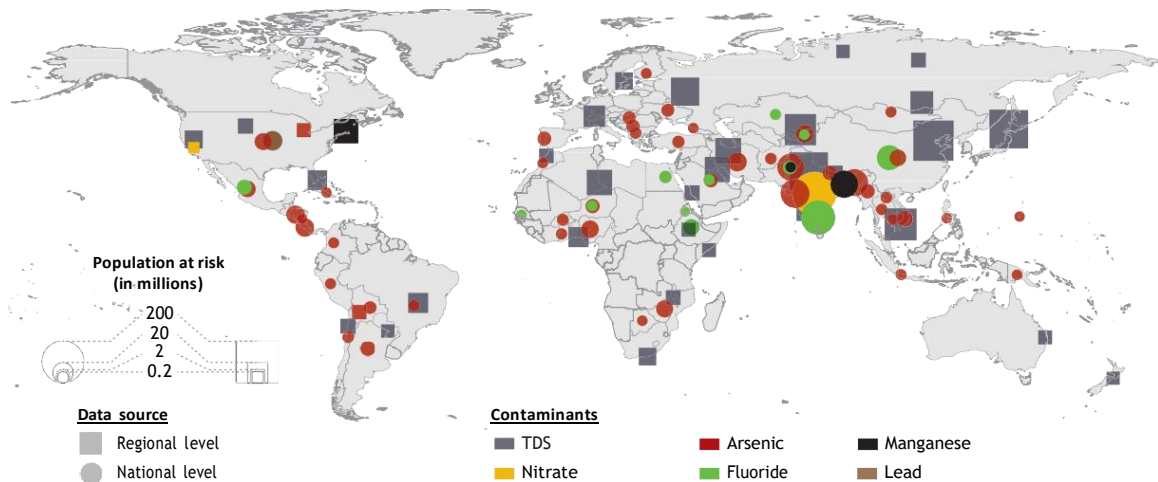
2.5.3 CHLORIDE

Because of its high concentrations in feces and considerable mobility in the underground, chloride has been the most extensively examined chemical indication of latrine pollution in groundwater. But while chlorine in drinking water causes no recognized health hazards, concentrations greater than 250 mg/L may impact the flavor and acceptability of water according to the World Health Organization. [3]

Table 2 Major chemical contaminants in drinking water

Contaminant	Sources in drinking water	Primary effects on human health	WHO	EPA	BIS
Arsenic	Geogenic (mining, smelting)	Cancer, skin effects, liver disease, diabetes	10 µg/L	10 µg/L	10 µg/L
Cadmium	Geogenic, plumbing, mining, industry, landfills, sewage sludge, fertilizers, urban areas	Kidney disfunction, bone toxicity	3 µg/L	NA	3 µg/L
Chromium	Geogenic, electroplating/textile industries, wood treatment, corrosion control	Cancer	50 µg/L	100 µg/L	50 µg/L
Fluoride	Geogenic (fertilizers, aluminum refineries)	Mottled tooth enamel, bone deformities (fluorosis)	1.5 mg/L	4 mg/L	1 mg/L
Lead	Corroding pipes, faucets, and plumbing fixtures (geogenic)	Cognitive and developmental impairment, hypertension	10 µg/L	15 µg/L	10 µg/L
Manganese	Geogenic, industry, mining, landfills	Cognitive, motor, and speech impairment	400 µg/Ld	50 µg/L	100 µg/L
Nitrate	Fertilizers, manure (septic tanks, wastewater)	Methemoglobinemia, cancer, thyroid disease, birth defects	50 mg/L	10 mg/L	45 mg/L
Selenium	Geogenic, coal mining, combustion	Parkinson's disease, ALS, cancer	40 µg/L	50 µg/L	10 µg/L
Uranium	Geogenic, mill tailings, nuclear activities, fossil fuel combustion, fertilizers	Kidney inflammation, cancer	30 µg/L	30 µg/L	NA
TDS	Geogenic, seawater intrusion (drainage from irrigated fields)	Hypertension, (pre)eclampsia	NA	500 mg/L	500 mg/L
EOCs	Pesticides, inadequate wastewater treatment, hospital discharge	Unknown; no consensus	Varying values for specific organic		

Table 3 Global chemical contamination



2.6 HEAVY METALS

Soil contamination with heavy metals and other chemicals is caused by the accumulation of solid, liquid, and gaseous pollutants in the soil, from both residential and industrial process. There is a considerable chance that the natural activity of elements such as copper, zinc, and chromium-cadmium in the soil may grow and accumulate throughout heavy metal pollution, negatively affecting living organisms through plants and water. On the other hand, soil pollution is also a high-risk source of contamination for surface and groundwater, air, and vegetation since soil cover provides the foundation for the transfer of environmental substances and energy.

There is a great chance that heavy metals with a density more than 5 mg/cm³ will be accumulated into plants and water and produce harmful health consequences in people and animals. [11]

Heavy metal cations, hydrocarbons, pesticides, nitrogenous chemicals, pharmaceutical residues, detergents, and phosphorus are the most prevalent chemical contaminants found in wastewater.

3 STUDY AREA

According to information from the Ulaanbaatar statistics office, Nalaikh, one of the 9 districts of Mongolia's Ulaanbaatar city, has 38929 residents and 8 sub-districts covering 687.6 square kilometers. The main research area, 1st sub-district of the Nalaikh district, has 6227 residents (1521 households) and is located west of the Nalaikh district. In this subdistrict, there is no apartment area and all of the citizens are from ger settlement area. [8] Apart from this, the primary feature of 1st subdistrict which made it to choose this subdistrict as a study area is a number of households, organizations, and industries such as military units, secondary school as well as meat industries using private wells for the purpose of drinking and irrigation. Landscape-ecological profile of 1st subdistrict has a gentle slope on the valley side. So that surface run-off with contaminants from those pit latrines could accumulate in the downstream in 1st subdistrict. (Figure 10)

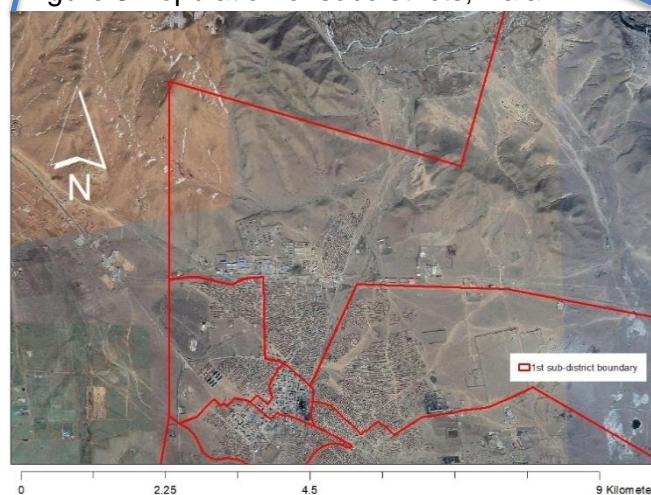
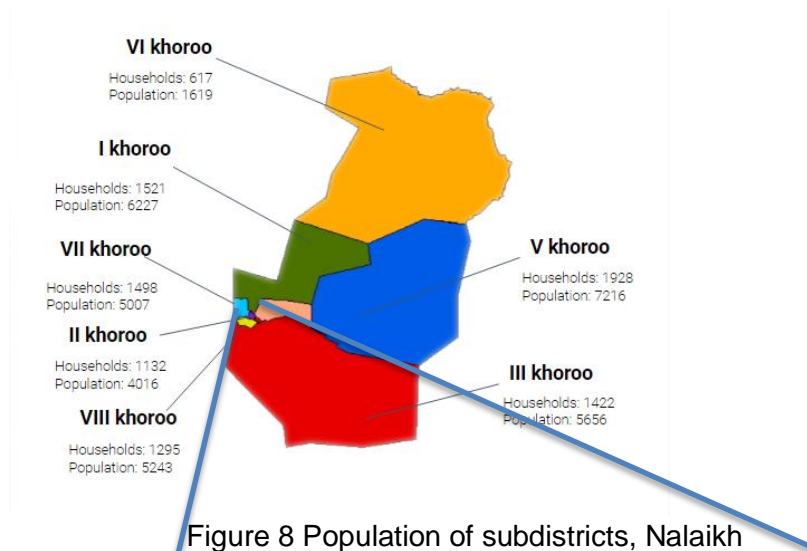


Table 4 Deep well information (1st subdistrict)

	№	Name	Address	Depth of well, m	Intended use	
					For drinking water	For irrigation water
	1	World vision, Private well	25-12 Uurkhaichid		+	+
Sampling point	2	Khos Uyanga secondary school, Private well	9-467 Uurkhaichid	80	+	
	3	Private well	9-5 Engershand			+
	4	014-military unit	2-b Engershand		+	+
Sampling point	5	Private well	13a-1 Engershand	70	+	+
Sampling point	6	Flowing artesian well	Engershand		+	+

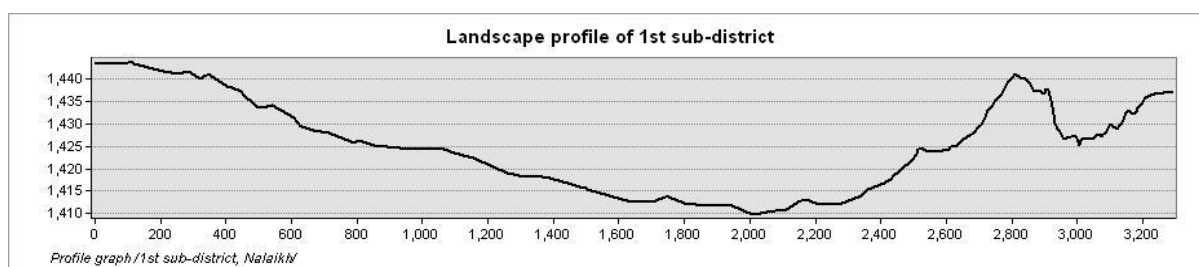


Figure 10 Landscape profile of 1st sub-district, Nalaikh

4 METHODOLOGY

4.1 SAMPLE COLLECTION

4.1.1 WELL WATER SAMPLING

For water sampling, water from three wells, including a private well, a flowing artesian well, and tap water, was collected from the 1st sub-district of Nalaikh district once a month between January and April. All the wells' depths are between 70-80 meters below and are used for drinking water and irrigation. Each sample was collected in sterile plastic bottles.

Flowing artesian wells are water wells in which groundwater is forced above the ground surface by the pressure in the aquifer, allowing the well to flow without the use of a pump. The water from the artesian well rushes up and freezes in the winter. Even if the artesian well was frozen, residents use it in the wintertime by breaking the ice structure.

A private well is used for domestic purposes supplying ger settlement area with need of a pump system. There are 3 households in the 1st sub-district that have private wells and one of them was chosen. Due to the family's refusal to provide water samples for several months, only one month's water sample was taken in January.

In the 1st sub-district, several organizations and industries rely on groundwater including meat industry, 014 military unit and Khos-Uyanga secondary school. Tap water sample is from the secondary school well and is taken between February and April.

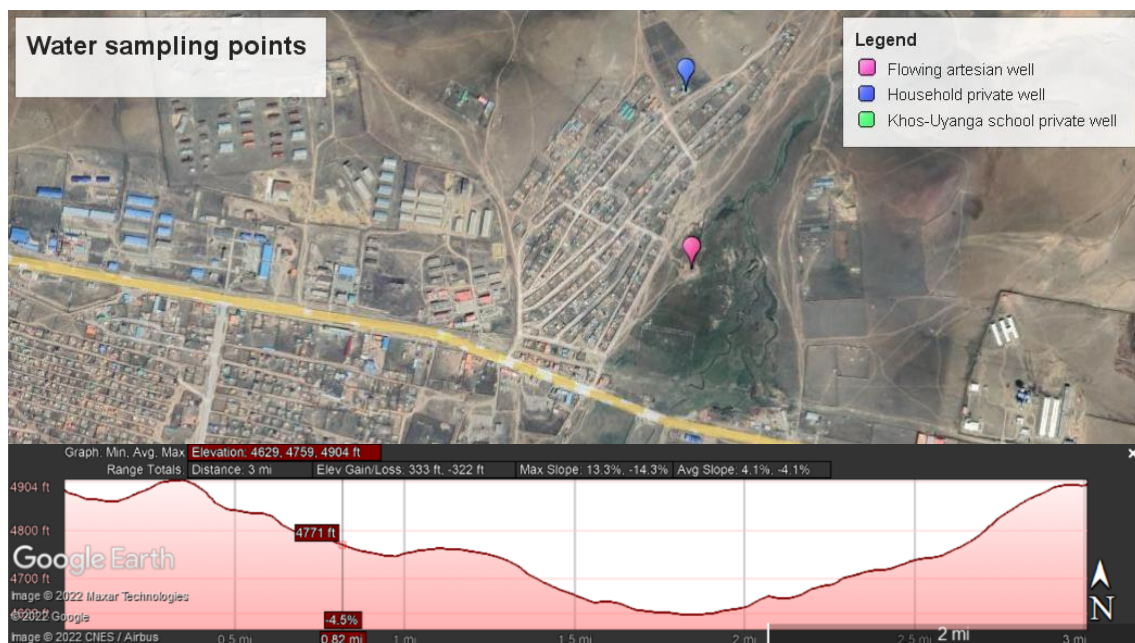


Figure 11 Map illustrating water sampling points

Table 5 Well water sampling point

Sample ID	Address	Type	Coordinates	
			North	East
1	Engershand	Flowing artesian well	47.791056	107.26871
2	Engershand 13a-1	Private well	47.796497	107.267987
3	Uurkhaichid 9-467	School tap water	47.781247	107.254828

4.1.2 SOIL SAMPLING

In total 14 soil samples were collected from the 1st sub-district ger settlement area. 12 of them were from the lowest point of the 1st sub-district at 1410 m above sea level and the rest of the soil sample was reference soil. There are two basic methods for soil sampling: zone-based sampling and grid sampling. However, fall is the best time for sampling, soil samples were collected in March. As a matter of fact, frozen soil was the main problem with the sampling. In this study, heavy metals were analyzed in the topsoil samples with a depth range between 0.15-0.3m. For marking the sampling bags, ST_01 to ST_09 are for the grid sampling and RF01 and RF02 are for the reference soil. SL_01 to SL_03 samples which show soil profiles between 0.15 to 0.5 m, were collected for the soil texture analysis of this study area. (Figure 12)



Figure 12 Soil profile of sampling area

Table 6 Coordinates of soil sample points

ID	Depth, m	Latitude	Longitude
SP_01	0.15	47°47'49.29"N	107°16'24.55"E
SP_02	0.15	47°47'49.03"N	107°16'25.99"E
SP_03	0.15	47°47'48.80"N	107°16'27.31"E
SP_04	0.15	47°47'48.36"N	107°16'24.11"E
SP_05	0.15	47°47'48.09"N	107°16'25.54"E
SP_06	0.15	47°47'47.87"N	107°16'26.91"E
SP_07	0.15	47°47'47.48"N	107°16'23.73"E
SP_08	0.15	47°47'47.20"N	107°16'25.16"E
SP_09	0.15	47°47'46.95"N	107°16'26.52"E
RF01	0.15	47°47'52.70" N	107°16'04.50"E
RF02	0.4	47°45'52.95" N	107°13'25.44"E
SL_01	0.15	47°47'50.94"N	107°16'26.50"E
SL_02	0.35	47°47'50.94"N	107°16'26.50"E
SL_03	0.5	47°47'50.94"N	107°16'26.50"E

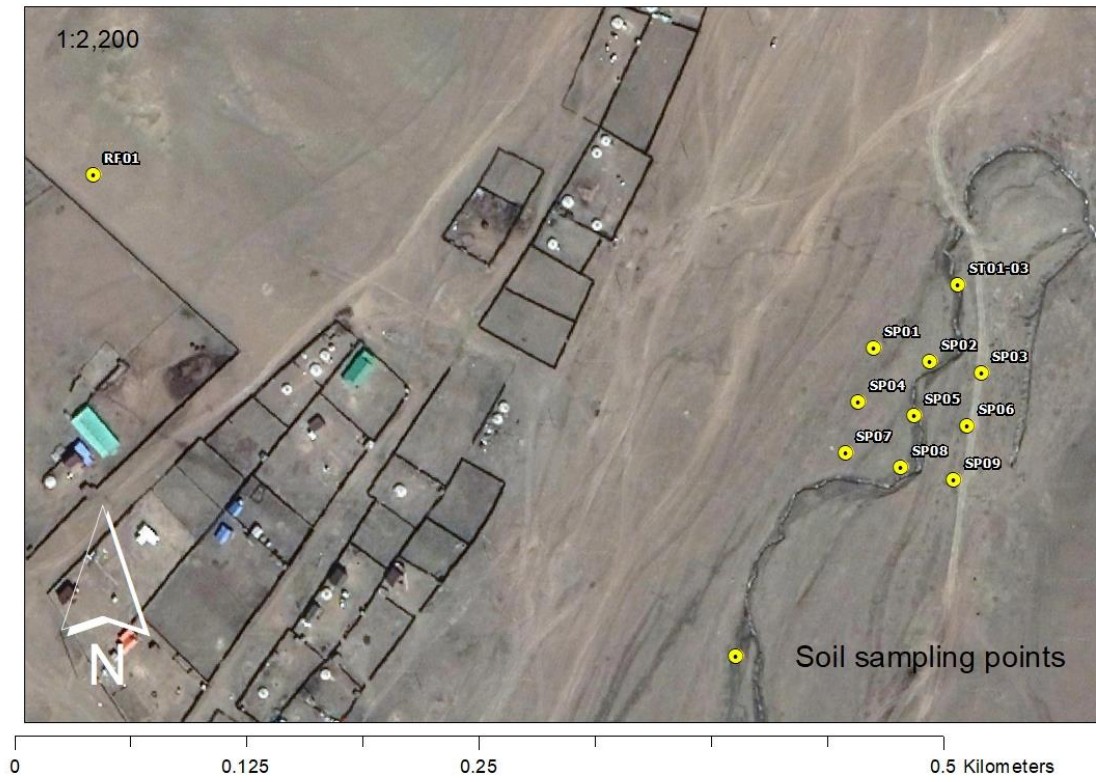


Figure 13 Soil sampling points, 1st sub-district

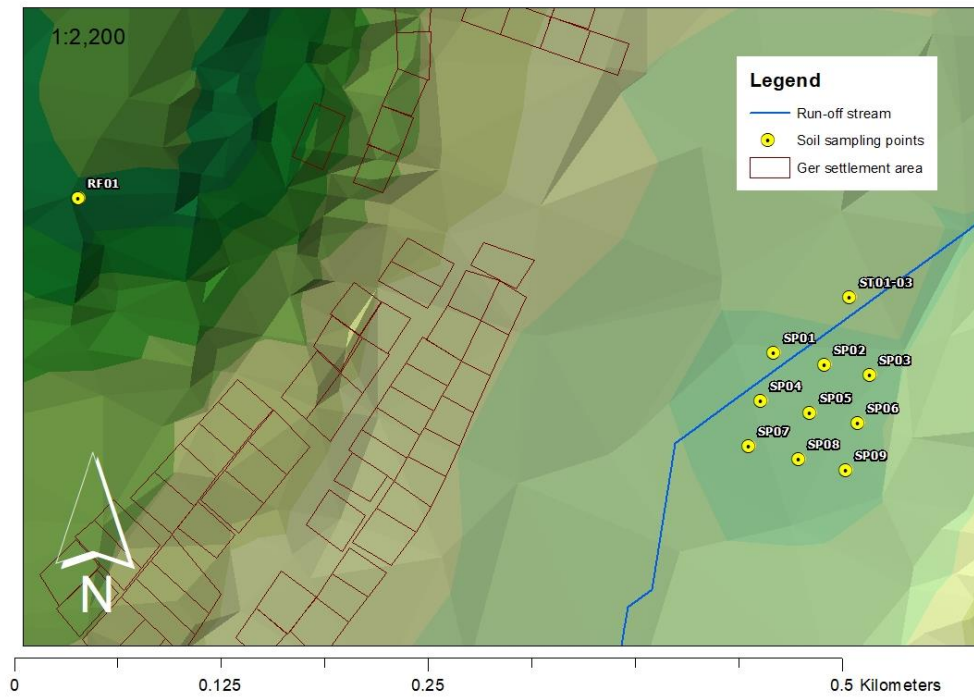


Figure 14 Soil sampling points with the illustration of lowest point

4.2 ANALYSIS METHOD

4.2.1 COLIFORM BACTERIA

Analysis of coliform bacteria was performed in environmental laboratory at GMIT. Water samples in a sterilized bottle from the wells was carried to the environmental laboratory in 20 minutes and kept in room temperature for analysis. Then HI-9829 Multiparameter from Hannah instruments was used to determine pH, temperature and atmospheric pressure of the water samples. (Fig)

For the coliform bacteria analysis, IDEXX 51-Well Quanti-Tray, 2 incubators, Quanti-Tray sealer and Spectro line Ultraviolet Viewing Cabinet were used. It was assumed that the water samples did not need to be diluted as it was drinking water. At first, water samples were poured in to the 100ml sample vessels. The Colilert 18 reagent was added directly to the 100 mL undiluted samples and mixed thoroughly to dissolve the reagent. After that, the samples were transferred to 51-Well Quanti-Trays and sealed using the Quanti-Tray sealer. Samples were incubated at incubated for 24 hours at $35\pm 0.5^{\circ}\text{C}$ for total coliforms and $44.5\pm 0.2^{\circ}\text{C}$ for fecal coliforms and Escherichia coli (E. coli).



Figure 15 Samples in Quanti-Tray after incubation

For the enumeration of coliforms and E. coli, the Colilert-18 test employs the Defined Substrate Technology (DST) nutritional identifier ONPG and MUG. Coliforms metabolize ONPG and turn it from colorless to yellow with their β -galactosidase enzyme. E. coli use β -glucuronidase to metabolize MUG and create fluorescence color. It can be seen under the Spectroline Ultraviolet Viewing Cabinet using 365nm UV light. Afterwards, the most probable number of each sample were interpreted using MPN table which is provided IDEXX. (Annex)

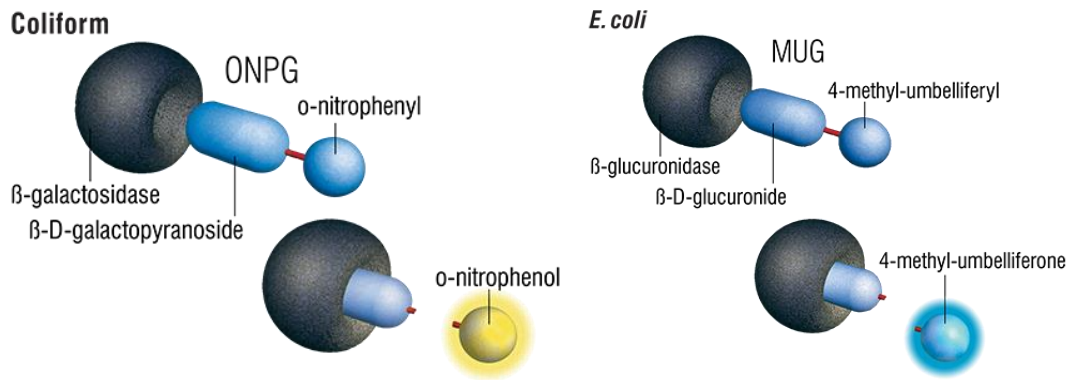


Figure 16 Colilert-18 Working Principle

4.2.2 CHEMICAL PARAMETERS

In order to investigate the chemical contamination of water samples, nitrite, phosphate, sulphate, iron and free chlorine were analyzed in by using DR/870 portable datalogging colorimeter as well as Permachem reagents for 10ml of water samples of 2 months (January and March). The Hach DR/870 Colorimeter is a microprocessor-controlled, LED-sourced filter photometer that can be used in the lab or in the field for colorimetric testing. Only the aforementioned parameters were measured due to the inability to use several equipment in the chemical laboratory. In addition, the arsenic content was determined as part of the thesis work of the student in my class.

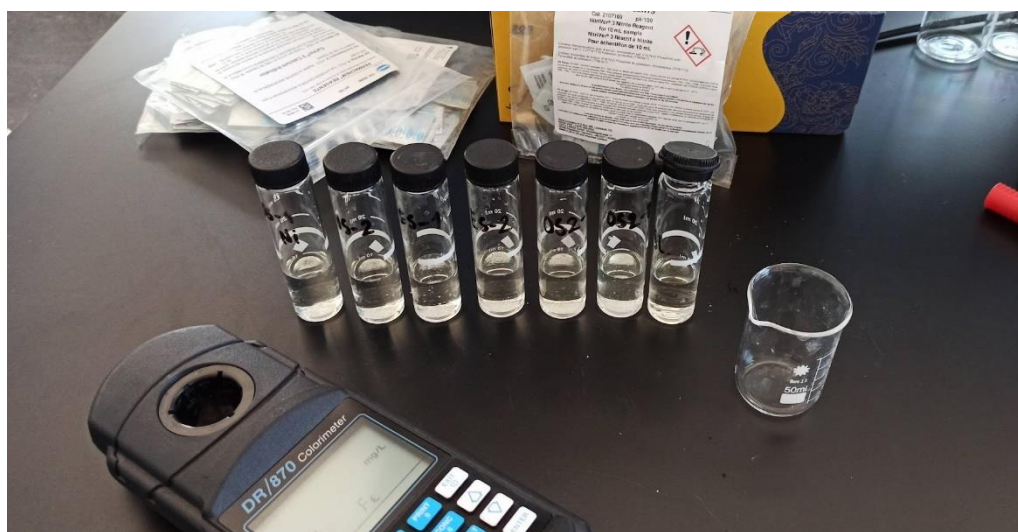


Figure 17 Measurement of nitrite concentration using NitrVer reagent



Figure 18 Measurement of iron concentration using FerroVer

4.2.3 HEAVY METALS IN SOIL AND CALCULATION

First of all, all the soil samples were air-dried and passed through 2mm sieve prior to analysis. Sieving is a technique for separating soil particles depending on their size and is typically used for aggregate separation. Then sieved soil samples were mixed with a spatula to homogenize soil samples for heavy metals analysis. The total content of heavy metals of soil samples can be determined quickly using X-ray Fluorescence Spectrometry (XRF). For the XRF analysis, around 50 g of sample was ground for 4 minutes each sample using a soil grinder, which can reduce caked soil agglomerations to individual grains with consistent results. The prepared sample was then placed in a XRF cup for analysis. To obtain maximum contact between the XRF and the sample, the XRF was placed parallel to the sample surface and examined.



Figure 19 Soil sample preparation for XRF analysis

To indicate degree of soil contamination, geo-accumulation index, contamination factor and pollution load index were calculated as follows:

Geo-accumulation index I_{geo}

Geo-accumulation index to evaluate metal contamination in soil by comparing current metal concentrations to background metal concentrations, and it can be computed using the following formula: [12]

$$I_{geo} = \log_2 \frac{C_n}{1.5B_n}$$

where, C_n is the concentration of metal “n” and B_n is the geochemical background value. The factor 1.5 is used for the equation to correct for probable lithogenic effect variation in the background data. The geo-accumulation index (I_{geo}) scale has seven grades (0-6) that range from unpolluted to heavily polluted. (

Table 13)

Contamination Factor

The contamination factor is used to evaluate the soil's contaminated status. [12]

$$CF = \frac{C_{metal}}{C_{background}}$$

Where C_{metal} is the metal concentration and $C_{background}$ is the background value of soil

Pollution Load Index

The pollution load index value is PLI, the contamination factor for each metal is CF, and the total number of parameters is n. The number $CF=1$ indicates low contamination, $1=CF<3$ indicates moderate contamination, $3=CF\leq 6$ indicates significant contamination, and $CF>6$ indicates severe (extremely high) contamination. [13]

$$PLI = \sqrt[n]{PLI_1 * PLI_2 * PLI_3 * \dots * PLI_n}$$

4.2.4 SOIL TEXTURE

The quantity of sand, silt, and clay in the soil determines the texture of the soil. One of the most major factors on soil physical features is particle size distribution. Determination of soil texture is an important indicator for assessing and evaluating the physical properties of groundwater, land use, agriculture, construction of roads and buildings, soil

monitoring and rehabilitation. There are various methods for determining soil texture. In the laboratory, it is determined by laser diffraction, pipette method, hydrometer method and sieving method, while in the field it is determined by feel method and volume method.



Figure 20 Dry sieving method

In soil texture analysis of the collected samples', dry sieving method was used with series of sieve in a sieve shaker which has sizes of 2mm, 50 μ m and 25 μ m.

4.2.5 SOIL PH

Soils can be typically acidic or alkaline, which can be determined with a pH test. The acidity or alkalinity of soil is defined by the pH of the soil, which is measured in pH units. The negative logarithm of hydrogen ion concentration is used to calculate the pH of soil. The pH of the soil lowers as the number of hydrogen ions in the soil rises, making it more acidic. The soil becomes progressively acidic from pH 7 to 0 and more alkaline or basic from pH 7 to 14.

The samples, which were sieved with a 2mm sieve, were measured by using a pH meter in the laboratory. Around 10g of sample was prepared and transferred in a 100ml beaker before the analysis. The samples were then given 50ml of distilled water and stirred thoroughly. The pH of the samples was determined using a pH meter after 1 hour.

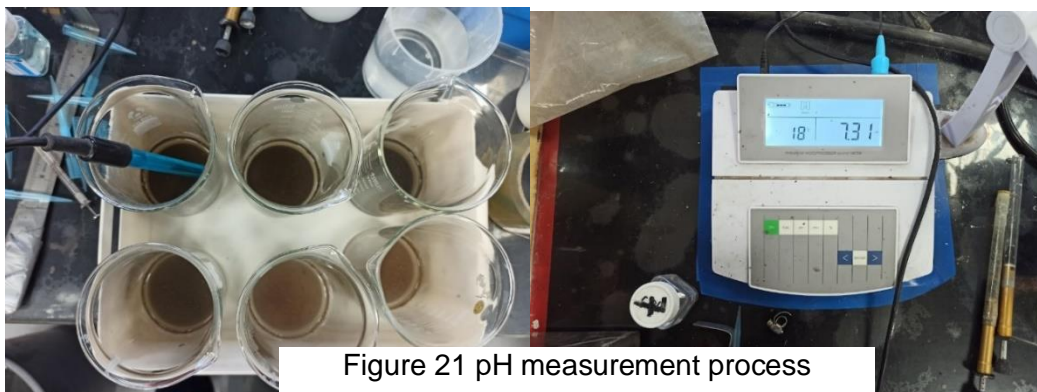


Figure 21 pH measurement process

5. RESULTS & DISCUSSION

5.1 RESULT OF THE WATER SAMPLES

The findings of water and soil sampling data, including coliform concentrations in water samples and heavy metal concentrations in soil samples, are presented in this section.

In the case of groundwater, the study area, bacterial contamination was detected in three water samples. During the coliform bacteria analysis, the first three months test did not proceed in the biosafety cabinet in the environmental laboratory which serves as a means to protect the laboratory worker and the surrounding environment from pathogens. Therefore, it may have influenced the results of coliform bacterial analysis of the water sample.

Table 5 shows the results of 4 months (January to May) of water sample testing. The main target measurement for the well water samples was coliform bacteria concentration. In January, Total coliform concentration in flowing artesian well and private well were counted at 109.1 MPN/100ml and 9.9 MPN/100ml respectively. For both of the samples, E. coli presence was observed respectively for 1MPN/100ml. In March, the Total coliform concentration of the flowing artesian well was found 11.1 MPN/100ml which represented lower than in January. However, the Fecal coliform concentration of that sample was counted as 15 MPN/100ml and E. coli presence was not observed.

Table 7 Water sampling data

Sample ID	Address	Type of water	Date	Time	TC MPN	FC MPN	E coli MPN	pH	Temp °C	DO, mg/l	Pressure, atm
1	Engershand	Flowing artesian well	20-Jan-22	11:12	109.1	11.1	2	8.05	3.6	-	0.8226
			20-Jan-22	11:12	109.1	11.1	1	7.85		-	0.8226
2	Engershand 13a-1	Private well	20-Jan-22	11:21	6.4	9.9	1	8.01	4.32	-	0.8228
			20-Jan-22	11:21	9.9	7.5	1	7.98		-	0.8228
1	Engershand	Flowing artesian well	10-Mar-22	11:15	11.1	15	0	8.24	6.53	-	0.809
3	Uurkhaichid 9-467	School tap water	10-Mar-22	11:30	16.4	8.7	0	8.59	10.77	-	0.8089
1	Engershand	Flowing artesian well	18-Apr-22	13:05	<1	<1	0	8.27	14.92	-	0.8281
3	Uurkhaichid 9-467	School tap water	18-Apr-22	13:20	17.8	5.3	9.9	7.95	18.21	-	0.8282
1	Engershand	Flowing artesian well	6-May-22	10:36	5.3	<1	0	8.17	9.83	3.18	0.8359
3	Uurkhaichid 9-467	School tap water	6-May-22	11:01	>200.5	13.7	13.7	8.04	15.7	4.8	0.8359

In April, the Total coliform concentration of the Khos-Uyanga school tap water sample was counted at 17.8 MPN/100ml. It was slightly higher than in March, which was counted at 16.4 MPN/100ml. Moreover, E. coli was found in school tap water 9.9 MPN/100ml as blue fluorescent color under UV light. This school is located among the ger settlement area and the nearest pit latrine is 35-60m meters away. As a matter of fact, Although the General Agency for Specialized Inspection concluded that groundwater could be used for drinking, school staff reported that the well water was not used for drinking purposes, but only for bathing and washing dishes.

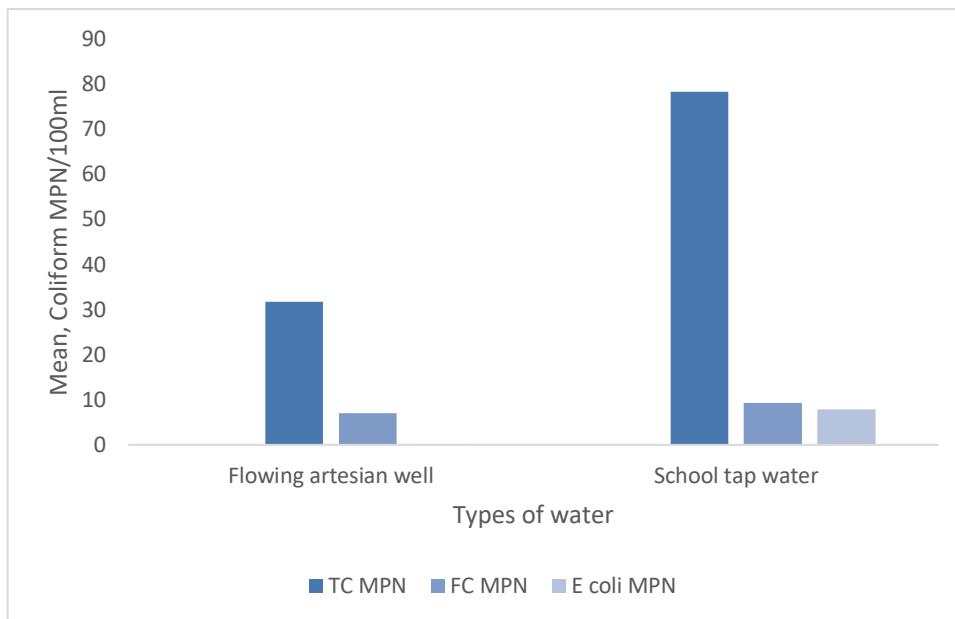


Figure 22 Coliform concentrations of water samples

For the last coliform test, Total coliform and E. coli concentrations of school tap water samples were determined as 200.5 MPN/100ml and 13.7MPN/100ml respectively. In Figure 16, the mean concentrations of the all-water sample were shown. The most bacterial contamination of total coliform, fecal coliform, and E. coli was counted in school tap water.

Furthermore, In the winter, the water from the flowing artesian well rushes up and freezes. Residents utilize the artesian well even if it is frozen in the winter by breaking the ice formation. During the first months of sampling, the well faucet was submerged under the ice, and water was sampled from in the middle of the frozen ice. Therefore, there was a hypothesis that there may be bacterial contamination in that artesian well. But from the test results of the last 3 months, concentrations of the flowing artesian well water were determined free of bacteria.

Table 8 Coliform bacteria analysis data in each sample

Type of water	95% Confidence Limits	Jan			Mar			Apr			May		
		TC MPN	FC MPN	E coli MPN	TC MPN	FC MPN	E coli MPN	TC MPN	FC MPN	E coli MPN	TC MPN	FC MPN	E coli MPN
Flowing artesian well	Counted	109.1	11.1	2	11.1	15	0	1	<1	0	5.3	13.7	13.7
	Lower	78.6	6.1	0.6	6.1	10.8	0	0.3	0.3	0	2.3	7.9	7.9
	Upper	158.7	20.5	7.3	20.5	29.4	0	5.6	5.6	0	12.3	23.9	23.9
Private well	Counted	6.4	9.9	1	-	-	-	-	-	-	-	-	-
	Lower	3	5.3	0.3	-	-	-	-	-	-	-	-	-
	Upper	13.9	18.8	5.6	-	-	-	-	-	-	-	-	-
School tap water	Counted	-	-	-	16.4	8.7	0	17.8	5.3	9.9	>200.5	1	0
	Lower	-	-	-	9.8	4.5	0	10.8	2.3	5.3	146.1	0.3	0
	Upper	-	-	-	27.5	17.1	0	29.4	12.3	18.8	infinite	5.6	0

From the table 9, it can be seen that concentration of nitrite was 0.002 to 0.006 mg/l, phosphate was 18 to 48 mg/l and phosphate were 0.9 to 2.2 mg/l in water samples. Besides, arsenic concentration of flowing artesian well and private well water samples, which was measured by Inductively coupled plasma-optical emission spectrometry (ICP), was 0.5 mg/l and 1.1 mg/l respectively. The permissible level of arsenic in drinking water is 0.01 mg / l, and the measured value in the water sample is much higher than this standard, indicating a high level of arsenic contamination.

Table 9 Chemical parameters in each sample

Jan						
Type of water	Nitrite, NO ₂ ⁻ (mg/L)	Phosphate, PO ₄ ³⁻ (mg/L)	Sulphate, SO ₄ ²⁻ mg/L	Iron, Fe (mg/L)	Free Chlorine Cl ₂ , (mg/L)	Arsenic, As ICP [0.1-10000mg/L]
Flowing artesian well-1	0.002	0.9	19	0.01	0	0.5
Flowing artesian well-2	0.004	0.91	24	0	0	-
Private well-1	0.003	2.21	28	0	0	1.1
Private well-2	0.003	1.04	27	0	0	-
Mar						
Flowing artesian well-1	0.006	1.38	25	0.26	0	-
Flowing artesian well-2	0.003	1.18	18	0.32	0	-
School tap water-1	0.003	0.13	47	0.12	0	-
School tap water-2	0.006	0.28	48	0.1	0	-

5.2 RESULT OF THE SOIL SAMPLES

Regarding the result of the soil samples, heavy metals concentration, soil texture, and soil pH were determined. Table 7 shows the Measurements of the physical characteristics of soil samples.

Soil pH in soil samples ranges from 7 to 9 which means that soil is more alkaline. For the reference soils, RF01 and RF02 were 6.82 and 7.73 respectively. Most plant nutrients are most accessible to plants in the pH range of 6.5 to 7.5, according to research. [14]

Table 10 Measurements of physical characteristics of soil samples

ID	pH	Eh mV	Initial mass, g	Soil texture size, %			Soil type
				sand, 2-0.05 mm	silt, 0.05-0.002 mm	clay, <0.002 mm	
SP_01	8.33	-110	52.14	86.44	12.71	0.85	Loamy sand
SP_02	7.91	-89	51.8	85.09	14.43	0.47	Loamy sand
SP_03	8.33	-111	52.34	94.76	4.54	0.69	Sand
SP_04	8.31	-109	51.61	99.44	0.56	0	Sand
SP_05	8.26	-107	51.54	83.9	14.98	1.11	Loamy sand
SP_06	8.09	-98	51.75	89.96	9.67	0.37	Sand
SP_07	8.02	-93	50.83	88.35	10.04	1.61	Sand
SP_08	7.82	-83	51.13	83.48	14.76	1.76	Loamy sand
SP_09	8.82	-137	50.72	88.99	9.4	1.61	Sand
ST01	7.86	-85	52.98	95.8	3.56	0.65	Sand
ST02	8.46	-118	52.32	96.11	3.68	0.21	Sand
ST03	9.01	-147	52.36	94.65	4.8	0.56	Sand
RF01	6.82	-28	52.82	87.94	10.25	1.81	Sand
RF02	7.73	-78	52.25	95.51	4.2	0.29	Sand

All soil texture of the samples was determined as sand (2-0.05mm), silt (0.05-0.002mm), and clay (<0,002mm). The soil type of the samples was determined as sand and loamy sand by using a soil texture triangle. The optimal soil composition is termed loam, and it consists of around 40% sand, 40% silt, and 20% clay. But for reference soil was recorded as sandy soil.

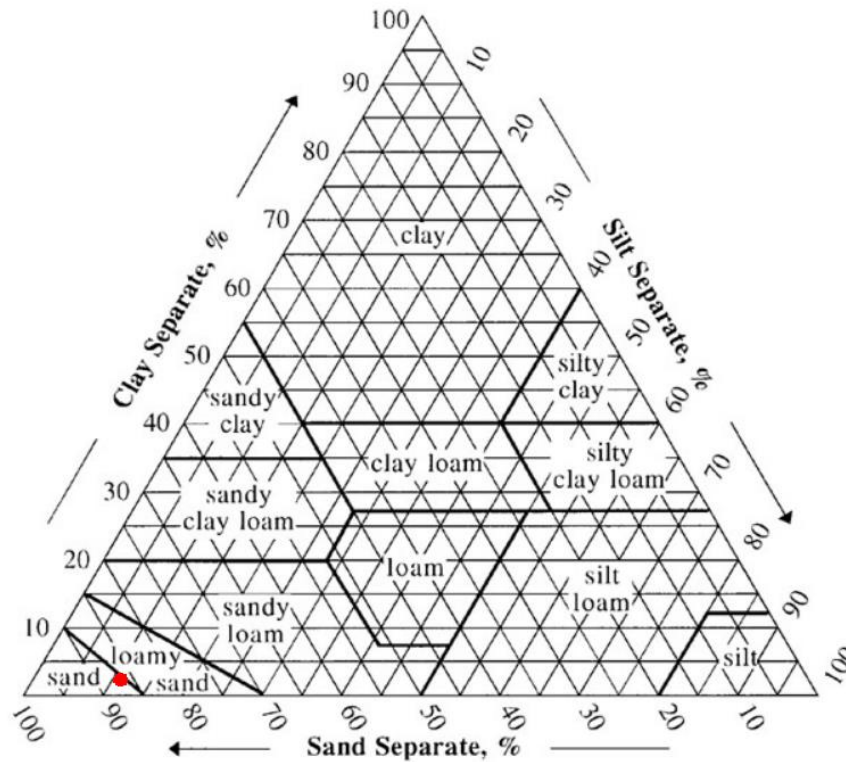


Figure 23 Soil texture triangle, (Source: United States Department of Agriculture website)

In addition to human excreta, the ger settlement areas are not connected to the central sewage system, so sewage and other wastewater enter the pit latrines, thus heavy metal analysis was performed in soil samples at the lowest point of 1st sub-district. A total of 13 heavy metals concentrations were recorded and compared to the standard of MNS 5850:2008 in Table 8. The exceeded concentration of metals cobalt, copper, zinc, and

arsenic was determined. However, at some sample points, the heavy metal concentration was found to limit detection by XRF.

In order to more accurately determine soil contamination, calculations were made on the geo-accumulation index (Table 9), the contamination factor, and the pollution load index. (Table 11)

Table 11 The measured concentration of heavy metals (mg/kg) by mobile XRF (X-ray fluorescence)

ID	Ti	Mn	Fe	Co	Ni	Cu	Zn	As	Rb	Sr	Zr	Ba	Pb	Type
SP01	3195	650	23185	<LOD	<LOD	135	145	15	80	325	220	300	25	Lowest point sample
SP02	8585	685	28535	220	<LOD	525	370	15	75	415	190	<LOD	25	Lowest point sample
SP03	2515	355	10605	<LOD	<LOD	165	125	<LOD	85	255	180	<LOD	20	Lowest point sample
SP04	4770	495	23665	<LOD	<LOD	475	335	20	80	380	200	<LOD	20	Lowest point sample
SP05	4905	650	27455	200	<LOD	615	415	20	80	465	185	110	25	Lowest point sample
SP06	2775	740	17855	<LOD	<LOD	260	225	20	80	320	180	90	20	Lowest point sample
SP07	5880	575	20195	<LOD	<LOD	590	390	10	80	345	290	<LOD	20	Lowest point sample
SP08	3710	560	24195	200	30	395	295	10	75	460	230	155	20	Lowest point sample
SP09	3770	520	18020	140	<LOD	185	160	10	80	330	225	<LOD	20	Lowest point sample
ST01	3645	780	26675	170	<LOD	210	185	10	90	335	235	180	15	Lowest point sample
ST02	2560	555	21210	<LOD	<LOD	255	195	15	85	400	240	210	15	Lowest point sample
ST03	1745	410	18900	<LOD	<LOD	230	175	15	80	450	260	220	15	Lowest point sample
RF01	1880	605	24415	170	30	150	165	10	100	290	225	320	30	Reference soil
RF02	1220	1070	28060	190	40	110	270	20	80	310	250	570	20	Reference soil
Mean	3653.9	617.9	22355	184.3	33.3	307.1	246.4	13.8	82.1	362.9	222.1	239.4	20.7	
Median	3420	590	23425	190	30	242.5	210	15	80	340	225	210	20	
MNS_5850:2008				50	150	100	300	6		800			100	
WHO		2000	50000	50	35	36	50	20					85	
EU standard						140	300						300	

Geo-accumulation index for the most of the soil sample were interpreted as moderately polluted with arsenic.

Table 12 Calculation of geo-accumulation index in soil samples

ID	I(geo) for Co	I(geo) for Cu	I(geo) for Zn	I(geo) for As
SP01	-	1.018	-0.464	1.907
SP02	2.722	2.977	0.888	1.907
SP03	-	1.307	-0.678	-
SP04	-	2.833	0.744	2.322
SP05	2.585	3.206	1.053	2.322
SP06	-	1.963	0.170	1.322
SP07	-	3.146	0.963	1.322
SP08	2.585	2.567	0.561	1.322
SP09	2.070	1.472	-0.322	1.322
ST01	2.350	1.655	-0.112	1.322
ST02	-	1.935	-0.037	1.907
ST03	-	1.787	-0.193	1.907

Table 13 Geo-accumulation index proposed by Muller (1979)

I(geo) value	Class	Soil quality
≥0	0	Unpolluted
0-1	1	From unpolluted to moderately polluted
1-2	2	Moderately polluted
2-3	3	Moderately polluted to strongly polluted
3-4	4	Strongly polluted
4-5	5	Strongly polluted to extremely polluted
>5	6	Extremely polluted

Table 14 Calculation of Pollution Load Index for each heavy metals

ID	CF for Co	CF for Cu	CF for Zn	CF for As	PLI for Co	PLI for Cu	PLI for Zn	PLI for As
SP01	0.000	1.350	0.483	2.500	0.000	0.338	0.121	0.625
SP02	4.400	5.250	1.233	2.500	1.100	1.313	0.308	0.625
SP03	0.000	1.650	0.417	0.000	0.000	0.413	0.104	0.000
SP04	0.000	4.750	1.117	3.333	0.000	1.188	0.279	0.833
SP05	4.000	6.150	1.383	3.333	1.000	1.538	0.346	0.833
SP06	0.000	2.600	0.750	1.667	0.000	0.650	0.188	0.417
SP07	0.000	5.900	1.300	1.667	0.000	1.475	0.325	0.417
SP08	4.000	3.950	0.983	1.667	1.000	0.988	0.246	0.417
SP09	2.800	1.850	0.533	1.667	0.700	0.463	0.133	0.417
ST01	3.400	2.100	0.617	1.667	0.850	0.525	0.154	0.417
ST02	0.000	2.550	0.650	2.500	0.000	0.638	0.163	0.625
ST03	0.000	2.300	0.583	2.500	0.000	0.575	0.146	0.625
RF01	3.400	1.500	0.550	1.667	0.850	0.375	0.138	0.417
RF02	3.800	1.100	0.900	3.333	0.950	0.275	0.225	0.833

The result of PLI for arsenic (As) was calculated lower than 1 which was evaluated as not polluted (PLI<1).

6. CONCLUSION AND RECOMMENDATION

The purpose of this thesis was to measure the water and soil contamination parameters of the deep wells in the 1st district and to examine whether the quality of the groundwater and soil was affected by the pit latrines. As a result of this study, bacterial contamination was observed in all three-water samples and two of them were drinking water. Furthermore, the soil texture of samples at the lowest point in 1st sub-district was sandy or loamy sandy, which means contamination from pit latrines moves faster through wide pores in sandy soil than through smaller pores in clayey soil. For the heavy metal analysis, the exceeded concentration of metals of cobalt (Co), copper (Cu), zinc (Zn), and arsenic (Ar) was determined.

In addition, overall, 5686 pit latrines were counted in Nalaikh district. From which 1141 pit latrines were counted in the 1st sub-district. The nearest pit latrines are located 30-110 meters away from flowing artesian well and Khos-Uyanga secondary school. Pit latrines and flush holes should be located as far away from gers and houses as possible, 15 meters from apartments and service areas, 20 meters from water kiosks, 150 to 250 meters from mines and drilled deep wells, and at least 200-250 meters from river banks, according to Mongolian technical requirements. Besides, arsenic concentration of flowing artesian well and private well water samples, which was measured by Inductively coupled plasma-optical emission spectrometry (ICP), was 0.5 mg/l and 1.1 mg/l respectively. The permissible level of arsenic in drinking water is 0.01 mg / l, and the measured value in the water sample is much higher than this standard, indicating a high level of arsenic contamination.

In the future, it is necessary to create a database of deep wells in Nalaikh district, conduct regular water analysis monitoring and regular disinfection of pit latrines, and commence work to connect ger settlement area to the sanitation network.

In addition, there is an urgent need to take management measures to reduce soil pollution, such as restricting and banning the use of pit latrines in ger settlement areas, installing toilets that meet MNS 5924: 2015 standards.

REFERENCES

- [1] J. P. Graham and M. L. Polizzotto, "Pit latrines and their impacts on groundwater quality: A systematic review," *Environ. Health Perspect.*, vol. 121, no. 5, pp. 521–530, 2013, doi: 10.1289/ehp.1206028.
- [2] "Нүхэн жорлон, угаадасны нүх. Техникийн шаардлага." <https://estandard.gov.mn/standard/reader/1873> (accessed May 01, 2022).
- [3] J. P. Graham and M. L. Polizzotto, "Pit Latrines and Their Impacts on Groundwater Quality: A Systematic Review," *Environ. Health Perspect.*, vol. 121, no. 5, pp. 521–530, May 2013, doi: 10.1289/ehp.1206028.
- [4] S. Selections, "News | Science Selections Pit Latrines and Groundwater Contamination," vol. 121, no. 5, p. 2013, 2015.
- [5] UNDP Mongolia, "Water and Sanitation in Mongolia 2008-2011," p. 25, 2008.
- [6] H. Sato, "Mongolia : The Water Situation in Ulaanbaatar," *Social System Review*, vol. 3. p. 9, 2011. [Online]. Available: http://www.cgu.ac.jp/Portals/0/09-kenkyu/publication/vol.3/3_9.pdf
- [7] Oyunbat. PUlaanbaatar Mayor's Office by the Mongolian Academy of Sciences' Institute of Geography-Geoecology, "PPT_UB_Laterine_2022." Ulaanbaatar, 2022.
- [8] : "Нийслэлийн статистикийн газар - Ажлын хүснэгт :," 2021. <http://ubstat.mn/JobTables.aspx> (accessed May 01, 2022).
- [9] "Coliform Bacteria and Drinking Water," no. April, 2011.
- [10] V. Demir and S. Ergin, "Occurrence and assessment of chemical contaminants in drinking water in Tunceli, Turkey," *J. Chem.*, 2013, doi: 10.1155/2013/238374.
- [11] P. Gomboluudev, S. Dorligjav, and E. Sumiya, "Газарзүйн асуудлууд сэтгүүл Journal of Geographical Issues," vol. 22, no. March, 2022.
- [12] Z. Banu, M. S. A. Chowdhury, M. D. Hossain, and K. Nakagami, "Contamination and Ecological Risk Assessment of Heavy Metal in the Sediment of Turag River, Bangladesh: An Index Analysis Approach," *J. Water Resour. Prot.*, vol. 2013, no. 02, pp. 239–248, Feb. 2013, doi: 10.4236/JWARP.2013.52024.
- [13] S. Saroop and S. Tamchos, "Monitoring and impact assessment approaches for heavy metals," *Heavy Met. Environ. Impact, Assessment, Remediat.*, pp. 57–86, Jan. 2020, doi: 10.1016/B978-0-12-821656-9.00004-3.

- [14] “Effects of pH, sodicity, and salinity on soil fertility - Salinity Management.”
https://ucanr.edu/sites/Salinity/Salinity_Management/Effect_of_salinity_on_soil_properties/Effect_of_pH_sodicity_and_salinity_on_soil_fertility/ (accessed May 02, 2022).

APPENDICES

ANNEX 1 INSTRUCTION OF COLILERT QUANTI-TRAY, 51 WELLS

Quanti-Tray®

Introduction

IDEXX Quanti-Trays are 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, seal it in a Quanti-Tray Sealer and incubate per the reagent directions. Then count the number of positive wells and use the MPN table attached to determine the Most Probable Number (MPN).

Contents

This package contains 100 sterile, 51-well Quanti-Trays.


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. Open the Quanti-Tray by pulling the foil tab away from the well side. 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. Allow foam to settle.



5. Place the sample-filled Quanti-Tray onto the rubber tray carrier of the Quanti-Tray Sealer with the well side (plastic) of the Quanti-Tray facing down to fit into the carrier.

6. Seal according to Sealer instructions.

7. Incubate according to reagent directions.

8. Count positive wells and refer to the MPN table on the back of this Instructions sheet 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 207-856-0496**

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

* Quanti-Tray and Defined Substrate Technology are trademarks or registered trademarks of IDEXX Laboratories, Inc. in the United States and/or other countries. US Patent Numbers 4,925,769 ; 5,426,933 ; 5,519,892. Other patents pending.



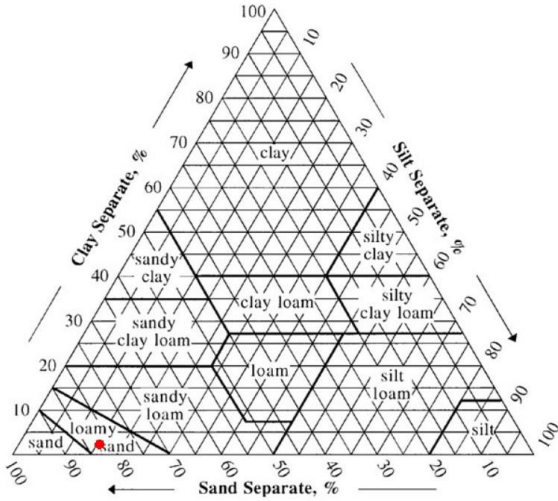
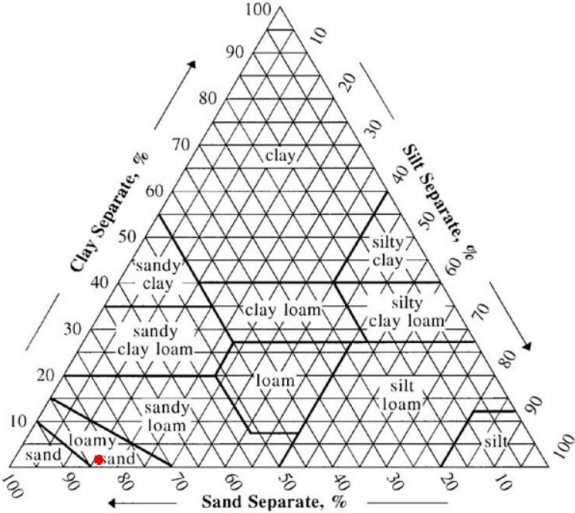
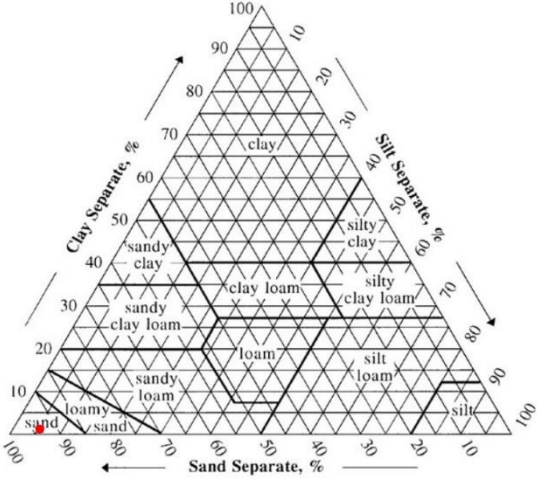
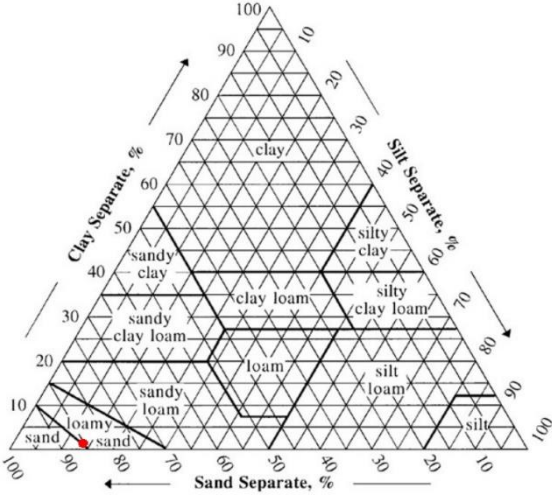
ANNEX 2 IDEXX 51-WELL QUANTI-TRAY MPN TABLE

No. of wells giving positive reaction	MPN per 100 ml sample	95% Confidence Limits	
		<u>Lower</u>	<u>Upper</u>
0	<1.0	0.0	3.7
1	1.0	0.3	5.6
2	2.0	0.6	7.3
3	3.1	1.1	9.0
4	4.2	1.7	10.7
5	5.3	2.3	12.3
6	6.4	3.0	13.9
7	7.5	3.7	15.5
8	8.7	4.5	17.1
9	9.9	5.3	18.8
10	11.1	6.1	20.5
11	12.4	7.0	22.1
12	13.7	7.9	23.9
13	15.0	8.8	25.7
14	16.4	9.8	27.5
15	17.8	10.8	29.4
16	19.2	11.9	31.3
17	20.7	13.0	33.3
18	22.2	14.1	35.2
19	23.8	15.3	37.3
20	25.4	16.5	39.4
21	27.1	17.7	41.6
22	28.8	19.0	43.9
23	30.6	20.4	46.3
24	32.4	21.8	48.7
25	34.4	23.3	51.2
26	36.4	24.7	53.9
27	38.4	26.4	56.6
28	40.6	28.0	59.5
29	42.9	29.7	62.5
30	45.3	31.5	65.6
31	47.8	33.4	69.0
32	50.4	35.4	72.5
33	53.1	37.5	76.2
34	56.0	39.7	80.1
35	59.1	42.0	84.4
36	62.4	44.6	88.8
37	65.9	47.2	93.7
38	69.7	50.0	99.0
39	73.8	53.1	104.8
40	78.2	56.4	111.2
41	83.1	59.9	118.3
42	88.5	63.9	126.2
43	94.5	68.2	135.4
44	101.3	73.1	146.0
45	109.1	78.6	158.7
46	118.4	85.0	174.5
47	129.8	92.7	195.0
48	144.5	102.3	224.1
49	165.2	115.2	272.2
50	200.5	135.8	387.6
51	> 200.5	146.1	<i>infinite</i>

ANNEX 3 SOIL INORGANIC (HEAVY METAL) CONTAMINANTS MAXIMUM PERMISSIBLE LEVEL (MG / KG)

Heavy metals	Soil texture			Maximum permissible level
	Clay	Silt	Sand	
Lead (Pb)	100	70	50	100
Cadmium (Cd)	3	1,5	1	3
Mercury (Hg)	2,0	1,0	0,5	2
Arsenic (As)	6	4	2	6
Chromium (Cr)	150	100	60	150
Tin (Sn)	50	40	30	50
Strontium (Sr)	800	700	600	800
Vanadium (V)	150	130	100	150
Copper (Cu)	100	80	60	100
Nickel (Ni)	150	100	60	150
Cobalt (Co)	50	40	30	50
Zinc (Zn)	300	150	100	300
Molybdenum (Mo)	5	3	2	5
Selenium (Se)	10	8	6	10
Boron (B)	25	20	15	25
Fluorine (F)	200	150	100	200
Cyanide (CN)	25	15	10	25

ANNEX 4 SOIL SAMPLES TEXTURE ANALYSIS BY SOIL TEXTURE TRIANGLE



ANNEX 5 EQUIPMENT USED FOR WATER SAMPLE ANALYSIS



Incubators



UV light darkroom



Hanna instrument HI9829



IDEXX Quanti-Tray Sealer



Portable DO meter

ANNEX 6 DRINKING WATER QUALITY AND SAFETY MONITORING INDICATORS

	Indicators	Unit	Permissible level
Microbiological indicators			
1	Total Coliform	MPN/ 1ml	<100
2	E. coli & Thermophilic bacteria	MPN/100ml	0
Physicochemical indicators			
3	Ammonium, NH ₄	mg/l	1.5
4	Nitrate, NO ₃	mg/l	50.0
5	Nitrite, NO ₂	mg/l	1.0
6	Free Chloride, Cl ₂	mg/l	0.2-0.3
7	Sulphate, SO ₄	mg/l	500.0
8	Iron, Fe	mg/l	0.3
9	Turbidity	NTU	5.0
10	pH		6.5-8.5
11	Electrical Conductivity	µs/cm	1.0
Heavy metal			
12	Arsenic	mg/l	0.01

ANNEX 7 WATER AND SOIL SAMPLING SITES



Private well



Khos-Uyanga secondary school

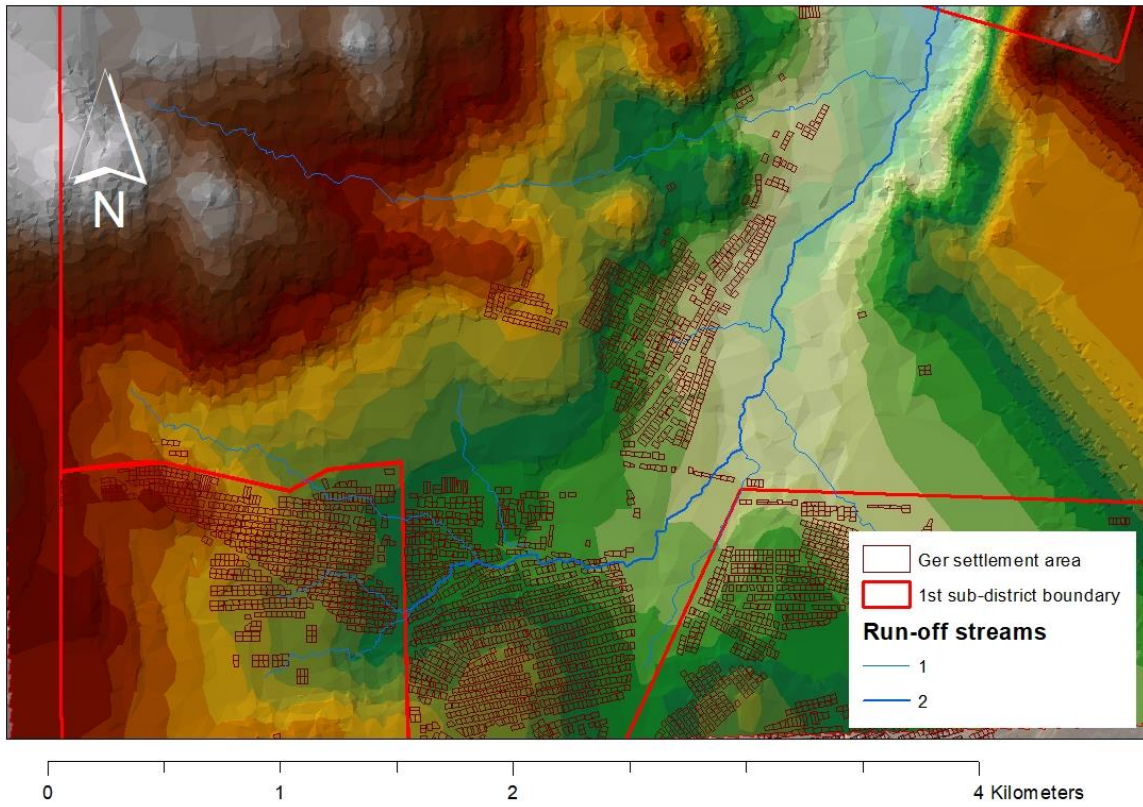


Flowing artesian well

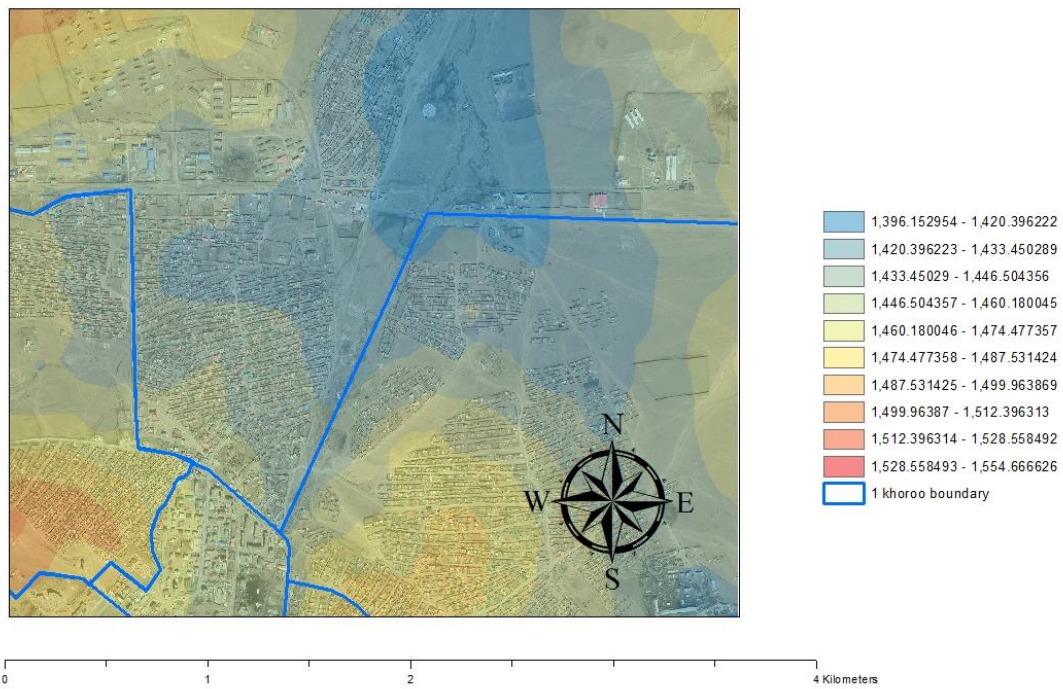


Soil sampling around 1st sub-district

ANNEX 8 MAPS OF 1ST SUB-DISTRICT GENERATED BY ARCGIS



Watershed Analysis map



Elevation map