GERMAN - MONGOLIAN INSTITUTE
FOR RESOURCES AND TECHNOLOGY

The present work was submitted to the Faculty of Engineering

ARSENIC MONITORING IN NALAIKH'S SURFACE WATERS PARTICULAR "BUS NUUR" LAKE

Bachelor Thesis

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Ulaanbatar/Nalaikh, 31st of May, 2018

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ABSTRACT

Nalaikh is located in Ulaanbaatar, Mongolia, known for illegal mining activity. Earlier investigations concerned mining land disturbance and pointed on air, soil and importantly water. Which revealed in unexpected arsenic, which is a highly toxic element, exposure in the Bus Lake. The research is aimed to find seasonal and weather changes of the Bus Lake characteristics and indicating level of toxicity.

The research continued from November 2017 till May 2018. Samples were taken from the local groundwater, stream water and the Bus Lake totally 48 samples measured. Main Water characteristics which are pH, redox potential, dissolved oxygen and dissolved solids measured by field equipment, and total and dissolved arsenic content was examined in the central geological laboratory (CGL). Stream water and groundwater arsenic concentration were low. However, Bus lake appearance and arsenic specie was particularly related to temperature and seasonal changes and transition from winter to summer period trivalent arsenic [highly toxic] was found. Plus, entirely arsenic load was exceeding WHO recommended limit [0.01mg/L].

Key word: arsenic, water, Nalaikh, monitoring, water quality, surface water, Bus Lake,

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ACKNOWLEDGEMENTS

I would like to thank to my thesis advisors, Professors Martin Knippertz and Daniel Karthe, for supporting me during thesis research. Additionally, I would like to express my special appreciation towards Dr. Ariuntuya for making a huge support for the thesis writing. All of your advice on my research have been precious. I am thankful for Mr.Veit and Mr.Walk for being huge data source. I would also thank to my GMIT family members, Mr.Guyen, Mr.Baasandorj, Mrs.Yaruunaa, Mr.Ganbaatar and Mr. Demberel for enormous kindness, serving and supporting through my struggling moments. Geological Central Laboratory members were so easy to communicate and shows very pleasant service to me. Moreover, I would like to thank you for respecting my intellectual property.

I am very glad that I have beautiful supporting family, my grandfather, my grandmother, my father and my mother with me. Word cannot possible to express how grateful I am to my beloved brother, who was in charge for my transport. At the end I would like to mention about my colleagues and friend who gave me strength and power to overcome challenges.

1 INTRODUCTION

This thesis is based on the project “Environmental impacts of small scale coal mining in Nalaikh” funded by the GIZ.

The project has been started from 2016 which follows Figure 1 concept purposed by Knippertz (34).The interaction and interpretation of these datasets lead to the identification of mitigation measures and finally to the derivation of a site specific rehabilitation concept.

By mentioning brief background information of the Nalaikh, Ulaanbaatar, Mongolia. Opened in 1922, the Nalaikh Coal Mine of State was the nation’s first industrial mining operation particularly in ground mining. Its official closure was in the 1990s, after the collapse of the Soviet-backed state economy. Nowadays during the peak season [which is in winter, when the soils are frozen] up to 2000 “Ninja”-miners work in around 200 mine shafts, however, a very few shafts are authorized. As informal statistic, about 70% of the million ton of Nalaikh’s coal has been annually used for heating of the ger district in winter season of Ulaanbaatar (1).Mining activities are directly related to environmental impacts. These impacts include land use, changes or erosion in the soil- [e.g. heavy metals], water- [As-content] and air-quality. The aspect of rehabilitation [all anthropogenic induced processes with the aim to reevaluate degraded areas] in mining areas is becoming more and more important in society. Lately for the mine sites in Mongolia, rehabilitation concepts are available. However, in the smaller mine sites, especially, the Ninja-mine sites, no concepts are available, even if the necessity is given and commonly accepted.

Small scale coal mining areas are generating several environmental problem. One of the biggest emission and influence is release of heavy metals into the environment. The project work has been already covering socio economic features and physical geographical features in the Nalaikh region. The project sub research are founded unexpected high arsenic contamination in Nalaikh surface water especially in Bus Lake which is located near to mining area.

By applying mitigation measures for instance restoration and reclamation, stabilize the heavy metal concentration is required. Select from variety of rehabilitation concepts without meaningful data’s of particular areas characteristics and changes would not be effective. Thus, environmental monitoring is necessary to assess pollution the over a longer period of time. Information gathered through monitoring is important and helpful to locals and government hygiene. Result can be realize how Nalaikh citizens are affecting environment and how environment will affect Nalaikh citizens and livelihood. A first presentation of the results was given in March to the high officials of Nalaikh's government, another presentation will follow after the completion of this thesis.

The thesis reports environmental study from November 2017 to May 2018 on Nalaikh surface water arsenic concentration with supporting water measurements. The document will follow the order of behavior of arsenics in the environment and will determine sampling and analyzing methods, in this particular area. In conclusion, results are discussed.

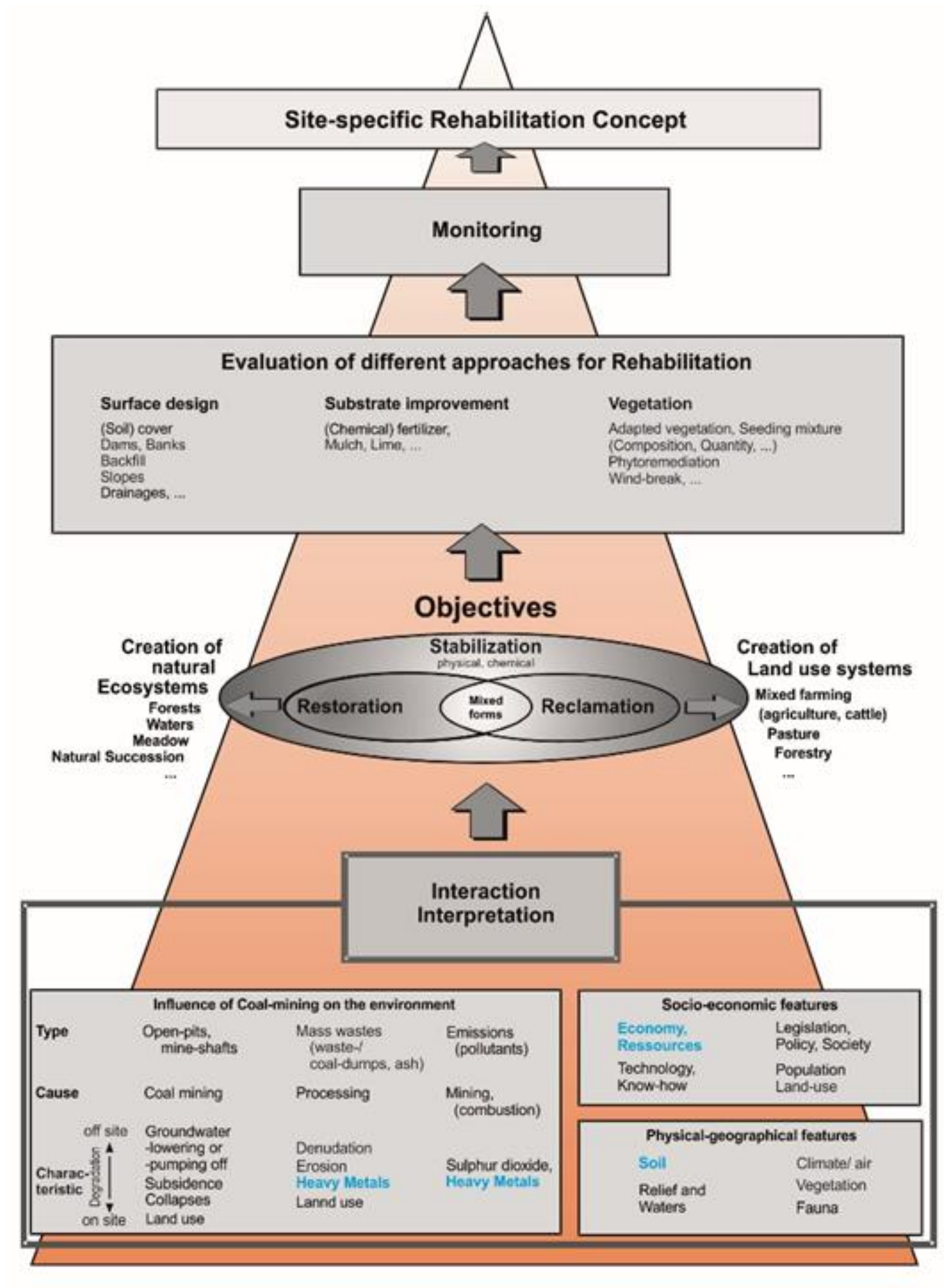

Figure 1. The figure is describing main concept of the rehabilitation knowledge in practice especially in Nalaikh area. Further studies has been done to implement this concept into the study area to fulfill interaction and interpretation stage (34).

2 STATE OF THE ART

2.1 Arsenic

Arsenic is the 33rd element in the periodic table and its atomic mass is 75 (1). Arsenic is a metalloid, but it can be considered to be similar with heavy metals, under the Priority List of Hazardous Substances and classified as Category-A stands for carcinogen in the EPA (2). Commonly distributed around the world occurs with sulfur and metals and can exist in various allotropes (3).

Arsenic is defined as an evil in humanities since it is the main ingredient of common poison (4). Thus, the drinking water standard recommends of world health organization daily intake of the arsenic less than 10 µg/l (5). But at some point, drinking water can be contaminated by naturally or surrounding industrial activities (3).

The element can occur several states of -3, 0, +3 and +5 in the environment but naturally are found common of inorganic form as oxyanions of trivalent arsenite (As-III) or pentavalent arsenate (As-V) (6). Oxidation state of arsenic highly influences geological behavior and toxicity. Arsenite considered to be more toxic than arsenate (6).

Eh and pH are important factors for determination of the arsenic. In Figure 2, there has been shown relationship between redox potential and acidity of the water in common arsenic species and in different ion forms (7). Oxidizing conditions would be favorable and dominant for the pentavalent arsenate. Surface water contain more turbidity and electro conductivity than ground water in practice. In water, the pH level is usually less than range of 6 to 9, so dominantly Arsenite and Arsenate are of importance (7).

Pentavalent arsenate oxides (H_3AsO_4, $H_2AsO_4^-$, $HAsO_4^{2-}$, AsO_4), As (V) - acids are characterized by relatively high Eh value. Besides from redox potential, dominant species stability and mobility's are depends on pH value (6).

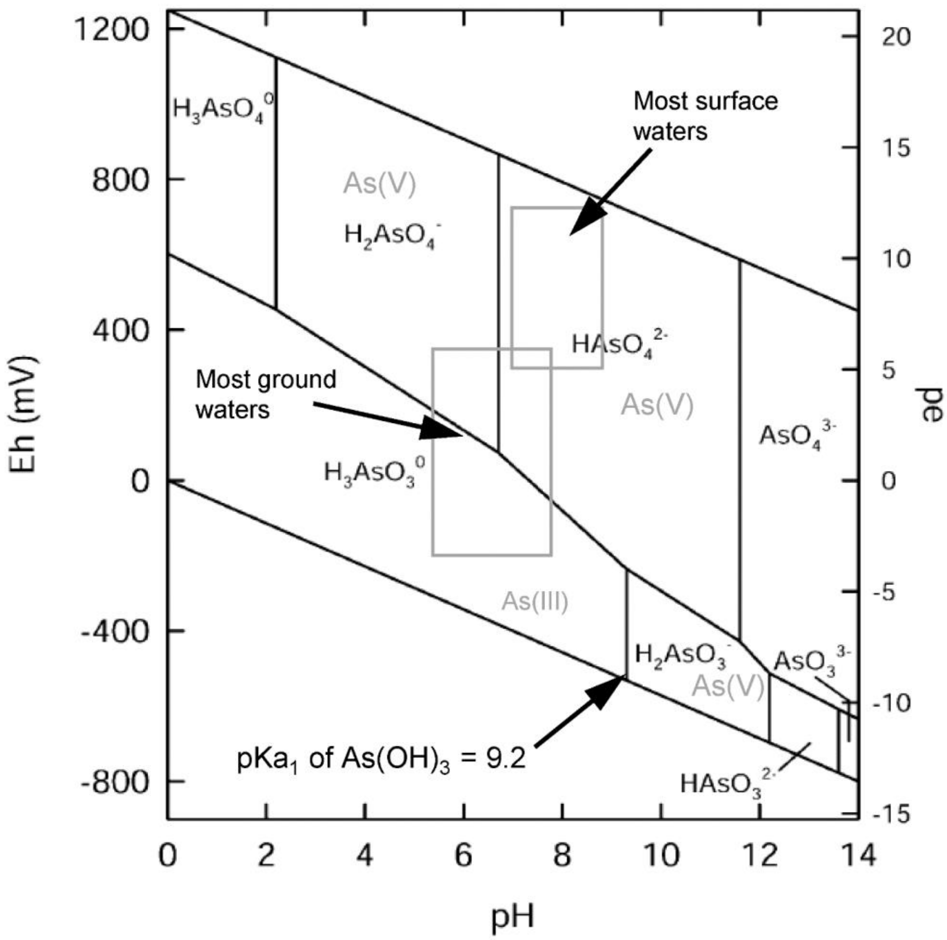

Figure 2. Redox potential (Eh) vs pH value. Which indicates typical aquatic arsenic formation type and specie under standard condition AT 1 bar 25 °C. The study suggest typical ground water pH level is in between 6-8 and surface water is in 7-9. And the main difference in the redox potential because of access to anoxic and aerobic conditions of the water body (7).

Unloaded H_3AsO_4 is only stable under very acidic conditions and AsO_4^{3-} only in strongly alkaline waters with pH values greater than 11.5 (9). In most natural waters come H_2AsO_4 or $HAsO_4^{2-}$ (7). Under low-reducing conditions (EH < 200 mv) as well as lower pH values – the three-quality arsenic acids are thermodynamically stable (9). With increasing pH value disassociate also successively, from H_3AsO_3 over H_2AsO^{3-} to $HAsO_3^{2-}$ (9). Under more reducing conditions, sulphides such as Realgar and Orpiment (As_2S_3, AsS) can occur as a stable solid phase, but with very low pH values, dissolved $HAsS_2$ and pH values of about arsenic disulfide are dominant (9). Eh value -200 mV to-600 mV metallic As and, under acidic conditions, also arsenic hydrogen or Arsin (AsH3) are stable (9).

As mentioned above redox reaction is important for distinguish species of the arsenic. Redox potential (Eh) in natural takes slow in case of arsenic. Same as oxidation (from dissolved oxygen) of trivalent arsenate principally gentle reaction (9). Some studies reveals ratio of the main states of arsenic (As-V)/(As-III) unchangeable over periods over few weeks. Moreover, acid condition of pH<5 the reaction is the slowest and suitable for in site sampling (9).

Under natural conditions, groundwater has highest concentrations of arsenic because of under more affinity on the geochemical as well as physical condition in aquifers (9). Typical countries groundwater arsenic concentration is less than 10 µg/l but accepted natural occurrence range can be up to 5000 µg/l (9). River water concentrations are defined by surface recharge, base flow and bedrock composition. In short, main source is geological composition and forms (9). The Lake tend to have similar with rivers value or less. The lake waters main contamination sources are mining activity or alkaline closed-basin, which is result of extreme evaporation and geothermal inputs (9). Additionally, arsenic can enter water bodies from anthropogenic sources such as smelter operations and fossil-fuel combustion(9). Arsenic absorbed particulate matters mainly Arsenic (As_2O_3) form. After arsenic oxides wet or dry deposition, simultaneous oxidation takes place then arsenic reconverts to nonvolatile forms (8).

Naturally arsenic can occur in more than 200 types of minerals, which commonly occurred hydrothermal veins and vein deposits or as secondary formation. As noted previously highest concentration ranges are in Sulphide minerals and Oxide minerals as for favorable bonding with sulfide and iron (9). In fact, trivalent Fe oxydroxides, hydroxides and oxides have important role in arsenic sink (8). Calcium carbonate and clay minerals is also arsenic absorbent, but lesser significance than irons (9).

Rocks, sediments and soils generally have low arsenic content. The average concentration of the lithosphere is around 2 mg/kg (9). Earth crust is between 0.5 and 2.5 mg/kg average is 1.8 mg/kg (10). Arsenic concentration average in igneous rocks are range of one digit mg/kg. Metamorphic rocks also have similar characteristics, phylite/slate metamorphic rock has the highest 18 mg/kg (9).

According to coal and arsenic correlation investigation researchers concluded arsenic content in coals has related with time forming duration of the coal. Resulted highest concentration was Paleogene and Neogene (11). After that in order Late Triassic, Late

Permian, Late Jurassic and Early Cretaceous, Early and Middle Jurassic, Late Carboniferous and Early Permian order of highest to lowest (11).

In all phases of the ecosystem some form of arsenic (organic, volatile) is present (12). The particle, which can be of mineral and biological origin, in the water bodies influence arsenic concentration by solid-solution interaction. Mineral-water interaction geochemically parted as precipitation- dissolution and adsorption-desorption (9).

Erosion and weathering, which mineral structure, structural ions or thermodynamically equilibrium is long in practical scales rated reactions, involved in precipitation-dissolved chemical action (9). Weathered arsenics are available future to microorganisms, plants and animals. On agronomic ecosystem, Sandberg and Allen purposed arsenic 12 pathway transferring model and they proved arsenic mobile and no accumulative in phases of the agronomic ecosystem, therefore, environmental transfer of arsenic can distribute through water, air and soil cycle (12).

In addition to the natural cycle, manmade sources can result high concentration at certain location. For example, coal and oil combustion, smelting of ores, fertilizer and pesticide uses. In fact, coal fired steam plant in Tennessee, USA studied arsenic recovery in fly ash but 52–64% lost from air by volatile form (12).

Adsorption-desorption reactions involve broad range of ions (9). Sorption of arsenic species has negative charges attached to positive charged surfaces dependence of minerals origin and equally pH value (13). Arsenic species in sediments mostly bonded with iron, aluminum and manganese oxides and carbonates and clays tend to absorb arsenic as similar characteristic with oxides (9). Ion exchange rate is defined by depending on specific surface and concentration of competing anion as well as bonding positive charge space (13).

In practice, when pH range nearly or above 8, most metal oxides and iron-rich clay minerals adsorb actively. Respectively, arsenate on iron hydroxides (mainly goethite), however Ferrihydrite bonding with arsenate has low dependence on pH value. Example of competing ions with sensitive arsenic species are phosphate anions, sulphate, silica and organic acids. Groundwater high concentration arsenics in lower than 8 pH values are commonly result of alkali desorption. Caused from high occurrence of oxygen secondary's are NO_3 and $SO_4^{2.}$ (13).

2.2 Arsenic studies in Mongolia

Trough out the history, Arsenic was considered valuable element due to its ability to poisoning as well as healing effect to humans. Many facts has been founded widespread use of arsenic in Europe during since Napoleon Empire. At the same time, arsenic contained medicine was launched and advertised as tonic or base for drugs (12).

Arsenic containing food, water and air are direct way to expose. Individual person's daily limit is 10 μg/L according to WHO (14). Thus, preventing contamination of the source is important and indirectly can be seen in old buildings, pesticides in the past fish accumulates toxins in higher amount (15). Airborne arsenic particles deposition slightly increases concentration in water (9). Even though arsenic accumulated minor atmosphere arsenic threatens serious health issues for drinking water source (9). Absorption of arsenic leads liver, spleen, lung and digestion track problems, additionally, damage of organs and skin, hair, and nail illness and symptoms, furthermore, cancer grow and develops (12).

Despite of its toxicity, proper amount of arsenic needed for healthy nervous system (4). Meaning level of 0.00001 percent is needed arsenic as an essential element as our physiology (4). Recent medical researchers are founding vitro model of arsenic trioxide, has ability block spread and stage of a cancer (5)&(3).

Several reports are recommended arsenic under biologic effects at concentration could not describe physiologic significance. For example, the trivalent forms of arsenic reactive with dithiol lipoic, supports metabolism. Also, arsenic is known protection against selenium poisoning. But arsenic has high toxicity in the large scale and concentration (12). Comparing sensitiveness to arsenic poisoning between wild animals and domestic species, wild animals were more easily offended. Mice lose its ability to resist against common diseases when exposed to high concentrations of arsenic and arsenicals are also toxic to plants. Except from its expression of toxicity, arsenic contaminated soils can be reduced by zinc or iron.(12)

Mongolia legislated Arsenic contamination in nature to prevent previously mentioned its toxicity (16). As following Mongolian MNS standard, arsenic contamination in soil tolerance level is 30 mg/kg is and hazardous level considered as above 50 mg/kg (16). And follows WHO recommended acceptance level in water concentration [10 μg /l] (14).

In Mongolia, there has been several studies has been done related with arsenic in the water bodies. One of the research study was conducted on arsenic detection from surface water that “Arsenic occurrence in water bodies in Kharaa river basin”. Aim of the study was to understand water bodies of geochemical arsenic distribution in most gold productive mining area located in Kharaa river basin. Study area covers between latitudes 47°53′ and 49˚38′N, and longitudes 105˚19′ and 107˚22′E total 17667.7 km^2 catchment area. The data was collected groundwater wells, river and spring total of 100 started 26 June to 3 July, 2016 (17). Water quality parameters, 21 heavy metals, arsenic species and cations were examined. The study resulted, according to Mongolian national drinking water standard few samples were exceeded the limit [MNS 0900:2005, As10 µg/l] (17). Dominant specie was lesser toxic which is As (V). Average Kharaa river basin concentration 4.04 µg/l with range of 0.07−30.30 µg/l. Groundwater arsenic was 2.24 µg/l, but near to Gatsuurt mining area was 24.90 µg/l, double times exceeded WHO standard. In contrast, Boroo gold mining area shows 6.05−6.25 µg/l. Researchers summed, founded concentration of arsenics might from the geological or chemical process (17). However the research work was only based on particular time period, can be changes in seasonal factor.

In fact, according to Mongolian ministry of health statistics in 2004, 867 samples from nationally contamination of arsenic was 14 ± 3 µg /l (18).

Moreover to the Kharaa river research, “investigating arsenic (As) occurrence and sources in ground, surface, waste and drinking water in northern Mongolia” paper published 3 years ago includes the study region . The study covers investigation of arsenic concentration and contamination in ground, surface, waste and drinking water in between May 2007 and 2013. Totally, 309 samples from upper basin of focused Selenga river basin with Kharaa, Tuul and Orkhon rivers sub basins were studied (18).

Gold mining technical water and effluent had extreme concentrations. Not only from bedrock material characteristics, which solved into technical waters from grinding and processing, but water quality was 121 µg /l, 136 mg/kg, 2820 µg/l, 1,746 µg/l and 46 µg/l concentration of arsenic as follows Gatsuurt mining effluent, Gatsuurt mid river, Bor Tolgoi mining effluent, Boroo gold mining effluent and Boroo gold mining monitoring wells (18). Arsenic contaminated water would directly discharge into tailing ponds, however by following natural cycle arsenic enriched water has access to birds, livestock in general nature (18). And 10 percent of tested ground water was surpassed WHO safe level up to 330µg/L. Based on 5 years of data research suggested continuous environmental monitoring for prevent and mitigation due to arsenic pollution dangers.(18)

Pfeiffer et al. also studied nearest thermal heating power plant, which uses coal combustion process called Darkhan TPP. In the settling pond of plant resulted max- 1,170 µg/L, the total of 19 sample average was 372 µg/L. (18)

Overall, on this thesis document, Nalaikh surface water and Bus Lake has been studied over 3 months to polish and emphasize the previous research outcomes. Additionally several tests and analyses were planned in order to assess arsenic existence in drinking waters.

3 RESEARCH AREA

Nalaikh is one of the districts of the Mongolian capital city, Ulaanbaatar. Nalaikh district has 7 sub-districts, covers 687.6 square km with 329000 citizens as statistic information in 2017 (19).

Back in the history, in December 1922 Nalaikh coal mine registered the first Mongolian coal mine (1).Between 1954 and 1958, the mine was upgraded and expanded which results in a major mining center. Nalaikh mine employed 1200 workers and 200 engineers (1). The ground mining was officially closed down in January 1995 (1). With the minister of Fuel and Energy citing “difficult technical conditions”.

Coal deposit estimated resource is 75 million tons and extractable resource is 15 million tons. In 1978, Mongolian and Russian researchers, used 6-phase exploring method, concluded reserve potential might be higher than the estimated number. Up to now, 25 million tons were mined in the last 50 years (1).

According to Davaabal study in 2016 (20), Nalaikh’s coal ash composition was SiO_2 +Al_2O3 +Fe_2O total 56.92- 58.32 % and Calcium Oxide 16.16-18.15 percent (20). This results prove Nalaikh coal type is lignite. In addition, research founded the ash content. First sample, from traditional stove was containing 90 mg/kg arsenic (20). Second sample, from complete combustion stove had 141 mg/kg. In comparison, Baganuur coal ash had following average of 76 mg and 86 mg total content of arsenic per kilogram (20).

Since its official closure, illegal miners continued to work. In fact, at the present 2000 illegal miners working on site and total 300 shafts and holes connected into coal lines. Many of them uses old and non-safe equipment to do the work. During the last 22 years, about 240 occupational fatality and 735 accidents occurred (21). Nowadays, the illegal small scaled coal mining activities in winter period are located between the, horse farm and Mongolian air military airport next to Bus Lake.

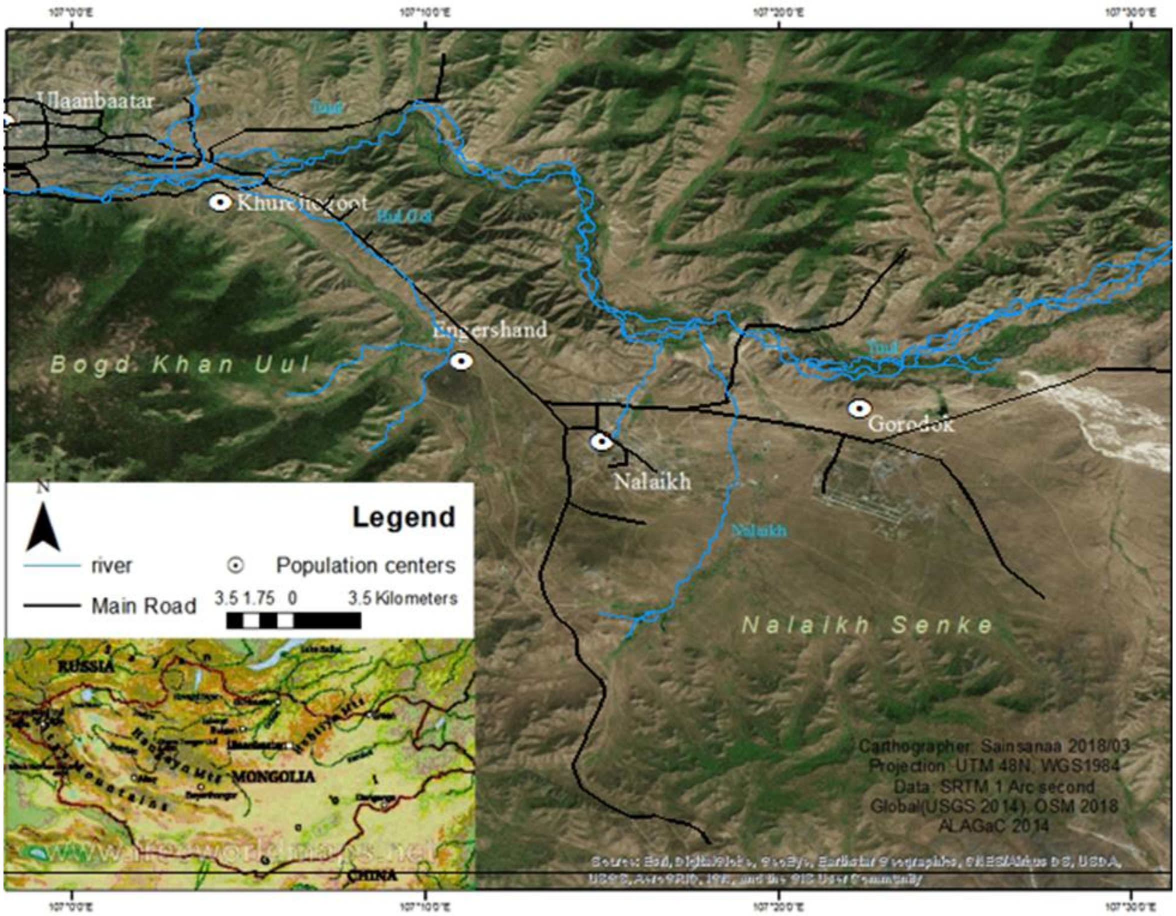

Figure 3. Study area position map

Figure 3 map is showing main transporting road, river and importantly, location of the Nalaikh valley. Nalaikh located around 40 km distance from capital city, Ulaanbaatar of Mongolia.

Nalaikh coal deposit consist of three main parts, which is eastern western and central. Currently, center part is almost excavated by active illegal miners (1). Western part is almost untouched and more than 60 percent of the reserve is accumulated there. Unfortunately the eastern part is under the riverbed that arises unfavorable condition (1). Nalaikh valley is considered rich with elements like Au, Ag, Au alloys, Fe, Al, Sn, and minerals such as crystal, spar and lime (1).

Nalaikh is associated with its coal illegal mining activity's result, have shown several environmental impacts namely land disturbance and damage through excess occurrence of arsenic in water, soil and other environmental issues which could be arising impacts for human health. Thus, the research work aims to collect valid data.

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3.1 Climate

In general, Mongolian climate condition is extremely cold and dry and categorized as a semi-arid climate or steppe climate. Cold semi-arid climates tend to have cold winters. Mongolian continental regions prone to extreme winter disasters [Dzuds] (22).Cold climate lasts over 5 to 6 months typically between October to April (22). There are four seasons, with a dry and short summer [June to August], spring [April to June] and fall [August to October] (23). Transitional seasons are also short covering extreme temperature moves around 10°C range(22).

In winter, air temperature is between -15°C to -30°C and in summer time it is between 10°C to 26.7°C (23). From 1951 to 1990 annual temperature was 0.4°C, however recent study presented ~1.5°C increase. Overall changes are related to footprint climate change etc.(24).

The grassland regions has lower precipitation, comparing to mountainous regions around 150-250 mm per year (23). But comparably humid condition than Gobi desserts. Annual evaporations rate is high as follows dry climate 650-750mm (23). Totally, 85 percent of precipitation takes place from April to September. Reasonably, 50 percent is in between July to August (23).

Based on a Nalaikh valley's week summarized data, leading wind direction is from North West and WNW and NNW total above 40 percent dominating overall directions (25). Moreover, strong wind above 15 m/s blows from NW and rarely blows from north-east side (25). Predicting secondary direction is from S to SE originates from mountain valley destructions (13).

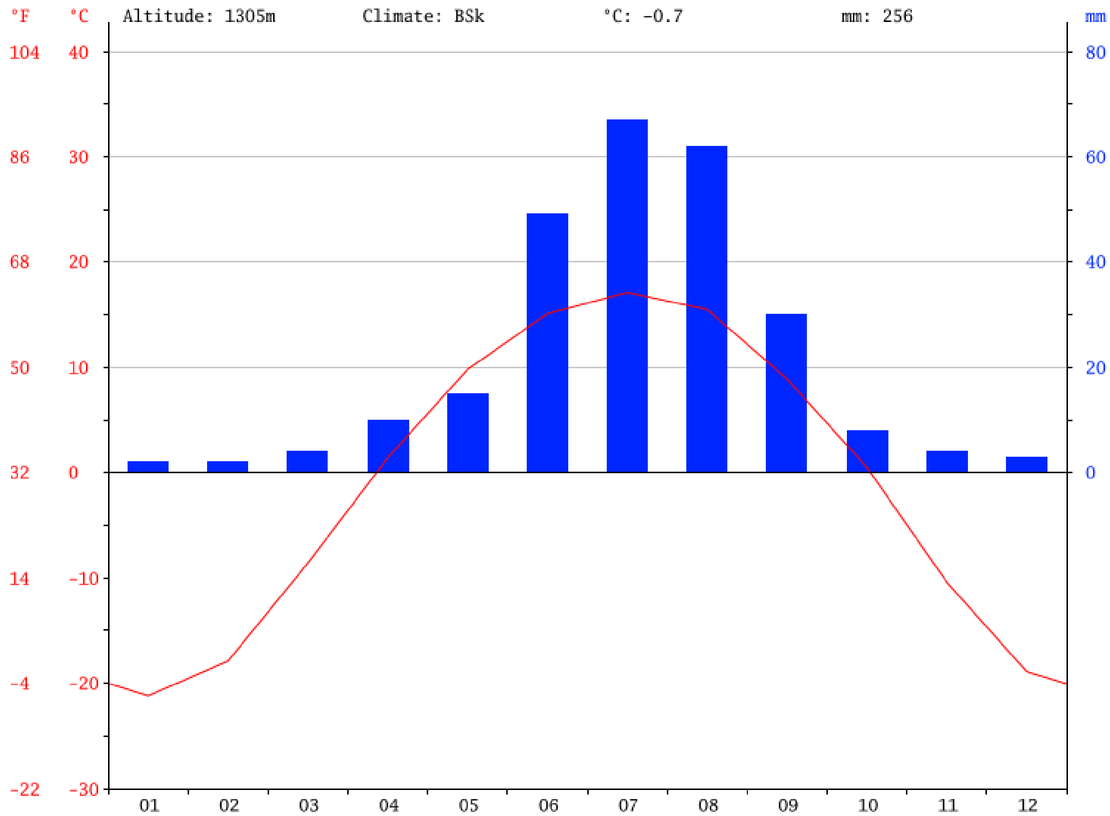


Figure 4. Climate diagram of the Ulaanbaatar

Ulaanbaatar is located nearby Nalaikh around 40 km. Driest Month is January and position is in semi-arid climate. Figure 4 data is based from climate model [weather station data's are collected from 1982 to 2012] and location models (26).

Khenthii's mountain range elongate to NE direction, which south of Nalaikh, extends into W and SW side of Khangai Mountains (13). The barrier enhances cyclone pressure differences caused by air masses penetration from Selenga and Baikal lakes basin, characterizes climate condition, precipitations are originated from the catchment area and the zone in summer time (13). Siberian heavy cold air influences persistent winter by ground hardening lower than -40 ^{0}C. Anticyclones in large pressure from Siberia are cause of soft wind winter blow W to NW direction, however during spring anticyclones collapses low pressured warm climates resulted strong and extreme weather changes (13). Gradually, the low pressure air transports moist condition to region around Ulaanbaatar and Nalaikh by moving towards to SW direction (13). Mostly, eastern part of summer precipitations from monsoon (13).

By following climate condition hydrological processes described (13). Thus, during summer months Tuul river outflow predicted to reach above 50 m^3/s in regular circumstances. Hence, potential rainfall lesser than evaporation the time of the year average outflow shrinks to up to 10 m/s (13).Tuul river is main sources of Ulaanbaatar and Nalaikh citizens fresh water source called upper water source station. Which supply 32-34 percent of total daily consumption 48000-51000 m^3/day. Has 56 well implemented (Water supply model excursion to Upper reservoir of Ulaanbaatar, Water supply officer).

3.2 Geology

Nalaikh region covers Khentii's Mountain range partly, which connects to SW with Khangai Mountains. The Khentii Mountains are part of the Altai-Central Asian belt, which formed during Proterozoic till early Mesozoic age (6,27). Collision of massive tectonic collisions caused Khangai-Khentii structure, which shaped as complex and sharp(28).

According to Mongolian geological map, Ulaanbaatar city is located above the Lower Cretaceous right next to Devonian Y shaped crossing layer, which formed in present Nalaikh Valley are up to 2500m to 3000m thick (29). Assumption to the sediment from the carbon NW of the basin size 1500 to 2000m (1)& (13). Active magma tension influenced starch of land whereby coal basin formation. After Cretaceous sediments fill up the basin resulted coal dominated lithological area (13) & (29).

Surrounding massifs are great and thin toward the center of the basin and creates unsorted sediments on the edges of the Nalaikh valley by erosion discordance. Mixed genesis loose sediments are quaternary loose and covered about 5 to 20m (30). Alluvial sediments characteristics are mainly clay and different grain sized sands and occasionally some gravel could occur (29). Loamy sand and rock soils are mainly covers mountain ranges. Thus, overall by result loess sediments are predominantly and primary loess possibly occurs locally with low range (29). The study area is can described as multiple geological disturbed region that covers different variation as well as generations (30). . By Altai's mountain ranges Paleozoic units can be traced down in position NE-SW. Majority of the disturbances in Nalaikh basin is demonstrated by sheet shifts as well as Mesozoic structures are considerably troubled (30). Reason of continental collision of the India with Eurasia in the Cenozoic, considerably results tectonic remote effect into Mongolia. Therefore, disturbance of the geology will continue and the area from the investigation, is located potentially reachable 6 to 7 magnitude seismic active region (30).

Tuul aquifer contains quaternary alluvial sediments as well as lower side of the valleys. In the Basin Neogene sediments and the sandy gritty sequences of the Upper Cretaceous contains important aquifers (13). Groundwater pressure investigation wells is in the urban region, theoretically proving existence of the groundwater tension (13). Similar strong hydraulic gradient flow path into Nalaikh position, which occurs in W, SW of the sink consensus.(13)

Bottom of the Bogd Khan Mountain discontinuous, dominant permafrost underlies (13). In bigger parts of Nalaikh Valley frozen over entire year. Permafrost is main factor that supports mining activities stability, however as noted earlier climate warming roughly 1.5 °C (22) change depth and size(13).

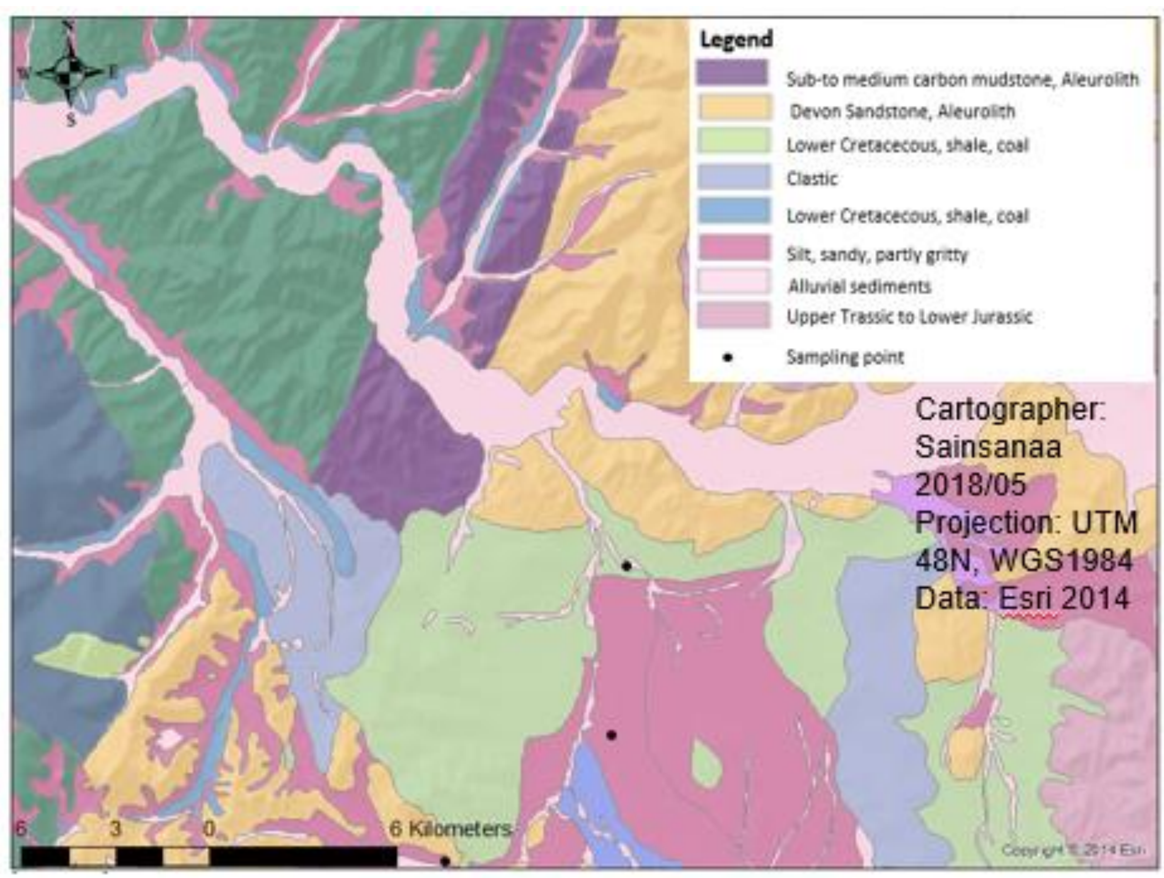


Figure 5. Geological map of Nalaikh valley (13).

Figure 5 is showing geological origin of the Nalaikh valley and black points are representing water sampling location.

3.3 Vegetation and soils

Vegetation zones covers taiga forest steppe and steppe in the study area. Study area is in short grass steppe region and adopted to dry cold winter, which are mainly herbs shrubs and brushes (13). Green vegetation cover commonly lasts in June. Even though April is warm in daytime, in nighttime and spring extreme condition as well as dehydration and dry weathers are major obstacles to grow grass (13). Starting from end of August land color changed green to yellow (13). Annual grass production in particular area is 600 to 1800 kg per hectare.(22) In general, Mongolia has high quality soils which are rich in nutrients and micro nutrients. Thus, vegetation only characterized by rainfall and access to water. Common type of soils in steppe regions are Kastanozems and Chernozems (13). According to Walk's vegetation map the river and surrounding area had alluvial sediments, which are a result of water transport (13). Kastanozems are brighter than Chernozems and moisture content is higher. Also rich in Calcium (31). Often loose materials formed into Kastanozems but sometimes can be noticed heterogeneous or clay or pebble like rocks. Typical soil depth is in between 1 m in higher elevations (13).

Analyzing google earth imagery between different seasons of Bus Lake founded significant difference on its scale (32). On 6th of July 2015, the lake was wider than on 5th of September 2015 in decent amount. More over reviewing time-lapse imagery started from 1984 to 2016 from Google Earth, shape of the Lake quite changed (32) From 2003 to 2014, Bus Lake suffered drastic water loss (32). And 2015 water level has been arisen again similar size as previously as.(32) Currently Bus Lake size is approximately 300 m longest and 240 m widest triangular shaped lake within the center of knoll (32) .

3.4 Arsenic study in Nalaikh valley

In his thesis Walk [2017] studied Nalaikh Valley environmental issues. According to the results air-, soil -and water, quality are not related with the mining activities.

In general, the surface waters were rich in Na, Ca and Mg (13). Precipitation sample shows the lowest result on TDS and hardness value. Na^+/ (Na^++Ca_2^+) ratio describes geochemical influence of the water from rock weathering over oceanic precipitation (13). Evaporation from sea transfers into precipitation becomes Na rich. On the other hand high values of Ca indicate weathering of rocks, like feldspar rocks (13).. Precipitation ratio resulted 0.91, thus it is possible to assume in the atmosphere humidity highly related with intercontinental freshwater source(13).. Groundwater was influenced by rock weathering in other hand, Bus lake sample shows high evaporation from the ratio (13). This concludes, standing water is more influenced by weathering and run-offs are tend to have higher Na content due to relation between precipitations (13).

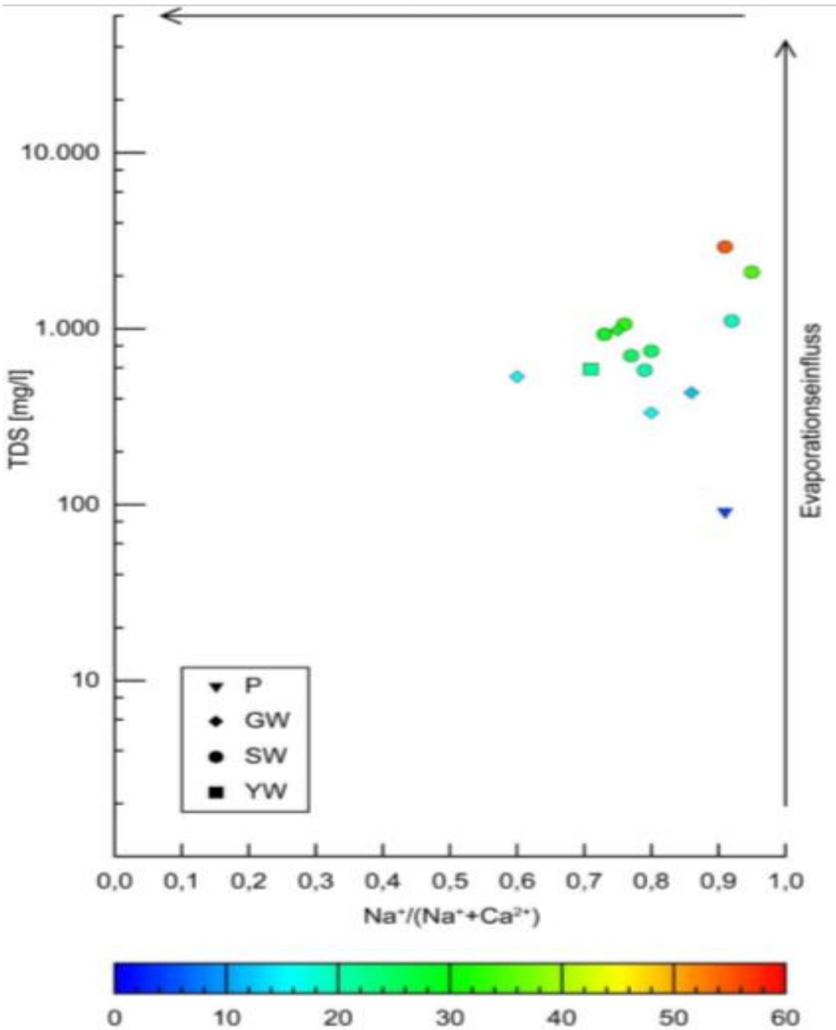


Figure 6. Total dissolved solids vs weathering parameter and hardness color bar. Walk different types of water sample result (13).

P* precipitation, GW* groundwater, SW* surface water and YW* industrial water

High value tend to occur in stable water. Bus Lake had 9 and other surface waters range was in between 7.7 to 9.6. By determining oxygen content, groundwater samples had 2.36 and 1.5 mg/l (13).. Surface water has higher values than groundwater 5.75 to 18 mg/l because of air exposure circumstance(13).

Microorganism use dissolved oxygen as electron acceptor to produce energy under aerobic conditions (8). On the contrary, Nalaikh water have slightly high, meaning reduction processes are a bit lower. However, in the precipitation sample total metal concentrations exceeds more than 10 times the accepted guidelines, which is indicating air pollution. In addition, ash basin of the thermal power plant predicted suspended particle has higher concentrations than dissolved concentrate (13).

A total of 16 water samples, dissolved and total arsenic has been measured in normal and acidic condition (acetic acid). In contrast, not such a big difference in diverse conditions(13). The samples are filtered and suspended particles were not considered. Arsenic possibly bonded sulfides is not necessary be in ionic form in low acidified samples. Thus, total arsenic value is not accurate counted by ICP-MS. Geologically, dissolved arsenic content is more important and by method result is more significant.

By recognizing Table 1, at stream near to this document sampling point, Bus Lake and groundwater in one point has been exceeded. Water sample results are from the study of October 2016. Average values are from precipitation, surface stream water, stream water close to fault line which has been studied below, Bus Lake and ground water maximum arsenic concentrations.

Table 1: As concentration in types of water sample (13).

Type of water sample	As_{dis}[µg/l]	As_{tot} [µg/l]
Rainfall	1	2
Surface	3±1	3±2
Stream close to this thesis research point	11	14
Bus Lake	97	101
Groundwater (max)	16	17

PH-value and Eh (redox potential) relation resulted, pentavalent hydrogen arsenate is dominant and depending on pH changes transfers into arsenite (13). Overall quality was positive on water quality.

In Table 2, solid sample result from the study on October 2016.Average values are from heap, topsoil, fluvial sediment, geological influence and air dust has been studied.

Table 2: As concentration in solid samples (13).

Type of solid sample	As surface [mg/kg]	As below the surface 15cm[mg/kg]
Material of the storage heap	49±0.5	
Topsoil	14.3±0.5	13±0.4
Fluvial lacustrine Sediment	9±0.6	
Geogenic	5	
Anthropogenic substrates	40.5±67.4	

As for solid results, anthropogenic substrates arsenic content is the highest same as heap storage. Which concludes airborne particles are mainly from industrial activity [e.g. thermal heating plant] and the particles are depositing. In fact, there is slight difference about 0.0013 mg/L on 15 cm changes in soil. But, there is geological influence to the water quality is still existed.

4 OBJECTIVES: Research question and hypothesis

Walk studies approved arsenic occurrence is exceeding in particular “Bus nuur” Lake. Predicted long period of a water cycle, evaporation was a major reason. Suggested air distribution arsenic and precipitation also could be the source(13).

Therefore, Seasonal weather changes of nature might changes arsenic existence or changing mobility condition of the water bodies.

Hypothesis 1: There is a linear correlation between arsenic mobility and seasonal weather change.

Also, geological composition and alluvial sediments characteristics where containing a proper amount of arsenic, which might be a potential influencing parameter. In the previous research, results, exceeded WHO standard following fault line. Also, determining spring water in Nalaikh valley could be control point of the Bus Lake

Hypothesis 2: There is a direct geological influence to the Bus Lake in terms of Arsenic concentration

Depending on pH value and redox potential mobility and toxicity rated. By measuring these parameters possibility to detect arsenic species. In October 2016, Bus lake pH value resulted in 9. The value represents pentavalent arsenide, lesser toxic than another form [trivalent arsenite] dominance.

Hypothesis 3: Pentavalent arsenite is preferred in Bus Lake.

The surface of water bodies was frozen during November to March because of cold temperatures. Therefore, evaporation and chemical reaction slow down. Transmission of arsenic in the water body possibly became stationary.

Hypothesis 4: At low-temperature arsenic transmission is stopped.

5 METHODOLOGY

In the course of the study water bodies were sampled in the Nalaikh region. In following parts, samples have been described in detail. In addition, the applied field and laboratory methods and analyses of samples and primary data are presented.

To prove first hypothesis, monitoring was done from November 2017 to May 2018. In addition Walk result data were on October 2016. Summer time was not predicted overall research.

One of the biggest challenges in monitoring was extreme cold weather condition. In addition, large amount of precipitation during winter time was the biggest obstacle to continue monitoring project. Snowfall was high comparing with previous years, lead to blocking the road.

Second, by following fourth hypothesis November and beginning of March samples, which are both ice where compared. Frozen samples collected at least 2 cm below the surface. During this time data's had been recorded after melting under room temperature.

Water samples were taken from 3 different areas. Total 48 samples were collected from as shown on Figure 7 fixed locations.

Table 3. Locations of the sample

Location	N	E	Main reason to choose sampling point
Spring	107.265007	47.686998	Represents ground water also located below geological fault line
Stream	107.33301	47.726035	Represents natural surface water
Bus	107.341006	47.778318	Highly contaminated with arsenic

Spring water drives from ground water to nature. And the locals using this water as drinking and herding water. Also which is laid above the geological fault line.

By examining stream water, possible to predict alluvial sedimentation into water relation directly. Stream water also collects run-off water from precipitation. Thus, seasonally water quality changes over the time.

The Bus Lake has the highest concerns in terms of Arsenic concentration. Run off water from surrounding area tend to stream into the Lake. Ground water supply is not predicted yet, but which has not have out stream from the Bus Lake.

Overall, frequency of the sampling date in spring time was around a week or more and as for particular interest Bus Lake intervals 9 and stream water and groundwater had 7. However groundwater sampled overall seven times, to compare difference between ice and water characteristic additional sampling has tested.

Figure 7. The map of sampling area.

Two aliquots of approximately 50 ml were taken into PE sample bottles (Falcon vessel, square bottle). Both, to separate suspended solids, filtered with Millipore Millex-HV hydrophilic PVDF filter with a mesh size of 0.45 µm on HSW syringe. One of them added 1ml of 99.9% $HNO3$ to stabilize for the analysis of Arsenic. By lowering pH value less than 2 has ensured to prevent metal complexes from remove from sample during transporting and storage. Another sample was used to measure main ion content without influence with the acid. Samples were stored at 6-7 °C condition until measure. Some iced samples were melted in room temperature and stored with same condition. State of the water bodies described in Table 4.

Table 4. Date and water state of the samples

Date	Spring	Stream	Bus
24-Nov-17	ice	ice	ice
10-Mar-18	-	-	ice
18-Mar-18	ice/water	water	ice
26-Mar-18	water	water	water
1-Apr-18	water	water	water
8-Apr-18	water	water	water
15-Apr-18	water	water	water
22-Apr-18	-	-	water
1-May-18	water	water	water

Water bodies investigated important parameters on-site or from sample due to solid cover. Prepared samples were analyzed in in laboratory analysis at the Central Geological Laboratory (CGL) in Ulaanbaatar.

In field, selected parameters were measured on-site or at the water samples. The redox potential and pH-value with a Professional Waterproof Portable pH/ORP Meter (HI98190 HANNA Instruments) dissolved oxygen in the water with a Luminescent dissolved oxygen and temperature meter (YSI ProODO optical dissolved oxygen meter)and the temperature and mercury thermometers integrated in the equipment sensors been used. Electro conductivity were measured by conduct meter (nova conductometer). Multipara meter pH/ORP/DO/Pressure/Temperature Waterproof Meter (HI98196 HANNA Instruments) was measured total dissolved solids (TDS).

Organoleptic such as color odor etc. have not been considered. Prior the sampling pH meter was calibrated at pH=4.01 and pH=7.01and exactness of oximeters were checked by air with protection of metal cover and distilled water induced sponge. Conductivity meter is necessitated to calibrate.

In Central Geological Laboratory, total of 48 were inspected which half of them were containing nitric acid. Mass spectrometry (ICP-MS XSERIES II) is used to determination of arsenic by ICP-124 method. Accuracy of detection by comparison measured values standard solution had error ± 0.002 μg/l.

Additionally, secondary parameters calculated from primary parameters in order to observe extra confirmation to compare measured and calculated factors. And finally, how did result has been presented and evaluated by statically is described below.

To analyze correlation and creation of the measurements, bar and scatter plot diagrams Excel 2010 and SPSS Statistics Data vol. 17 has been used.

6 RESULT AND DISCUSSION

6.1 Findings

6.1.1 Overview

In this section, the hydro chemical properties and characteristics and total concentration of arsenic of the water sample [Bus Lake, stream water, and groundwater] are described. Overall measurement and monthly mean values on the samples has been shown on Annex 2. Overall monitoring measured factors and values. To describe complete and logical picture values are published by monthly and sample locations.

Table 5. Dissolved and total arsenic concentration results

Sample Location	November [pre-winter] average		March [pre-spring] average		April [spring] average		May [pre-summer] average	
	As_{ds} [µg/l]	As_{tot} [µg/l]	As_{ds} [µg/l]	As_{tot} [µg/l]	As_{ds} [µg/l]	As_{tot} [µg/l]	As_{ds} [µg/l]	As_{tot} [µg/l]
Bus Lake	73	76	13±3	10±7	18±9	23±8	67	65
Stream water	10	2	4±3	6±4	5±3	3±1	4	3
Ground water	2	8	5±3	3±3	4±4	7±2	2	5

6.1.2 Degree of arsenic load in water types

Figure 8and Figure 9is showing overall monitoring results of dissolved arsenic concentration and total arsenic concentration in 3 particular sampling points. Because of samples transported in the acid conditions are not necessarily solved with the low pH values in the acidified samples moreover, a release of adsorbed arsenic is possible. Therefore, Total As cannot be determined precisely correctly by a mass spectrometer. Walk results were only referred to dissolved arsenic concentration due to present methodical uncertainty (13). As well as, the concentration is the more important role in nature cycle and furtherly discussed foremost. In addition, national Mongolian standards and world health organization directive recommended tolerable arsenic concentration in drinking water is below 0.01 mg/L.(14, 15)

At first glance, groundwater and stream water arsenic concentrations are below WHO standard and seem to be normal. However, samples from groundwater (GW) in mid-march and mid-April 8-9 µg/L dissolved arsenic were detected as same as in winter, total arsenic. Stream water results frequency is a bit higher than groundwater reason of surface active movement. Constantly, stream water values are slightly higher than groundwater results. As shown in Figure 8, the values are right under the WHO limit and reached within begging of winter and mid-march.

As predicted, Bus Lake contains high arsenic loads in documented data. The highest concentration was noted in November. As shown on the graph starting from pre-spring concentration level is dramatically increased by the time period. Moreover, in the beginning of the summer arsenic level is increased up to 67 µg/L which is 6 times higher than the tolerance level. The results on the Bus Lake describes water quality is risky in each season. Below 100 µg/L does not cause acute poisoning effect but may cause chronic diseases (13).

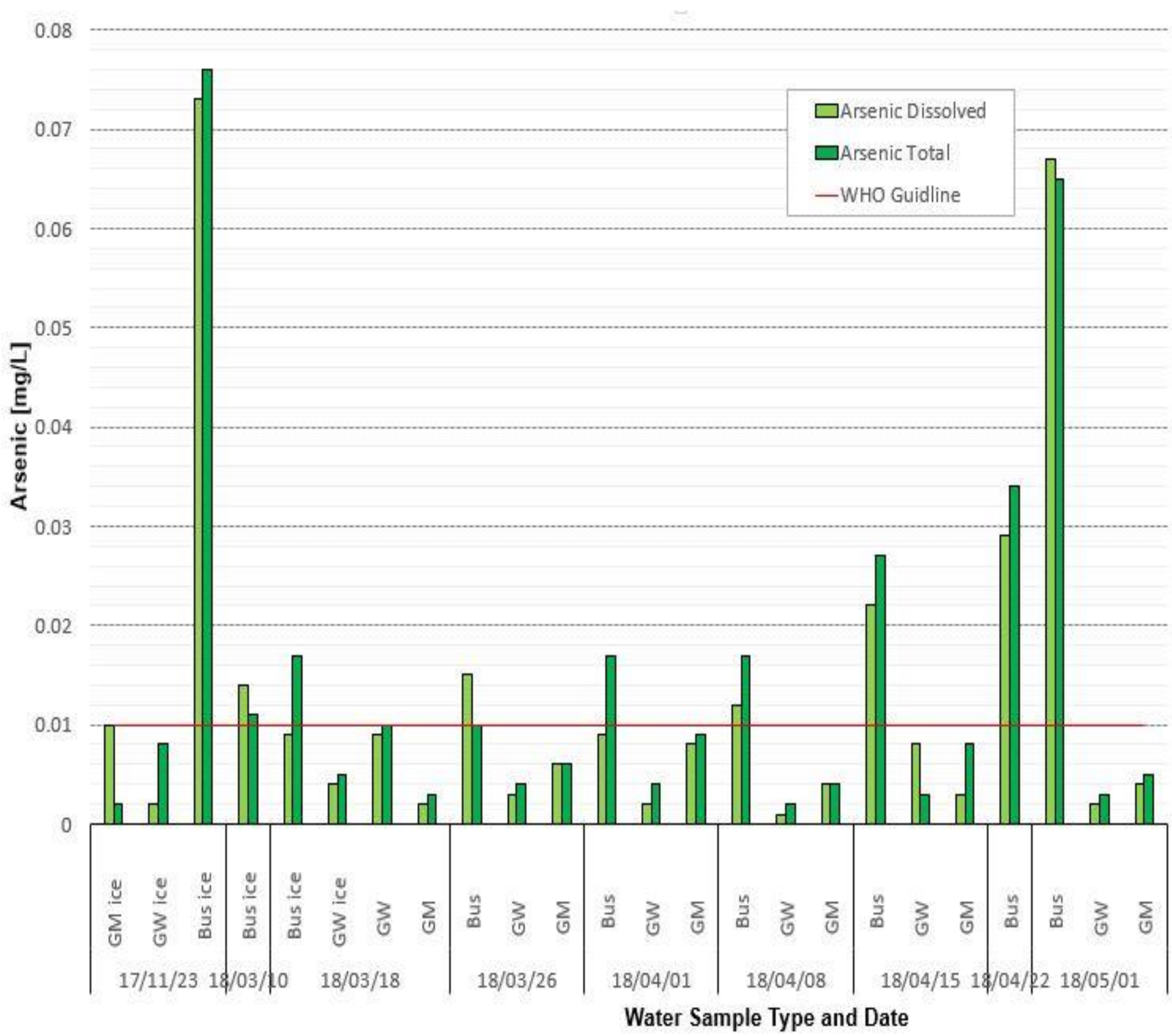
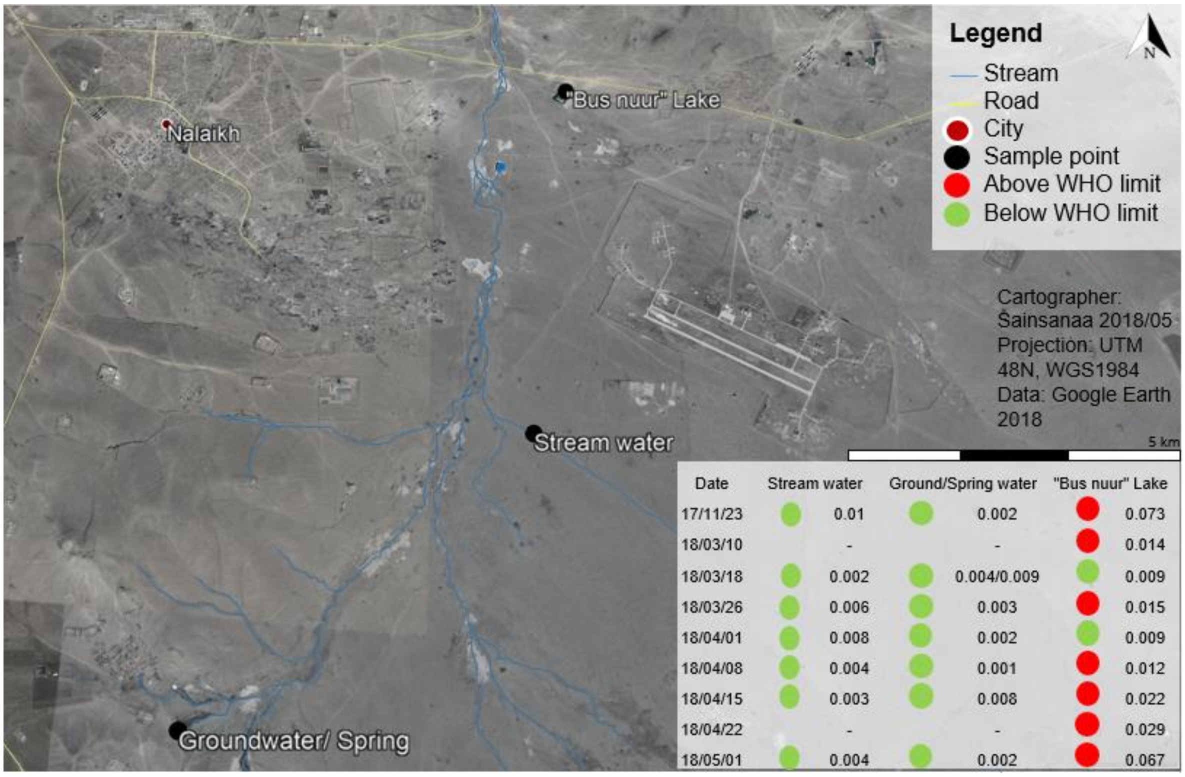


Figure 8. Samples are from stream water (GM), groundwater (GW) and Bus Lake (Bus) water in November till May. Dissolved arsenic concentration and total arsenic concentrations are compared by types and dates. Maximum tolerable concentration of arsenic in drinking water suggested by WHO [0.01 mg/L] showed as redline (14).



Date	Stream water	Ground/Spring water	"Bus nuur" Lake
17/11/23	0.01	0.002	0.073
18/03/10	-	-	0.014
18/03/18	0.002	0.004/0.009	0.009
18/03/26	0.006	0.003	0.015
18/04/01	0.008	0.002	0.009
18/04/08	0.004	0.001	0.012
18/04/15	0.003	0.008	0.022
18/04/22	-	-	0.029
18/05/01	0.004	0.002	0.067

Figure 9. Arsenic concentration delimitation of WHO standard

6.1.3 Evaporation in water bodies

TDS concentration is an indicator for an evaporation rate as well as associated concentrations of the dissolved ions and/ or ingredients of the water bodies. Higher total dissolved solids value indicates higher evaporation rate (13).

Due to faster runoff and constant feed to the groundwater and stream water was not highly affected by evaporation. The Lake has dramatically increased results of total dissolved solids. Meaning lake is most affected by evaporation with higher salinity. All of the samples had the smallest value in winter times. Contrasting between liquid form and a frozen sample of the groundwater, which sampled in same day have the noticeable difference. The meaning dissolved particles such as ions or mineral in the water more than a solid phase of the groundwater.

To finding a correlation between arsenic concentration and TDS concentration from Figure 8 and Figure 10 in water bodies and water types, ice and snow waters have minor correlation could recognize. Surprisingly, water state of Bus Lake had relatively strong similarity with

TDS and arsenic content. Which indicates frozen water of arsenic concentration feasibly diluted.

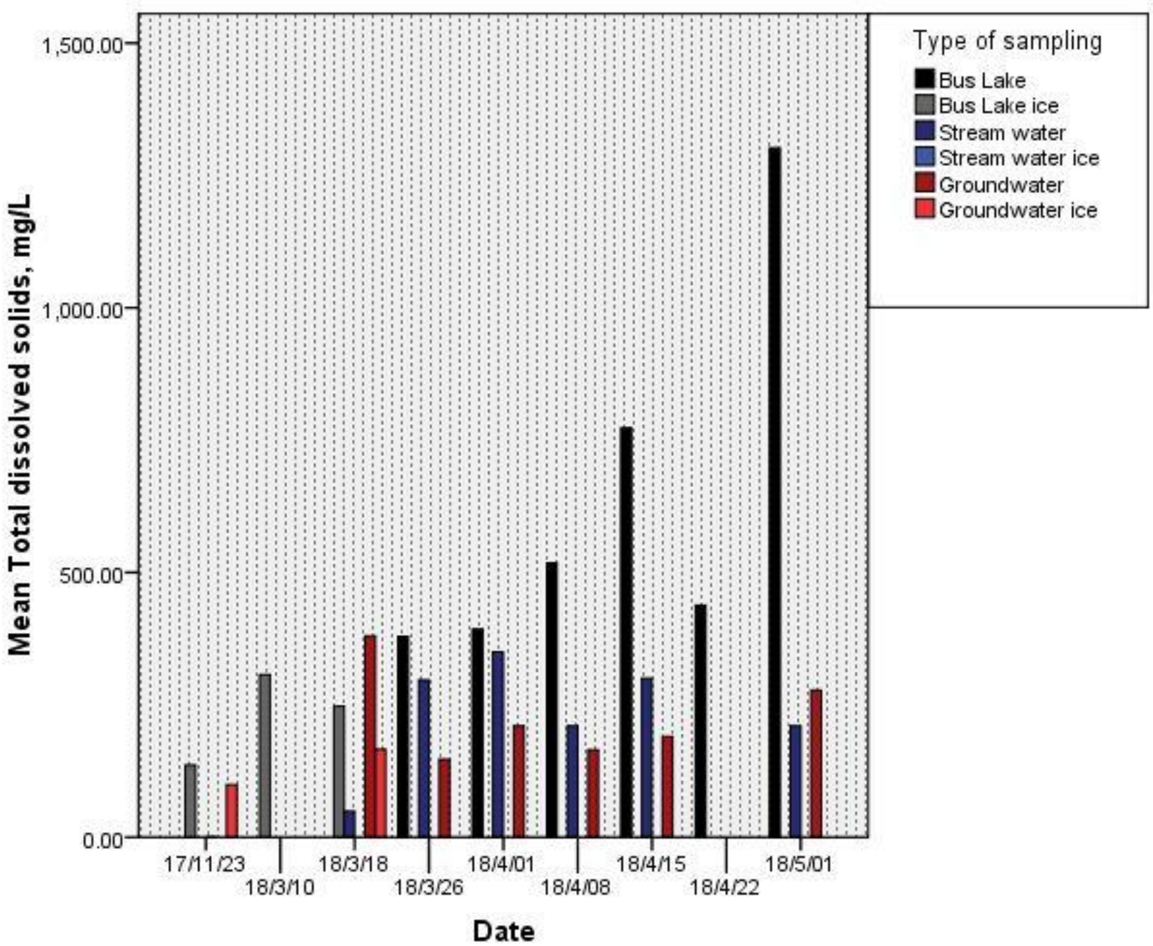


Figure 10. Total dissolved solids changes in time duration within sample types.

6.1.4 Arsenic specie

Surface water has higher oxygen levels than groundwater, are characterized by higher pH level. In general, groundwater has not direct contact to an atmosphere which creates typically anoxic conditions. Figure 11 and Figure 12 contrasting the pH value and dissolved oxygen and dissolved arsenic can represent redox potential and the pH value of the arsenic load in different locations. If the dissolved oxygen level is above 0.5 mg/L, oxic-conditions a redox potential is around 250 mV can be assumed (13).

Stream water means pH range is alkaline in between 7-8.5. In Figure 11, looking by time relation pH level is increasing as warmer it gets. Groundwater has also decent variation in terms of Dissolved oxygen and pH level. A range of pH level was 6.5-8.5 similar to Bus Lake in Figure 12.Overall dissolved oxygen parameter was similar and ranges in between 5.5-9 mg/L. First and second dissolved oxygen concentration of the Bus Lake is much smaller than other Bus lake measurements and other than water types. Possible because of the ice cover and which formulating anoxic condition.

And in general, mid-spring and beginning of summer times pH range are dramatically increased.

Referencing Figure 2, Bus Lake and stream water and groundwater all of them defined as trivalent arsenic. In Figure 12, last scatter plot diagram clearly showing sampling value redox potential ranges -80 to 60 mV and pH value is in between 6 to 9. Measurement values are showing water are relatively oxic conditions and pH range indicates the importance of dominant species are Arsenite [trivalent arsenic] than Arsenate [pentavalent arsenic] (6). Trivalent arsenic is considered higher human toxicity than pentavalent arsenic which Walk was resulted in October 2016 (12) & (13).

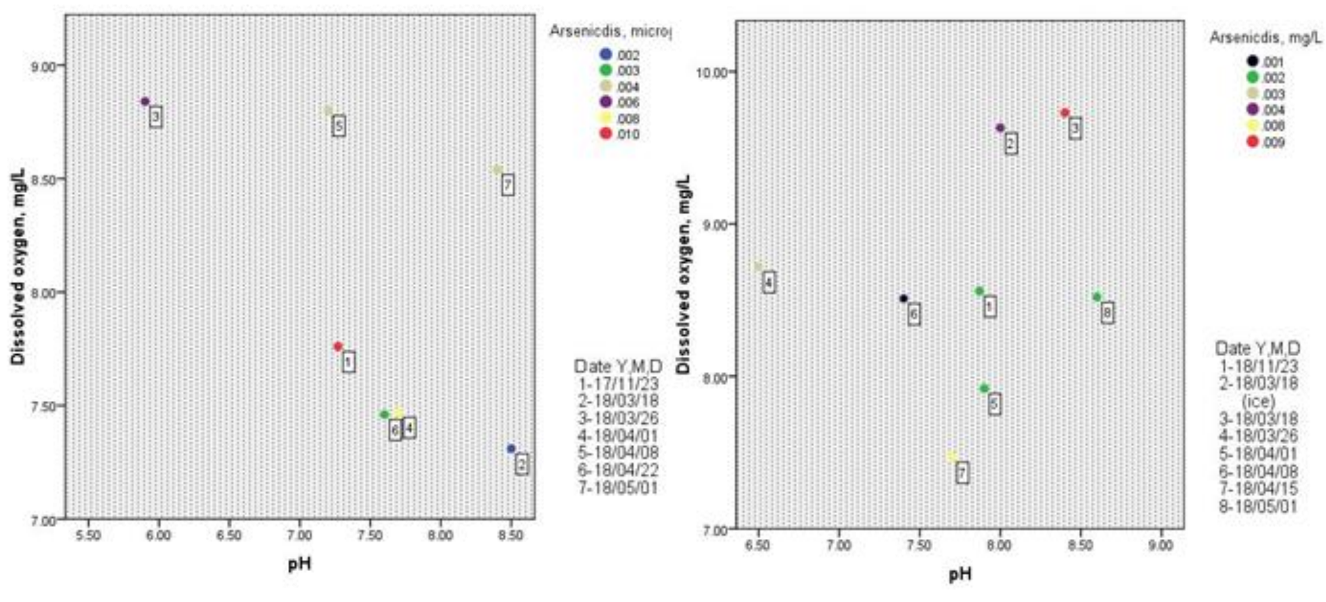


Figure 11. The relation between dissolved oxygen and pH of the stream water and groundwater colored by arsenic concentrations.

In Figure 11.dissolved oxygen vs pH graph. Front plot diagram describes dissolved oxygen and pH relation of the stream water colored by arsenic concentrations and numbered by sampling date. Next diagram showing dissolved oxygen and pH level relation in groundwater differentiated by arsenic concentration and dates by number.

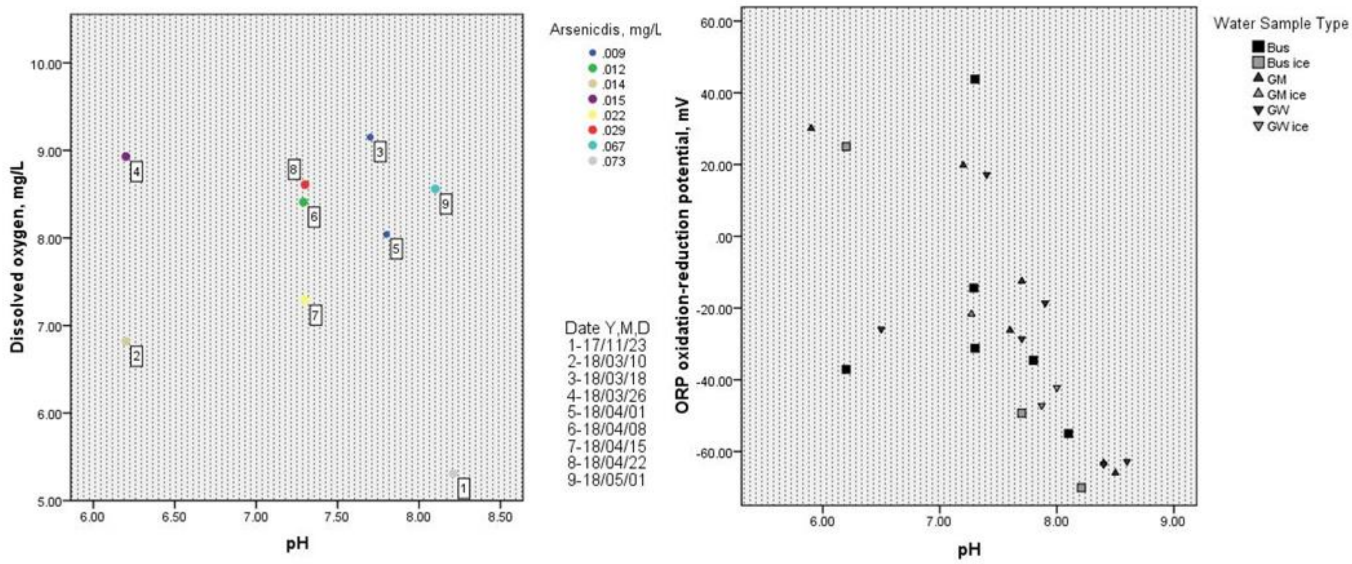


Figure 12. Relation between dissolved oxygen and pH value and distinguished by arsenic content of Bus lake.

[1]Bus- Bus Lake water sample [2]GM-Stream water sample [3]GW- Groundwater sample

In Figure 12, front scatter diagramm describes relation between dissolved oxygen and pH value and distinguished by arsenic content of Bus Lake. Number order are representing sample dates. Another diagramm is redox potential and ph valuecomparison between three types of samples.

6.2 Discussion

In this section, the result of arsenic load in Nalaikh surface water has been compared with different works of literatures and different factors especially follow hypothesis question and prediction. Discussion content focuses on Bus Lake and its differentiation with surface waters from other points.

According to the **first hypothesis**, arsenic load supposed to have a linear relation with climate and seasonal weather change. To predict the assumption dissolved arsenic values were noted in Nalaikh's monthly average temperature and precipitation measures described in the Figure 13 climate data of the Nalaikh is from World Weather Online weather forecasting portal aimed to provide current past future weather data to researchers and data is delivered using standard HTTP request (33). Precipitation amount of December to February was nearly 11.5 cm thick with snowfall. Which can be the main reason for the drastic drop dissolved arsenic concentration in Bus Lake. In mid-springtime, arsenic concentrations were growing overall rate as similar as temperature growth.

To conclude, by the end of the summer, based on the drastic growth of the arsenic occurrences of arsenic, overall concentration tends to get intensify.

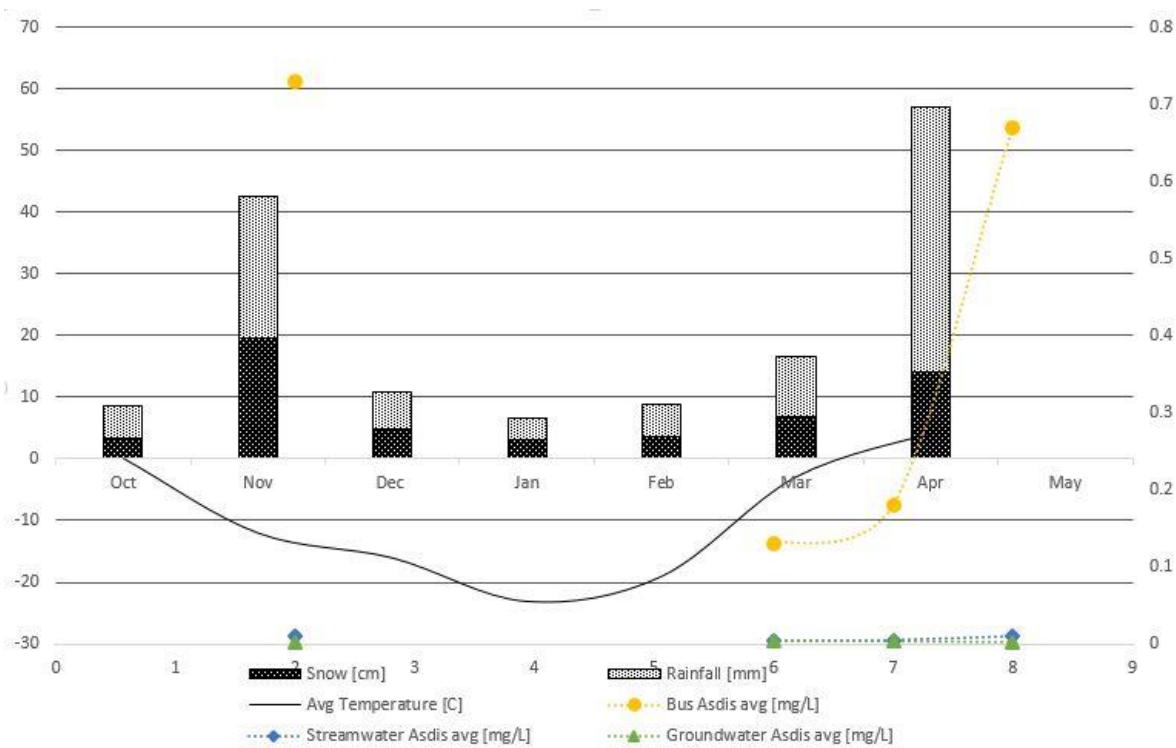


Figure 13. Arsenic concentration of the water bodies has changes trough climate variation (33).

[1]Bus- Bus Lake water sample

Bar chart describes average rainfall and snowfall of the month. Water samples average arsenic content of the month is plotted on the chart. Linear graph curve stands for average temperature by October 2017 to April 2018. From the graph, November and April had highest precipitation rate. On December to February temperature was lowest as predicted.

Refers to results on the section 6.1.3 Total dissolved solids concentration in the water bodies are reasonable. November and March result of the TDS was not high due to the lower temperature. Even though April TDS is slightly higher than March results from warmer temperature, comparison with May, average precipitation amount directly influences the value. Differentiation between 3 different water bodies, as predicted Bus Lake had the highest correlation between climate and weather changes. [Figure 14]

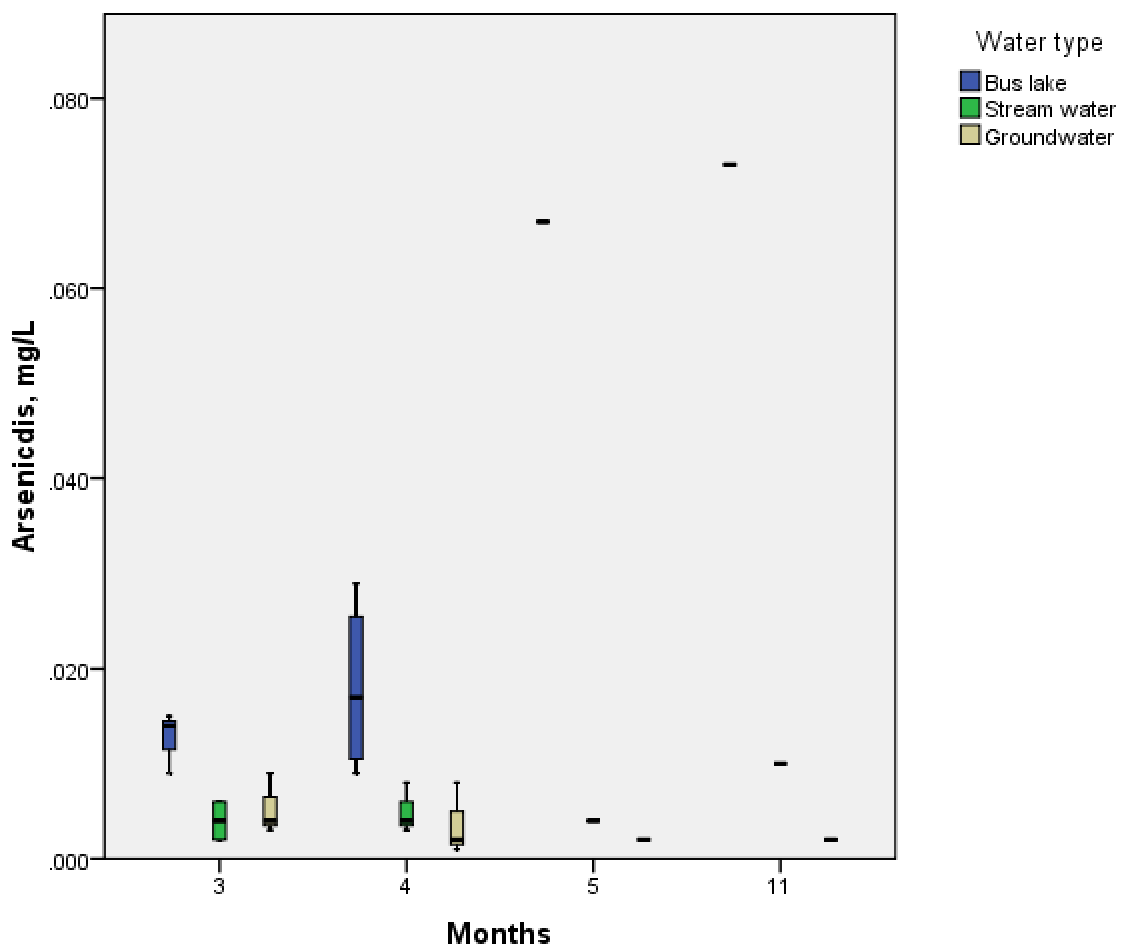


Figure 14. Arsenic concentration by mg/L of Lake, Groundwater and stream water compared with averaged by month.

At this point, measurements describe Bus Lake is exceeded WHO and MNS standards. Therefore, the **secondary hypothesis** question brings to figure out an unknown source of the huge amount of sudden arsenic concentration. To predict the geological influence into the Bus Lake, groundwater and stream water has been observed.

Refers to Walk studies, groundwater sample on October 2016 highest concentration occurred 16 microg/L (13). Walks prediction was supported by aquifers in the Nalaikh groundwater which fed from Devonian Sergelen formation region. Trassic period formation of the geology is highly associated with Arsenic and pyrite and which could be geological arsenic concentration influence in the area. Groundwater highest concentration in between the studies was on 18th of March 2018 with 10 microg/L. Both results clearly detecting there is geological influence into heavy metal concentration. However, geological entry into water is not strong as it presented by Walk. To support the sentence, out of 8 ground water sample highest concentration was in total arsenic reached WHO limit (14). The average of dissolved arsenic concentration is 3.8 microg/L and median was 3 microg/L.

Additionally, in this region particular land disturbances could be found (13). Run off stream had similar level as geogene background content in October result [As_{dis}-11 microg/L, As_{tot}-14 microg/L] (13). Seasonal monitoring arsenic measurements had average of 5.4 microg/L, median was 5 microg/L. Maximum level occurred in November 10 microg/L and again in April [9 microg/L].

Table 6 Comparison of arsenic concentration monitoring with Walk result (13).

Location	**August [pre-examination] 2016**	**October [post-fall] 2016**	**November[pre-winter] 2017**	**March [pre-spring] average 2018**	**April [spring] average 2018**	**May [pre-summer] 2018**
	As[μg/l]	As_{dis}[μg/l]	As_{dis}[μg/l]	As_{dis}[μg/l]	As_{dis}[μg/l]	As_{dis}[μg/l]
Bus Lake	138	97	73	13±3	18±9	67
Stream water	.	11	10	4±3	5±3	4
Ground water	.	16(max)	2	5±3	4±4	2

Lastly, anthropogenic sources can be titled. According to Walk studies on soil, topsoil concentration of arsenic was relatively harmless but near to mining settlement area anthropogenic source was detectable. According to Davaabal research, Nalaikh coal concentration of arsenic was high (20). Bus Lake is to be found close to ger district as well as, to the western direction about 10 km distance coal fired Nalaikh thermal power plant is located. Wind compass indicates dominant wind blowing direction is from the West (25).

Third hypothesis, as a result arsenic species were highly toxic trivalent arsenite type detected. [Chapter 6.1.4]. Generally, all three water bodies where containing trivalent arsenic during monitoring period. However, Bus lake water was alkaline so concluded by pentavalent specie of arsenic dominant on October [Figure 15, red point] (13). Thus, arsenic specie in the Lake is changing overall climate and seasonally when pH and redox potential changes. Measurement seams during winter period specie is ionic formation of trivalent and over the transition to summer, Lake Arsenic species are transferring into pentavalent ionic form.

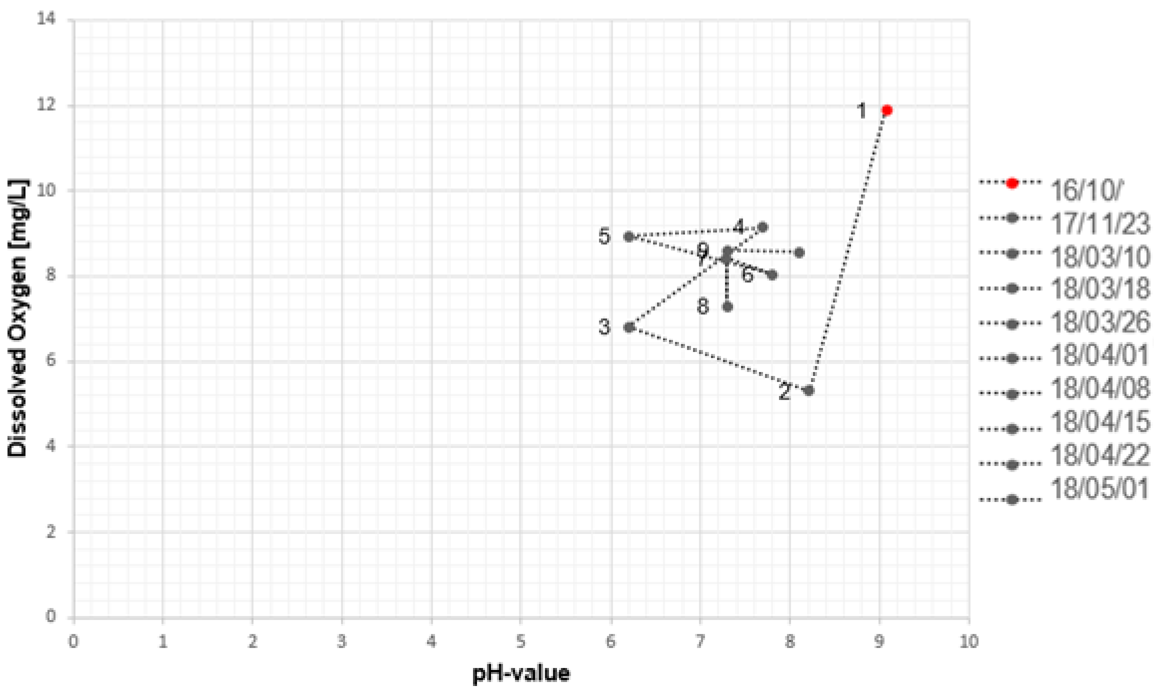


Figure 15. Bus Lake arsenic specie changes by period

Fourth hypothesis was considered winter won't have dramatic changes in terms of concentration in the water bodies. Comparing between beginning of the winter and beginning of the spring, there is drastic difference. Overall assumption was solid form of water would lock the arsenic phase and transition and dilution. From solid and liquid state of the groundwater resulted, ice was containing much smaller amount of arsenic on both dissolved and total arsenic on March 18th.

Precipitation amount in December to February, snowfall is 11.4 cm and rainfall is 14.9 mm which possibly causes dilution effect or coverage on the Bus Lake surface (33).

To conclude the hypothesis results, some unpredicted outcomes to be found. In comparison with a study by the WHO [2005], in which over 867 wells were sampled in complete Mongolia and an average as concentration was found in drinking water from 14 microg/L wells, and maximum concentration was on Walk study was 16 microg/L (13) & (13). The conclusion was groundwater quality in Nalaikh Valley was good as similar as this monitoring results maximum point was 10 microg/L. Seasonal weather changes and temperatures are high role to determine concentration as well as specie transition. Comparing with Mongolian arsenic studies Kharaa river summer season research founded pentavalent dominance (13) and Bus Lake concentration level is at least doubled contamination. However, comparing with Boroo and Gatsuurt mining area water effluent the Lake hazardous contamination is almost negligible (13). The Lake scale is increasing last 2 years examined from Google time-lapse, so that water concentration possible diluted by increasing water volume (13). Geological influence in the Bus Lake is in level of minor level according to groundwater and stream water concentrations. Rock and soils mobility into the water is also small (13). Air pollution of surrounding area is possibly manipulating Bus Lake contamination. Similar affect as in Darkhan power plant which surrounding water arsenic contamination averaged 372 mg/L (13).

7 RECOMMENDATIONS

For the further researchers should monitor summer and autumn characteristics of the Bus Lake. Bus Lake is used as many times for livestock and birds potentially wild animals watering. The Lake arsenic concentration was constantly exceeding WHO limit. Thus, the water should not be used frequently as possible. Highly recommend not to ingest water in winter to summer seasonal changes. An advance research possibly be on health and safety factors and measurement on heavy metal accumulation of Nalaikh citizens as well as livestock lifetime.

8 CONCLUSION

Monitoring of arsenic concentration of Nalaikh Valley water bodies were continued from November 2017 to May 2018 continued nearly 7 months. Even if winter season was impossible to make measurements due to harsh climate complete monitoring result where valid to recognize characteristic arsenic in the water.

Samples near to household well represents ground water characteristics. Limitation of the sample is water samples where already exposed into the air. In addition, this groundwater sample is directly used for household drinking water. Average value arsenic concentration was 3.8 microg/L. In addition, surface water result averaged 5.4 microg/L. Both, direct influence risk to health is almost negligible. However, over the time load of arsenic might accumulate in human and animal body.

Concluding Bus lake arsenic concentration, which is definitely in risky resulted max 7 times higher than recommended daily intake limit. It is hard to assume Bus Lake arsenic life cycle. Whether arsenic only accumulated in the water or actively participate natural water cycle. Gorodok citizens stated about dispose waste into Bus Lake during soviet period. Also Nalaikh locals know unwritten story about soviet mining was flushing excess mine water in the Lake. However, people used to use Bus Lake mud for traditional health treatments. Arsenic concentration about 100 microg/L won’t risks health directly, but possibly develops chronic diseases. The study highlights that, winter to summer transition period arsenic specie is in highly toxic form.

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APPENDICES

Annex 1. Monitored arsenic concentration and field measurements result by monthly mean

Months	Water type	Arsenicdis, mg/L Mean	Arsenicdis, mg/L StdDev	Total dissolved solids, mg/L Mean	Dissolved oxygen, mg/L Mean	pH Mean	ORP oxidation-reduction potential, mV Mean	Electroconductivity, mS/cm Sum
3	Bus lake	.013	.003	311.00	8.30	6.70	-20.47	1422.00
	Stream water	.004	.003	173.00	8.08	7.20	-17.95	355.10
	Groundwa ter	.005	.003	231.00	9.36	7.63	-43.90	914.00
4	Bus lake	.018	.009	530.50	8.09	7.42	-9.10	3360.00
	Stream water	.005	.003	286.67	7.91	7.50	-6.30	1258.00
	Groundwa ter	.004	.004	188.33	7.97	7.67	-10.00	828.00
5	Bus lake	.067	.	1302.00	8.56	8.10	-55.00	1980.00
	Stream water	.004	.	210.00	8.54	8.40	-63.20	305.00
	Groundwa ter	.002	.	278.00	8.52	8.60	-62.80	289.00
11	Bus lake	.073	.	136.00	.00	8.21	-70.10	204.00
	Stream water	.010	.	.00	.00	7.27	-21.65	.
	Groundwa ter	.002	.	99.00	.	7.87	-47.20	134.00

Annex 2. Overall monitoring measured factors and values

Date	Type of sampling	Arsenictot, mg/L	Arsenicdis, mg/L	ORP oxidation-reduction potential, mV	pH	Total dissolved solids, mg/L	Dissolved oxygen, mg/L	mmHg	Electroconductivity, mS/cm	Temperature, Celsius
17/11/23	Bus Lake ice	.076	.073	-70.10	8.21	136.00	.00	622.03	204.00	-19.68
	Stream water ice	.002	.010	-21.65	7.27	.00	.00	618.35	.	.20
	Groundwater ice	.008	.002	-47.20	7.87	99.00	.	626.98	134.00	-8.08
18/03/10	Bus Lake ice	.011	.014	25.00	6.20	307.00	6.82	641.50	459.00	-19.00
18/03/18	Bus Lake ice	.017	.009	-49.30	7.70	247.00	9.15	640.70	369.00	1.30
	Stream water	.003	.002	-66.00	8.50	49.00	7.31	640.80	58.10	7.70
	Groundwater	.010	.009	-63.60	8.40	380.00	9.73	640.80	429.00	8.90
	Groundwater ice	.005	.004	-42.20	8.00	166.00	9.63	640.80	248.00	2.60
18/03/26	Bus Lake	.010	.015	-37.10	6.20	379.00	8.93	637.80	594.00	11.30
	Stream water	.006	.006	30.10	5.90	297.00	8.84	637.80	297.00	12.20
	Groundwater	.004	.003	-25.90	6.50	147.00	8.72	637.80	237.00	11.30
18/04/01	Bus Lake	.017	.009	-34.60	7.80	393.00	8.04	641.30	487.00	14.70
	Stream water	.009	.008	-12.50	7.70	350.00	7.47	641.30	447.00	14.40
	Groundwater	.004	.002	-18.60	7.90	210.00	7.92	641.30	276.00	14.70
18/04/08	Bus Lake	.017	.012	-14.40	7.29	518.00	8.41	633.00	703.00	15.30
	Stream water	.004	.004	19.80	7.20	210.00	8.80	633.00	374.00	15.90
	Groundwater	.002	.001	17.20	7.40	165.00	8.51	633.00	257.00	14.90
18/04/15	Bus Lake	.027	.022	-31.20	7.30	773.00	7.29	629.50	1034.00	13.90
	Stream water	.008	.003	-26.20	7.60	300.00	7.46	629.30	437.00	13.40
	Groundwater	.003	.008	-28.60	7.70	190.00	7.47	629.40	295.00	13.80
18/04/22	Bus Lake	.034	.029	43.80	7.30	438.00	8.61	638.50	1136.00	16.30
18/05/01	Bus Lake	.065	.067	-55.00	8.10	1302.00	8.56	638.50	1980.00	15.80
	Stream water	.005	.004	-63.20	8.40	210.00	8.54	638.40	305.00	17.10
	Groundwater	.003	.002	-62.80	8.60	278.00	8.52	638.40	289.00	17.10

Annex 3. Location: Groundwater sampling area. Water state, distribution through different months shown in the figure. It is proven that local herders and livestock using the water directly from the spring.

Annex 4. Location: Nalaikh stream sampling area. Because of harsh weather transition March stream was streaming through Nalaikh area, but in April the water is in solid state. Local livestock, especially horses are drinking the water.

Annex 5. Bus Lake State and condition throughout different seasons. It was noticeable that herders are constantly using Bus Lake water for watering livestock purpose during the monitoring. Particularly, sheep, goat, horses, cow and yak. Dimension of the Lake has been shrinking during March till May comparing the photos. Additionally, surface state of the water has not been changing different from the stream water. In fact, the Lake has melted complete late mid-April.

Annex 6. On May 1st, crane was observed during monitoring in groundwater sampling point. Thus, during warm seasons became suitable condition to special types of birds migrate and settle in this region

Annex 7. On May 1st, Duck family was observed in the Bus Lake lakeside, however one duck captured on the photo.