

DETAILED ENVIRONMENTAL IMPACT  
ASSESSMENT, CONSULTING  
SERVICE  
“NATURE FRIENDLY” LLC



“Boroo Gold ” LLC

## The Project of BIOX<sup>®</sup> Plant to Process Oxidizing Sulphide Ore with Flotation and Cyanidation



DETAILED ENVIRONMENTAL IMPACT ASSESSMENT REPORT

ULAANBAAT 2010

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**"The Project of BIOX® Plant to Process Oxidizing Sulphide  
Ore with Flotation and Cyanidation"**  
**DETAILED ENVIRONMENTAL IMPACT ASSESSMENT REPORT**

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## **Executive Summary**

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Environmental friendly, economically beneficial technology is constant requirements for metal processors. The best choice to meet the criteria and best industrial solutions for metal processors is biological oxidation technology of sulfide ore and this technology is approved as a most economic and environmental friendly beneficial choice of developed countries' bio-oxidizing industries.

According to Mongolian law on Detailed Environmental Impact Assessment, it requires to conduct environmental investigation and analysis and impact assessments before commencing any project implementations.

“Nature Friendly” LLC, environmental assessment and consulting company has developed DEIA of the project report under the collaboration contract between Boroo Gold Co.,Ltd and Nature Friendly LLC. The report is based on the project implementation, operation plans, environmental protection plan, environmental monitoring plan, annual reports of reclamation and environmental protection and study results referred some data, picture and study summarized in prior reports, which are developed by international and national organizations. Report has been developed in accordance with Mongolian law on environmental protection, Mongolian law on minerals, Mongolian law on environmental impact assessment and other related laws, guidance, procedure and standards.

Detailed environmental assessment work and development of the report has been conducted by Nature Friendly company experts: meteorologist Dr. G.Namkhaijantsan, soil-vegetation expert Dr. Sh.Batsukh, soil expert Dr. D.Batbayar, hydrogeology-geo-ecologist PhD Dr. M.Alei, chemist Dr.D.Burmaa, zoologist B.Munkhtsetseg, hydro-construction engineer M.Sc P.Bold and president of mineral processing association of Mongolia Dr PhD M.Damdinsuren has worked as a consultant engineer.

We are thankful to “Boroo Gold” LLC's management team in charge of operations in Mongolia, as well as engineering and technical employees for providing all necessary materials and assisting us on preparation of detailed environmental impact assessment.



## **Section 1. Project Description**

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### **1.1. Project Introduction**

**Project Title:**

Boroo Plant Expansion - The Project of BIOX® Plant to Process Oxidizing Sulfide-Bearing Ore from Gatsuurt hard rock gold deposit with Flotation and Cyanidation.

**Project Purpose:**

The purpose of the project is to recover 986,000 ounce of gold by oxidizing sulfide in sulfide and transition ore with BIOX® technology and cyanide.

**Project Implementer:**

“Boroo Gold” LLC

State registration No 9019011029

Tax registration No 2094533

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**Project Locations:**

The project will be implemented in the Boroo mine site. The Boroo Gold Project is located in northern Mongolia in the Selenge Province, approximately 140 km north of the Ulaanbaatar, the countries capital. It is in 11.5 km from Ulaanbaatar-Darkhan-Selenge highway. The nearest towns of Baruunkharaa and Zuunkharaa are regional centers and are located 19 and 25 km of the mine site respectively. The area of the site is considered a part of the Ikh Dashir watershed that generally drains eastwards towards the Boroo River.

**Other Projects:**



BIOX® plant will be built in the Boroo mine site. Currently, Mondulaan Trade LLC is mining alluvial deposit, which located in the area under the BGC mining license and Ukhaa Khalzan LLC is mining in the Boroo River bed.

## **1.2. Project Capacity, Technique and Technology**

### **1.2.1. Project Capacity**

The construction works of BIOX® plant will commence in 2011 and continue during five months. The plant will process 4800 tons of sulfide and transition ore. The production rate (concentrate) at full processing is 5 000 t/d.

### **1.2.2. Project Equipment**

Feasibility Study and the Design of the project have been developed by SNC Lavalin from Canada. BIOX® plant with capacity of 5000 tons per day will be located in 300 meters south from Boroo processing plant and occupying 6.32 ha area. In accordance with feasibility study, oxidized and sulfide ore from Gatsuurt will be transported to Boroo mill plant. Oxidized ore from Gatsuurt gold mine will be processed by technology of direct cyanidation and sulfide and transition ores from Gatsuurt deposit will be processed by biological oxidation prior cyanidation at Boroo mill plant.

Therefore, it is planned to expand Boroo facility. To provide regular operating condition of mine site facilities including Boroo processing plant, heap-leach facility and tailings facility, following facilities and equipments will be installed in addition to equipments present from the beginning of processing plant.

- Sulfide ore flotation circuit
- Primary and secondary BIOX reactors
- Slurry washing and neutralization
- Leaching and adsorption
- Other equipments (limestone preparation, cooling tower, wastewater treatment/reuse, reagents)

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**Figure 1. Bio-oxidation plant layout**

### **1.2.3. Biological oxidation BIOX® technology, experiment and technological process**

#### **1.2.3.1. Biological oxidation BIOX® technology**

The BIOX i .e. bio-oxidizing process is a mill process for oxidizing sulfide-bearing ore with bacteria that increases the release and recovery of gold. It is a well-studied process that is generally considered as environmentally friendly (Gold Field Limited, 2006, van Aswegan, et al. 2007). In 2008, Bateman Engineering acquired the BIOX process from Gold Fields Group. For last 20 years, industrial use of BIOX processing is grown, improved and increased its capacity. Details of existing operations and recent advances of the BIOX technology are discussed in van Nieakerk (2009).

The bacteria are grown in the reactor from inoculums, with fertilizer-grade ammonia nitrogen, phosphorus, and potassium added as nutrients. Carbon dioxide is necessary for cell growth and is supplied from air and limestone, if needed. The sulfide oxidation reaction is exothermic and generates acid, leading to a more efficient oxidation reaction. The reaction is effective for pyrite ores, because the oxidation of iron and sulfide are both promoted in warm, acidic solutions. The reaction processes are optimized for the specific deposit minerals, to maximize gold recovery from the sulfide bearing minerals and eventual recovery. An air sparge ring supplies oxygen to form solid bodies. The dissolved oxygen concentration is kept above 2 mg/L. Cooling water and limited amounts of sulfuric acid and limestone are needed to maintain an optimal temperature of 40 to 45 °C and pH in the range of 1.2 to 1.8. The reactors are corrosion resistant and operate at ambient pressures.

Crushed ore material goes through a flotation process and floated sulfide-bearing minerals flow to a processing stock tank, where nutrients are added prior flow to the primary BIOX reactors. The retention time for the minerals in each reactor is approximately 4 to 6 days. Percent solids in the reactors may range from 10 to 20%, depending on optimization. Secondary oxidation is also used to increase the overall efficiency of the reactors. Sulfide-depleted ore and tails are then washed with water, and the acidity is neutralized with limestone. The washed ore and tails (pulp) are then brought to a cyanidation process for gold recovery. Boroo mill plant is practicing environmentally friendly cyanidation for years. The total cyanide concentration of Boroo ore mine liquid tailing constantly kept as a state standard 1mg/L.

Signifying flotation process of releasing metal from depleted non-ferrous ore by using biological oxidation is concerned the most low-priced with favorable and technology not harmful to the environment all over the world. For last few years, experimental studies for bio-oxidization and bio-leaching technologies have been intensified to introduce and produce low cost products replacing traditional production technologies.

One of real example is study on biological leaching of copper ore with microorganisms. Mongolian metallurgist engineer Kh.Sereedorj has found native genera Thiobacillus ferrooxidans from ore of Erdenet copper-molybdenum mine site and determined physiological and biochemical properties. He developed methodology to extract the bacteria culture, conducted laboratory experiment for bio-leaching process of oxidized sulfide, and mixed ores by using bacteria culture. Kh.Sereendorj mentioned about bacteria Thiobacillus ferrooxidans that included in his patent “Alkalinize copper from oxidized ore with bacteria”, obtained on 20<sup>th</sup> of June 1995. In addition, chemist, scientist S.Davaasuren and B.Altannavch have found and patented Leptospirillum ferrooxidans, Thiobacillus thiooxidans from water of Erdenet and Tsagaan-Suvarga copper-molybdenum mine. (Patent 772 Leptospirillum ferrooxidans native genera, 773 Thiobacillus thiooxidans native genera)

#### **1.2.3.2.Bio-oxidation experiment**

An experiment agreement has been concluded between Centerragold LLC and BIOMIN for the performance of a continuous BIOX® pilot run on a bulk concentrate sample from Gatsuurt deposit. The principal objective of the experiment was to optimize the performance of the BIOX® process to maximize the subsequent leach gold recovery. Standard BIOX® parameters were used for the continuous pilot work with plant retention being the only variable.

##### Purpose of bacterial oxidation experiment:

1. Performing a series of laboratory batch BIOX® experiment on a bulk concentrate sample from the Gatsuurt gold deposit;
2. Performing a continuous BIOX® pilot plant run at different operating parameters to:
  - Determine the rate and extent of sulfide oxidation and the corresponding gold dissolution;
  - Determine the acid and limestone consumptions required for pH adjustment;



tank 3-4 : 1,30-1,20  
 Dissolved oxygen : 3,5-4,5 mg/L  
 A description of the different phase of the pilot plant run is listed in Table 1.

**Table 1. Phases of Pilot Plant Operation**

Phase	Retention, days	Duration, days	Description
A	10	3	Adaptation
B	8	3	Adaptation
C	7	3	Adaptation
D	6	25	Bulk concentrate
E	5	20	Bulk concentrate
F	4	16	Bulk concentrate

The average sulfide oxidations and gold dissolutions for the phases of the pilot plant operation are shown in Table 2.

**Table 2. Experimental results**

Phase	Retention, days	Sulfide oxidation, %	Gold dissolution, %
D	3.0	68.4	87.6
	4.0	86.0	91.8
	5.0	92.6	94.0
	6.0	97.0	95.8
	Overflow	97.2	96.0
	2,5	61.5	86.9
	3,3	81.4	90.7
	4,2	88.0	92.9
	5,0	94.8	94.5
	Overflow	96.1	95.1
F	2,0	58.9	85.3
	2,7	77.2	89.6
	3,3	84.4	91.8
	4,0	93.2	94.2
	Overflow	94.5	93.4
<b>Average</b>			95.6

Circumstances for cyanidation experiment of BIOX® product samples:

Liquid/solid ratio : 4:1 (20% solid)  
 Leach period : 24 hrs  
 Cyanide sodium addition : 20 kg/t for BIOX® feed  
 Method for Cyanide sodium addition : bulk  
 Carbon concentration : 12,5 gr/L  
 Slurry pH : 10,6-11,5

The average gold dissolution of the Gatsuurt concentrate, without BIOX® pre-treatment was 65.9 %. After bio-oxidation of the concentrate, gold dissolutions of > 96 %



Has been achieved on the pilot commencement samples. Standard cyanidation leach tests were performed on daily overflow solids and the results are presented in Table 3.

**Table 3. Cyanidation result of overflow sample**

Phase	Retention, days	Content, gr/t Au		Gold dissolution, %	Sulfide oxidation, %
		Analyzed head	Residue		
A	10	17.5	1.1	93.9	93.0
B	8	13.4	1.1	92.7	98.4
C	7	15.1	1.0	93.7	96.6
D	6	21.0	0.9	96.0	97.2
E	5	25.1	1.3	95.1	96.1
F	4	25.2	1.8	93.4	94.5

There was a strong correlation between sulfide oxidation and gold dissolution for the different phases of the pilot plant operation. The gold dissolutions achieved during phases D, E, and F were 96.0 % to 93.4 % and the sulfide oxidations were 97.2 % to 94.5 %. The cyanide consumption was relatively low ranging from 9.5 kg/t to 10.4 kg/t BIOX® feed with a free sodium cyanide concentration in solution of >1.5 g/l at the end of the leach. An initial cyanide addition of 20 kg/t BIOX® product was required to achieve this final concentration.

*Preferred conditions for Gatsuurt BIOX® product cyanidation:*

Liquid/solid ratio	: 3:1 (33,3% solid)
Leach period	: 24 hrs
Carbon addition	: 10-20 gr/L
Slurry pH	: 10,6-11,5
Lime addition	: 50kg/t BIOX® feed for 1g/l Fe in CIL feed

Effective liquid and solid separation at various stages in the processing of the Gatsuurt concentrate will be essential in limit the consumption of fresh water and the amount of process water that has to be discarded. The work reported in this section details the experiments undertaken to determine the settling rates of the slurries associated with the BIOX® process. Outokumpu Mintec was approached to simulate the thickening of the various BIOX® process slurries using their pilot scale test unit. The following slurries were tested:

- Flotation concentrate,
- Flotation tailings,
- BIOX® product,
- AR-Grade Limestone/Lime Neutralized product,

- Limestone(Drill Core) Neutralized Product and
- Flotation Tailings/Limestone (Drill Core)/Rock Lime Neutralized Product.

The summary of test work shown in the following table.

**Table 4. Result of settling experiment**

Samples	Flocculents, gr/t	Rise rate, m/hrs	Solids loading, t/m <sup>2</sup> .hr.
Flotation Concentrate	25	2,38	0,25
Flotation Tailings	25	4,93	0,53
BIOX® product-4 days	25	2,49	0,15
Tails/Limestone(Drill Core)/Rock Lime Neutralized Product	22	2,04	0,20
Limestone(Drill Core) Neutralized Product	35	2,83	0,20
AR-Grade Limestone/Lime Neutralized Product	50	2,04	0,20

**Grinding test:** *(was conducted by the following laboratories)*

- Vizon Scitec (sulfide and transition ore by ball mill)
- Ammttec (Oxidized, transition and sulfide ore from Central zone, transition and sulfide ore from Main zone)
- SGS LRA (pilot plant bulk sample)

Ammtec laboratory was selected central and main zone samples with representative of sulfide and transition ore. Central zone sulfide and transition ore samples has taken at the end of the north Central zone and this represents Kharaa meta-sedimentary rock. Sulfide ore sample of Central zone has taken from end of the south Central zone granite base. Mostly the ore sample of Main zone hosts rhyolite rocks. Kharaa meta-sedimentary rock, granite and rhyolite from Central and Main zone sample contains Ammttec lab's central and main zone oxidized ore sample. The summary of grinding test is shown below.

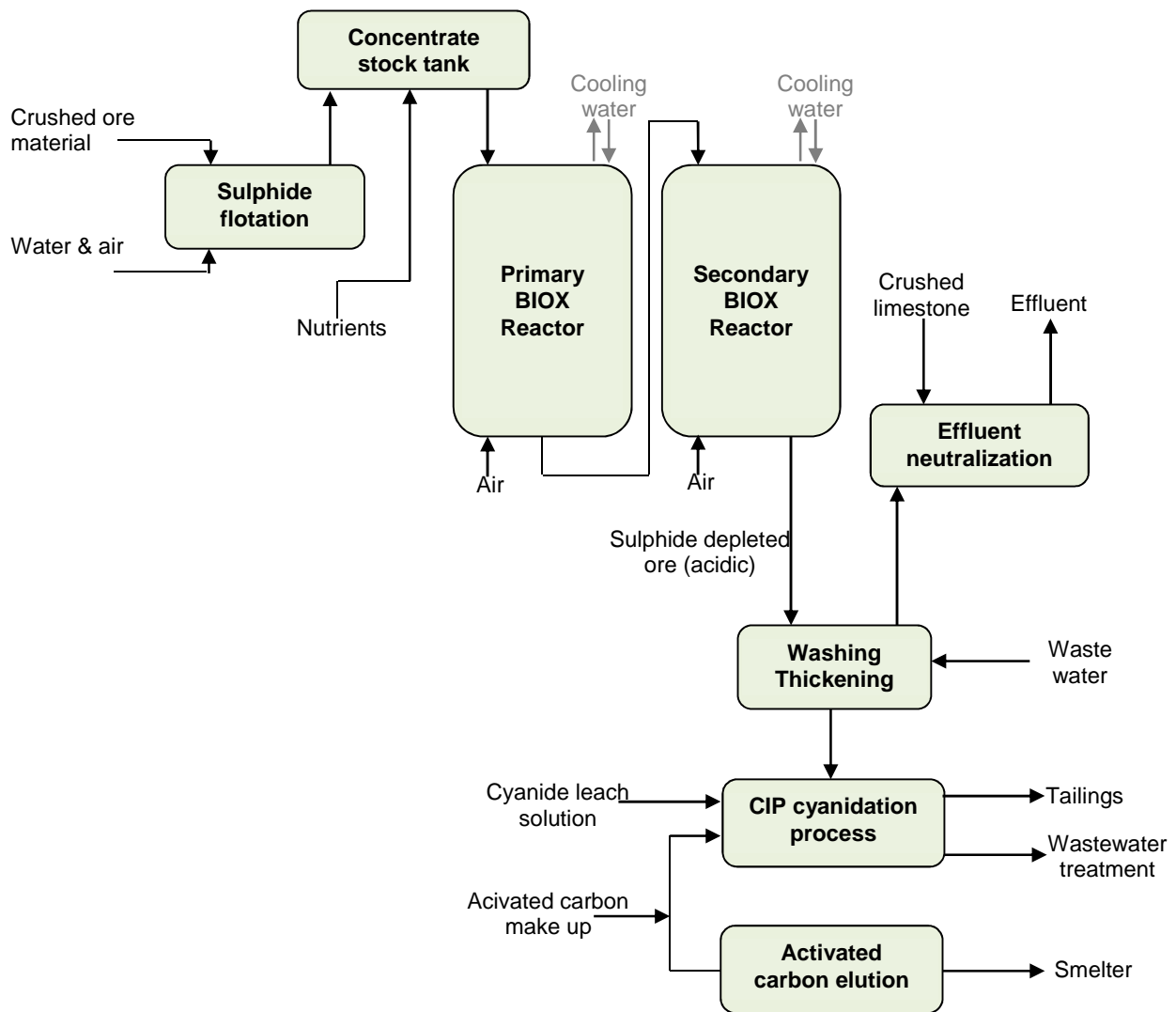
**Table 5. Grinding results**

Samples	Laboratory	Bond rod mill work index		Bond ball mill work index		Bond abrasion index
		W	P <sub>80</sub> ,µm	BW	P <sub>80</sub> ,µm	
Central zone transition	Vizon	-	-	12.43	77	-
Central zone sulfide	Vizon	-	-	13.54	73	-
Central zone transition/sulfide	Ammtec	17.9	825	18.8	84	0.370
Central zone sulfide	Ammtec	18.5	878	19.1	85	0.386
Main zone transition/sulfide	Ammtec	21.8	843	19.9	85	0.378
Main zone transition	Ammtec	20.6	879	21.6	84	0.381
Central zone pilot plant bulk sample	SGS LRA	14.4	932	17.4	81	0.390
				26.3	57	
Central/main zone oxide	Ammtec	18.7	913	16.8	81	0.174

**Preliminary biological oxidation testing:** Flotation concentrates generated from the April 2004 Lakefield Research program were subjected to preliminary batch biological oxidation tests. These samples were selected from Central zone mineralization focus element ore of Boroo granite and Kharaa rock. In sulfide and transition ore concentrate, applied with cleaner flotation concentration, contain 56 g/t gold, 33% sulfur and 66 g/t, sulfur 27% respectively. The ratio gold and sulfur is 1,7:2,4. These concentration ratio by pre oxidizing method before cyanidation process could show economic profit. Preliminary bacterial leaching tests conducted on cleaner flotation concentrates indicated approximately 96% gold extraction at 99% sulfide oxidation. The average cyanide consumption is 2 kg/t and lime is 3kg.

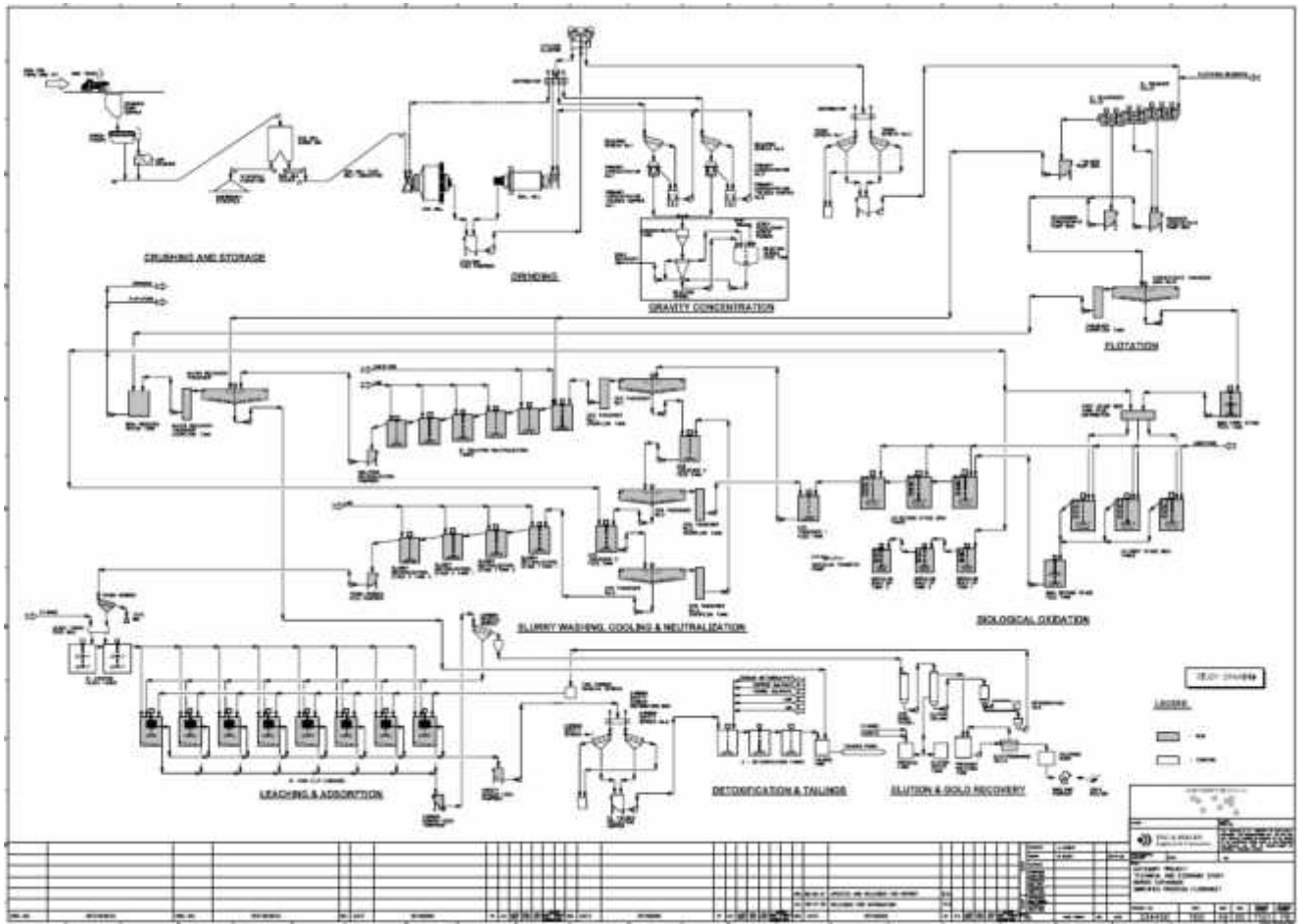
#### **1.2.3.3. Biological oxidation plant technology**

BIOX® plant design and technology were developed by SNC Lavalin from Canada. The process flow sheet is described in this section.



**Figure 2. BIOX® Process flow sheet**

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**Figure 3. BIOX® plant layout**

### **1.2.3.3.1. Crushing and Storage**

Extracted ore from the mine pit is delivered to the existing crushing and storage facilities of the processing plant using dump trucks. The trucks dump the ore into a 140-ton capacity hopper. The ore from the hopper discharges into an apron feeder, which in turn feeds the 150 kW single toggle jaw type primary crusher. Crushed ore will be conveyed to a 67-ton capacity SAG mill surge bin. Key production rates of the crushing and storage facilities are summarized in Table 6.

**Table 6. Ore crushing and storage**

<b>Ore crushing and storage</b>	<b>Unit</b>	<b>Value</b>
Operating hours	h/d	24
	d/y	265
Capacity	%	92
	h/y	8,059
Processing rate	t/y	1,752,000
	t/h	217.39
Crushed product 80	mm	129

### **1.2.3.3.2. Grinding**

Grinding of the crushed ore will be carried out in the existing grinding equipment of the plant. Crushed ore from SAG mill surge bin will be conveyed to a SAG mill. Discharge ore from the SAG mill will flow by gravity to the mill discharge hopper. Process water will be added, as required, to the ore slurry in the mill discharge hopper to meet the density requirements before pumping to the classifying cyclones. The cyclone underflow discharges by gravity to a distribution box consisting of three compartments where the ore slurry can be distributed to the following equipment: 1. SAG mill; 2. Scalping screens; 3. Ball mill. The cyclone overflow slurry flows by gravity to two trash screens and into the pre-leach thickener feed hopper from where it will be pumped to the flotation circuit. The mass balance assumes no cyclone underflow goes to the SAG mill. Key process variable for the grinding circuit are summarized in Table 7.

**Table 7. Grinding circuits**

<b>Grinding circuits</b>	<b>Unit</b>	<b>Value</b>
<b>SAG mill</b>		
Number of mills	pcs	1
Circuit configuration		open circuit
Mill fresh feed rate (dry)	t/h	217
% Solids mill discharge	%	75
Water to trammel washing		22
Design mill feed size F80	mm	129
Design mill product size 80	mm	0,73
Trammel screen on SAG mill	yes/no	yes
<b>Ball mill</b>		

Number of mills	pcs	1
Circuit configuration		closed circuit
% Circulating load		245
% Solids mill discharge		70
Water to trammel washing		10
Design mill feed size F80	mm	0,73
Design mill product size 80	mm	0,073
Trammel screen on ball mill	yes/no	yes
<b>Primary cyclone</b>		
Cyclone feed % solids w/w	% solids	54
% Solids cyclone U/F	% solids	73,5
% Solids cyclone O/F	% solids	32,7
Fraction of cyclone U/F to ball mill	%	83
Wash water to O/F trash screens	m3/t	2
% Solids feed to flotation	%	30

The suitability of the crushing and grinding facilities will be investigated during the phase 2B of the expansion project and it will be given the interfacing of the existing plant with the new installation.

#### **1.2.3.3.3. Gravity Concentration**

Underflow slurry from the classifying cyclones distribution box will flow to two scalping screens. Each screen will discharge its underflow to the primary concentrators located underneath the screens. The overflow from both the screens and the concentrators will be collected in the Knelson tails hopper and recycled to the ball mill discharge pump box. The underflow from the primary concentrators will be forwarded to the acacia reactor vessels and then pumped to the gold recovery facility. Process descriptions are summarized below.

**Table 8. Gravity concentration**

<b>Gravity concentration</b>	<b>Unit</b>	<b>Average</b>	<b>Max</b>	<b>Min</b>
Wash water to Scalping screen	m3/t	0,02		
Scalping screen overflow (mass pull)	%	5		
Scalping screen overflow (% solids w/w)	%	80		
Primary concentrator wash water	m3/h	5		
Primary concentrator ( solid SG)	-	5,18	5,20	5,13
Primary concentrator (% solids w/w)	%	90		
Primary concentrator (Au)	gr/t	10 000		
Primary concentrator (gangue)	%	5		
Primary concentrator (% R Au-global)	%	15,8		
Primary concentrator (% R Ag-global)	%	15,8		
Primary concentrator (% R Hg-global)	%	15,8		
Water addition to ACACIA concentrator	m3/h	5		
ACACIA liquid SG (pregnant solution)	-	1,1		
ACACIA residues (solid SG)	-	4,13	4,1	4,27
ACACIA residues (% solids w/w)	%	30		
ACACIA concentrator (mass pull)	%	10		
ACACIA concentrator (% R Au)	%	95		



ACACIA concentrator (% R Ag)	%	95		
ACACIA concentrator (% R Hg)	%	95		

The suitability of the gravity concentration circuit for the Boroo expansion project will be evaluated in phase 2B.

#### **1.2.3.3.4. Flotation**

The flotation circuit will be equipped with a single train of flotation cells consisting of five rougher cells and two scavenger cells. This circuit is designed to produce the required amount of sulfur in the rougher concentrate 12 %. The duty of the scavenger cells is to ensure the target recovery of the circuit is achieved as per the laboratory test work. The hydro cyclones overflow slurry will be pumped to the rougher/scavenger flotation circuit. Five flotation cells will be used as a rougher circuit followed by two cells of scavenging. Each of the rougher cells reports its tails to the following cell. The final rougher tails produced from cell No.5 flow to the scavenger cells (cell No.6 and 7). The circuit final tails from cell No.7 will be pumped to the Water Recovery Thickener. The concentrate produced from the flotation cells will be thickened in the Concentrate Thickener prior to treatment in Biological oxidation (BIOX®) circuit. Over all flotation, circuit is summarized in the following table.

**Table 9. Flotation circuit**

<b>Flotation circuit</b>	<b>Unit</b>	<b>Average</b>	<b>Max</b>	<b>Min</b>
<b>Flotation</b>				
Global mass pull	%	6,84	8,86	4,46
Global % R Au	%	94,95	94,95	94,95
Global % R Ag	%	94,95	94,95	94,95
Global % R Hg	%	94,95	94,95	94,95
Global % R S		98,39	98,39	98,39
<b>Rougher flotation</b>				
Flotation feed flow rate	m3/h	587,73	587,72	587,75
% solids rougher feed	%	30		
% solids rougher concentrate	%	30		
SG rougher concentrate (solids)		3,15	3,24	2,93
Water to rougher launder	m3/h	3,5		
<b>Scavenger</b>				
Scavenger mass pull	%	0,83	1,14	0,57
Scavenger % R Au	%	15,25	15,25	15,25
Scavenger % R Ag	%	15,25	15,25	15,25
Scavenger % R Hg	%	15,25	15,25	15,25
Scavenger % R S	%	33,33	33,33	33,33
Scavenger feed flow rate		557,3	548,41	568,63
% solids scavenger feed	%	29,8	29,8	29,8
% solids scavenger concentrate	%	20,0	20,0	20,0
SG scavenger concentrate (solids)		2,71	2,69	2,70
Water to scavenger launder	m3/h	1,40		

Cell type		Tank cell		
<b>Flotation cell design</b>				
Cell type		Tank cell		
Air supply		n/a		
Air hold-up		15	15	15
Residence time rougher bank	min	15,9	15,9	15,9
Total volume required for rougher	m3	185,7	186,5	185
# of rougher cells		5	5	5
Volume per rougher cell	m3	37,1	37,3	37
Volume per selected rougher cell	m3	40	40	40
Froth carrying rate (standard)	t/h/m2	0,8-1,5	0,8-1,5	0,8-1,5
Froth carrying rate (actual)	t/h/m2	1,24	1,60	0,81
Residence time scavenger bank	min	4,7	4,7	4,7
Total volume required for scavenger	m3	51,5	50,6	52,5
# of scavenger cells		2	2	2
Volume per scavenger cell	m3	25,7	25,3	26,3
Volume per selected scavenger cell	m3	40	40	40
Total residence time (rougher+scavenger) using selected cell's volume	min	28,7	28,8	28,6

#### 1.2.3.3.5. Concentrate Thickening

Recovered concentrate from the flotation circuit will be pumped to a single deck-vibrating screen that feeds into the concentrate thickener feed box/de-aeration tank. The concentrate slurry from the tank flows by gravity to the concentrate thickener where flocculents will be added to aid in slurry thickening. Overflow solution from the concentrate thickener will be pumped to the BIOX® process water tank. The thickened concentrate slurry from the thickener underflow will be pumped to the BIOX® feed tank. A description of the concentrate thickener is illustrated in the below table.

**Table 10. Concentrate thickening design criteria**

<b>Concentrate thickening circuit</b>	<b>Unit</b>	<b>Value</b>
Wash water for concentrate trash screen	m3/t	0,5
# of thickeners		1
Thickener type		high rate
Design factor		1,1
Design feed rate	t/h	21,2
Thickener design solids handling	t/h/m2	0,25
% Solids w/w product thickener underflow	%	54,0
Flocculent addition	gt/t	25
Flocculent dilution (source)	%	0,05
Flocculent dilution (final)	%	0,01

#### 1.2.3.3.6. BIOX® reactors (new)

The concentrate underflow will be pumped to the BIOX® surge tank, which will have a total capacity of 24 hours. The slurry from the surge tank will be diluted to 20% solids by injecting water into the BIOX® feed line the mass flow to BIOX® will be controlled by a

mass flow meter regulating the feed pump speed. The bio-oxidation feed will be split between four 1200 m<sup>3</sup> stainless steel primary reactors operating in parallel. The primary reactors will overflow via risers into to semicircular shaped launders, which will deliver the semi-oxidized concentrate to the secondary reactors, which will consist of three 1200 m<sup>3</sup> stainless steel tanks in series. By-pass launders will allow any one of the reactors to be taken off line for maintenance. The BIOX® culture will be kept active in the tanks by controlling the slurry conditions in certain ranges. The temperature will be controlled around 42°C by circulating cooling water through coils fitted inside the tanks. The pH will be controlled to between 1,2 and 1,6 by adding limestone. Whilst the dissolved oxygen level, at a minimum of 2 mg/L, will be maintained by blowing in large volumes of air via a sparge ring located under the tank agitator. The BIOX® reactor agitators will be axial flow turbines specifically designed for the efficient dispersal of the air. From the final BIOX® reactor the oxidized concentrate will gravitate to the counter current decantation (CCD) section. Nutrients are essential for bacterial growth and a solution consisting of a 15% (w/w) mixture of ammonium sulfate, potassium phosphate and mono ammonium phosphate will be added to the BIOX® feed splitter. Blowers equipped with after coolers to cool the air to below 60°C will supply air to the reactors. Cooling water for the blower and after coolers will be supplied from the blower-cooling tower.

#### **1.2.3.3.7. Counter Current Decantation (CCD) Thickener**

During bio-oxidation iron, sulfur and arsenic are solubilized these will be washed from the BIOX® product in a series of three CCD thickeners. The BIOX® product will gravitate into the first inter-stage mixing tank mixed with the overflow from the second CCD thickener plus flocculent before being fed to the first CCD thickener. The first CCD thickener overflow will flow into the acid solution tank and pumped to neutralization. The first CCD thickener underflow will likewise to be mixed with the third CCD thickener overflow and flocculent before feeding the second CCD thickener. The second CCD thickener underflow will then mixed with wash water and flocculent then fed to the third CCD thickener. The third CCD thickener underflow will be pumped to the leach and adsorption section.

#### **1.2.3.3.8. CIP leaching and Adsorption**

Design criteria of CIP leaching and Adsorption will be evaluated in the 2B phase of the Boroo expansion project. Existing CIP tanks will be used and KEMIX is designing CIP layout.

#### **1.2.3.3.9. Neutralization**

The acid solution from the CCD section will flow through a series of six neutralization tanks. Either all or at least some of the flotation tailings will be added to the first tank to assist in neutralization and to provide nucleation sites for the precipitates. Limestone will be added to the third tank and, if required, lime to the fifth tank to give a final pH of 7. The neutralization discharge slurry will then be pumped to the water recovery thickener. The launders will be arranged so any tank can be bypassed for maintenance. Provision will also be made to draw effluent from the third and fourth tank for recycle to the neutralization feed if no flotation tails are available. Neutralization/detoxification design criteria will be evaluated in the 2B phase of the project.

#### **1.2.3.3.10. Water Recovery Circuit**

Although the BIOX® process consumes a relatively large amount of water, much of this water can be recovered at the end of the process. It is important to recover water for recirculation before it is contaminate with cyanide or thiocyanate. Flocculation of the neutralized effluent and flotation tailings will be achieved in the feed well of the water recovery thickener. The water recovery thickener underflow pumps will pump the underflow from the water recovery thickener to the Tailings Storage facility. The overflow from the thickener will be pumped to the process water tank. Spillage generated in the water recovery thickener bund area will be pumped to the WRT feed well by the WRT spillage pump. A description of the WRT is illustrated in the below table.

**Table 11. Water recovery thickener design criteria**

<b>WRT design</b>	<b>Unit</b>	<b>Value</b>
# of thickeners		1
Thickener type		
Design factor		1,1
Design feed rate	t/h	217,9
Thickener design solids handling	t/h/m2	0,2
% solids w/w product thickener underflow	%	48,5
Flocculent to WRT	gr/t	25
Flocculent dilution (source)	%	0,05
Flocculent dilution (final)	%	0,01
% solids w/w CIP feed	%	35
Cyanide addition	kg/t	15
Cyanide concentration	kg/t	15

#### **1.2.3.3.11. Limestone Preparation**

Quarried limestone is crushed at the existing crusher and stockpiled in a 2000-tonne capacity storage area. Limestone from the stockpile will be fed to a 20-tonne capacity feed dump hopper and conveyed to the milling circuit. The milling circuit consists of a ball mill and a hydro cyclone cluster. Crushed limestone is conveyed to the ball mill and mixed with the hydro cyclone underflow slurry at the ball mill feed chute. Product limestone from the ball mill discharges to the hydro cyclone feed pump box and pumped to the limestone grinding hydro cyclone cluster. The coarse underflow discharge from the hydro cyclone will be recycled back to the ball mill. The hydro cyclone overflow will be forwarded to a limestone storage tank and distributed to the plant through a loop. A description of the limestone preparation area is illustrated in the following table.

**Table 12. Limestone preparation**

<b>Limestone preparation</b>	<b>Unit</b>	<b>Value</b>
Feed (average)	t/h	8,53
Feed (design)	t/h	12
Limestone moisture	%	3
% solids mill feed	%	65
<b>Ball mill</b>		
# of mills		1
Circuit configuration		closed
Variable speed on mill		no
Design mill feed size $F_{80}$	mm	12
Design mill product size $_{80}$	mm	0,074
Work index	kW.h/t	12,1
Hydro cyclone feed pump box residence time	min	1
Circulation load	%	300
% Solids hydro cyclone feed	%	61,1
% Solids hydro cyclone O/F	%	40
Circulating load mill	%	300
# of hydro cyclones in cluster		3+1
# of hydro cyclones operating at design feed tonnage		3
# of hydro cyclones operating at average feed tonnage		2
<b>Limestone loop</b>		
% circulating load loop	%	350
Line speed	m/sececc	2

#### **1.2.3.3.12. Gold recovery**

The existing desorption, electro winning and smelting facilities of Boroo mine will be used for the new plant. The equipment consists of separate three-ton acid washing and AARL (Anglo American Research Laboratory) pressure desorption columns. Two electro winning feed tanks with four electro winning tanks. Two calcining furnaces and a single diesel fired smelting furnace. Gold recovery design criteria will be evaluated in the 2B phase of the project.

### 1.3. Raw Materials and Auxiliary Materials, Intermediate and Final products, Wastes

#### 1.4.1. Bacteria

In 1887, a Russian microbiologist S. N. Vinogradskii discovered bacterium *Thiobacillus thiooxidans*, which is able to oxidize sulfur to sulfuric acid, and in 1922 an American microbiologists C. Backman and J. Joffy isolated the pure culture of the bacterium. In 1949 A. Colmer and M Hinkle have identified that bacterium *Thiobacillus ferrooxidans* isolated from mining water has strong impact on sulfide oxidations. Since then sulfide oxidation, methods by bacteria have been used commonly in mining industry. Nowadays sulfide oxidizing bacteria *Thiobacillus ferrooxidans*, *Thiobacillus thiooxidans*, *Thiobacillus thioparus*, *Thiobacillus thiocyanooxidans*, *ferrobacillus sulfooxidans*, *ferrobacillus ferrooxidans* from thio-species, *Leptosperillum ferrooxidans* from *Leptosperilli* species have been identified. Bacteria are microorganisms within 0.5-2 micrometer in size, abundant in soil, air, and underground water, and able to grow through dividing. The growth of bacteria can be categorized as adaptation, active growth (logarithmic phase), stationary (lag) phase and death. In bio-oxidation technology, bacterial adaptation and active growth phase are explained by exponential growth.

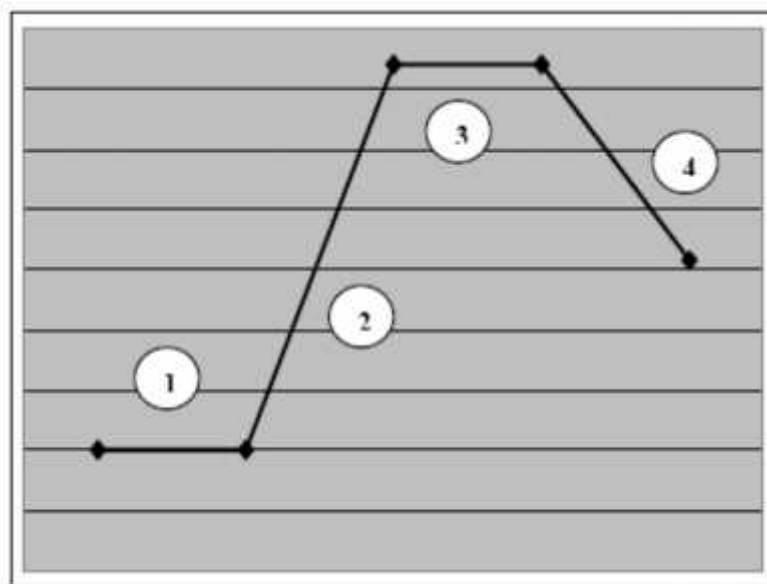


Figure 4. Bacterial growth phases  
1-adaptation, 2-active, 3-stable, 4-fatality

In order to utilize successfully bio-oxidation, bacterial adaptation time can be shortened as much as possible, but the active growth phase needs to be extended. Moreover, maintaining optimal conditions for the growth activity and culture media is necessary. The

optimal bacterial growth conditions are dependent on physical, chemical, biological, technological factors. Physical and chemical factors are medium acidity, oxidation-reduction potential, aeration, and oxygen-carbon dioxide content. The biological factors are number of bacteria, growth, mineral contents in media. The technological factors are solid and liquid ratio in the pump, aeration and mixing methodology, particle sizes in pulp, solubilization duration. The extended information on three types of bacteria for sulfide ore oxidation in bio-oxidation industry is illustrated in the Table below.

**Table 13. Morphological properties of BIOX® bacteria**

	<b>Properties</b>	<b>Acidithiobacillus ferrooxidans</b>	<b>Acidithiobacillus thiooxidans</b>	<b>Leptospirillum ferrooxidans</b>
<b>Characteristics of culture grown in hard nutrient environment</b>				
1	Colony shape	round	round	bacilli
2	Structure	homogeneous	homogeneous	homogeneous
<b>Morphological property</b>				
3	Tissue shape	bacilli	bacilli	spiral bacilli
4	Tissue size, mkm	0,3-0,5 1-1,7	0,85 1-2	0,3-0,4 1,2-1,4
5	Tissue wall, gram	minus	minus	minus
<b>Bio-chemical property</b>				
6	Fe oxidizing property	+	+	
7	Temperature limit	5-40 <sup>0</sup> , 28-35 <sup>0</sup>	5-40 <sup>0</sup> , 28-30 <sup>0</sup>	30-40 <sup>0</sup>
8	limit	1,2-6 (2,5-2,8)	0,5-0,6 (2-3,5)	1,9-2,4

## **1.4.2. Chemical Agent and Reagents**

### **1.4.2.1. Sodium Cyanide**

“Boroo Gold” Co.,Ltd utilizes sodium cyanide for their ore processing plant. “Boroo Gold” LLC has developed a procedure to store, utilize, transport and dispose sodium cyanide and the procedure has been certified by related authorities. the project is overemphasized sodium cyanide due to its highly toxic and hazardous characteristics. Chemicals currently used in processing are:

- Caustic soda
- Hydrochloric acid
- Sodium cyanide
- Flocculants
- Ferric sulfate
  
- Sodium metabisulphite
- Sulfuric acid
- Hydrated lime Detox/CIP
- Copper sulfate



**A. Sodium cyanide impact on environment:**

When cyanided ore of gold discharges with derivative cyanide, the products comes out with any kinds of the solution components as ammonia ( $\text{NH}_4^+$ ), cyanate ( $\text{CNO}^-$ ), thiocyanide ( $\text{CNS}^-$ ) etc. When the obtaining process of thiocyanide from solution of gold-cyanided discharge is originated as cyanide solution excess with atmosphere and assimilating with sulfide or mono sulfur. Thiocyanide ions and cyanides can originate insoluble salt by combining with argentum, mercury, plumbum, cuprum, and zinc. When thiocyanide react with carbonate and sulfate, it breaks down. The main environmental impact of thiocyanide is that high concentrated sodium cyanide will generate quantity of hazardous hydro cyanide (HCN) when it reacts. Oxidizing elements (chlorine, ozone, oxygen peroxide, hydrogen peroxide) will alter cyanide to cyanate. Cyanate alters gradually to ammonium or carbonate ( $\text{CO}_3^{2-}$ ) hydrolyzing in acidy atmosphere. Cyanide and thiocyanide generate ammonia ion ( $\text{NH}_4^+$ ) or carbonate by slowly reacting with water in indoor atmosphere and this reaction accelerates when its temperature increases.

**B. Hazards:**

When acid, acidic salts, water, humidity, and carbon peroxide obtain cyanide, it discharges hydro cyanide gas that has toxic and combustible characteristics. The cyanide solution has highly base property that reacts with acid incredibly fast and it is caustic. In addition, it is explosive and reacts with strong oxidants such as nitrate, chloride, nitrogen, and peroxide fast. In program of International Program on Chemical Safety (IPCS), assigned following dozes for cyanide permissible level in work places.

- Permissible level TLV: (CN) 5 mg/m<sup>3</sup>; (skin); (ACGIH 2003)
- MAK: (breath) 2 mg/m<sup>3</sup>; maximum limit classification: II(1); infiltrate to skin (H);
- Risk category: C; (DFG 2004).

Ministry of MNET has assigned the permissible level of sodium cyanide and comprised it to the limited substances type on the authorized «Classification of prohibited and restricted chemical substance in Mongolian» on 11<sup>th</sup> of April 2007.

**Table 14. Permissible levels of sodium cyanide and hydro cyanide in the soil, drinking water, and central sewage system**

Description	Unit	Value
1. Permissible level in the drinking water	mg/L	0,01
2. Permissible level of pollutants (in pond, lake and its tributary streams)	mg/L	0,05

3. Permissible level in sewage which allowed to spill into the soil	mg/L	0,2
4. Permissible level in the process wastewater drained to central sewage system	mg/L	0,1-1,5
5. Permissible level of hydro cyanide gas in the work place air	mg/L	0,0005

In accordance with WB standard, cyanide permissible level in tailings pond is up to 50 mg/L and cyanide concentration of tailings to the TMF of Boroo mine site is lower than 1 mg/L.

#### **1.4.3.2. Reagents**

The following reagents will be used in the proposed new facilities of the process plant.

- Flotation collector
- Spare collector
- Flotation promoter
- Flotation frother
- Flocculent
- BIOX® defoamer
- BIOX® nutrients
- Hydrated lime
- Cooling tower chemicals (corrosion inhibitor, biocide, anti-scalant)

##### Flotation collector (PAX):

Potassium Amyl Xanthate (PAX) will be used in the rougher and scavenger flotation circuit to recover sulfide minerals. PAX solution will be prepared in a collector mix tank and transferred to a collector storage tank. The flotation collector reagent will be distributed to flotation circuit addition points using piston diaphragm dosing pumps. Design criteria of flotation collector reagent equipment are summarized in table given below.

**Table 15. Flotation collector**

<b>Flotation collector</b>	<b>Unit</b>	<b>Value</b>
Reagent		PAX
Form of reagent		liquid
Package		220 L barrel
Solution storage at average consumption	hrs	24 (min)
Method of delivery to process		Dosing pump

##### Spare collector (SIBX):

Sodium Isobutyl Xanthate (SIBX) will be used as spare collector in the flotation circuit. SIBX solution will be prepared in a spare collector mix tank and transferred to a spare

collector storage tank. The spare collector reagent will be distributed to the flotation circuit addition points using piston diaphragm dosing pumps. Design criteria of spare collector reagent equipment are summarized in table given below.

**Table 16. Spare collector**

<b>Spare collector</b>	<b>Unit</b>	<b>Value</b>
Reagent		SIBX
Form of reagent		liquid
Package		250 USg tote
Solution storage at average consumption	hrs	24 (min)
Method of delivery to process		Dosing pump

*Flotation promoter (SENKOL):*

SENKOL reagent will be used as flotation promoter in the flotation circuit to increase the recovery of sulfide minerals and metallic gold. SENKOL solution will be stored in a promoter storage tank and distributed to the flotation circuit addition points using piston diaphragm dosing pumps. Design criteria of flotation promoter reagent equipment are summarized in table given below.

**Table 17. Flotation promoter**

<b>Flotation promoter</b>	<b>Unit</b>	<b>Value</b>
Reagent		SENKOL
Consumption	gr/t	10
Form of reagent		liquid
Package		220 L barrel
Solution storage at average consumption	hrs	24 (min)
Method of delivery to process		Dosing pump

*Flotation frother (Dowfroth 250):*

Propylene Glycol Ethers (Dowfroth 250) frother will be used in the flotation circuit to generate a stable froth on the surface of the flotation cells. Dowfroth 250 solution will be stored in a frother storage tank and distributed to the flotation circuit addition points using piston diaphragm dosing pumps. Design criteria of flotation frother reagent equipment are summarized in table given below.

**Table 18. Flotation frother**

<b>Flotation frother</b>	<b>Unit</b>	<b>Value</b>
Reagent		Dowfroth 250
Consumption	gr/t	10
Form of reagent		liquid
Package		250 USg tote
Solution storage at average consumption	hrs	24 (min)
Method of delivery to process		Dosing pump

*Flocculent:*

Flocculent will be added to the thickener feed to capture and settle fine solids particles that would otherwise report to the thickener overflow solution. Flocculent will be supplied in powder form and stored in the reagent storage area. The flocculent will be dissolved in water and stored in the flocculent storage tank at the process plant. Flocculent solution will be distributed to the thickener addition points using flocculent feed hose pumps. A description of flocculent reagent equipment is summarized in Table 20.

**Table 19. Flocculent**

<b>Flocculent</b>	<b>Unit</b>	<b>Value</b>
Reagent		Cationic flocculent
Form of reagent		Dry powder
Package	t	1
Solution storage concentration	%	0,1-0,3
Solution storage at average consumption	hrs	24 (min)
Method of delivery to process		Dosing pump

**BIOX® defoamer:**

Details of the type and consumption of the BIOX® defoamer will be defined in phase 2B of the project.

#### **1.4.4. Radioactive Substance**

None of radioactive substances will be used in the Boroo plant expansion project-BIOX® biological oxidation facilities. Two ion generators of cesium -137 and amerisium -241:BE are have been used in the Boroo processing plant to measure slurry density in cyclone feed, control the quality of tailings storage facility dam and to measure the moisture and density of the soil. An approval to use these generators is authorized by the state department of Radiation and Special control of the SSIA on May 17 2007 and these are stored in the Boroo site warehouse, located 19 km far from the Baruunkharaa, Bayangol soum of the Selenge aimag.

#### **1.4.5. Power Supply**

Site power distribution from the BIOX switchyard to the various major load centers will be from a 35 kV high resistance grounded system. In each major process area, local substations will step the voltage down to 6 kV, high resistance grounded. Power at 6 kV will be distributed radially to the larger motors (above 160 kW), and to 6 kV to 380 V outdoor transformers. The transformers will supply motor control centers (MCCs) which will supply the 380 V motors as well as lighting and heating loads. The grounding system was chosen to provide a high level of continuity of service while at the same time ensuring personnel safety using appropriate ground fault relaying. Three 1250 kW standby diesel

power genets will be installed next to the BIOX utilities substation and connected to 6 kV bus to supply the projects emergency electrical power requirements in the event of the utility supply outages.

#### **1.4.6. Water Management**

Water consumption for the BIOX® plant is 300 tones per hour and the raw water make-up to the bio-oxidation process water tank is 227 t/h and to the cooling, towers 57 t/h. The existing water supply facilities for the Boroo plant is from a well located approximately seven kilometers to the east of the process plant. Process water will be supplied from the wells and from the tailings dam. The highest rate of the water supply is estimated 80 l/sec. CIP circuit will be operated with closed water circuit. Water from tailings dam will be recycled in order to reduce fresh water consumption. During warm seasons, water amount reused from the tailings facility will reserve the fifty percent of the total water usage. In winter seasons, it will be reserved ten percent of the total water usage. Technological i.e. industrial water will be transmitted through detoxification unit for precipitation and neutralization. The water will be stored in technological water tanks for use. Fresh water will be used as an additional source to technological circulation water, especially during cold seasons. There will be zero discharge from the tailings pond, and water will not be recycled back to the plant because it will contain trace amounts of cyanide that is harmful to the bacteria in the oxidation circuit.

#### **1.4.7. Waste Management**

##### **1.4.7.1. Tailings management facility**

Tailings generated from sulfide ore BIOX® process will be stored in the existing tailings management facility. Tailings management facility in Boroo site will be expanded. Treated effluent from BIOX® neutralization circuit will be pumped to the existing Boroo tailings facility through the polyethylene pipeline. Tailings are discharged by gravity to the permanent tailings facility five kilometres from the processing plant and it will be expanded doubling its capacity. Solid residues will be settled on the bottom of the tailings pond and water will be reused back to the plant process. Current tailings area can be safely expanded with certain phases each year. A two-stage grinding circuit, which includes a SAG mill and a ball mill in closed circuit with cyclone classification, will produce 80% passing 75 micron material. Waste unit weight is indicated as 1,248 t/m<sup>3</sup> in the calculation. 1,5 mm thick Geo-membrane of will installed in inner wall of the tailings dam on compacted clay liner. Initially, waste unit weight will be 1,08 t/m<sup>3</sup> then will settle until

1,4 t/m<sup>3</sup> furthermore. Due to impossibility to circle water to BIOX® process plant, 5000-10000 m<sup>3</sup> filtration facility should be constructed in tailings dam by the end of 2013. The flotation concentrates will be pumped to the concentrate thickener and thickened to 55 % solids by weight before pumping to the bacterial oxidation circuit. To reduce environmental impacts, cyanide and arsenic contents of the tailings will be neutralized until the standard permissible level. Cyanide and arsenic levels in the tailings should be below 1 mg/L.

#### **1.4.7.2. Solid waste**

Solid waste from the construction camp, construction activities and from the permanent facilities will be hauled to the landfill site. Construction wastes are inorganic wastes like rocks, clay and other residuals. Actually, it is not possible to estimate the construction waste amount and after the completion of the plant construction, no more construction waste will be generated. If solid waste is generated from the expansion or maintenance work to support the project operation, it will be removed to the landfill site promptly. There are two landfill sites with 5 x 10 square metric areas that allowed by local authorities and these will be buried when filled.

#### **1.4.8. Intermediate products**

None of intermediate product to be produced through the BIOX® processing operation

#### **1.4.9. Final products**

It is planned to mine 1.8 Mt of oxide ore and 7.1 Mt of primary and transition ore and total outcome is 986,000 oz (26.3 t) of gold.

### **1.5. Economical Description**

Estimated total capital cost is 71 mln USD, including BOIX plant at Boroo plant (direct investment 35,8 mln USD), Expansion of Boroo site construction, infrastructure (direct investment 6,06 mln USD), Contractors cost (indirect cost 15,9 mln USD), heavy trucks and machineries (7,5 mln USD) and Owners indirect cost (5,8 mln USD).

**Table 20. BIOX® capital cost summary**

<b>Projects</b>	<b>Capital cost (thous.USD)</b>
Mine site construction	189
Service structures	277
Power substation	425,1
Flotation and recrushing	3573
BIOX®	6166

CCD circuit	7802
CIP circuit	1665
Reagents	3119
Utilization and service	4508
Automatization	1240
<b>Total</b>	<b>28964.1</b>

The cost estimate for chemicals and reagents to used flotation, BIOX®, neutralization, and leaching is based on results of pilot project in 2005. Gold recovery for sulfide and transition ores is estimated at 85,6 percent. Depreciation has been calculated on a “units of production”.

**Table 21. Unit cost of gold recovery**

Unit cost for per ounce gold	Sulfide ore	
	\$ M	\$/oz
Earth works	87,684,047	121.36
Ore processing cost	122,896,485	170.09
Ore haulage coste	36,146,025	50.03
Administration	26,169,722	36.22
Office at UB	37,736,450	52.23
<b>Total cost</b>	<b>310,632,729</b>	<b>429.92</b>

## **1.6. Options and implementation phases**

### **1.6.1. Options of ore processing**

In 2005, “SNC Lavalin” evaluated the relative economics of three process options considered pressure oxidation of flotation concentrates (POX), biological oxidation of flotation concentrates (bio-oxidation) and whole ore direct cyanidation.

This trade-off study concluded that:

- Both POX and bio-oxidation options would have significantly higher net present values than whole ore direct cyanidation; and
- The relative economics of stand-alone POX and bio-oxidation processing plants were considered equal, given the intended accuracy of the trade-off study.

Although the economics of both concentrate oxidation, options were similar, selected bio-oxidation process option. Because the processing result of pressure oxidation of flotation, concentration was not enough.

### **1.6.2. Implementation phases**



The engineering for the Boroo expansion will commence third quarter of 2011 and will continue for six months. This period can support the possibilities to assemble the design of the new processing facilities and locate the additional facilities in proper sequences. Detailed engineering works will commence first quarter of 2011.

Construction earthworks and temporal camp facilities will start in second quarter of 2011 will continue until the mid of the year. Mining department of “Boroo Gold” company and contractor company will execute construction earthworks. In the construction season will focus on the preparation of building sites, buried services and concrete work. These will be followed by structural steel erection, siding and roofing and the mechanical, piping, electrical and instrumentation installations. Construction on earthwork, exterior concrete and steel, siding and roofing will take place from the spring to fall period. This will allow mechanical, piping, and electrical and instrumentation work to proceed indoors during the winter months in preparation for plant commissioning. New BIOX® plant will be completed by the third quarter of 2011. The oxidized ore feed to process plant will be altered to the sulfide ore processing.

## **1.7. Land Utilization and Site Infrastructure**

### **1.7.1. Land utilization**

Planned site for Boroo expansion-BIOX® plant is located in the southern part of the Boroo mine site at 300 meters distance. This area includes 0,07 ha in the 198A mining license and 6,32 ha in the 238A mining license respectively. Information about land tenure was borrowed from a report, entitled “The state guarantee report of Land properties and Quality on mining licensed areas acquired by “Boroo Gold” Company in Bayangol and Mandal soums of Selenge aimag”, developed in June 2009 by land and resource use professional company “Geotsenoz” Company on behalf of BGC. Report concludes that not all of licensed area was affected by mine operations and there are many lands remaining in their natural form and vegetation coverage. Boroo mine site is located in Ikh Dashir valley the southern part of the Bayangol-Mandal soums in Selenge aimag. This area ground surface is basically mountainous, the highest point of this area is Zurkh mountain that exists 1363,2 meters high from sea-level which is south-west side of mine site. Ikh Dashir mountains consists of Chandagatai (1336,8 m), Makhai (1261,5 m) and Nariin hill stretched from north to south, Bayanzurkh hill (1086,8 m), Chandagatai (1077,5 m) and Dashir Nuruu (1156,8 m) and surrounding mauntains in east stretched from south to north. Also broad, narrow passes and mountain ranges called “Tsagaan chuluut” range, “Sairiin am”, “Ikh Tashir” range exists on south of Ikh Dashir mountain. Between the

mountains broad, narrow ranges and passages have many crop-fields. Some of them already included in mine operation area, therefore most of them are not in use. Entire territory has numerous cuts and 860-1280 m above sea level, high points fluctuation between 1100 m to 1280 m above sea level, low point or hill site fluctuation 900 m to 1000 m above sea level. During mine operations deep cut open pits were formed, also new roads and rock dumps were established thereby destroying the natural landscape. Also, disturbance in vegetation cover was observed. The report classified BGC property into following groups depending on their land characteristics, erosion condition (from impacts of human and machinery during mining) and other features:



**Figure 5. General ground surface not impacted by mining operation**

1. Pastureland
2. Farmland
3. Land affected by Mine operation
4. Soil stockpiles
5. Roads
6. Area where technical reclamation has been conducted
7. Area where biological reclamation has been conducted
8. Construction lands (processing plant, employee residence)
9. Tailings facility
10. River watershed

11. Land where earthworks were performed
12. Explosives magazine

The 6,32 ha areas of bio-oxidization plant is severely impacted by mining activity that is fully changed its natural characteristics of ground surface and covered with manmade waste rock dump, topsoil stockpile. Therefore, technical and biological reclamation should be conducted to restore natural existence after the project activity completed.



**Figure 6. The presence of impacted areas**

The company worked intensively at its operating licenses excavating gold and the land surface has been scarred with pits and openings, as well as dumps and soil stockpiles established. In the report, it is noted that construction works might cause the disturbance on soil surface, which will raise the dust in the air. Therefore, reclamation should be conducted forthwith in order to prevent soil and vegetation cover. Native plants (alfalfa, sweet clover, wheat grass, brome grass, and couch grass) are biologically significant to strengthen the soil and accumulate the soil fertility. So it is recommended proceed to collect and keep the native plant seeds with participation of local residents and use for biological reclamation. It is proper to strip and stockpile topsoil before earthworks, then use topsoil stockpile for reclamation.

#### **1.7.2. Site infrastructure**

Mine site is located approximately 145 kilometers northwest of the Ulaanbaatar and 137 km of which is paved road and 11.8 km is improved dirt roads. Mine site is located in the developed infrastructure area, connected with improved dirt roads to Bayangol and Mandal soums of Selenge aimag and railway station Tunkhel. Mine site facilities are:

- Heap Leach CIC Plant
- Process Plant and Ancillary Facilities
  - Processing Plant
  - Reagent Storage
- Workshop for heavy duty machinery
  - Workshop for heavy duty machinery
  - Contractors workshop
  - Fuel storage
- Employee and Contractors Camps
- Miscellaneous Structures and Facilities

The water supply and sewage system installed in the above facilities and assembled directly to septic tank. Boroo mine site has year around mill operation with infrastructure such as roads, power supply, domestic water supply, telecommunication, camps, septic facility and security.

#### **Power transmission system:**

The power transmission system with capacity of 40 MW is connected to the 110 kVA main Mongolian power network. A power supply agreement has been conducted with the Power Supply Office of Darkhan Province, a Mongolian-registered company. The power feeds a substation on the site that distributes power to a number of Motor Control Centers which feed power to the individual buildings and work areas. A diesel generator is also connected to the 415kV Main Switchboard for providing back-up power during electrical power outages.

#### **Communication:**

Telecommunication service providers are Mongolian Tele-communication and Mobicom. Internet Service - Underground fiber-optic cables with a total length of 20 km are located to provide fast speed internet service for users throughout the mine site area. The length of cabling within the mine site is around 9 km and another 11km that links the site to the main paved road where the service provider (Mobicom) has its main fiber-optic cable line running.

### **1.8. Project socio-economical benefits**

Project implementation, expanding Boroo ore processing plant with new facilities of biological oxidation has significant positive effects for the socio-economy of the country and local development. Since “Boroo Gold” company has commenced its activities, it has contributed substantial shares to the local development. Boroo expansion project will extend mine lifetime that will keep social-economic positive effects furthermore. Socio-economic benefits of the project summarized in the Section 2.

### **1.9. General requirements for strategy and general assessment**

The mining sector is a major contributor to the economy, forming about half of GDP and 60 percent of export earnings. The government issued policy guidelines in 2002 outlining mineral development and sector promotional goals for 2002-2010. This policy document includes a commitment to reinforce the already favorable legal environment for private mineral exploration activities. This policy document includes a commitment to reinforce the already favorable legal environment for private mineral exploration activities. Main objective of this guideline is consists favorable regulation and reinforce the environment on private mineral exploration activities. The guidelines also recognizes that the general structure of the mining industry in Mongolia has moved away from state ownership and control, under which exploration was focused on developing deposits, regardless of the economics, toward a market-driven, private sector oriented industry regulated by the government. Mitigation of the negative environmental impacts of the mining sector is an integral part of the government’s policy thrust and is reflected in the Minerals Law and related acts. While the legislation embraces many aspects of international best practice, limited institutional capacity undermines the implementation of environmental laws and regulations at existing operations.

There are three main areas of policy to be considered to make the mining sector an engine of growth for Mongolia:

- Macroeconomic policies,
- Management and organizational system and its strengthening,
- Regional and local development policies

The main thrust of macroeconomic management should be to prevent spending sprees in response to significant expansions of mining revenues during boom years. Allowing the public and financial sectors to invest in foreign financial assets can help offset the

economy's absorptive constraints. This policy would moderate wide fluctuations in the balance of payments and wide swings in private expenditures. Finding an effective formula for sharing mining revenues with local and regional governments is a priority for Mongolia. The adjustments proposed in the PFMR to clarify priorities and responsibilities through the central budget and reform the arrangements between central and regional governments are urgently needed.

Detailed environmental impact assessment report has been developed in accordance with decree 6/707 of Minister of NET “General Environmental impact assessment conclusion” on 9<sup>th</sup> March 2010 and decree 3104 “Environmental impact assessment guideline” attachment approved on 12<sup>th</sup> January 2010 and other relative rules and guidelines ordered by MNET.

Following issues should be indicated in conclusion of General Environmental impact assessment and DEIA:

- Baseline condition of environmental components
- Determining and assessing potential environmental impacts of project operation
- Develop plan of measures to mitigate and eliminate potential environmental impacts
- Safety guideline of handling and storing chemicals, evaluating chemical storage, risk assessment
- Recommendation to store bacteria culture of sulfide ore oxidization, transportation and usage, developing bio safety recommendation

In DEIA report includes baseline research of geological structure surface and underground water, climate and air quality, soil and vegetation cover, fauna, human settlement and their socio-economic condition situated at and around proposed bio-oxidizing project operation; prepared conclusion of the research and determined potential impacts as well. In addition, bacteria bio safety handling guideline for bio-oxidization technology has been developed.



## **Section 2. Environmental Baseline and Impact Assessment**

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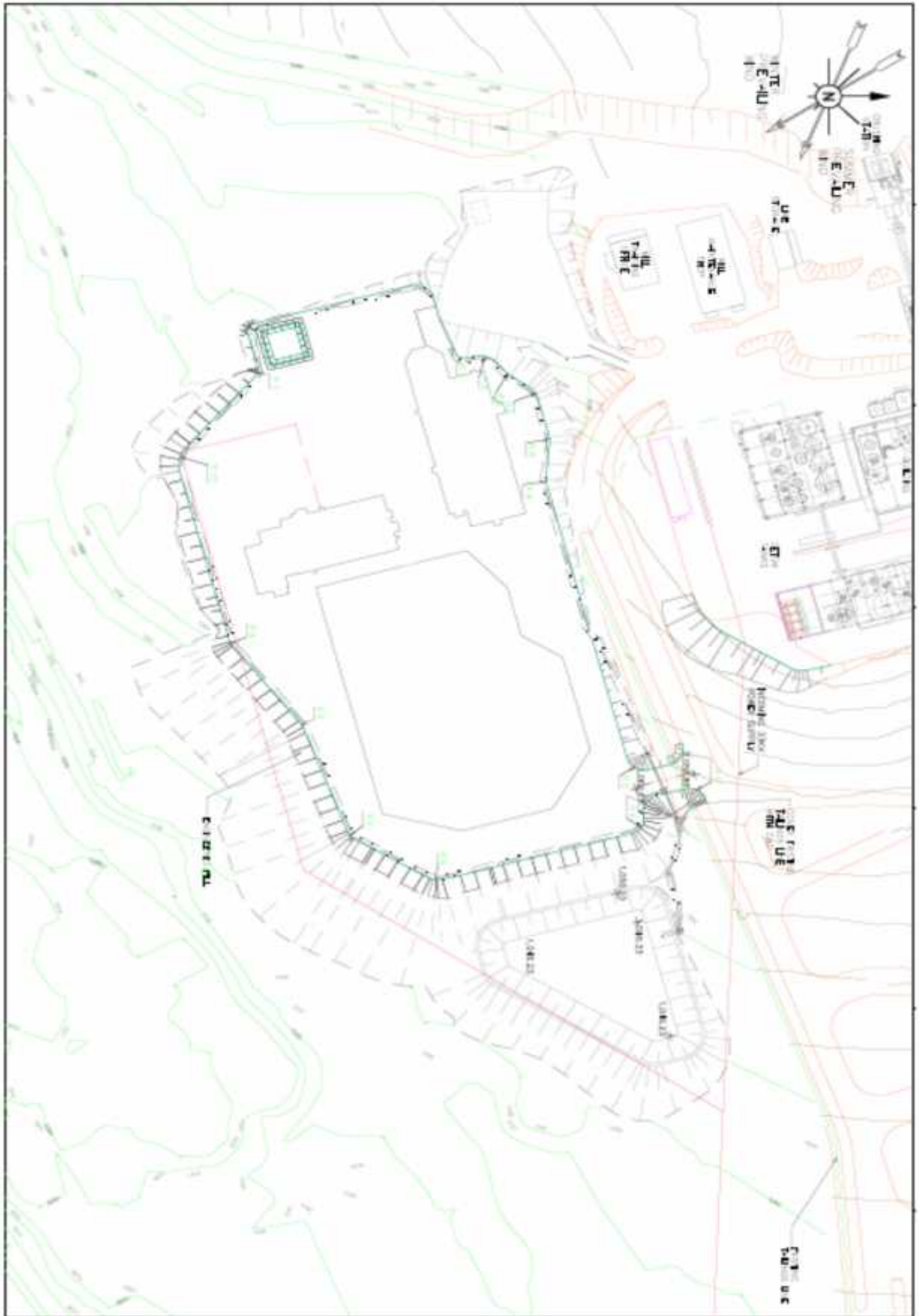
### **2.1. Research Overview**

Environmental baseline study has been conducted by “Nature Friendly” LLC, a consulting company between February and April. The purpose of the study is to determine the environmental impacts that might be caused by bio oxidation technology of Boroo expansion and facility restoration to oxidize Gatsuurt sulfide ore and compatibilities of existing facilities crushing, grinding, gravitation, flotation, and gold recovery. Research works on below environmental components have been conducted at the proposed project areas:

- Soil study
- Hydro geological study
- Flora and fauna
- Climate
- Air quality measurement
- Cultural heritage and monument sites
- Socio-economic study
- Other researches

Previous studies and DEIA reports summarized by foreign and national organizations have been used in the study.



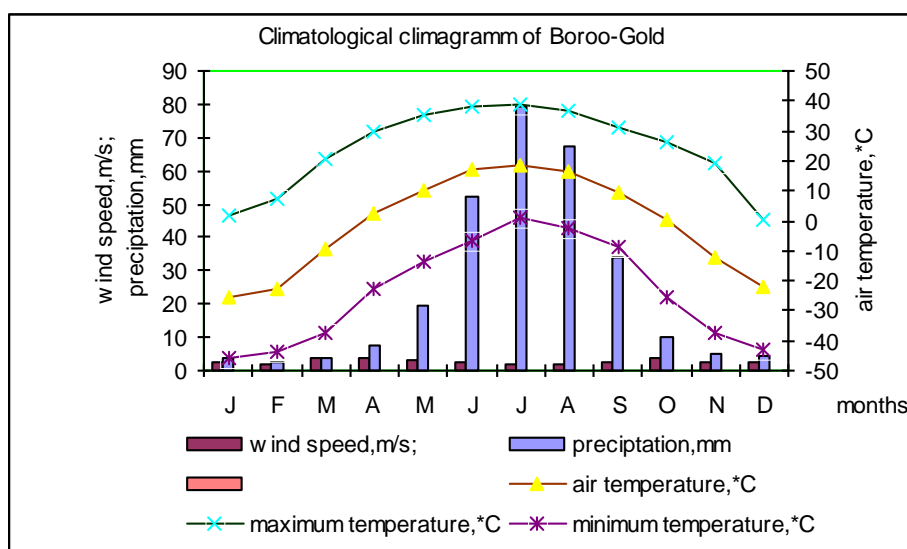


**Figure 7. BIOX® plant layout**

## 2.2. Weather and climate

### 2.2.1. Weather parameters

Main specific of formation of the climate is location of 1000-1200 m high mountains, valleys, and valleys surrounded by Boroo and Kharaa rivers. Another specific that forms the climate is distribution of sunlight, precipitation and moisture circulation at above mentioned micro climate. Weather data of the Boroo expansion-bio oxidation plant area and Ikh Dashir valley is collected from weather stations located near project area i.e. Weather stations at Baruunkharaa and Zuunkharaa as well as Boroo weather station. Deeply cut open pits, soil and rock stockpiles, tailings storage facility, water ponds and its environment caused by mine operations of “Boroo Gold” company has created a microclimate in the area. The climate in the area is generally cold and dry, with an extreme continental climate consisting of 4 seasons (Figure 8).



**Figure 8. Regional climagram**

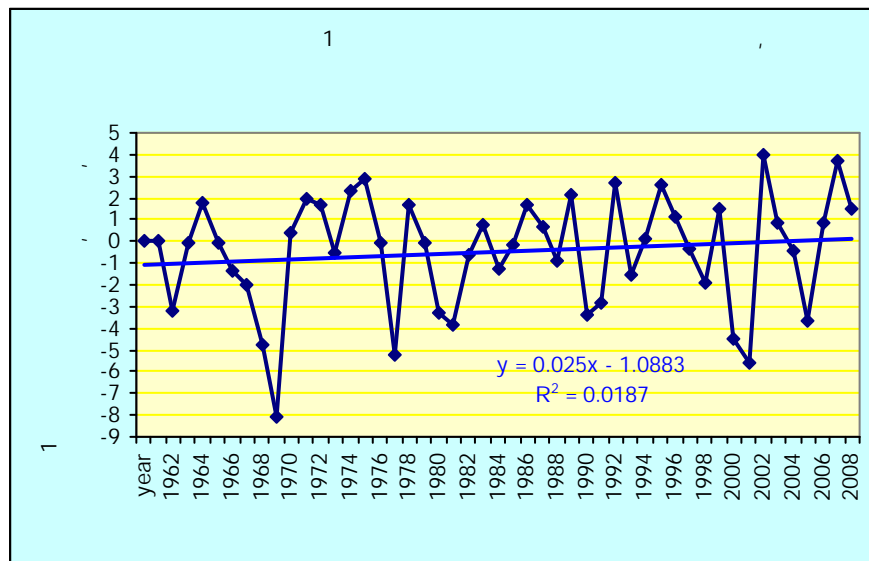
At the project area, seasonal variations occur depending on weather conditions. Overall, the number of winter days has been fewer by 5-7 days annually, which is favorable for mining operations. Summer season became longer and hotter. Table 23 shows multi-year average temperature change recorded by Baruunkharaa weather station. BGC weather station and Baruunkharaa station 2006-2008 weather data differences are shown in Figure 8-9. To conclude from this data range, standard norm of the multi-year average temperature in the project area is  $-0.5^{\circ}$  and it is  $-24.6^{\circ}$  during the coldest month of January and  $19.2^{\circ}$  during the hottest month of July. According to 1991-2008 norms, annual temperature for warm and cold seasons is  $20.4^{\circ}$  and  $-24.2^{\circ}$  respectively and standard variations are increased by  $1.2^{\circ}$  and  $0.8^{\circ}$ .

**“The Project of BIOX® Plant to Process Oxidizing Sulphide Ore with Flotation and Cyanidation”**  
**DEIA report**

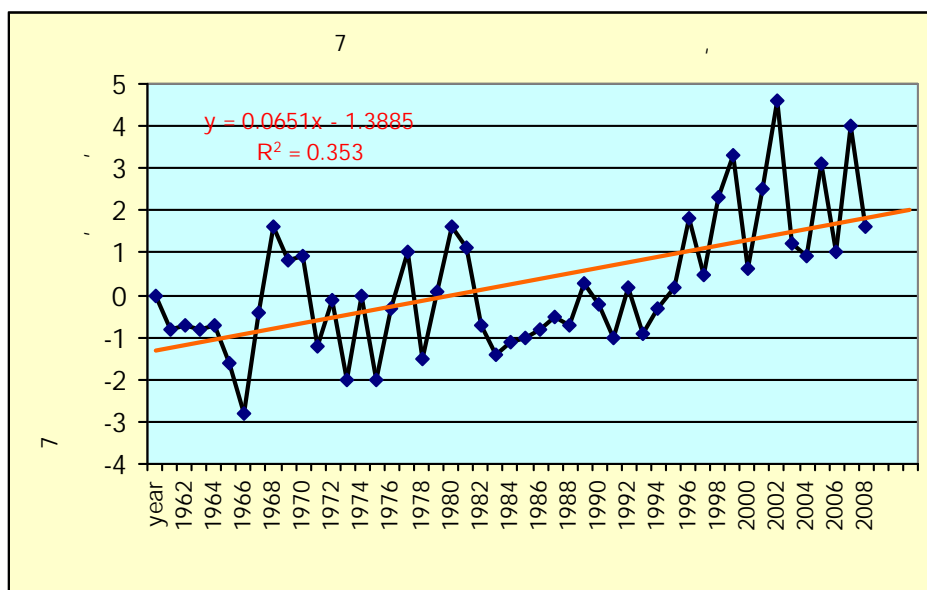
**Table 22. Air temperature and its change**

Compared years	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year ly
1961-1990	-24.6	-19.8	-7.7	3.1	11.2	17.0	19.2	17.1	9.9	0.8	-11.0	-20.8	-0.5
1991-2009	-24.2	-18.3	-6.6	4.0	11.7	17.9	20.4	18.1	10.8	1.1	-10.7	-20.6	0.3
1999-2009	-24.3	-19.2	-7.0	4.1	11.9	19.1	21.3	18.6	11.6	1.2	-11.4	-21.4	0.4
change 1991-2009	0.4	1.6	1.1	0.9	0.5	0.9	1.2	1.0	0.9	0.3	0.3	0.3	0.8
change 1999-2009	00.3	0.7	0.7	1.0	0.7	2.1	2.0	1.5	1.7	0.4	-0.4	-0.6	0.8

Note: “+” change of warmth, “-“ change of coldness.



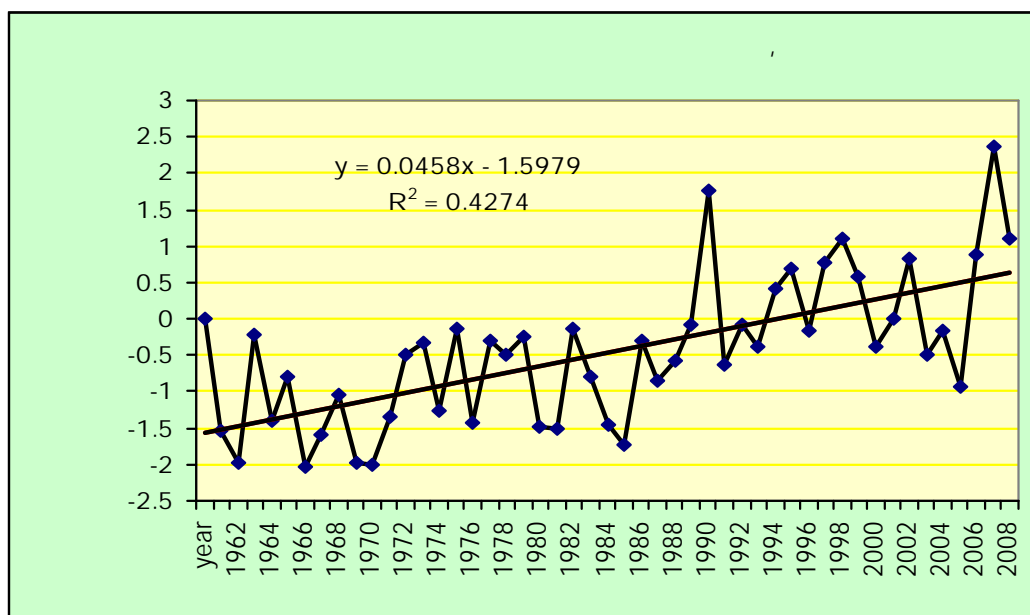
**Figure 9. Temperature fluctuation and its change on January  
(Between 1961-2008)**



**Figure 10. Temperature fluctuation and its change on July**

**(between 1961-2008)**

Fluctuation occur in 2-3 year periods, the warming effect has been gradual in the winter and sudden in the summers. Some data show that the annual average temperature has gone up by 1 to 5<sup>0</sup> . Although Baruunkharaa weather station is the base station at the region, Kharaa river valley operates under the impact of growing urbanization. There is not much temperature difference in monthly, daily, and annual data recordings between two stations as shown in Figure 9, and Baruunkharaa weather station data comparison sheet for 2006-2008 weather conditions has been developed on monthly and annual basis in Table 24 and Figure 10.



**Figure 11. Temperature fluctuation and change of many years' average, (1961-2008)**

**Table 23. Air temperature at Boroo weather station, degree**

Years	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	yearly
2006	-20.0	-16.9	-5.2	0.4	9.1	16.5	19.0	17.9	11.2	3.2	-7.4	-14.0	1.2
2007	-17.4	-8.6	-6.5	5.2	12.7	18.0	21.7	17.5	13.0	0.5	-8.1	-15.8	2.7
2008	-25.6	-19.0	-1.5	5.4	8.9	17.5	19.7	17.2	11.4	1.9	-6.8	-17.8	0.9
<b>Average</b>	<b>-21.0</b>	<b>-14.8</b>	<b>-4.4</b>	<b>3.7</b>	<b>10.2</b>	<b>17.3</b>	<b>20.1</b>	<b>17.5</b>	<b>11.9</b>	<b>1.9</b>	<b>-7.4</b>	<b>-15.9</b>	<b>1.6</b>
<b>Su-Bx</b>	<b>1.1</b>	<b>2.0</b>	<b>0.0</b>	<b>-0.4</b>	<b>-0.8</b>	<b>-0.8</b>	<b>-1.1</b>	<b>-0.6</b>	<b>-0.1</b>	<b>0.2</b>	<b>0.4</b>	<b>1.8</b>	<b>0.1</b>

**Air temperature at Baruunkharaa weather station, degree**

Years	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	yearly
2006	-23.2	-17.8	-5.2	1.0	9.7	17.3	20.0	18.8	11.1	3.0	-8.2	-16.0	0.9
2007	-20.4	-10.4	-6.8	5.6	13.6	18.5	23.0	18.3	12.9	0.4	-8.9	-17.4	2.4
2008	-22.6	-22.2	-1.3	5.5	9.9	18.6	20.6	17.3	12.0	1.6	-6.5	-19.7	1.1
<b>Average</b>	<b>-22.1</b>	<b>-16.8</b>	<b>-4.4</b>	<b>4.0</b>	<b>11.1</b>	<b>18.1</b>	<b>21.2</b>	<b>18.1</b>	<b>12.0</b>	<b>1.7</b>	<b>-7.9</b>	<b>-17.7</b>	<b>1.4</b>

As Boroo weather station located relatively in higher elevation than Baruunkharaa weather station, it is often warmer by 0.2 to 2.0<sup>0</sup>C degrees in the cold seasons. In river and mountain valleys, the temperature in April to October is often cooler by -0.4 to -1.1<sup>0</sup>

degrees, showing the gradient effect. At the pits, it is cooler in the summer and warmer in the winter.

**Warmest and coldest conditions:** the maximum and minimum temperatures in this region varied from -40 to up to 43<sup>0</sup>, annual absolute temperature reached 83<sup>0</sup> representing continental climate marked by extreme weather variations. On the warming horizon, the cold strength has been reducing. The number of standard norm days with -30<sup>0</sup> has been 4 days less between 1991 and 2005 than in 1960 to 1990.

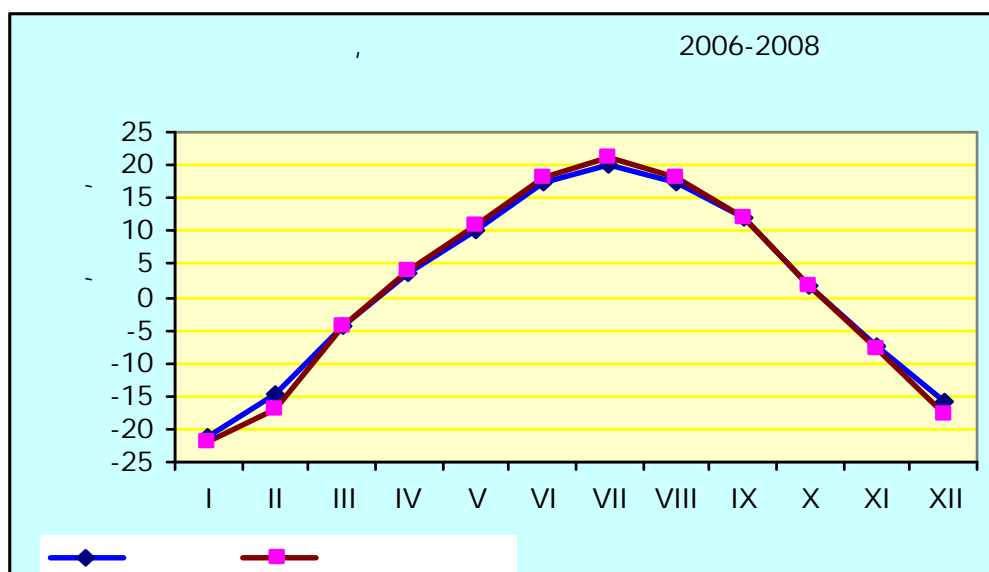
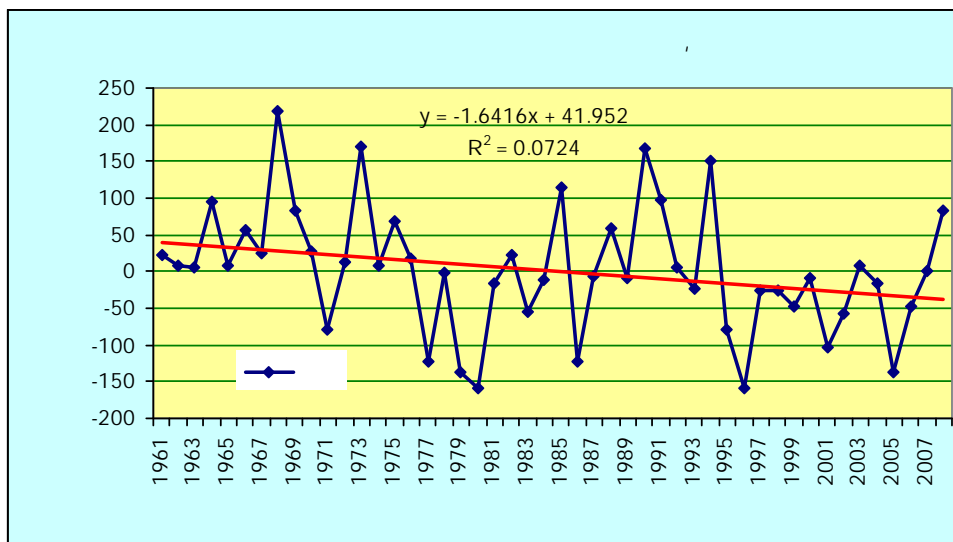


Figure 12. Parallel measurement of Boroo and Baruunkharaa weather station

**Precipitation fluctuation:** Annual cumulative precipitation in the project area fluctuates between 290 and 305 mm. Although precipitation in the area is lower than in mountainous regions it's still significantly higher than in Gobi desert zone. 282 mm or 92% of precipitation occurs during warm season months from April to October in a form of rain. The remaining precipitation occurs in the cooler months between November and March in the form of snow. There is significant precipitation variation from year to year. In the last 50 years, precipitation has diverted from the norm as seen in Figure 13. Reduction in perception amount is visible. As in the table below, the monthly precipitation between 1991 and 2008 has been reduced by 23 mm. Similarly, during warm seasons a reduction of -21.4 mm was recorded. In the last 10 years, there was an average drop by -32.4 mm and precipitation reduction during warm days by -37.9 mm.



**Figure 13. Precipitation fluctuation and change around Baruunkharaa**

**Table 24. Precipitation**

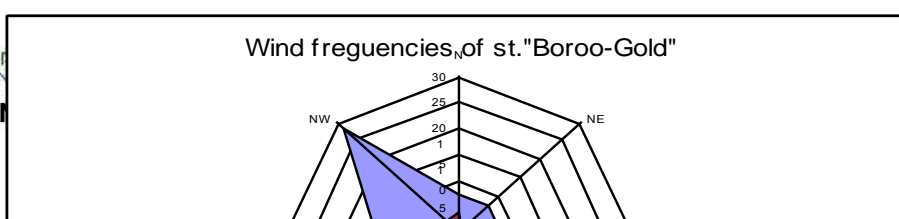
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	yearly	IV- X	%
Norm	3.5	2.7	3.8	8.8	25.6	53.2	76.5	71.7	34.8	11.2	6.9	4.8	303.5	281.8	92.8
1991-2008	2.5	1.8	3.1	8.2	25.0	49.1	67.8	66.8	33.0	10.5	8.5	4.3	280.6	260.4	92.3
2000-2008	3.1	2.4	4.1	6.8	36.6	52.3	55.1	60.3	21.6	11.2	12.1	5.6	271.2	243.9	89.8

**Difference**

Norm	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Yearly	IV- X	%
1991-2008	-1.1	-	-0.7	-0.6	-0.6	-4.1	-8.7	-5.0	-1.8	-0.6	1.6	-0.5	-23.0	-21.4	-0.5
2000-2008	-0.5	0.3	0.3	-1.9	10.9	-0.9	-21.4	-11.5	-13.2	0.1	5.2	0.8	-32.4	-37.9	-3.0

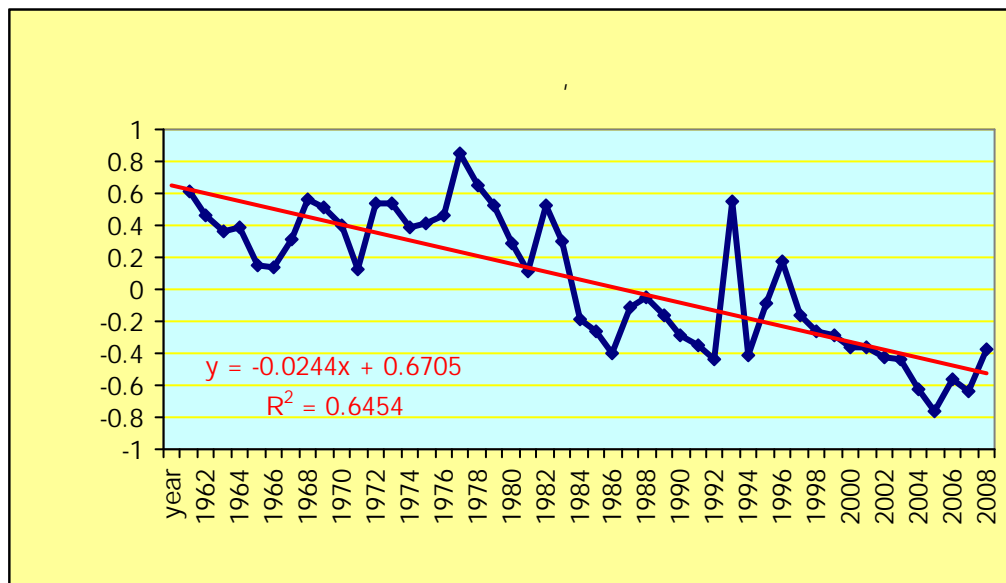
Note: “-“ decreased, “+” increased.

**Wind fluctuation:** Mining operations may have significant impact on the microclimate and wind regime of project area. This was clearly mentioned in previous EIAs and addendums. It is important to note that main lining operations and field works can be suspended due to wind, snow and storms dominating in the area. The wind direction falls into the regional category. The dominating wind pattern is observed at mine pits and employee camp from mountain towards valley. During ore excavation, employees must be aware that soil and overburden material loading, transportation and unloading can adversely impact on air quality and increase dust levels. Here the dominating wind direction is at a ground surface up to 200 m high and blowing from northwest and southeast. Change of wind direction during different seasons, particularly in winter season when the wind blows from Boroo river valley on Southwest. This is common to mountain valley winds. The mountain and



valley wind regime is from the valley during the daytime and from the mountains in the night (Figure 14-15).

**Figure 14. Wind speed, frequency and direction at Boroo site**



**Figure 15. Wind speed and fluctuation around Boroo site**

Although there have been no changes in prevailing wind speed, some changes are observed in micro winds. The other characteristic of wind regime here is that recurrence of no-wind conditions. This is particularly observed near gold mine at all seasons where wind is 23-35% and considered windier than in valley terrains. This is seen also in wind speeds. The prevailing wind direction often dominates other winds, for instance the west to eastward direction was recorded, particularly in fall and spring seasons. Maximum wind speed is recorded during the spring at 14-24 m/sec, and in other months it is 10-20 m/sec. High wind speed reaches up to 20-34 m/sec and sometimes it damages gers, houses, mining equipment, and wire poles. Snowstorms occur for 15-20 days each year, and dust storms occur for 20-25 days in a year, mainly from March to May. A wind speed of 5-6



m/sec could cause dust storms around the mine. In the last years between 1999 and 2008, the average wind speed has been reduced by 1 m/sec compared to study done in 1960. Wind speed and its reduction, the number of sandstorms in mining environment at the project area have reduced by 9 days. This is not directly impacted by BGC operations, although wind speed and direction have been moderately impacted by the rough topography: presence of open pits, waste rock dumps, heap leach stockpiles, pond and residential constructions thus creating a “micro wind”. For example, “beach wind” (or sea breeze) was created at tailings pond beaches and water ponds blowing from the pond towards the beach in the day time and in opposite direction (land breeze) at night time. In the high gradients such as rock stockpiles “mountain valley” micro wind regime was also established as a result of human activities.

### **2.3. Air Quality**

Environmental consulting JEMR Company has conducted initial environmental baseline studies of the Boroo Gold Mine Project in 1999 at proposed project area. Air quality samples at BIOX® plant area and camp have been collected and analyzed. BIOX® plant area is located in the south side of the Boroo processing plant. In order to analyze current air quality condition, Nature Friendly had sampled air at three points BIOX plant area, camp and coal burner on 26 Feb 2010. Also air quality conditions have been studied based on previous observation data and investigation results.

#### **2.3.1. Air quality condition**

Experts of Central Environmental Laboratory measured air quality indicators near BIOX plant area and camp. Specified air sampling tools used to measure a dust, highest air polluter, during 24 hours, sulfur dioxide (SO<sub>2</sub>) and nitrogen dioxide (NO<sub>2</sub>) for 20 minutes and carbon monoxide. The study result shows that daily average content of sulfur dioxide, nitrogen oxide and carbon monoxide are within the permissible level of the air quality standard. However, dust content exceeds the permissible level of the air quality standard. It was concluded that dust is generated as a result of earth works and transportation in the previous reports.

**Table 25. Air quality indicators, 1999**

Date	Time	Air pressure, h	Air temperature, °	Wind speed, m/sec	SO <sub>2</sub> mg/m <sup>3</sup>	NO <sub>2</sub> mg/m <sup>3</sup>	CO mg/m <sup>3</sup>	Dust mg/m <sup>3</sup>
PL*					0.03	0.040	3	0.2
VIII/5	11.30	665	19.1	2.0	0.005	0.029	0.1	
	16.40	664	18.9	3.0	0.006	0.042	0.4	

VIII/6	10.00	660	24.0	1.5	0.004	0.030	0.2	
	16.30	663	29.0	2.4	0.010	0.044	0.1	
Daily average					0.006	0.036	0.2	0.522

*\*-PL-permissible level, Source: JEMR, DEIA of Boroo Gold Mine*

### 2.3.2. Current air quality condition

An expert of Central Environmental Laboratory sampled the air near BIOX plant area, camp and coal burner on 26 Feb 2010. Specified air sampling tools used to measure a dust, highest air polluter, during 24 hours, sulfur dioxide (SO<sub>2</sub>) and nitrogen dioxide (NO<sub>2</sub>) for 20 minutes and carbon monoxide. Results of analysis are shown table below. In addition, noise is measured.

**Table 26. Air quality indicators, 2010**

	Sampling points	Sampling hours	Pressure, mmHg	Temperature, °C	SO <sub>2</sub> mg/m3	NO <sub>2</sub> mg/m3	CO mg/m3
1	Coal burner	11:35	664.0	-13.8	0.005	0.062	1.21
2	BIOX® plant area	12:40	670.	-19.0	0.009	0.041	2.01
3	Camp	13:48	677.0	-16.0	0.011	0.029	0.59
<b>Air quality standard</b>					<b>0.450</b>	<b>0.085</b>	<b>60.0</b>

	Sampling points	Dust content / 10/, mg/m3			Noise, dBa
		Average	Maximum	Minimum	
1	Coal burner	0.019	0.530	0.009	65
2	BIOX® plant area	0.012	0.025	0.007	48
3	Camp	0.008	0.011	0.006	54
<b>Air quality standard</b>		<b>0.100</b>			<b>60</b>

Weather was bright, sunny, calm and snow covered the ground surface during the investigation. The study result shows that daily average content of sulfur dioxide, nitrogen oxide, and carbon monoxide did not exceed the permissible level of the air quality standard. However, noise level exceeds the permissible level near coal burner. When person works under the condition of 1000 Hz, 85 dBa noises, it might damage human hearing ability.

### 2.3.3. Air quality monitoring at Boroo site

Air quality conditions have been studied at the mine site. Observation data has been taken from the DEIA report of Heap leach project (JEMR, 2007).

**Pollutant gases:** In accordance with measurement results between 2004 and 2009, CO, NO, SO<sub>2</sub> levels are within the permissible level of the air quality standard.

**Toxic chemicals:** Boroo gold uses sodium cyanide for its gold processing plant. Annual consumption is 600-800 tones. Results of analysis conducted inside the processing plant to measure content of cyanide revealed no violation of standard levels.

**Noise:** Traffic of heavy machinery, vehicles, and blasting causes significant noise and vibration. Noise increases to about 10-17 dBA when wind speed increases. According to the study, outdoor noise mean level around the Boroo Mine is within healthy norms. The mean daily level international norm is 60 dBA.

**Odor:** There is no significant operational odor source to impact on human health at the mine. Plant, administration, employee camp, wastewater treatment facilities are clean and fulfill requirements of petroleum, chemicals, and general waste management. There is no odor impact present.

#### **2.3.4. Impacts on air quality**

During Boroo expansion and construction stage, dust dispersion and noise from earthworks, transportation will be increased impacting air quality. However, the air quality pollutants will affect for short-term duration. Use of BIOX® process for oxidation of sulfide ores is preferred over thermal oxidation methods, primarily because of reduced energy consumption and lack of sulfur dioxide emissions in the BIOX® process. Emissions from the BIOX® process affecting air include water vapor, CO<sub>2</sub>, heat, and mist and aerosols from the aeration. As such, air emissions are expected not to be harmful.

#### **2.4. Geographic feature and landscape**

The Boroo Mine Site is located in the northern part of Mongolia at the western end of Khentii mountain ranges, at west longitude 106°, north latitude 49°. It is located in a valley surrounded by hills with an elevation of 1230 m above sea level (ASL). The region belongs to the Khentii zone of the Khangai-Khentii Mountain region. Mainly dark chestnut fertile soil with rich humus contents dominates the Ikh Dashir and Boroo River valley. Soil freezes up to 3 m deep, but there is no permafrost. Soil with non-sticky sand and a gravel layer dominates in the Boroo River valley. Geographic features are sourced from the DEIA report of Boroo gold mine developed by JEMP Company in 2000.

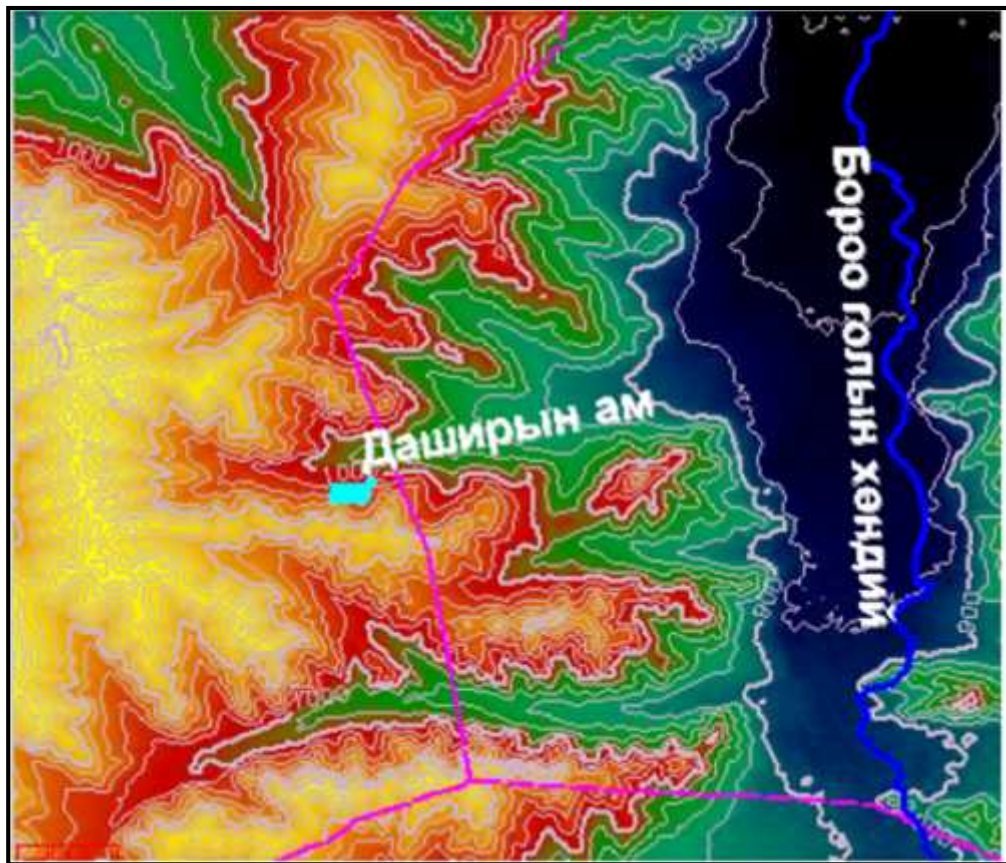


Figure 16. Boroo river basin, Ikh Dashir valley

#### 2.4.1. Boroo geological formation

According to the Regional Geological and Tectonic Map, the Boroo district belongs to the Mongol-Zabaikal Fold Zone and is located within the elevated sub-zone of North Khentei Arc. This sub-zone is constrained from the north and southeast by the Bayangol and Yeroo River faults. In addition, this sub-zone has been cross cut by multiple small faults of various trends and divided into several blocks. The Boroo Gold Deposit is located in the eastern part of the Boroo ore field, between the Nariin Khondii and Arangat faults. The deposit is crosscut by many perpendicular faults. The geological formation consists of Cambrian-Ordovician altered sedimentary rocks; Mesozoic and Cenozoic sedimentary rocks and intrusive rocks of Boroo complex.

#### 2.4.2. Previous geological research

Once “Mongolor” association found and commenced their mining process around 1910 for the first time and Ministry of Internal Affairs conducted mine operation works in 1920, 1943 to 1955 as well as exploration works have been conducted to update the minerals reserve from 1965 to 1969. Chekhovsky.V summarized the Boroo water supply. He declined construction of water facility as permafrost was found in depth of 1-1.5 m and

information on riverbed, valley scope, geotectonic, rock fall was insufficient. In 1982, Mongol-Germany associated expedition discovered that Boroo ore deposit merged as a bed formed huge matter and placer mine. Byambadorj.Ya and Erdenetsetseg.B investigated and studied underground water, detailed research for Boroo water facility in 1983-1985. Here: Alluvial sedimentary consists of 34 m thick aquatic level which is Q<sub>iii</sub> year old, gushing forth at borehole was 12,74 to 20,1 l/sec, water diminishing level 0,9 to 9 m and the underground water would pertain to hydro carbonic-calcium-magnesium grade by its chemical component. Mineralization was 0,2 to 0,3 gr/L and underground water reserve of that area was +C<sub>1</sub> grade or 4460 m<sup>3</sup>/day and 51,6 l/sec. Byambadorj.Ya and Oyunchimeg.A performed investigation research of underground water for water supply of Boroo ore processing plant in 1990-1991 and identified the water resource of Boroo area was 8640 m<sup>3</sup>/day , ground water level 25,8 to 51,2 m, filtration co-efficient was 47,5-55,3 3/day.

In 1991-1994, Tumur.S, Lhagvasuren.J, Gerelmaa.N prepared 1:50000 scale geological mapping of Boroo, zuunmod ore zone, Noyon Mountain area, developed general exploration report and developed geological condition map and processed and integrated reports of previous researcher (gold). In addition, detailed exploration has been conducted in 2 fields with gold prospective. Gold contained secondary quartzite zone by 2 grade was assessed as Au-50 t, Ag-500 t, and (Davhar Uul, Chandgatai Uul) and gold contained quartzite's berezit zone with fibre by 2 grade was assessed Au-104kg (Honichiin Nuruu).

Namsrai.T, Batbayar.B and Damba.P conducted assessment work of mercury and gold reserve at abandoned Boroo Plant construction facility in 1994. They also made an assessment on remained mercury, its absorbed gold resource from basement of construction in main deposit of Boroo and Tsagaan Chuluut on 1940 to 1950. Waste mercury amount was 198,5 kg, its remained gold resource was 1,5 kg.

“JEMR” LLC made detailed environmental impact assessment of Boroo deposit exploration project on 2000. The assessment work considered air pollution, surface and underground water, soil, flora, fauna and waste management and protection management. Doctor of science, professor Jadambaa.N conducted a research work on underground water of leaching area of “Boroo Gold” LLC Heap Leaching Project drilling and analyzing monitoring 3 borehole in 2008. Burenjargal.U conducted a research work of distributed mercury which was 418 kg over Boroo river valley in 2008.



### 2.4.3. Stratigraphy

**Ordovician rocks ( )** the altered sedimentary rocks of Kharyn series are located mostly in the south-west and south parts of the deposit area. Some of large xenoliths of these rocks are located among intrusive rocks spread in the east part of the deposit. (Figure 3.4) The Kharyn series consists mostly of oligomictic (but sometimes polymictic) sandstones, aleurolites, shales and some layers of volcanic rocks. The texture and composition of the sandstone is rather simple and contains approximately 30-35% clasts. The foliated greenish grey color aleurolite (siltstone) has aleuro-pelitic or aleurolitic structure, and sheeted texture. The shales have green, greenish grey color and contain some silica-chlorite, mica-chlorite, and sericite-chlorite components.

**Trias sediment ( $K_{2-3}$ ):** Researchers discovered grey, light grey sedimentary rocks and consist of large sandy rock texture along Kharaa and Boroo river of foot slopes between big valleys. (Marinov, 1973) It determined as mid-top cretaceous age according to Shariin gol layer. Anthracite aleurite and compressed dung thin layer found below side, aliuritic ampelites consist of clay and sandy rock found in top side from this thickness. Cretaceous sediment was discovered in Boroo river valley's depth of 45 m as beneath kainozoic sediment.

**Kainozoic sediment ( $Q_{ii}$  -  $Q_{iii}$ ):** Talus-proluvium and wind-borne loess like sediment which mid-top age and spread in the upper streams of Ikh Dashir valley covers the entire area of foot slopes between small valleys. These rocks with approximately 10 m (sometimes more) thickness have light yellowish, light grey color and consist of sandy loam, loam, and clays. The kainozoic ( $Q_{ii}$  -  $Q_{iii}$ ) alluvial, alluvium-proluvium and alluvium-lacustrine sedimentary rocks are widespread in the Boroo river valley and its tributaries and consist of gravel, sand with gravel, sand and aleurites. These rocks sometimes create sedimentary terraces along the valleys. (Ref: 2000, JEMR DEIA)

### 2.4.4. Intrusive rocks

The Boroo River complex of intrusive rocks spreads to the east and northeast from the Boroo ore field. The Boroo River complex consists of the following Ordovician age intrusive rocks, (Kampe, 1968) including:

- Boroo River type granodiorites ( $\gamma$  PZ)
- Ikh Dashir type biotite granites ( $\gamma$ PZ)
- Light grey granite (Campe, 1968)

The Boroo River intrusive complex consists of grey, medium-grained granodiorites. Depending on the K-feldspar phenocryst sizes and their quantitative ratios, the granodiorites became rather spotted. The Ikh Dashir type biotite granite and the light grey granite are spread along the contact zone of the Boroo River intrusive complex with the metamorphosed sedimentary rocks of Kharyn series, as a narrow zone of NE-SW trend. The biotite granite is reddish grey in color and medium to coarse grained in texture and contains quartz (32 vol. %), K-feldspar (30 vol. %) and biotite (5 vol. %). The light grey granites are yellowish grey; reddish grey in color and medium to fine grained in texture.

#### **2.4.5. Tectonics**

Project territory is situated in north Mongolia's Mongolian at folded system's north Khentii raised structure's southeastern part, the tectonic belt is restricted by Yeroogol fault systems, but area is wholly belongs to Khentii northern boundary area. Main formation of tectonics structure divided into three different blocks of Trias activation, Gerstein, and Caledon ages. Gerstein and Caledon age is divided into 4 rift zones formed in intrusive magmatic, continental, magmatic and magmatic crusts at edge of continental section. The metamorphosed sedimentary rocks of Kharyn series are intensively folded in the sub-longitudinal direction and the asymmetrical, steeply dipping wings have different thickness of rocks. The sedimentary rock foliation has a northeast trend and steep dip to the west, but shearing creates a sharp angle with foliation. Multiple tectonic events have been experienced in this region and intensively developed long-life faults cover the area, and in their turn these faults divide the project locality into several blocks. There are many fault systems in this area and their dominant trend is north-west, north, north-east; and they dip steeply to the west or east.

#### **2.4.6. Landscape**

According to the Mongolian vegetation zonal division, the project area belongs to the forest steppe zone. The area has mountain dark chernozem and dark mountain chestnut soils, predominantly covered by grasses and small bushy pretidophytes with small birch-pine and birch-poplar forest. In the locality we explored, there are a forest steppe on the top, meadow in the middle and arid steppe in the mountain slopes and sides. The forest steppe is unusual with its dense needle grass and *Festuca sibirica* vegetation. Most of the arid steppe land is cultivated and has small species of pretidophytes, such as *Koeleria*, *Poa* and *Stipa Krylovii* etc. Between these two types of steppe, there is a specific meadow steppe with grasses and *Artemisia gmelinii*. There are three categories of surface such as



tectonic-erosion, erosion-transport and accumulation in the Boroo deposit area. Tectonic erosion surfaces are characterized by 300-600 m elevation, strong erosion and V shaped ditches and ravines with steep slope. The northern and central parts of the Boroo deposit have such surface. The erosion-transport surface consists of low elevated hills and undulating mounds. Deluvium-proluvium deposits containing rare primary rock are dominant. The river and narrow ravine belong to the accumulation surface and proluvium and proluvium - alluvium deposits are dominant there. The shape of the river valley is flat and its end is characterized by the steppe. A landscape of the project area is shown below and photos captured in January 2010.



Figure 17. Project area view

## 2.5. Soil cover

### 2.5.1. Soil properties

A land being flattened near Boroo Gold ore processing plant in Ikh Dashir valley is planned for building bio-oxidation plant and the land shaft is in lower valley area of small mountain range where original soil structure has been lost completely due to the cold mining and building by the company. Thus to give soil assessment of the area we gathered samples from the original and rich soil left behind the industrial area and the soil found as pressed beneath the sedimentary rocks. The analyses from these soil samples were compared to the previous years' soil studies.



**Figure 18. Flattened project area**

Results of previous studies of profile of 31st (near workers camp in the hill valley JEMP, 2007) and 35th (north of Bayanzurkh ovoo and in Ikh Dashir valley, JEMP, 2007) vertical soil cut shows that light clayey, dark brown soil with medium thick and thick humus is distributed within the area. We used last soil documentation and analysis as a baseline in our comparative study taking in consideration general morphologic formation and common characteristics of soil layers.

**Profile 35.** Light clayey, dark brown soil with thick humus layer. The area was used in agriculture.

- A 0-30cm Dark brown colored cut layer, wet, light clayey lump composition with low containing small sandstones; transfer into the next stratum its deep color and transferring border flat.
- B 30-45cm Lighter than beyond layer and brownish colored, wet, lump composition, clayey, transfer into the next stratum its deep color and transferring border flat.
- BCa 45-80cm Lighter than beyond layer and brownish colored, wet, lump composition, clayey, transfer into the next stratum its deep color and transferring border flat.

In order to give a comparison assessment of this soil, we have shown a characteristic of Soil cut-1 from the soil wall that was pressed below by 30-80 cm sedimentary rocks in the south of the designated area for building bio-oxidation plant.



**Figure 19. Southwestern side of the project area**

**Soil profile 1:** Southwest of proposed BIOX construction

- 0-30 m Light dark brown colored, 0-5cm surface is with well developed plant roots, shattery lump composition with low contant of small crumb rocks (5-10%), loose and wet, light clayey, transition noticeable, borders are not even.
- 30-63 m More plae than upper layer with brownish color, wet, well-developed thin roots, more small crumb rocks content (20-30%), compact and wet, bottom part boils in the influence of hydrochloric acid, extreme noticibility of transition and borders are wavy.
- 63-90 m Grayish light yellow colored, humid, carbonate spot formed in some part, rich in crumb rocks (40-50%), compact, light carbonate loam.



These soil cut morphological formation record shows humus layer (A+B) is thick and carbonate layer is relatively well developed. Carbonate accumulation is found absorbed into the layer B<sub>ca</sub> and B<sub>ca</sub>C fine soil part as powder and found as a solid cover or scurf form as a result of periodic soaking process (washout) under large pebble rock in soil formed from proluvial meta-sediment.

**Table 27. Soil properties and particles**

	Profile No	Stratum, depth, cm	Mechanic composition, % (particle size, mm)						
			1.0-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	<0.01
Dark brown soil (JEMR, 2007)									
1	31	0-20	12.4	41.3	28.0	5.7	6.2	6.4	18.3
2		35-45	18.6	42.4	26.0	2.0	7.0	5.0	13.0
3		65-75	25.6	41.6	20.4	1.1	6.2	7.3	12.4
Dark brown soil with thick humus layer (JEMR, 2007)									
1	35	0-20	18.0	38.0	28.0	8.0	11.2	6.0	24.0
2		35-45	21.7	39.4	21.0	2.7	10.4	4.8	17.9
3		80-90	19.2	39.8	24.0	0.9	8.9	7.2	17.0
Soil analysis-2010									
1	Soil 1	0-20	7.8	63.0	10.7	2.9	10.4	5.2	18.5
2	Soil 2	0-20	18.6	45.6	14.6	6.8	10.4	4.0	21.2
3	Soil 3	0-20	14.4	43.6	18.6	7.5	8.9	7.0	23.4
4	Sediment 1	60-80	8.1	28.6	32.1	5.6	18.3	7.3	31.2
5	Sediment 2	100-120	26.8	35.3	25.9	4.1	3.1	4.8	12.0

According to N.A.Kachinsky classification of soil particles (Table 27), dominated dark brown soils are included in sandy light loam type and mostly distributed fine grained sand (0,25-0,05 mm), coarse dust particles (0,05-0,01 mm) in the stratum except proluvial sediments. However, the rates of clay particles (<0,001 mm) are found even and low fluctuation on all humus stratum of soil types. Light yellow colored (golden) loess of fine grained sediment (Sediment 1) that occasionally seen in the flattened area for BIOX® plant construction obtain clay particles (Figure 20). According to particle size classification small-grained brown brick colored rocky sediment (Sediment 2) may classified as an almost matted sand because various sized sand particles and thick dust particles predominated (88 %) in the content (Figure 21). Data indicate the humus content in dark brown light clayey soil is between 1,9 and 2,6 % in 0-20 cm depth. For the light clayey soils, 58,5 t/ha is relatively lower quantitative of humus amount per hectare area. It is explained that the area were used as cropland for years, therefore previous soil study showed absolutely higher 58-70,8 percent of sand particles (1-0,05 mm).



**Figure 20. Light yellow sediment**



**Figure 21. Chestnut sediment**

In the humus stratum, the amount of exchangeable calcium cation is 19-21 mg-equ distributed 66,9-80,5% of absorbed basis and remained percent allocated for exchangeable magnesium cation. This type of soil almost have no humus layers, contain lower content of 1.1-1.4% and show least boiling property by hydrochloric acid experiment.

**Table 28. Chemical properties of soil and sediment samples**

Table 20: Chemical properties of soil and sediment samples									
1	Profile No	Depth, m		pH <sup>2</sup>	Humus, %	Exchangeable base, mg-equ/100 gr		Nutrients, mg/100 gr	
						Ca <sup>2+</sup>	Mg <sup>2+</sup>	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Dark brown soil (JEMR, 2007)									
1	31	0-20	7.2	-	2.5	18.0	4.0	2.1	15
2		35-45	7.3	2.0	1.2	12.0	2.0	1.5	10
3		65-75	7.5	6.0	-	8.0		-	-
Dark brown soil with thick humus layer (JEMR, 2007)									
1	35	0-20	7.3	-	3.2	20.0	6.5	2.2	15
2		35-45	7.3	-	2.1	19.0	4.0	1.4	12
3		80-90	7.5	2.4	-	16.0	2.0	-	-
Soil analysis-2010									
1	Soil 1	0-20	7.6	-	2.6	19.0	9.4	2.5	16
2	Soil 2	0-20	7.8	1.1	1.9	21.0	6.2	3.0	12
3	Soil 3	0-20	8.0	1.4	2.3	19.0	4.6	2.3	20
4	Sediment 1	60-80	8.6	4.7	-				
5	Sediment 2	100-120	8.2	0.8	-				

pH is alkaline (pH 7,6-8) with less fluctuation due to presence of carbonate content. However, carbonate is unevenly distributed in sedimentary rocks and pH is from alkaline to over alkaline. Surface of the brown soil sustained in this area is supplied with moderate movable phosphorus and minor movable potassium (Table 28).

### 2.5.2. Soil contamination, erosion and disturbance

During our investigation, five samples were taken and analyzed the agro-chemical composition by certified laboratory of Mongolian State University of Agriculture and heavy metals by Central Geological Laboratory respectively.

**Table 29. Heavy metals content in the soil and sediment samples, mg/kg**

Profile No	Date	Heavy metals										
		Pb	Cd,%	Hg	As	Cr	CN total	Zn	Co	Ni	Cu	Sr
Results of former studies												
Dark brown soil	2000	24	-	-	-	105	-	57	-	34	-	-
Dark brown soil	2007	27.3	-	4.9	3.2	4.4	-	15.0	49.9	10.1	9.0	-
Results of our studies												
Soil 1	2010	16	<0.005	<0.8	9	69	<1.0	80	14	28	24	310
Soil 2	2010	16	<0.005	<0.8	358	48	<1.0	76	14	19	22	238
Soil 3	2010	29	<0.005	<0.8	34	67	<1.0	84	15	28	45	302
Sediment 1	2010	15	<0.005	<0.8	11	67	<1.0	70	16	33	36	402
Sediment 2	2010	26	<0.005	<0.8	39	122	<1.0	50	6	51	21	85
Permissible levels in the clayey soil, mg/kg												
MNS5850: 2008		70	1.5	1.0	4	100	15	150	40	100	80	700



Soil samples were taken at 5 points: two samples from flattened area for new BIOX construction that covered terraces of different colors (sediment 2), bare soil (sediment 1), and three samples from vicinity areas. Laboratory result showed that heavy metals Pb, Cd, Hg, Cr, CN, Zn, Co, Ni, Cu, and Sr contents are below the permissible level of Mongolian national standard (MNS 5850:2008) except As. Thus, confirm sedimentary soil not affected by heavy metals. However, previous soil analysis (2007) presented Co and Hg exceeded permissible levels of MNS, that result could be caused by ore characteristics that contain cobalt contents. It should be noted that the existing valley is impacted from historic placer mining operations by using mercury. Even arsenic is not a metal, it is included into heavy metal classification due to its hazardous properties similar to heavy metals and as well as its content is detected in the soil samples taken by other companies working along Boroo river valley.

Flattened area for construction is completely disturbed technogenic impacts such as existing mining and construction operation. Following technological safety and environmental protection issues should be taken in consideration:

1. To prevent from soil subsidence and sliding, provide construction stability, consider the results and data of drilling record and engineering geological study, which completed for Boroo mine site previously.
2. Flattened area for Boroo expansion has a high barrier in western side of the project area which has positive affect to prevent from storm water runoff, it require to build water diversion dams and ditches around construction area.
3. Area located on north of the Boroo expansion area should be kept in natural existence as a baseline condition.



**Figure 22. Western side of the project area**

### **2.5.3. Impacts on soil cover**

Destruction of soil will generally be limited by the new BIOX® facility over an area of approximately four hectares and modified tailings disposal areas. The facilities will be constructed in a previously disturbed area, upgrading of the Boroo facilities. Additional mineral processing not expected to have impacts on soil resources away from the mine site as wastes and pollution effects will be isolated to the facility. Site improvement after construction will bring better soil condition around the area.

## **2.6. Surface and underground water**

### **2.6.1. Surface water**

There is no surface water within the Boroo mine project area. In 2000, JEMR executed the study of surface water regime and resources and determined Boroo river hydro geological conditions and its runway. Boroo River flows at 12 km distance from the mine site. Runoff distribution of Boroo river is unbalanced and it is estimated that annual runoff factor of Boroo river is 25-30 percent of spring melting snow, 50-70 percent of summer rainwater and 7-12 percent of winter runoff. No surface water will be used by BIOX® process.

### **2.6.2. Underground water**

### 2.6.2.1. Underground water properties

#### **Hydrogeological condition of the project area:**

In terms of Mongolian hydro geological region, Boroo river valley is situated within Khangai Khentii hydro geological complex according to N.A. Miranov (1970). According to hydrogeological study results, several water-containing layers are recorded in different lithologies.

**Holocene-Upper Quaternary alluvium-proluvium water-containing layer:** occurs at area's central and northern parts. Water containing layer often are filled with sand and gravel. Water found at depth of 9.4-12.6 m. Thickness of water containing layer: fluctuates between 12.5-64.4 (well no.11, 5) m. Well water discharge rate, level drawdown 0.9-6.9 m (well no. 7,8) . Discharge from a well drilled here is 12 to 20 l/sec Water is pure, mineral content is 0,2 to 0,4 g/dm<sup>3</sup>, HCO<sub>3</sub>-Ca-Mg hardness is low (4,1 to 5,8 mg equ/l) and alkaline with pH=7,8 to 8,1.

**Lower Paleozoic age sedimentation water complex:** distributed at area's south and western parts. Water containing rock is sandstone, dark brown grapholite. Water found at depth 25.8-39.6 m, water containing layer thickness 13.2 m (well no. 113). The well discharge rate for 11.0 m drawdown is 1.11 L/sec. Water mineralization 0.3 gr/L, hydrocarbonate, calcium-sodium water. Hardness is 5.2 mg-eq/L, =7.3.

**Lower Paleozoic age intrusive rock water containing region's water:** is found in the area's western and northeastern parts. Water containing rock is granite, granidiorite. Water is found at depth of 25.0-32.5 m (well no.120, 121). Water containing layer thickness is 19-30 m (well no.114, 121). Well discharge level 1.5-3.0 m drawdown 1.18-1.25 L/sec. Water mineralization 0.3-0.4 gr/L, hyrdocarbonate-sulfate-calcium-sodium containing water. Hardness is 4.0-7.4 mg-eq/L, =7.6.

#### **Hydro geological properties of Boroo river:**

**Factors contributing to existing hydro geological condition:** water containing rock's collect characteristic, hydro geological structure, underground water chemical composition, underground water movement, underground water type should be considered.

**Underground water regime:** underground water regime is natural and historic process that defines underground water composition, quality, level, speed, conductivity, permeability, temperature, chemical and bacteriological composition and their changes.

**Collector quality:** defined by the capacity to contain water. The rock types occurring at the project area are porous and fractured collectors. Collector quality and sedimentation thickness are not the same for Recent or Upper Quaternary porous sediments distributed throughout the project area. This type of sediment is distributed 0.5-20 m thick at middle and upper parts of Boroo river valley and Ikh Dashir river valley, at some areas reach 50 m thick. This is loess type clay material. Water saturation is 0.00267-0.0000388 m/day or meaning that it has almost non-saturation characteristics. Because loess has antizotrop qualities, it saturates more in vertical position. Ikh Dashir valley opening extended period, Boroo river valley alluvi-prolluvium sands, sandy, pebble containing small size, gravel sediment is dispersed and its thickness is 29.7-66.8 m. Water drainage capacity is 8.035-86.4 m/day. Porous layer of loose sediment layer are from lower Paleozoic era that have bonded sediment rocks thickness (sandstone, grapholite, quartz), also same age granodiorite, granite and other magma rock collector exists. These fissures are at upper layer collector upper part was weathered and fractures were created. In addition, tectonic fractures deeply cut granite, granodiorite weathering depth is 66.8 m, tectonic fault reaches up to 100 m. Weathering process was most active during Tertiary period. Fracture average density is 3-10 cm, and sometimes there are pores with 0.5 m. In the weathering process, fractured granite, granodiorite turned into gravel and the region's water permeability at upper part of mountain reaches 49.25 m/day. Bonded sedimentary rock water drainage capacity at sedimentation zone is 0.008-0.000026 m/day, suggesting that it has low collector capacity.

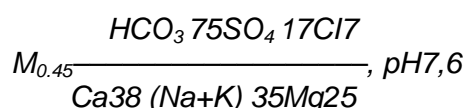
**Types of underground water:** Based on the conductivity of the rocks the following two types of underground water can be identified in the area:

- Inter-granular (porous and permeable) aquifer
- Fractured aquifer
- a) Intergranular aquifer: The first type of loess is loam, distributed in the upper and medium parts of Ikh Dashir valley, and it does not contain water. The highly permeable small sandy loam, similar to loess, might contain water. Underground water level is 9,4 to 13,6 m in the pluvial and alluvial deposits formed in the Boroo river valley and Ikh Dashir mountain valley. This is an unconfined aquifer. Conductivity and thickness of rocks differs from place to place. Recent and Quaternary scattered clastic rocks create a sandwiched aquifer layer. Discharge from a well drilled here is 12 to 20 l/sec, sometimes reaching a specific discharge of 12 to 30 l/sec. The specific discharge (q) is a ratio of the well discharge (Q) and

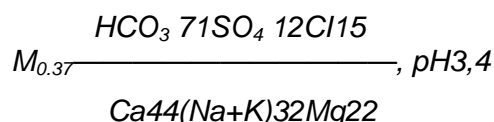
the differences of water tables before and after the pumping out the water from the well ( $S=S_1-S_2$ ) or  $q=Q/S$ , where  $q$ -specific discharge (l/ms);  $Q$ -well discharge, (l/sec);  $S$ -water table (m). This indicates that the water content is different in different localities. In general, it does not have sufficient water. Water is fresh, mineral content is 0,2 to 0,4 g/dm<sup>3</sup>, HCO<sub>3</sub>-Ca-Mg hardness is low (4,1 to 5,8 mg equ/l) and alkaline with pH=7,8 to 8,1.

- b) Fractured aquifer: water in fault zones is distributed beneath the inter-granular aquifer in all areas of Ikh Dashir and the Boroo river valley, creating a hydro geological formation. Depth of fracture aquifer water is 25,8 to 38,6 m and the depth of distribution depends on the thickness of weathered zone and tectonic faulting. The hydro geological water zone has low pressure. The discharge rate of a well drilled in the sandstone-shale layer is 1,1 l/s, with specific discharge as low as 0,1 l/sec. The water resource is limited, but it is pure fresh water (TDS-0,3 g/dm<sup>3</sup>), HCO<sub>3</sub>-Ca-Na hardness is 5,2 and alkaline (pH=7,3). The underground water level in the fractured zone of granite/granodiorite is 25 to 32.5 m. Discharge is 1,18 to 1,25 l/sec, specific discharge is 0,4 to 0,6 l/sec. Water content is low but higher than that of sandstone and shale rocks. Well discharge of a recently drilled well (summer in 1999) on the drained bed of Ikh Dashir valley, near the camp of “Undram Sed” Co. Ltd., is 0,8 l/sec. The water is pure and fresh (0.3 to 0.4 g/dm<sup>3</sup>), containing HCO<sub>3</sub>-Ca-Na, with high hardness and alkaline pH levels.

Factors of underground water formation and chemical properties: Underground water in the Ikh Dashir mountain valley is formed in the upper layers of the geological cross-section and is fed by precipitation. It was concluded that the underground water table is not high, it had phreatic (open) water, and the water is fresh. The formula for the chemical composition of fractured aquifer water is:



The Kurlov formula of inter-granular aquifer water of Boroo river valley:



Chemical content of the underground water is composed by lixiviation. Concentration of NO<sub>3</sub>, NH<sub>4</sub> ions shows that the underground water is polluted by ancient and recent pollution. Underground water is fed by precipitation. The coefficient of underground water

stream flow in the Kharaa and Boroo river region is 0,03. Applying this to the study area, the underground water resource in the Ikh Dashir valley is estimated as 8,4 mm. (Annual average precipitation is 320 mm). Underground water flow in the area of the confluence of Kharaa and Boroo rivers is about 6250 m<sup>3</sup>/hour.

**Hydrogeological structure:** In the area, the following two hydrogeological structures were distinguished:

1. Hydrogeological massive
2. Hydrogeological water-bearing fault

**Hydro geological massive** of the Ikh Dashir is composed of sandstone, shale, granite, and granodiorite of the lower Paleozoic age. The water content of this is defined by the weathered zone of rocks, tectonic faulting, and erosion. Water is mostly distributed in the fractured aquifer. The distribution area overlaps with the feeding area and underground water flows toward the Boroo river valley. The hydro geological massif is covered by loess type loam. It has low water containing abilities and precipitation does not feed it. The weathering, tectonic fracture and fault created secondary minerals which accelerated metamorphism, filling fissures and fractures. The biggest water-bearing faults in the area are Tsagaan Chuluut and the Boroo river fault, which divides the Ikh Dashir mountain valley. Although many faulting zones erode the alluvial gold deposit, the water content of this fault is not high. Deep metamorphism has taken place in the fault area. This is also evidenced by the fact that there is no natural indication (spring) of underground water.

**Connection between underground and surface water:** Underground water distributed in the area has an indirect hydraulic connection with the Boroo river open water, which feeds the riverbed, and the water beneath. According to our exploration works, underground water feed flow is 0.2 l/km<sup>2</sup>, which is very low.

#### **2.6.2.2. Underground water consumption**

Water demand of Boroo mine site is provided by five underground water wells of 50-62 m depth, located along Boroo river valley. Wells located 5 km distance between and north to south along Boroo River. Daily water consumption of ore processing plant is 6900 m<sup>3</sup> and annual consumption is 2518500 m<sup>3</sup> on in average.

Underground water resource:	Q=7500 m <sup>3</sup> /day
Infiltration coefficient :	=47,5 m/day

Transmission coefficient:  $=5,7 \cdot 10^4$  m<sup>2</sup>/day  
 Annual average precipitation: 301,47 mm/year  
 Underground water exploitation resource: by + + <sub>1</sub> category, 7500 m<sup>3</sup>/sec,  
 86,6 l/sec  
 Personal flow: q=0,9 l/sec m  
 Drawdown: S<sub>1</sub>=20,5 m

**Table 30. Wells description**

Well No	Depth, m	Static level, m	Coordinates		Elevation, a.s.l, m
Well 1	50	9,43	48.78227884	106.2830935	864,4
Well 2	50,2	9,61	48.77423661	106.2846528	866,5
Well 3	61	9,8	48.76581135	106.283877	869,22
Well 4	62	10,84	48.75635689	106.2855292	872,72
Well 5	51	11	48.75079345	106.2819182	875,6

**Table 31. Process water**

# of pumps	5
Wells capacity	
1 to 4 pumps, each m <sup>3</sup> /hr	65
5 <sup>th</sup> pump, m <sup>3</sup> /hr	72
Maximum water transmission, m <sup>3</sup> /hr	328

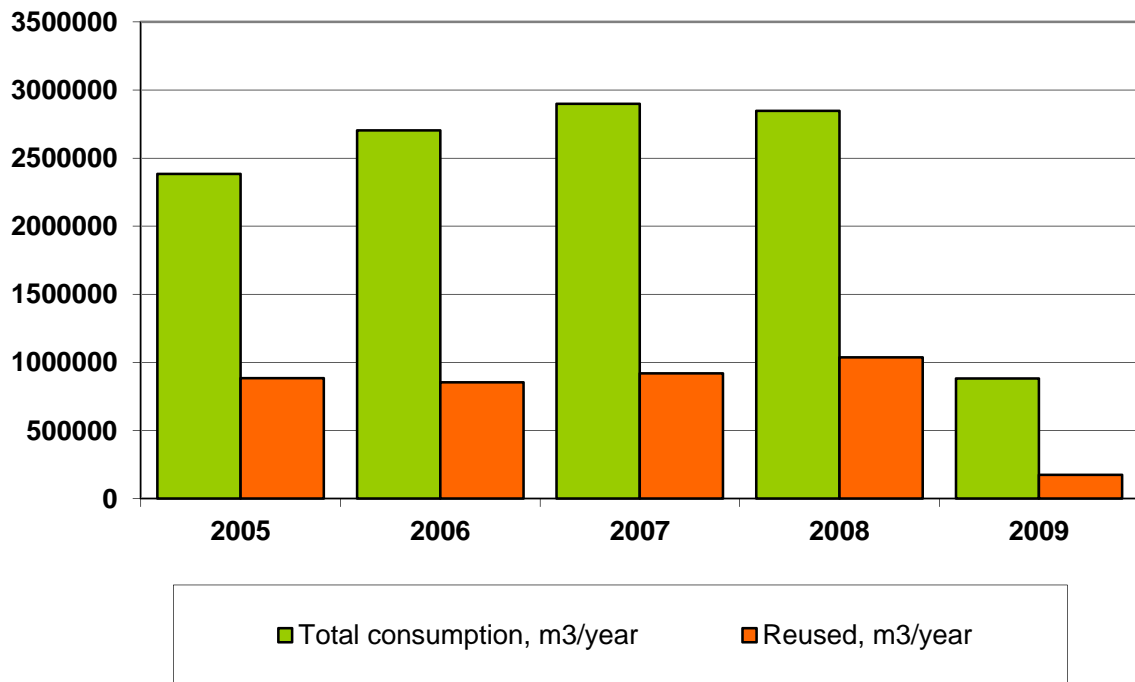
**Table 32. Water consumption, m<sup>3</sup>/year**

Years	2005	2006	2007	2008	2009
Total consumption, m <sup>3</sup> /year	2,383,637	2,702,704	2,898,678	2,847,343	882,622

**Table 33. Reused process water, m<sup>3</sup>/year**

Years	2005	2006	2007	2008	2009
Total reused water, m <sup>3</sup> /year	885,151	853,929	920,031	1,036,063	173,749





**Figure 23. Water consumption**

#### 2.6.2.3. Impacts on underground water

A comparison sheet was developed by using the water consumption and well data that shows water table fluctuations of 2007 and 2008 years.

**Table 34. Underground water levels of the wells in 2007**

Month	Pumped, m3	Well No	1	2	3	4	4
		Initial water level, m	9.43	9.61	9.8	10.84	13
March	263,670	Water lever after consumption, m	6.79	10.17	10.15	10.31	12.62
June	257,529		6.64	6.22	10.02	10.25	12.53
Sep	233,165		6.81	6.15	8.85	10.72	12.35
Dec	230,063		6.89	9.58	8.96	10.19	12.38

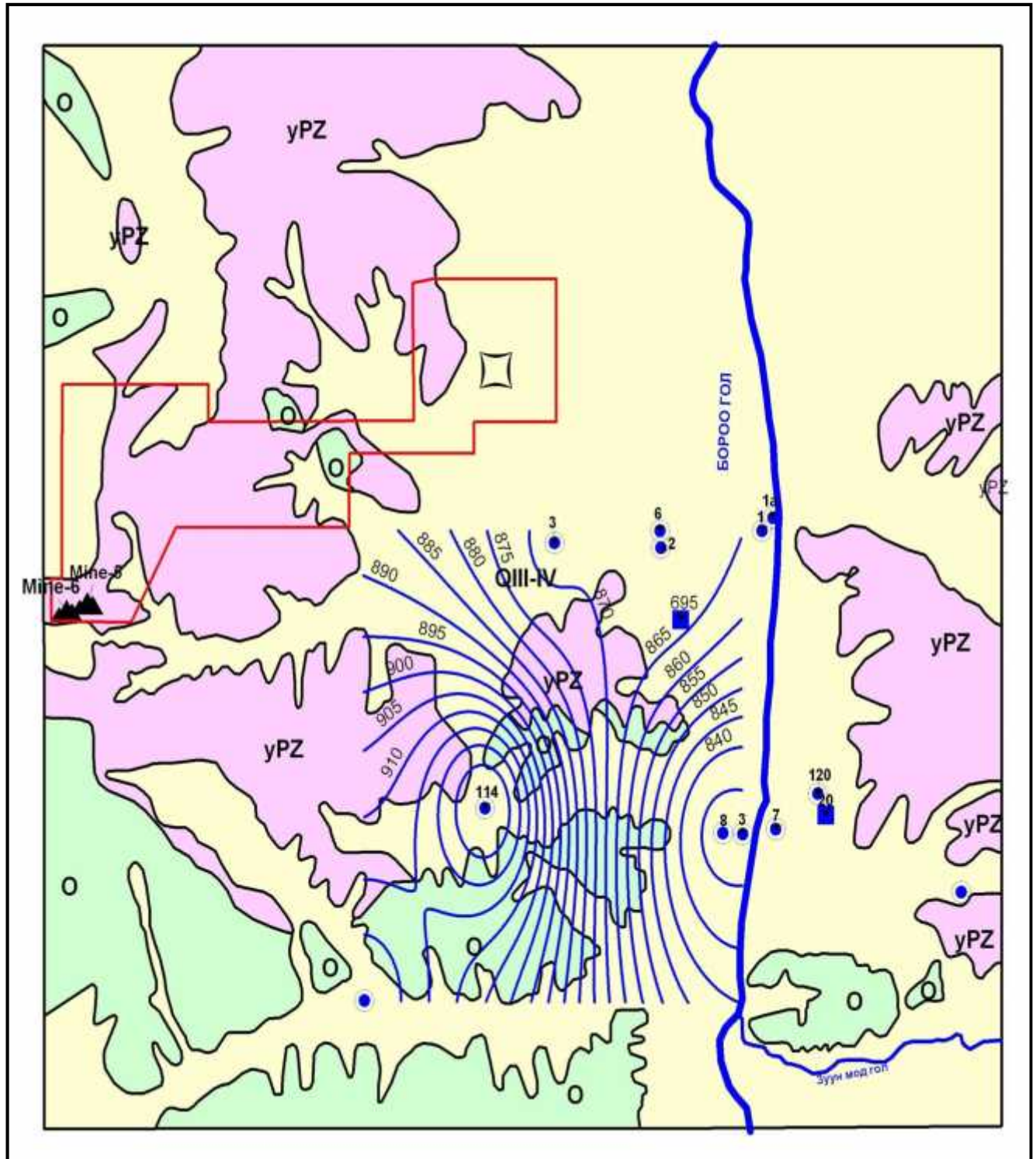
**Table 35. Underground water levels of the wells in 2008**

Month	Pumped, m3	Well No	1	2	3	4	4
		Initial water level, m	9.43	9.61	9.8	10.84	13
March	233, 923	Water lever after consumption, m	7.1	7.5	10.57	10.75	13.5
June	169, 802		7.27	8.41	10.55	10.87	13.1
Sep	121,452		6.9	7.72	10.12	10.54	12.75
Dec	217,572		7.55	7.55	10.34	10.64	12.87

The graph shows that Boroo gold mine operations are causing an impact on water supply wells as evidenced in water level changes. In March of 2007, water was not pumped from the tailings pond and approximately 263,67 m3 was pumped from the wells. During this time, water level reduced by 0.32-26.4 m. When 111,713 m3 water was pumped from the

tailings pond, 121.452 m<sup>3</sup> was pumped from the water wells. During this time, the water level fell by 0.65-3.64 m. This means that there is often less fluctuation to underground water levels when water at the process plant is reused from the tailings pond. In March of 2008, 136653 m<sup>3</sup> water was recycled from the tailings pond and approximately 92072 m<sup>3</sup> was pumped from the bore wells. During this time, water level reduced by 0.32-0.77 m. No water was pumped from the tailings pond in Dec and 224982 m<sup>3</sup> was pumped from the water wells. During this time, the water level change was 0,1-0,75 and fell by 0.65-3.64 m. In addition to the impact of water consumption at the process plant, weather data such as annual precipitation for that year is also important. For instance in 2006 and 2007, the total annual precipitation was 250 mm and water level was raised by 1.5 to 3 m. Water level at monitoring wells drilled in 1985 in Boroo river valley showed that hydro hypsographical line was curved. Underground water surface at Ikh Dashir valley falls into the Boroo river catchment and slope-shaped at the same level. Underground water drainage will drain in the direction of Boroo River. Water was studied at Boroo river valley's BGC water wells to record if there were changes in comparison to an earlier study report. Using water level info from 2008, a curved hydro hypsographical curve was made. During water consumption, surrounding the supply wells, following the river flow direction, long and ellipse-shaped depressions were found. This is an abnormal hydrodynamic form going in the direction of underground supply wells. Although there is not much change to the water table in the wells, there is visible change in hydrodynamics. Measures are planned to reduce water consumption, especially through recycling of industrial water. For example, overflow water from the tailings thickener will be used as dilution water for mill processing, filtration, and BIOX® process sections. Compared to thermal oxidation technologies, in which much more water is consumed, the BIOX® process may be considered ideally suited to arid regions. However, evaporative losses in the BIOX® process and cooling water portions of the mill are expected to be significant. Measures will be taken during plant operations to better understand the mill water balance, to increase water reuse, and to more efficiently manage overall consumption. Upgrades to existing mill operations and the construction of new facilities around the BIOX® process will include new flotation equipment, BIOX® process equipment, new counter-current decantation (CCD) washing of biological oxidation products, limestone neutralization equipment, new tanks, new adsorption carbon-in-pulp (CIP) and CIP tailings and cyanide reduction equipment, and several other upgrades. These upgrades will generally improve the level of containment and control for reducing discharges of process water and for improving recovery and reuse of collected water. Site work to improve earthwork and

storm water management will also reduce storm water contact with tailings and process waste materials, reducing impacts to local water resources.



The Boroo site at Ikh Dashir deposit is bordered with Bayangol and Mandal soums of Selenge aimag on east side of the Boroo River and 5 km east of the vertical road. Gold

has been extracted from early 20 century. The Boroo Gold LLC has been executing continual monitoring at the project area. Central Geological Laboratory and Laboratory of Chemistry, chemical technological institute of MSA, analyze independent third parties conduct monitoring on wells and surfaces and collected samples monthly. Study team of Geoecological institute carried out field study in 2009 and collected samples for laboratory analysis. Assessment on underground water quality was concluded from the previous study results. In addition, results of laboratory analysis of 2010 were included in this underground water quality assessment

#### **Water quality of Boroo river**

The total length of Boroo River is 118.5 km and Ikh Dashir valley is situated on east and about 7-8 km from mine site. Close to the main deposit, Khamar Zam LLC is exploring alluvial deposit by east of the river. Boroo river and its tributaries are classified as fresh and riffle water, rivers Shiver, Shavart, Buuruljuut, Sujigt, Arangat, Bayangols ( $C^{Ca}_I$ , mineralization 69.8 ml/gr, hardness, 0.70 -equ/l,) and Zuunmod ( $C^{Ca}_I$ , mineralization 73.5 ml/gr, hardness 0.75 -equ/l) are flow into the Boroo river. Bottom sediment of Boroo River consists of sandy, clayey material. River basin has infected by mercury used for alluvial mining operations. Although Boroo gold mine doesn't use surface water, the company implements monthly monitoring of surface water. Monitoring points of surface water are selected one for parallel to the Boroo River, two for downstream and upstream of the mine site. There is a pool in upstream of the Boroo River, which is used for washing gold with mercury. Therefore, experts of Geoecological institute selected three more points upstream, one point parallel to MB4 and one point in downstream for sampling. Water quality of Boroo was turbid, brown colored, hydrocarbonate, and calcium type with  $HCO_3^- > SO_4^{2-} > Cl^-$  anion and  $Ca^{2+} > Na^+ + K^+ > Mg^{2+}$  cation ratio at time of field study. Upstream water monitoring point was warm (temperature  $20.8^{\circ}$  ), fresh (mineralization 419 mg/l), soft (hardness 3.8 mg-equ/l), low alkaline (8.32) and slightly polluted (permanganate oxidation is 5.6 mgO/l, ammonia 0.074 mgN/l, nitrite 0.033 mgN/l, and nitrate 0.51 mgN/l). This kind of pollution might be caused seasonally by the livestock summer camping.





**Figure 24. 1) Upstream point of Boroo river, 2) Upward from a pool contaminated with mercury by gold wash**

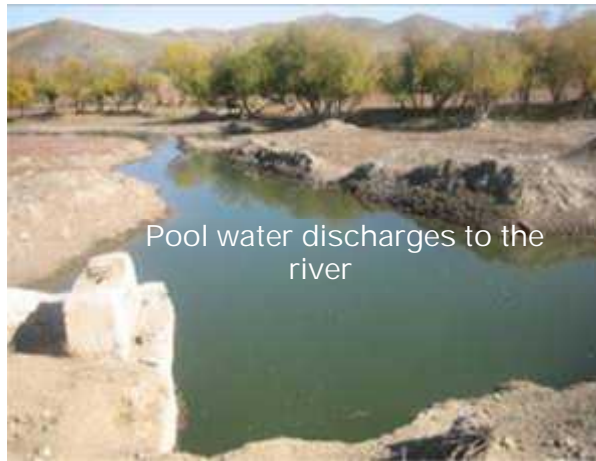
Sample has been collected upstream part due to an old stream that was used to wash gold using mercury. Bushes at this part of Boroo River are gone and herders already settled. Water quality and its component are generally same as upstream point. A sample from Boroo river was taken at N48°41'58.0", E106°16'35.1" and 889 m ASL on 2nd of Oct 2010 which is upward from the gold washing area with mercury. During field study, river was weedy, plants grown along the riverside, muddy, and gravel in the middle. The temperature was 11.5° , pH 8.57, electric conductivity 480  $\mu\text{S}/\text{m}$ , TDS 279 ppm,  $\text{Fe}^{2+}$  12 mg/l and  $\text{Fe}^{3+}$  244 mg/l. Two pools from placer mining operations flow into Boroo River. The location of first pool is N48°42'04.9", E106°16'32.6", elevation 881 m ASL and flow into the river.



**Figure 25. Pool contaminated with mercury by placer mining**

In the pool the temperature was 13.4° , pH 8.35, electric conductivity 500  $\mu\text{S}/\text{m}$ , TDS 290 ppm,  $\text{Fe}^{2+}$  3.0 mg/l,  $\text{Fe}^{3+}$  250.1 mg/l that demonstrate same results comparing the river. Second pool is located slightly downward with N48°42'21.9",

E106°16'33.0" elevation 879 m ASL with ruins of placer mining. Pool had green water with  $10.7^0$  , 8.42, electric conductivity 460  $\mu\text{S}/\text{m}$ , TDS 275 ppm,  $3^{2-}$  6.0 mg/l and  $3^{-}$  256.2 mg/l.



**Figure 26. Lower pool which used by placer mining**

During field study in 2009, a sample was taken from the parallel point with MB4 drinking water well which is upward from the previous selected point along Boroo river. Water quality slightly changed starting from this point because Zuunmod River with fresh, soft water discharges to west side at upper stream. Selected point in the middle of the river, located parallel to MB4 has approximate water quality and component compared with river and mineralization 329.6-358.4 mg/l, hardness 3.55 mg-eq/l. Main indicators are lowered than the upstream and pollutants are decreased. In addition, ratio of cations is changed, magnesium ion backed to second type of  $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^{+} + \text{K}^{+}$ . Water quality both upstream and middle of Boroo river shows almost same features and it has little change along river length. Study team of Geoecological institute had taken a sample Boroo river at N48°51'59.6", E106°15'54.8', elevation 821 m ASL which is upper part from Kharaa river discharge. During field study, sampling water was weedy, muddy and gravel sediments and temperature  $7.7^0$  , 8.45, electrical conductivity 460  $\mu\text{S}/\text{m}$ , TDS 271 ppm,  $3^{2-}$  6.0 mg/l,  $3^{-}$  244 mg/l.



**Figure 27. Boroo river, Downstream from Khamar zam, Dec 2009**

In 2009, Khamar zam LLC had operated placer mining in Boroo riverbank and muddy effluent water from sedimentation pool was flowing into the river. We had taken samples from effluent and river water and it indicated as fresh (mineralization 239.9-280.0 mg/l), soft (hardness 2.80-2.85 mg-equ/l) for weak alkalinity to alkalinity ( 8.32-9.02, permanganate oxidation 5.76-7.28 mg/l, ammonia 0.045-0.06 mg/l, nitrite 0.025-0.030 mg/l and not detected nitrite. Arsenic is detected showing impact of placer mining operation.



**Figure 28. Boroo downstream**



December 2010, experts from Geoecological institute in collaboration with Russian and American scientists investigated Orkhon River and its tributaries. At that time, Boroo River (downstream from the gold washing area of Khamar zam LLC) was turbid and muddy bed. Mercury, arsenic, lead and nickel has been detected in the floor of the riverbed.



**Figure 29. 1) Sedimentation pool of Khamar zam, 2) Effluent to the river**

Samples taken on June 29, 2009 from Boroo river were analyzed by Central geological laboratory and illustrated in the below table.

**Table 1. Result of chemical analysis in Boroo river (mg/l)**

	Indicators	Sample locations			MNS 4586-98
		upper	middle	down	
1	Potassium (K <sup>+</sup> )	4.11	3.67	4.22	-
2	Sodium (Na <sup>+</sup> )	33.0	31.0	31.0	-
3	Ammonium (NH <sub>4</sub> <sup>+</sup> )	<0.01	<0.01	<0.01	0.6
4	Calcium (Ca <sup>2+</sup> )	42.08	39.08	37.07	
5	Magnesium (Mg <sup>2+</sup> )	30.38	27.34	29.77	
6	Chlorine (Cl <sup>-</sup> )	28.01	20.92	20.92	300.0
7	Sulfate (SO <sub>4</sub> <sup>2-</sup> )	42.80	40.33	42.80	100.0
8	Nitrite (NO <sub>2</sub> <sup>-</sup> )	<0.01	<0.01	<0.01	0.006
9	Nitrate (NO <sub>3</sub> <sup>-</sup> )	2.62	2.36	4.50	40.0
10	Carbonate (CO <sub>3</sub> <sup>2-</sup> )	4.50	4.50	3.00	-
11	Hydrocarbonate (HCO <sub>3</sub> <sup>-</sup> )	234.9	219.6	222.7	-
12	pH	7.05	7.30	7.10	6.5-8.5
13	Sulfurous acid (H <sub>2</sub> SO <sub>3</sub> )	2.91	4.31	4.31	-
14	Total Dissolved Salt (TDS)	298.0	276.0	302.0	
15	Hardness (mg-equ/l)	4.60	4.20	4.30	
16	Cyanide (CN total)	<0.002	<0.002		0.01
17	Cyanide (CN free)	<0.002	<0.002		
18	Aluminum (Al)	<0.025	<0.025		0.5
19	Arsenic (As)	<0.05	<0.05		0.01
20	Barium (Ba)	<0.05	<0.05		0.7

21	Cadmium (Cd)	<0.005	<0.005		0.005
22	Chromium (Cr)	<0.02	<0.02		0.05
23	Copper(Cu)	<0.01	<0.01		0.01
24	Fluoride (F)	1.13	0.53	1.18	1.5
25	Ferrum (Fe)	<0.02	<0.02		0.3
26	Manganese (Mn)	<0.01	<0.01		0.1
27	Mercury(Hg)	<0.005	<0.005		0.0001
28	Molybdenum (Mo)	<0.03	<0.03		0.25
29	Plumbum (Pb)	<0.05	<0.05		0.01

### **Drinking water ( 1-5)**

Drinking water for Boroo mine site provided from the wells drilled in the Boroo river sediment. All wells are under regular control and maintenance. According to the investigation, five wells have close water quality and components and they are usually hydrocarbonate, calcium, and first type water with  $\text{HCO}_3^- > \text{SO}_4^{2-} > \text{Cl}^-$  anion,  $\text{Ca}^{2+} > \text{Na}^+ + \text{K}^+ > \text{Mg}^{2+}$  cation. For the quality, water is fresh (mineralization 384-622 mg/l), rather soft (hardness 4.30-4.95 mg-equ/l), weak alkaline ( 7.70-8.07), permanganate oxidation 0.64-2.40 mg /l, ammonia 0.030-0.053 mg/l, nitrite 0.015-0.038 mg/l, nitrate 0.332-0.562 / and none of microorganisms detected and it meets the standard requirements of MNS900-2005 "Drinking water. Health requirements and control". Results of laboratory analysis are illustrated in below table.

**Table 2. Results of laboratory analysis for BGC drinking water (mg/l)**

	indicators	Well No					MNS 900:2005
		MB1	MB2	MB3	MB4	MB5	
1	Potassium ( $\text{K}^+$ )	2.35	2.18	2.06	2.24	2.66	-
2	Sodium ( $\text{Na}^+$ )	22.38	21.29	20.03	21.36	33.77	200.0
3	Ammonium ( $\text{NH}_4^+$ )	0.40	0.40	0.20	0.40	0.40	1.5
4	Calcium ( $\text{Ca}^{2+}$ )	60.12	58.12	52.10	60.42	68.14	100.0
5	Magnesium ( $\text{Mg}^{2+}$ )	21.87	21.87	19.44	18.83	30.38	30.0
6	Chlorine ( $\text{Cl}^-$ )	35.10	42.49	42.19	35.10	42.19	350.0
7	Sulfate ( $\text{SO}_4^{2-}$ )	43.62	35.39	44.44	44.44	60.08	500.0
8	Nitrite ( $\text{NO}_2^-$ )	<0.01	<0.01	<0.01	<0.01	<0.01	1.0
9	Nitrate ( $\text{NO}_3^-$ )	1.30	1.20	1.50	1.88	1.30	50.0!
10	Carbonate ( $\text{CO}_3^{2-}$ )	1.50	<1.5	<1.5	<1.5	3.00	-
11	Hydrocarbonate ( $\text{HCO}_3^-$ )	244.06	158.64	207.45	231.86	268.47	-
12	pH	7.41	7.46	7.42	7.47	7.42	6.5-8.5
13	Sulfurous acid ( $\text{H}_2\text{SO}_3$ )	3.72	4.65	4.08	4.26	4.60	-
14	Total dissolved salts (TDS)	350.0	332.0	332.0	342.0	398.0	1000.0
15	Hardness (mg-equ/l)	4.80	4.70	4.20	4.55	5.90	7.00
16	Cyanide (CN total)	<0.002	<0.002	<0.002	<0.002	<0.002	0.01
17	Cyanide (CN free)	<0.002	<0.002	<0.002	<0.002	<0.002	

18	Aluminum (Al)	<0.025	<0.025	<0.025	<0.025	<0.025	0.5
19	Arsenic(As)	<0.05	<0.05	<0.05	<0.05	<0.05	0.01
20	Barium (Ba)	<0.05	<0.05	<0.05	<0.05	<0.05	0.7
21	Cadmium (Cd)	<0.005	<0.005	<0.005	<0.005	<0.005	0.003
22	Chrome (Cr)	<0.02	<0.02	<0.02	<0.02	<0.02	0.05
23	Copper (Cu)	<0.01	<0.01	<0.01	<0.01	<0.01	1.0
24	Ferrum (Fe)	<0.02	<0.02	<0.02	<0.02	<0.02	0.3
25	Manganese (Mn)	<0.01	<0.01	<0.01	<0.01	<0.01	0.1
26	Mercury(Hg)	<0.005	<0.005	<0.005	<0.005	<0.005	0.0005
27	Molybdenum (Mo)	<0.03	<0.03	<0.03	<0.03	<0.03	0.07
28	Plumbum (Pb)	<0.05	<0.05	<0.05	<0.05	<0.05	0.01

According to results, it meets the standard requirements of drinking water.

#### **Monitoring wells (MW7-14)**

In order to verify any impacts from tailing pond operation to the underground water quality, there have been started monitoring at three of monitoring well MW 7-9 since 2003, four of monitoring well MW 10-14 since 2005 and additional one monitoring well MW 10 since 2008. Monitoring wells are located at downhill areas along underground water flow; therefore, these could be fully monitored.

##### **Monitoring well MW7:**

It is located approximately 800 m distance at southeast of tailings pond and the farthest point which is located in the middle of cropland outside the mine license area. Water quality is saline and hard, composed from sulfate and mixed group of third kind water. The contents of the elements are high such as calcium 184 mg/l, magnesium 156 mg/l and total hardness is 22 mg-equ/l that results being harder than water in tailings pond. In addition, mineralization is same as tailings pond (mineralization 2102 mg/l) and salty and microorganisms are not detected.

##### **Monitoring well MW8:**

It is located 300 m distance at south of monitoring well MW 7. Water quality is extremely different from MW 7. Notably, it contains potassium 61.1 mg/l, manganese 22.5 mg/l and total hardness is 4.90 mg-equ/l i.e. rather soft type of water. Mineralization is 775 mg/l that shows fresh water type. None of indicators exceed standard requirements

##### **Monitoring well MW9:**

It is drilled in 250 m southeast of MW 8. Mineralization is close to the MW 8, total hardness is very high (total hardness 10.35 mg-equ/l). Microorganisms are not detected.

##### **Monitoring well MW10:**

It is located on southeast of tailings pond. Water quality and contents are approximate to MW 9 indicators. MW 10<sup>a</sup> was drilled near tailings dam on its west.

Chemical components are classified as mixed, calcium-manganese group, 3<sup>rd</sup> type and fresh (mineralization 728 mg/l), hard (hardness 8.60 mg-eq/l), weak alkaline (pH 7.96), microorganisms are not detected.

**Monitoring well MW11-14:**

Water quality is almost same as MW 8, mainly shows mixed, sodium group, 2<sup>nd</sup> type and fresh (mineralization 807-868 mg/l), from slightly hard to hard (hardness 5.85-7.60 mg-eq/l), weak alkaline (pH 7.83-8.0), microorganisms are not detected. Samples taken on June 29, 2009 from Boroo river were analyzed by Central geological laboratory and illustrated in the below table.

**Table 3. Laboratory results of tailings pond and monitoring well samples**

Indicators, (mg/l)	Monitoring well No							
	MW3	MW4	MW7	MW9	MW10	MW10	MW 11	MW12
Potassium (K <sup>+</sup> )	3.9	2.1	9.4	1.0	1.7	2.2	2.4	1.8
Sodium (Na <sup>+</sup> )	107.1	116.1	378.6	85.0	74.3	82.9	102.6	147.3
Ammonium (NH <sub>4</sub> <sup>+</sup> )	0.4	0.4	0.4	0.6	0.4	0.6	0.2	0.4
Calcium (Ca <sup>2+</sup> )	90.2	78.2	185.4	43.1	62.1	98.2	90.2	80.2
Magnesium (Mg <sup>2+</sup> )	68.0	34.0	168.9	23.1	30.4	45.0	42.5	40.1
Chlorine (Cl <sup>-</sup> )	143.9	136.8	407.0	112.4	91.1	119.5	126.2	185.6
Sulfate (SO <sub>4</sub> <sup>2-</sup> )	345.7	247.7		136.6	185.2	242.0	278.2	260.9
Nitrite (NO <sub>2</sub> <sup>-</sup> )	<0.01	0.04	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate (NO <sub>3</sub> <sup>-</sup> )	3.9	2.6	8.5	5.3	3.4	3.9	4.4	8.5
Carbonate (CO <sub>3</sub> <sup>2-</sup> )	<1.5	<1.5	<1.5	<1.5	<1.5	3.0	3.0	<1.5
Hydrocarbonate (HCO <sub>3</sub> <sup>-</sup> )	201.3	201.3	128.1	131.2	131.2	207.5	180.0	195.3
pH	7.37	7.37	7.32	7.33	7.38	7.39	7.35	7.38
Sulfurous acid (H <sub>2</sub> SO <sub>3</sub> )	4.26	4.08	3.72	2.05	4.47	3.17	3.51	3.70
Total dissolved salts (TDS)	992.0	766.0	2544.0	486.0	572.0	708.0	788.0	834.0
Hardness (mg-eq/l)	10.10	6.70	23.15	4.05	5.60	8.60	8.00	7.30
Cyanide (CN total)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cyanide (CN free)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Aluminum (Al)	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Arsenic(As)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Barium (Ba)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cadmium (Cd)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chrome (Cr)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Copper (Cu)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ferrum (Fe)	2.29	2.72	1.99	2.07	2.15	2.29	3.02	2.22
Manganese (Mn)	<0.02	<0.02	<0.02	<0.02	0.12	0.04	<0.02	<0.02
Mercury(Hg)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Molybdenum (Mo)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Plumbum (Pb)	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Potassium (K <sup>+</sup> )	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

There is almost no change between previous results and current results of 2010. Therefore, it is assumed no impact on monitoring wells from tailings pond and pollution indicators meet the requirements of MNS 4586-98 “Quality indicators of ambience water” standard.

#### **Monitoring well at HL pad (HL1-6)**

Heap leaching pad is located at south east of processing plant and south of placer mine deposit. It has started its pilot operation since 2008, but it was not operating during field study. There are five monitoring wells (HL4-6) and two more wells as NL1 new and NL2 new were drilled in 2009. Study results are illustrated in Table 39.



**Figure 30. Location map of HL tailings pond monitoring wells**

#### **Monitoring well 4-6:**

Monitoring well HL5 is located on north of HL road and east of Mon Dulaan placer mining. Water quality, contents are different from other wells of HL pad and classified as chlorine category, calcium-manganese group, 3<sup>rd</sup> type,  $\text{Cl} > \text{SO}_4^{2-} > \text{HCO}_3^-$  anion and  $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ + \text{K}^+$  cation rated. It is salty (mineralization 1097 mg/l), very hard (hardness 13.80 mg-equ/l), weak alkalinity (pH 7.89), less polluted and microorganisms are not detected. Chemical contents of HL4 that is located northeast of HL pad area is approximate to HL5 chemical contents but mineralization and hardness is a bit lower. It is fresh (mineralization 676 mg/l), hard (hardness 7.85 mg-equ/l), weak alkalinity (pH 8.16), less polluted and microorganisms are not detected. HL6 located at west side of the HL pad, water quality classified as hydrocarbonate category, mixed group, 2<sup>nd</sup> type,  $\text{HCO}_3^-$



$\text{SO}_4^{2-} > \text{Cl}^-$ , anion rated and  $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ + \text{K}^+$  cation rated. It is fresh (mineralization 524 mg/l), slightly hard (hardness 5.10 mg-eq/l), less polluted and microorganisms are not detected. There were drilled two monitoring wells in north margin of HL pad area. Water is classified as mixed category, calcium group, 3<sup>rd</sup> type,  $\text{HCO}_3^- > \text{SO}_4^{2-} > \text{Cl}^-$  anion rated and  $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ + \text{K}^+$  cation rated. It is fresh (mineralization 890 mg/l), very hard (hardness 11.50 mg-eq/l), neutral (7.01), permanganate oxidation 2.64 mg /l, ammonia 0.380 mg/l, nitrite 0.041 mg/l, nitrate 3.578 mg/l and microorganisms are not detected. Therefore, it could be concluded that there is no effluent impact from HL pad. The results of laboratory analysis conducted in 2010 are illustrated below table.

**Table 4. Laboratory results of monitoring well within HL pad**

indicators, (mg/l)	Monitoring well No				
	HL1 New	HL2 New	HL4	HL5	HL6
Potassium ( $\text{K}^+$ )	3.1	2.5	2.6	4.6	3.5
Sodium ( $\text{Na}^+$ )	52.7	90.0	72.0	288.0	47.0
Ammonium ( $\text{NH}_4^+$ )	0.40	<0.01	1.00	<0.01	<0.01
Calcium ( $\text{Ca}^{2+}$ )	144.3	116.2	72.1	49.1	38.1
Magnesium ( $\text{Mg}^{2+}$ )	48.6	66.8	79.6	75.9	41.3
Chlorine ( $\text{Cl}^-$ )	161.3	115.6	140.4	256.3	28.0
Sulfate ( $\text{SO}_4^{2-}$ )	283.9	263.4	301.2	284.8	56.0
Nitrite ( $\text{NO}_2^-$ )	<0.01	0.02	0.40	<0.01	0.02
Nitrate ( $\text{NO}_3^-$ )	1.20	5.46	<0.01	21.25	5.98
Carbonate ( $\text{CO}_3^{2-}$ )	<1.5	6.0	3.0	7.5	6.0
Hydrocarbonate ( $\text{HCO}_3^-$ )	213.6	277.6	170.8	335.6	247.1
pH	7.40	7.05	7.00	7.25	7.15
Sulfurous acid ( $\text{H}_2\text{SO}_3$ )	2.96	4.57	<1.5	3.2	3.0
Total Dissolved Salt (TDS)	978.0	856.0	882.0	1148.0	344.0
Hardness (mg-eq/l)	11.20	11.30	10.15	8.70	5.30
Cyanide (CN total)	<0.002	<0.002	<0.002	<0.002	<0.002
Cyanide (CN free)	<0.002	<0.002	<0.002	<0.002	<0.002
Aluminum (Al)	<0.025	<0.025	<0.025	<0.025	<0.025
Arsenic (As)	<0.05	<0.05	<0.05	<0.05	<0.05
Barium (Ba)	<0.05	<0.05	<0.05	<0.05	<0.05
Cadmium (Cd)	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium (Cr)	<0.02	<0.02	<0.02	<0.02	<0.02
Copper (Cu)	0.04	<0.01	<0.01	<0.01	<0.01
Fluoride (F)	1.59	<0.10	1.05	0.98	1.28
Ferrum (Fe)	0.04	<0.02	0.02	<0.02	0.05
Manganese (Mn)	<0.01	<0.01	0.22	<0.01	<0.01
Mercury (Hg)	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	<0.03	<0.03	<0.03	<0.03	<0.03
Plumbum (Pb)	<0.05	<0.05	<0.05	<0.05	<0.05

According to above results, water pollutants are within the standard requirements of MNS4586:98 “Quality indicators of ambience water”. It could consider that no pollution on ambience water from NL pad utilization.

*Ikh Dashir well:*

This old well is located in the middle of mine site and tailings dam. The result of 2009 and 2010 investigation, water quality is classified as hydrocarbonate category, calcium-sodium group, 2<sup>nd</sup> type,  $\text{HCO}_3^- > \text{SO}_4^{2-} > \text{Cl}^-$  anion rated and  $\text{Ca}^{2+} > \text{Na}^+ + \text{K}^+ > \text{Mg}^{2+}$  cation rated. It is fresh to fresh (mineralization 432-550 mg/l), soft to hard (hardness 4.80-5.10 mg-eq/l), neutral to weak alkalinity (7.05-7.94), permanganate oxidation 2.32 mg /l, ammonia 0.010-0.034 mg/l, nitrite 0.010-0.027 mg/l, nitrate 4.136-10.75 mg/l and microorganisms are not detected. Water quality meets the requirements of MNS900-2005 “Drinking water. Health requirements and control” standard.

## **2.7. Vegetation**

### **2.7.1. Vegetation cover and its specifics**

BIOX® process plant will be located on south of the current Boroo processing plant. As of vegetation cover classification, Boroo gold mine is located in Mongolia’s geographically Daurian steppe province Euro-Asian steppe region, West Khentii mountain belt and falls into the Kharaa region (N. Ulziikhutag, 1984). The study area is in low hill, valley, channel surface structure and the vegetation matches these physical features. The primary vegetation form is native to mountain steppe and its combinations. Although the forest steppe zone is not as large and has limited biodiversity, it is very easy to do vegetation composition classification. Pre-mining cover was dominated by pastureland mat-grass. In 100-m<sup>2</sup> land, 25 to 30 species of plant has been found and vegetation coverage is 94 %. Out of this, 32% was dominated by *Stipa borysthena*. In addition to *Stipa borysthena*, other grasses include smooth brome, *Poa pratensis* L, daurian wild rye, carex, *Veronica incana* L, *Anemone crinita* Juz, *Plantago major*, Geranium sibiricum, *Potentially anserine* L., *P. tanacetifolia* Wild, *Andros ace septentrionalis* L., *Lappula myosotis* Moench, *Artemisia dracunculus* L, *Artemesia macracephala* Jacquem. There is a small area of mostly *Salsola collina*, *Bassia dasyphylla*, *Chenopodium album*, which is not impacted by mining operation and keeps its natural features. Botanist doctor N.Manibazar (2000) indicated that the project area has low potential to be a habitat of endangered or near-extinct plant species.





**Figure 25. Mat-grass pastureland**

### **2.7.2. Impacts on vegetation**

Vegetation cover already has been impacted and destructed by mining operation. There is no forest in the project area. BIOX® process plant will be constructed on previously disturbed area by mining operation, no other area will be impacted.

## **2.8. Fauna**

### **2.8.1. Fauna distribution**

JEMR Co Ltd (2000) carried out an environmental baseline study for Boroo site area, and more than 160 species of animals of 22 orders and 5 classes have been registered in the area during the research. Within the list 116 species of insects (cl Insecta) from 5 orders have been observed, one species of amphibians, 2 species of reptiles, 23 species of birds, 19 species of mammals were recorded. The report wrote that the 6 types of birds commonly found in Boroo and Ikh Dashir valley must be protected: *Milvus migrans* (Boddaert, 1783) Black KYTE, *Falco tinniculus* (Linnaeus, 1758) Kestrel, *Grus grus* (Linnaeus, 1758) Crane, *Bubo bubo* (Linnaeus, 1758) Eurasian Eagle-Owl. Among butterflies recorded in the area, two butterfly species *Parnassius.apollo* and *Papilio machaon*, (shallowtail) are rare and are listed in the Red Book of Mongolia as requiring protection. From 16 mammal species recorded, there is no need for protection of particular rare species. It was noticed that marmots (*Marmota sibirica*), which were abundant before, have rapidly declined in recent years. From invertebrates found before

mining activity started, insect family representatives were: *Carabus*'s 2 species, *Cymindis binota*, *Saprinus ornatus*, Taphoxenus-species' insect predator beetles, *Coranus*, *Rhynocoris* specie's insect predators or beneficial insect species play important role in limiting the number of insect parasites at newly reclaimed lands. 16 species of Lepidoptera insects suggest that biodiversity index is high. If invertebrate population and distribution studies were conducted annually and at different seasons, biodiversity fluctuation/changes at the reclaimed lands would have been more apparent.

Darkhan Nagoon aral Co Ltd carried out a study of reclaimed lands in 2008. This report includes studies of all reclaimed lands between 2004 and 2008 that cover 155.8 ha. Experts studied post-reclamation ecosystem vegetation structure, and fauna distribution. There has been positive imprint left in 2004 reclaimed land where perennial grasses grow. Mongolian gerbil, daurian pika, striped hamster, badger, yellow fox and grey wolf's footprints were found. In addition, grouse was found lying on the road, which may have been attacked by a predatory bird. Many mouse holes and rodent tunnels were found in reclaimed lands, particularly at tree planted land. However, their numbers, density was not studied. Mining operations take place in Kharaa river valley. Here 24 species of fish, 2 species of lizards, 4 species of snakes were found. During the study at reclaimed area membranous and cross vein-winged insects were recorded too. This means that dynamic organism interactions within the ecosystem are taking place.

## **2.8.2. Impacts on fauna**

There is no impacts on fauna from project operation.

## **2.9. Historical, cultural and scientific findings**

There are no known historical, cultural and scientific resources in the project area. There are no reserved and special protected areas in the project area.

## **2.10. Socio-economics**

### **2.10.1. Socio-economic development of the project area**

Boroo mine site is located within the both Mandal and Bayangol soum territories of Selenge aimag. The center of Bayangol soum is Baruunkharaa town, and the center of Mandal soum is Zuunkharaa city. This place has well developed infrastructure. Baruunkharaa city is located along the main road between Ulaanbaatar and Russia.

*Socio-economic condition of Bayangol soum:* Population is 4512 people, about 46,9 percent of the population is female, about 50,4 percent is male and almost 43,3 percent of the population is children. There are 136175 ha of pastureland, where approximately 71483 livestock are herded and 16195 ha of arable land is cultivated. There is a library, a secondary school with about 1090 students, kindergarten attended by 120 children, cultural center, sport court, police station, post office, and hospital and recreation center. The soum has three steam boiler, fuel station, eight gold mines, two agricultural farms, 35 service centers, and other service places. There live about 1190 households, about 9 percent of total household or 107 female-headed household. Amount of female-headed household is comparatively decreased, by 39 percent than in 2000. BGC provided 160 people with stable workplace including 6,3 percent of working age in soum residents. There are registered 300 automobiles (25 of total households) in total. Living standard is low and unemployment is high. The main income sources are informal artisanal mining, child allowance, retirement benefit, and minor vegetable planting.

*Socio-economic condition of Mandal soum:* Population is 23646 people, 6543 of which are children, 1487 of which are elderly older than sixty. About 66 percent i.e. 15616 people are adults of working age. So far totally 359 business entities and organizations, including 27 government organization, 12 state organization, 2 state industry, 1 factory, 18 SME, 72 agriculture, 26 pubs and restaurants, 4 resorts, 4 TV and internet, 90 trade places, 7 fuel stations, 15 services and 5 bank services registered at the local tax office. There are 7 kindergartens and 7 secondary schools, where study 1161 preschool and 5237 school children respectively. Also there are 6 medical services including, 1 soum hospital, 1 administrative hospital, 2 health care centers, 3 family medicine, 1 private hospital, 8 pharmacies and 6 livestock cure centers. Approximately, 4519 households of 16640 people live in the soum center, 1562 households of 5348 people live in the village and 454 households of 1638 people in the countryside. Mobile operators Mobicom, Unitel, G-Mobile, Skytel and Mongolian telecommunication branched and provide communication services in the Mandal soum. As of 2008, it counted 132321 livestock and cultivated crops and vegetables in total 4904.2 ha areas. It is consisted 3990 ha of wheat, 20 ha of barley, 606 ha of potatoes and 288.8 ha of other vegetables and entirely harvested 20096.6 tons of yield. Last few years, agriculture sector increased and now it possess 26.8 percent of GDP of Mandal soum. SBB (Spirit Bal and Buram) Co.,Ltd, which produces products of

30.5 billion MNT, is main producer of Mandal soum industrial sector. An industrial sector increased by 1.0 percent compared last year.

### **2.10.2. Impacts on socio-economics**

By startup of Boroo mining activities, Mandal soum and Tunkhel village residents have been enlisted into company's community development fund since 2004 and have been receiving financial support for strengthening public institutions such as school, hospital, police, as well as improvement of infrastructure such as roads, lightning. The number of new employees expected to work at the Boroo Biox facility is 65 people including contractors and permanent staff. The effects of employment at the Boroo facility can be compared to the effects from former operations. In comparison to building and operating a mill elsewhere, the continuation of operations at the Boroo facility are generally less disruptive in terms of social impacts to local and regional residents, due to familiarity with the general operations and reduced requirements for new infrastructure.

The BIOX® processing circuit is expected to start processing sulfide ore from the Gatsuurt mine in the second quarter of 2013, when sulfide ore will be transported to the Boroo mill for processing. Local labor will be used for some of the facilities construction at Boroo, including earthwork, concrete, structural steel, mechanical equipment, plate work, piping, and electrical installation and control equipment. Labor for processing the sulfide ore will be drawn from changing operations at the Gatsuurt mine, but may also include new labor. The construction and operation of the BIOX® processes will require training, and the employees will gain new skills of plant operations, monitoring, and maintenance. Efforts to provide continuity of employment for the trained workforce are also positive. As the upgrades to the processing facility extend the period of operations at Boroo, the addition of the BIOX® facility may also be used for ore from other mines after the period of active mining at Gatsuurt.

Infrastructure improvements also include the improvements to roads and power transmission. These infrastructure upgrades aid regional development and make it much easier to deliver goods and services to communities in the region. Negative socio-economic impacts may include negative health impacts on miners and other people living nearby the processing facility, degradation of water, soil, and air resources from pollution, increased noise, and potential impacts on agriculture and wildlife from operations. Potential impacts to resources are discussed below. The upgrade of existing processing

facilities at Boroo will generally reduce risks of pollution and increase environmental controls and monitoring activities, relative to existing operations. Existing operations at Boroo are not known to cause negative health impacts. Similarly, the BIOX® process is well managed and produces tailings that are neutralized and generally less toxic. In order to greatly reduce risks to the health of people and the environment, the site design and environmental plans and operations will include strict control measures on transportation, chemical usage, and its storage.

As mentioned in Mongolia's jurisdiction and requirements on occupational health and safety, management will arrange employee duties such that employees can work under conditions that do not endanger their health and safety. In addition, company's employees will be incorporated into relevant benefits and receive salary that is higher from those in the sector nationally. Company will provide sufficient facilities and services so that company employees stay in warm housing, receive quality food, have access to first aid treatment, and receive transportation service to their hometowns. In addition, employees will receive annual medical check-ups, be enrolled in vaccination against flu and rabies and have access to sport facilities. The company will cover these costs. Near the mine site, there is relatively small number of residents and population concentration is rather sparse. In addition, human settlements vary depending on seasonal conditions. This means that the mining impact on human settlements will be limited.

It is considered as responsible mining obligation to keep information publicly open and it is recommended to BGC to organize public meeting to introduce reliable information about bio-oxidation technology, a pioneer in bio metallurgy technology in Mongolia, its potential impact on environment and human health that could be caused by bio-oxidation technology implementation. To deliver project information to public, following measures should be taken:

- Organize local public meeting about bio-oxidation, involve local environmental officers and give knowledge about technology and its advantages.
- Organize site visit or training for local government administrators at sites with similar bio-oxidation technology or implemented this technology successfully. Give proceeding information to local responsible administrators.
- In future, when project is commenced, organize site visit for local delegations and local responsible administrative officers to introduce new plant operation.

## **Section 3. Potential and Main Impact Assessment**

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### **3.1. Potential impacts, duration and severity**

Boroo Gold Company retained Nature Friendly Co Ltd to carry out a detailed study and assessment of potential impacts on the environment resulting from Boroo expansion and new facilities of BIOX® processing. Upon project site visit and fieldwork in Feb and April of 2010, Nature Friendly experts familiarized themselves with environmental baseline conditions at Boroo site, including visits to open pits, processing facility, Tailings Management Facility. Experts also reviewed company's current environmental pollution and environmental monitoring program. DEIA of sulfide ore processing by biological oxidation, cyanide concentration, tailings management facility and infrastructure facilities have been conducted based on the studies and integrated data presented in the previous sections of the report: project technique and technology; intermediate product; waste management; social issues of employees and environmental baseline. The impact assessment developed in accordance with Mongolian Law on Environmental Impact Assessment and Life Modified Organisms, Guideline of DEIA issued by MNET, Checklist method or EIA matrix and Battelle Environmental evaluation system issued by United Nations economic and social commission of Asia and Pacific (UNESCAP). It is reasonable to evaluate potential and main impacts on environment, ecology, and social life separately for each operating facilities. In order to correctly identify potential environmental impacts of any mining operations, a checklist method that addresses principal environmental characteristics is developed prior project commissioning, which assesses project impact type, scale, severity and duration on such aspects as local and regional environment and ecology, socio-economic and demographic features, as well as human health. These considerations have been clearly marked in guidelines developed by the World Bank and UNESCAP

#### **3.1.1. Potential impacts during construction stage**

Potential impacts that might rise during construction stage were identified by checklist method summarizing the evaluation and conclusion from experts study.

**Table 5. Potential environmental impacts during construction stages-impact type, scale, duration and severity**



<b>Environmental specifications</b>	<b>Direct</b>	<b>Indirect</b>	<b>Self-reversible</b>	<b>Short term</b>	<b>Long term</b>	<b>Reversible</b>	<b>Irreversible</b>	<b>High</b>	<b>Moderate</b>	<b>Low</b>
<b>1. Changes of ecosystem</b>										
Underground water flow change										
Surface water flow change										
Vegetation cover change										
Soil erosion and disturbance	+				+		+		+	
Geological formation change										
Wildlife habitats	+				+		+			+
Microclimate change										
<b>2. Natural resources and exploitation</b>										
Underground resources	+				+		+			+
Pastureland	+				+		+			+
Minerals and raw material recourses		+			+		+			+
Energy resources	+				+		+			+
<b>3. Environmental quality change</b>										
Deterioration of underground water quality										
Deterioration of surface water quality										
Air pollution	+			+			+			+
Soil pollution	+			+			+			+
Hazardous and toxic materials spilled into waterways and thus affecting wildlife, livestock and humans		+		+		+				+
Impact of noise and vibration	+				+	+				+
<b>4. Natural views, archaeological and historic resources, paleontological findings</b>										
Changes to visual aesthetics of nature	+				+		+			+
Impact on landscape and its features	+				+		+		+	
Impact on specially protected lands										
Impact on places of historic and cultural value										
Impact on archaeological and paleontological findings in project area										
<b>5. Socio-economics</b>										
Changes to private ownership and tax income										
Contribution to the Gross Domestic Product	+			+			+		+	
Poverty reduction	+			+			+		+	
Increase employment opportunities	+			+			+		+	
Increase in seasonal employment and income	+			+			+			+
Impact on public health	+			+			+			+
<b>6. Others</b>										
Soil disturbance from movement of machinery and heavy equipments	+			+			+		+	
Impacts caused by not complying the guidelines of bacteria application and safety										
Contamination caused by construction solid and liquid waste	+			+		+				+
Windstorm, fire, earthquake, thunderbolt		+		+		+				+
<b>Total</b>	<b>17</b>	<b>3</b>		<b>11</b>	<b>9</b>	<b>4</b>	<b>16</b>		<b>6</b>	<b>14</b>

There are 20 potential impacts were identified which could be resulted from constructing BIOX® processing plant. Based upon assessment of impact type, duration, severity on the natural environment and the socio-economic conditions following conclusion can be made.

Direct impact, duration, and severity:

17 of total impacts are anticipated to have direct impact, out of direct impacts, 5 on impacts on socio-economy are positive impacts, and the remaining are impacts. Herein: soil erosion and disturbance, change of landscapes and land surfaces caused from building base construction, flattening land surface, inventory transportation and waste disposal. These impacts are anticipated to extend moderately for a long term. Heavy machinery movement resulting in dust dispersion, gas emission those are anticipated to extend low in impact severity for a short term. Vehicle movement will generate slight deterioration of soil surface and vegetation cover. In addition, potential impact is anticipated due to spill of sewage and fuels from machineries thereby affecting soil and underground water quality during the construction stage. The above-mentioned impacts will also influence on public health of local community and employees. Impact severity is low and will comprise short period. Proposed project area impacted by mining operation and soil erosion, disturbance already happened throughout the ground.

Anticipated positive impacts during construction stage include generation of employment opportunities, increase in fiscal income, and reduce local poverty, contribution to gross domestic product and tax payment benefits. Former positive impacts will continue in moderate severity for a short term. There are no impacts on underground and surface water resources from construction activities.

Indirect impact, duration and severity:

The anticipated impacts during construction stage could be incidents caused by not implementing construction safety rules and contingent natural disasters and considered as indirect impacts. These impacts are in low severity for short term.

### **3.1.2. Potential impacts during processing stage**

Potential impacts on natural ecosystem, resources, and quality that might rise from biological oxidation processing and specific characteristics of technology are determined in this section.

**Table 6. Potential environmental impacts during processing stages-impact type, scale, duration and severity**

<b>Environmental specifications</b>	<b>Direct</b>	<b>Indirect</b>	<b>Self-reversible</b>	<b>Short term</b>	<b>Long term</b>	<b>Reversible</b>	<b>Irreversible</b>	<b>High</b>	<b>Moderate</b>	<b>Low</b>
<b>1. Changes of Natural ecosystem</b>										
Underground water flow change		+			+		+		+	
Surface water flow change										
Vegetation cover change	+				+		+			+
Soil erosion and disturbance	+				+		+		+	
Geological formation change										
Wildlife habitats	+				+		+			+
Microclimate change										
<b>2. Natural resources and exploitation</b>										
Underground resources		+			+		+		+	
Pastureland	+				+		+		+	
Minerals and raw material recourses		+			+		+		+	
Energy resources	+				+		+		+	
<b>3. Environmental quality change</b>										
Deterioration of underground water quality		+			+		+			+
Deterioration of surface water quality										
Air pollution	+				+		+		+	
Soil pollution		+			+		+		+	
Hazardous and toxic materials spilled into waterways and thus affecting wildlife, livestock and humans		+		+		+		+		
Impact of noise and vibration	+				+	+			+	
<b>4. Natural views, archaeological and historic resources, paleontological findings</b>										
Changes to visual aesthetics of nature	+				+		+			+
Impact on landscape and its features	+				+		+		+	
Impact on specially protected lands										
Impact on places of historic and cultural value										
Impact on archaeological and paleontological findings in project area										
<b>5. Socio-economics</b>										
Changes to private ownership and tax income	+				+		+	+		
Contribution to the Gross Domestic Product	+				+		+	+		
Poverty reduction	+			+			+		+	
Increase employment opportunities	+				+		+			+
Increase in seasonal employment and income	+				+		+		+	
Impact on public health	+				+		+			+
<b>6. Others</b>										
Soil disturbance from movement of machinery and heavy equipments	+				+		+		+	
Impacts caused by not complying the guidelines of bacteria application and safety	+			+		+				+
Contamination caused by construction solid and liquid waste	+			+		+				+
Windstorm, fire, earthquake, thunderbolt		+		+		+				+
<b>Total</b>	<b>18</b>	<b>7</b>		<b>5</b>	<b>20</b>	<b>5</b>	<b>19</b>	<b>3</b>	<b>13</b>	<b>9</b>

Direct impact, duration, and severity:

18 of total impacts are anticipated to have direct impact, out of direct impacts, 6 on impacts on socio-economy are positive impacts. All technological facilities of BIOX® process will operate in closed circuit and there will have no harm impacts on environment from the processing. Underground water will be used for the biological oxidation process

therefore underground water flow and resources will be impacted moderately. In general, the bacteria are not pathogenic, or otherwise harmful in nature, other than playing a significant role in acid rock drainage (ARD) and corrosion. More cautious measures to isolate the bacteria are not necessary, because they are already in abundance in nature. However, acids and metals, and other chemical products of the sulfide oxidation reactions that are either created or promoted by the bacteria, may be harmful to human health and the environment. Therefore, controls to prevent and contain spills should be in place to limit exposures or accidental discharges of the untreated byproducts. Overall, focus is given to proper engineering and management processes, such as the selection of appropriate materials for tank construction and regular monitoring practices.

*Indirect impact, duration and severity:*

Impacts such as air pollution resulting from chemical substance evaporation, soil contamination resulting from fuel and chemical spillage incautious or accidentally happened are considered as indirect impact. Impact severity is low. Indirect impacts include harmful substance impact on human or animal, soil disturbance and contamination from the facility decommissioning, underground and surface water contamination from the sewage, process water, fuel spillage and probable impacts caused from waste disposal of chemicals, processing and construction. Potential impact caused by natural disaster such as fire, earthquake, storming and lightning is considered as impact.

**3.1.3. Potential impacts caused by technological phases**

One of the important issues to mitigate potential impacts is identifying technological phases of entire biological oxidation plant and tailings management facility, which have most harmful impact on proper natural compound. In order to perform this action, a matrix method is used very commonly, which is concluded from expert's evaluation and considerations. Leopold matrix is one of the alternatives of the evaluation methods. We have slightly changed Leopold matrix for our evaluation to identify natural compound that might be impacted by BIOX® plant operation. To evaluate the phases, which might have potential impacts on natural compounds (air, soil, water, flora, fauna etc.); experts evaluations are included in this matrix. Expert evaluations are scored from 1 to 10 points. If it has lowest or no affect will be scored one points and if it has highest impact will be scored 10 points. Each cell of the table are divided by diagonal down line. Impact severity is noted above the diagonal line and impact importance is scored below the diagonal line.



**Table 7. Potential impacts connected by biological oxidation process**

№	Operation  Natural compound to be impacted	Construction					Processing technology										Total
		Earthworks and flattening ground surface	Automobile movement	Construction wastes	Fuel spillage	Noise	Crushing and grinding	Sulfide flotation	BIOX® reactors	Dissolving and concentration	CIP cyanidation	CIL process	Neutralization/detoxification	Bacteria and reagents application	Process water diversion	Water supply facilities	
1	Land and soil	6/6	1/1	2/4	2/4	1/4	-	-	-	-	-	-	-	-	1/1	1/1	14/21
2	Landscape	-	-	-	-	-	-	-	-	-	-	-	-	-	1/1	1/1	2/2
3	Pastureland	2/2	1/1	1/1	1/1	-	-	-	-	-	-	-	-	-	1/1	2/3	9/10
4	Air quality	2/3	2/3	1/1	-	2/3	2/3	-	1/1	1/1	1/1	1/1	1/1	1/1	-	-	15/19
5	Underground water	-	-	-	1/1	-	-	2/2	2/2	2/2	2/2	2/2	3/3	-	-	2/2	16/16
6	Surface water	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	Flora/forest	1/1	1/1	1/1	1/1	-	-	-	-	-	-	-	-	-	-	-	4/4
8	Fauna	1/1	1/1	-	-	-	-	-	-	-	-	-	-	-	-	-	2/2
9	Human health	1/1	1/1	1/1	-	1/1	1/1	-	-	-	-	-	2/2	1/1	-	-	8/8
<b>Total</b>		<b>13/14</b>	<b>7/8</b>	<b>6/8</b>	<b>5/6</b>	<b>3/7</b>	<b>3/4</b>	<b>2/2</b>	<b>3/3</b>	<b>3/3</b>	<b>3/3</b>	<b>3/3</b>	<b>6/6</b>	<b>3/3</b>	<b>3/3</b>	<b>6/7</b>	<b>70/82</b>

It is concluded that the operation phases that will have the largest magnitude on environment and its components are earthworks for BIOX® plant construction; vehicle movement to transport construction materials; waste disposal and industrial water neutralization. The environmental factors primarily impacted are local geology, underground water, and soil. Therefore, the section below on significant environmental impacts provides a detailed assessment on each of these components. In addition, there might be generated air pollution like dust dispersion during construction stage outside and vapor dusty atmosphere at indoor workplace. It requires to strictly following safety rules, guidelines, and technological procedures. Then no impacts on environment and human health will be derived as the processing cycle operates by closed circuit.

### **3.2. Main impacts, duration and severity**

The most affected natural compounds from BIOX® plant and further processing activities are land surface, soil erosion and disturbance and underground water. Besides, an impact on human health is considered as a main impact, because biological oxidation process will use bacteria for sulfide ore concentration. Processing will use bacteria, bacteria culture, and reagent; those of chemical substances may have harmful effect on human health. According to this DEIA, environmental protection plan must be developed and environmental protection actions should aim to reduce above-mentioned potential impacts as much as possible.



### **3.2.1. Soil erosion and disturbance**

Soil erosion and disturbance, change of landscapes and land surfaces will be impacted from building base construction, flattening land surface, inventory transportation, and waste disposal. Project area of 6,32 ha is already impacted by existing mining operation.

### **3.2.2. Impacts on underground water**

The purposes of the reassessment of underground water usage for Boroo expansion are to evaluate following problems:

- Increase the capacity of existing water supply facilities, water consumption will be increased by Boroo expansion biological oxidation plant;
- Upgrade authorized water resources, defined by previous investigation
- Study the possibilities to increase current resources by constructing new water supply facilities (at the area of existing well area or approximate area)

Mentioned above, underground water reserve of Boroo area (confirmed in 1990) reassessed based on previous underground water resource study. Total water requirement for sulfide ore bio-oxidation process is 300 m<sup>3</sup> per hour and 7200 m<sup>3</sup> per day. Underground water of Boroo area were used daily 4688,4 m<sup>3</sup> in average since 2004 (maximum use 5435,8 m<sup>3</sup> and minimum use 4001,8 m<sup>3</sup> per day). Within the scope of study, it is determined the possibility to use 2511,6 m<sup>3</sup> more water than current use. Analogical method (comparison) was used for this assessment. Underground water reserve was redefined by using hydro geological regime observed from multi-year water formation during use of underground water for existing water facilities. An advantage of this method is that collected hydro geological data defined by existing water supply facilities (existing and piezometer wells) defines all factors of formation of underground water. It is impossible to collect all these data during hydro geological field study of underground water reserve. There are two trends to reassess the underground water application reserve of existing water supply facilities by using analogical method.

- Herein:
1. Graph analytics
  2. Analytics

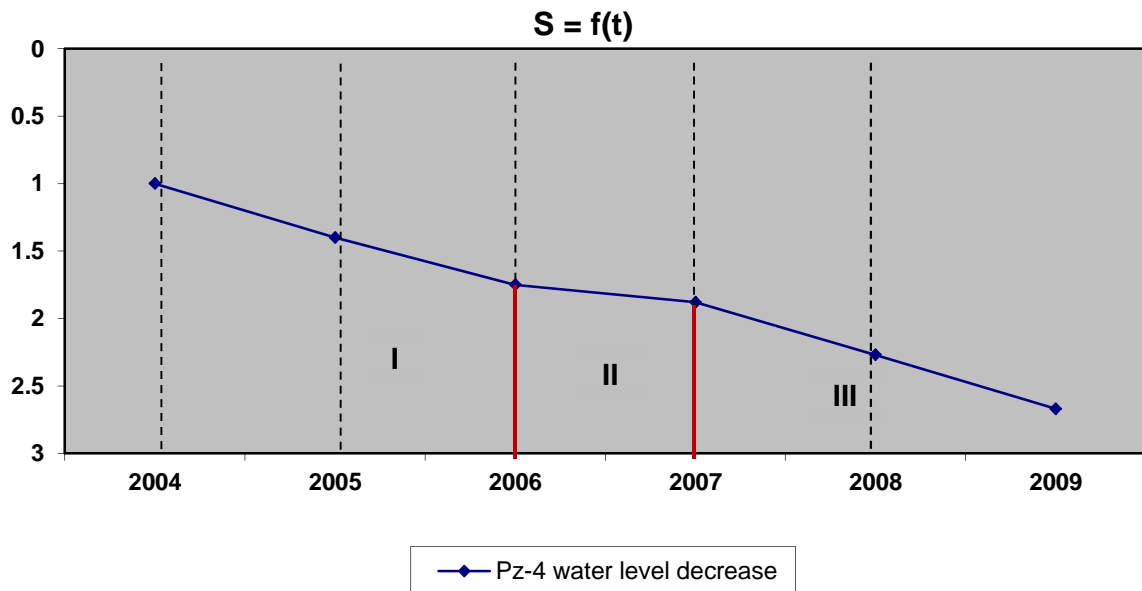
Consequently, reassessment of exploitation reserve is estimated by using graph analytical method. Graph analytical method is based on extrapolation correlation graphics of debt amount determined during reserve utilization and drawdown. Then  $Q = f(S)$  summarized graphic is drawn by using 5 year data from Boroo underground water exploitation. Therefore, there are drawn auxiliary correlation graphics  $Q = f(t)$  and  $S = f(t)$ . Scientist

N.V.Plotnikov found the main idea to convert parallel placed water supply facility conversion to “large well” scheme for underground water resource assessment by graph analytical method.

In this condition, underground water measurement of Pz-4 piezometer well, which has highest decrease, is applied into correlation graphic  $S = f(t)$ . (Table 40, Figure 31)

**Table 8. Pz-4 underground water level drawdown**

Pz-4 underground water level drawdown,	Measurement years				
	2005	2006	2007	2008	2009
	1,4	1,75	1,88	2,24	2,67
$S = 2 * S$	2,8	3,5	3,76	4,48	5,34



**Figure 31. Pz-4 Water level decrease**

**Table 9. Used water, Q m3/day**

Period, years	2004	2005	2006	2007	2008	2009
Water use, m3/year	1550782	14987486	1848774	1978647	1906152	1456650
Water use, m3/day	4260,4	4116,7	5079,05	5435,8	5236,7	4001,8

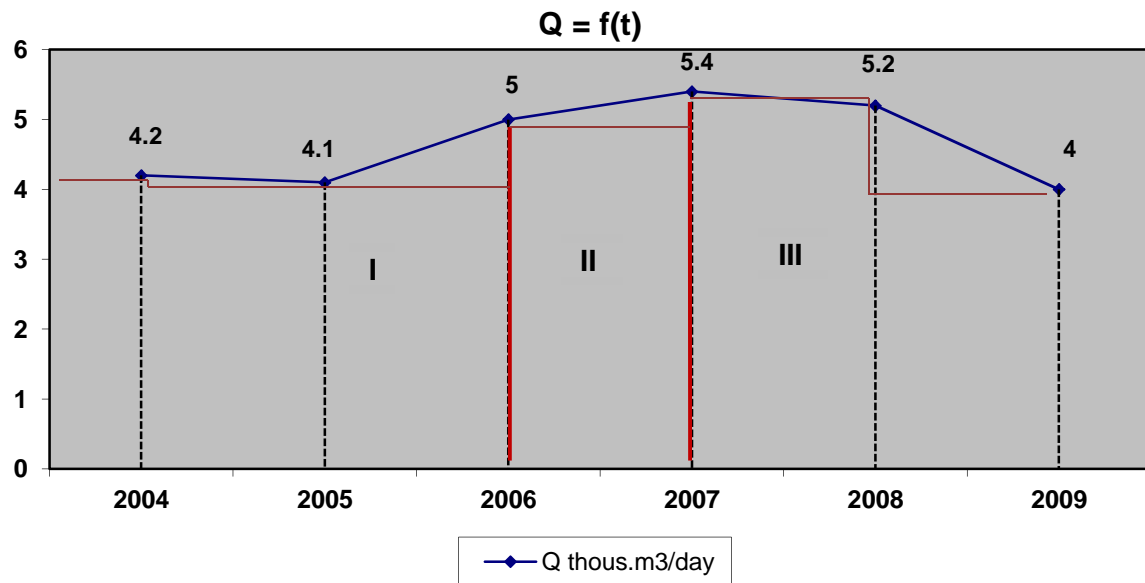


Figure 32. Used water

As a result of curve analysis, extrapolation limit of underground water level decrease is determined by formula of Dupu, Tima and Altovskii:

$$\text{allowed as } S_{\text{ext}} = (1,5 \div 2,0) S_{\text{max}}.$$

Herein:  $S_{\text{ext}}$ - drawdown by project application

$S_{\text{max}}$ - maximum value of underground water level decrease through the mining operation

As a result of graph analytical method, it is anticipated that it is possible to supply 7200 m3/day or 300 m3/hour of water if underground water level decreases by 6,8 meters (Figure 32). In other words, underground water reserve has potential to supply process and portable water need for bio-oxidation process. Aquifer of Boroo underground water is approximately 40 m thick and allowed margin of underground water decrease is defined as follows:

$$S_{\text{allow}} = (0,5 \div 0,7) \text{ and } S_{\text{allow}} = 0,5 * 40 \text{ m} = 20 \text{ m}.$$

If it is drawn 7200 m2/day water from water supply facilities, underground water level will decrease by 6,8-7 meters. Then water application reserve could be increased by remaining 13-meter decrease of underground water level.

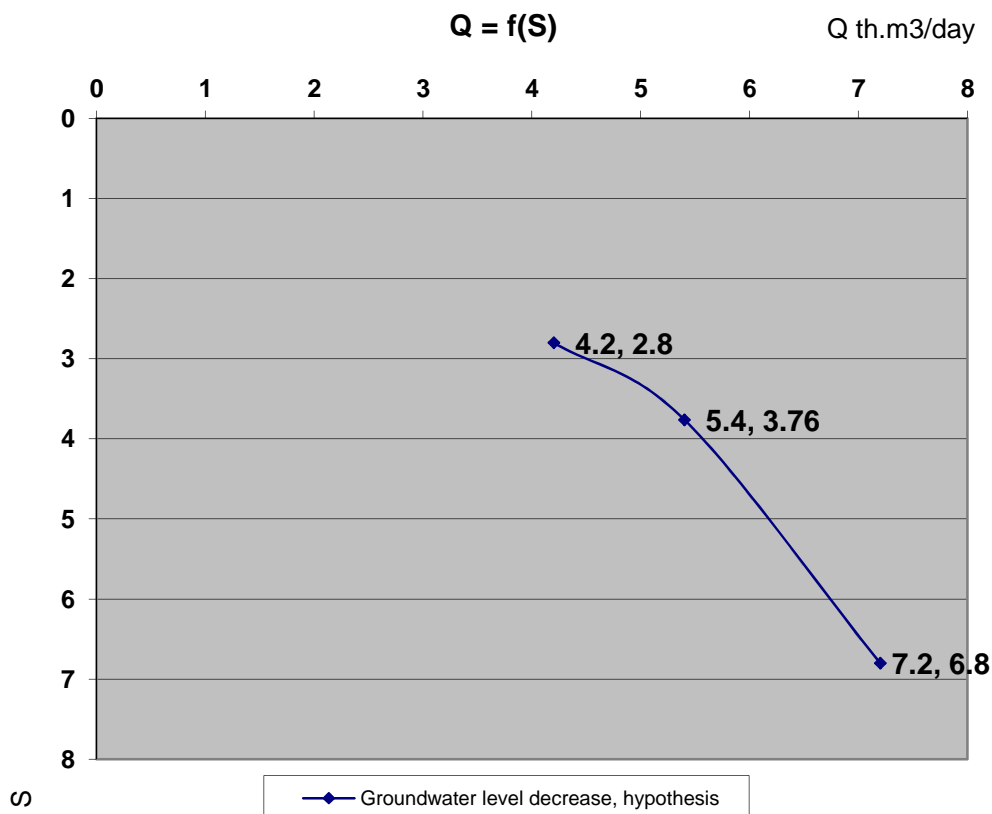


Figure 33. Underground water level decrease, hypothesis

During previous 5 years of water exploitation, there were no water quality change of underground water and it meets permissible level of Mongolian national standards on drinking water quality. Water supply facilities are filtration boreholes, so none of impacts on Boroo River formation and regime is indicated by underground water application. It only affects the underground water formation regime and reserve accumulated in alluvial sediments of Boroo river valley. However, underground water can recharge naturally, as it is three times less than the permissible decline level. It is proven that the underground water exploitation reserve is estimated as  $Q_{\text{application}} = 7500 \text{ m}^3/\text{day}$  by balance method during hydro geological study in 1990.

### 3.3. Cumulative impact

#### 3.3.1. Cumulative impact on land and soil

It is anticipated that there might occur long or short-term impact, which can have larger impact on environmental components, caused by integration of mining operation including Boroo expansion, construction, consequent operation and similar activities by other local projects. Accordingly, cumulative impact factors and its potential positive or impacts

caused by biological oxidation process of sulfide ore concentration and cyanide concentration are determined in this section.

**Table 10. Cumulative impacts on land and soil surface by project operation**

Impact factors	Description	Impact ratings	Score
Type of impact	Landscape change Soil erosion and disturbance etc.	high	3
		moderate	2
		low	1
		no impact	0
Degree of impact	Project area is impacted with previous mining operation and soil coverage already lost its natural patterns.	high	3
		moderate	2
		low	1
		no impact	0
Impact of previous activities	Impacted, eroded and disturbed	high	3
		moderate	2
		low	1
		no impact	0
Project implementation	Number of similar activities existing or proposed in the vicinity of project involving that resource	high	3
		moderate	2
		low	1
		no impact	0
Permanence	Temporary, permanent, alteration, recovery potential, habitat conversion	long term	2
		temporary	1
		no change	0
Location impact	Located in special protected area or national parks	located	3
		within 20 km distance	2
		within 75 km distance	1
		None present	0
Proximity to urban areas	Compatible with growth area, comprehensive plan, or approved Growth Management Plan	incompatible/planned	3
		incompatible/not planned	2
		compatible/not planned	1
		compatible/planned	0
Traditional use	Degree of compatibility with traditional use of area and resource in project vicinity (pastureland)	none	3
		low	2
		moderate	1
		high	0
Stability, persistence design	Design and construction methods appropriate for site and project; likelihood of unintended impacts to resource minimized.	no	1
		yes	0
Public health and safety addressed	Project provides some public service, such as fire protection, emergency access, travel safety	none/low	2
		moderate	1
		substantial	0
Project benefit	Project purpose identifies public needs	none/low	2
		moderate	1
		substantial	0
Total cumulative impact severity		Moderate	10

Above table shows that cumulative impacts on land and soil have moderate severity. Cumulative impact assessment covered entire Boroo mine site including extraction areas. Proposed project area of Boroo expansion is located in Boroo mine site and disturbed by mining operation. The appreciated benefits of Boroo expansion projects are continuity of

socio-economic impacts and cumulative impacts on local socio-economy. Even though impacts on land and soil will continue furthermore while extending process lifetime, this will be restricted by project area. In other words, soil erosion and disturbance will be accumulated more but within the project area.

### **3.3.1. Cumulative impacts on underground water**

It is anticipated that there might occur long or short-term impact, which may have larger impact on environmental components (vegetation cover and etc.), caused by integration of mining operation including Boroo expansion, construction, consequent operation and similar activities by other local projects. Accordingly, cumulative impact factors and it is positive or impacts caused by water facilities expansion are determined in this section. Cumulative impact on underground water, shortage and underground water table decrease might be caused from continued underground water exploitation. An assumption of cumulative impact on underground water exploitation is illustrated in below table.

**Table 11. Potential cumulative impacts on underground water by project operation**

<b>Impact factors</b>	<b>Description</b>	<b>Impact ratings</b>	<b>Score</b>
Type of impact	Underground water table drawdown, underground water regime, quality change, impact on surface water runoff (Although there is not much change to the water table, there is visible change in hydrodynamics)	high	3
		moderate	2
		low	1
		no impact	0
Degree of impact	Continued underground water exploitation effect on underground water table and regime	high	3
		moderate	2
		low	1
		no impact	0
Impact of previous activities	Water demand of Boroo mine site is provided by five underground water wells	high	3
		moderate	2
		low	1
		no impact	0
Project implementation	Almost 300 people are extracting gold illegally at Boroo river. Boroo river have polluted with mercury. Underground water has an indirect hydraulic relationship with the Boroo river, underground water feed flow is 0.2 l/km2	high	3
		moderate	2
		low	1
		no impact	0
Permanence	Temporary, permanent, alteration, recovery potential, habitat conversion	long term	2
		temporary	1
		no change	0
Location impact	Located in special protected area or national parks	located	3
		within 20 km distance	2
		within 75 km distance	1
		None present	0
Proximity to urban areas	Project area is located at 140 km from UB and 19 km from Baruunkharaa city of Bayangol soum	incompatible/planned	3
		incompatible/not planned	2
		compatible/not planned	1
		compatible/planned	0
Traditional use	Degree of compatibility with traditional use of area and resource in project vicinity (pastureland)	none	3
		low	2



		moderate	1
		high	0
Stability, persistence design	Design and construction methods appropriate for site and project; likelihood of unintended impacts to resource minimized	no	1
		yes	0
Public health and safety addressed	Project provides some public service, such as fire protection, emergency access, travel safety	none/low	2
		moderate	1
		substantial	0
Project benefit	Project purpose identifies public needs	none/low	2
		moderate	1
		substantial	0
<b>Total cumulative impact severity</b>		<b>Moderate</b>	<b>8</b>

As above table shows, affect severity of underground water is moderate. Cumulative impact assessment is restricted by boundary of proposed project area. Project operations i.e. constant exploitation of underground water may affect underground water table, regime and water quality. Water table measurement should be implemented constantly at the monitoring wells in order to control underground water level not to exceed above allowed application level. Underground water is fed by distribution and feeding areas that cover large territory, therefore, water could be restore. Overall plan to manage the interdependent water consumption and underground water exploitation should be developed in detail, consequently provide the possibilities not to exceed the water table requirements by allocating the underground water exploitation based on hydro geological parameters such as underground water level, aquifer massive. Despite the processing water will be supplied from wells located along Boroo river basin, impact on Boroo river runoff is relatively low. Because underground water has an indirect hydraulic connection with Boroo river water and underground water feed flow is 0,2 l/sec.km<sup>2</sup> that is very low. Approximately forty percent of the processing water will be recycled and reused for production cycle continually and underground water reserve will be utilized economically. Sustainable operation of Boroo mine contributes its proper benefits to the local economy development and has positive effect in long-term perspective.

### **3.4. Recommendation and mitigation measures**

The main objective of environmental assessment of Boroo expansion and Bio oxidation plant is to prevent from potential impact during construction and operation stages of the project; define impact mitigation and elimination measures; provide nature friendly consumption of raw materials; use, apply, demolish and dispose raw materials with lowest impact; and provide the natural condition without impacts on human, livestock and vegetation life. Therefore following mitigation measures to eliminate potential impacts of the project should be conducted. Recommendations for mitigation measures are determined separately for each environmental factors.

#### *Socio-economy:*

Measures to eliminate socio-economic impacts are implemented by BGC successfully and local residents have affirmative attitude for Boroo expansion and workplace enhancement.

#### *Water resource:*

Impacts on water resources are mitigated by effective designs, operations, and monitoring measures. Mitigation measures can include measures to greatly reduce additional inputs to water resources, measures to minimize the volume of water impacted, additional monitoring, and notification of government authorities regarding the impacts and measures taken to address them. As noted above, facility upgrades will generally improve the level of containment and control for reducing discharges of industrial water and for improving recovery and reuse of collected water. To conserve water, neutralized effluent can be mixed with the flotation tailings, with the overflow used as makeup in the mill, flotation, and BIOX plant operations. Spillage generated in the water recovery thickener (WRT) area will be pumped to the WRT feed well by the WRT spillage pump. Risks for accidental release of water suspensions containing high counts of bacteria from the BIOX process should be controlled by a spill prevention plan for the facility. Regular measures such as checking fluid levels, inspecting seals around the base of the tanks, and inspecting transfer piping and pumps should be taken. Focus should be on spill prevention to maintain risks in a low level. Because the activity of the bacteria is expected to drop precipitously when dissolved oxygen is depleted, carbon dioxide is limited, or the pH is neutralized. Therefore, mitigation methods for spills should include pH neutralization and reducing atmospheric exposure with a cover, measures that might be similar to treating acid spills. Soils affected by spills may also be excavated, neutralized with lime and placed in the lined tailings facility.

Interim mitigation measures to be taken to reduce impacts on surface water quality during the facility construction include the use of downstream sediment control measures during the construction phase. Provided that there is proper site management of erosion and sedimentation, which follows accepted construction practices, plus monitoring and maintenance of control measures, the project should not cause any significant direct or indirect impacts to surface water quality. Surface water quality impacts are caused by spills during the construction phase, are expected to be small-scale and of short duration.

*Land, soil erosion and disturbance:*

Soil at Boroo site is suitable for agricultural use. Mitigation measures to protect soil resources are connected with efforts to maintain flora and fauna, and water resources. In some cases, high quality soils are removed from site areas requiring development, and these soils may be moved to other suitable areas near the site to minimize any net impacts on soil resources. Evidence of soil pollution found during construction or during operations of the Boroo facilities will be addressed as part of Environmental Monitoring and Environmental Protection Plans. A closure and reclamation plan should include procedures, which will help restore the soil resources of the site. Mitigation measures to prevent the contamination of soil resources are related to mitigation measures for water resources. Wastewater that comes from washing of floors and equipment should be collected for reuse or disposal. A spill prevention plan should be followed to prevent or respond to potential spills that could impact soil resources.

*Flora and Fauna:*

Flora and fauna resources in areas of development for the Boroo operation will be managed to reduce any net impacts. Soil disturbance and transportation will be reduced, to the extent possible, to minimize impact on high quality flora and fauna resources. When this is not possible, measures will include restoring flora and fauna at nearby areas. Evidence of impacts on flora and fauna found during construction or during operations of the Boroo facilities will be addressed as part of Environmental Monitoring and Protection plans. A closure and reclamation plan should include procedures, which will help restore the flora and fauna of the site.

*Air quality:*

Mitigation of air pollution during facility construction can be accomplished by conducting operations that cause dust when the wind speeds are low and by using dust suppression methods. Dust and other pollutant levels should be periodically monitored and, if levels are in excess of set criteria, immediate controlling measures should be taken. Air quality monitoring during operation of the BIOX® process should be focused in terms of worker safety and air quality measurements at some nominal distance, such as 100 meters, away from the processing plant. Mists and other air emissions from the BIOX® process are expected to be minor, especially with distance away from the reactors. However, regular monitoring should be conducted to identify and mitigate impacts on air quality. Workers working directly over the BIOX® reactors may wish to wear face masks to reduce exposure to mists, which may be acidic and laden with heavy metals. Plans for appropriate health and safety monitoring of employees should be developed with consideration of the potential hazards of BIOX® process mists, if found or observed at other BIOX® process operations. Evidence of impacts on air quality found during construction or during operations of the Boroo facilities will be addressed as part of Environmental Monitoring and Protection plans. A closure and reclamation plan should include procedures, such as dust control, which will help mitigate air quality impacts during or after the operations.

*Chemical hazards:*

Chemical hazards are effectively mitigated by elements of design and protocols for operations that minimize wastes, effectively treat and neutralize chemical hazards in the process as they are produced, and from effective storage and monitoring measures. For example, metals and acid normally produced during biological oxidation of the sulfide ores are precipitated and neutralized with limestone prior to any discharge. Discharge is reduced by plant reuse of the thickener overflow water. The autotrophic, mesophilic, acidophilic bacteria used in the BIOX® process are common in nature and thrive in iron rich, wet, warm, acidic, and oxidized environments. Autotrophic bacteria use inorganic carbon for cell growth, mesophilic bacteria have a normal temperature range for growth of 8 to 45 °C (Rittman and McCarty, 2001), and acidophilic bacteria are active under acidic conditions. *Acidithiobacillus ferrooxidans* are the most important of the bacteria to the BIOX® process, but *Thiobacillus thiooxidans* and *Leptosperillum ferrooxidans* are also used. In aerobic conditions, these bacteria oxidize ferric iron to ferrous iron and sulfide to sulfuric acid. The bacteria are found in nature and developed environments, abundant where sulfide rocks are exposed near stream banks, on corroding metals and concrete in

municipal wastewater treatment plants, and from leaching tailings and waste rock piles. They are strict aerobes, and are inactive in dry and cold environments.

The biological oxidation strategy is selected based on the mineralogy of the ore. The bacteria are grown in the reactor from inoculums, a nutrient rich cocktail of the bacteria used to start the reactor with a suitably high number of active bacteria. A period of several days to weeks may be needed to establish the conditions needed for effective oxidation. While the BIOX® process maintains a very high retention of bacteria in each reactor, some bacteria also flow out of the reactor with the processed solids. However, follow-up steps of washing and cyanidation kill the bacteria. Beyond containment strategies to avoid spills and to provide secondary containment, spills can also be effectively managed with neutralization and other simple cleanup measures used to manage spills of slurries. In general, the bacteria are not pathogenic, or otherwise harmful in nature, other than playing a significant role in acid rock drainage (ARD) and corrosion. More cautious measures to isolate the bacteria are not necessary, because they are already ubiquitous in nature. However, acids and metals, and other chemical products of the sulfide oxidation reactions that are either produced or promoted by the bacteria, may be harmful to human health and the environment. As such, controls to prevent and contain spills should be in place to limit exposures or accidental discharges of the untreated byproducts. Overall, focus is given to proper engineering and management processes, such as the selection of appropriate materials for tank construction and regular inspection practices.

Arsenic, iron, and other metals are liberated by acidic oxidation of the ore in the BIOX process. However, as the effluent water pH is neutralized by crushed limestone, iron and other metals precipitate out of solution. Arsenic, in particular, can be a concern if there is not ample iron to scavenge it from the solution. In the case of sulfide ores from Gatsurt, however, iron is abundant and arsenic removal and other oxyanions will be effectively scavenged by iron precipitation. Most other metals are also effectively removed by neutralization and precipitation. Carryover of fine solids from the washing and thickening process may lead to minor loss of bacteria associated with fine solids to effluent neutralization, but the bacteria are not viable at the more neutral pH and without significant sulfide concentrations. In addition, the washing process leads to some precipitation, and coagulants and flocculents can be used to reduce the carryover of fine solids to effluent neutralization. Precipitation sludge should be dewatered and managed according to a solid and hazardous waste management plan for the site. Regular

monitoring and process control on the neutralization and precipitation process is typical. Effluent water can be reused for the flotation circuit or other processes, to reduce the amount of fresh makeup water needed.

Specific recommendations regarding the mitigation of chemical hazards include:

- All workers is required to be instructed how to safely handle any toxic chemical and be aware of its hazardous properties.
- Containers of chemicals should be tightly closed, secured, and clearly labeled.
- Floors should be sloped to drain to sumps with pumps, which will redirect any spilled materials back to the process.
- The process area should have spill control and neutralization equipment capable of detoxifying reagent spills.
- Personal protection equipment, including footwear, facemasks, and other appropriate equipment, should be provided to all workers that handle hazardous chemicals. In addition, safety shower and eyewash stations should be installed in the worker operations areas for quick removal of reagents from exposed skin via water flushing.



## **Section 4. Risk assessment and Management**

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According to Mongolian law on “toxic and hazardous chemical substances” (effective on 2006), risk assessment of chemical toxic and hazardous substances should be included in DEIA reports of entities that use chemicals for the production. Our risk assessment prepared under this law and legislation. To develop risk assessment of chemical/explosive in this report, applied the procedure, entitled “Guideline for exporting, importing, shipment, producing and selling of dangerous and hazardous chemical substances” confirmed under mutual decree No92/90 by the ministers of MNET and MFAT in 2008 and “Guideline for storage, protection, transportation and disposal of hazardous chemical” confirmed under decree No84 by MNET”. It is prohibited to import and use any of chemicals without material safety datasheet in these guidelines. According to the law on special business permission, only state central administrative body in charge of environmental issues authorized to permit or issue special license for importing, selling, using, and disposal of ozone depleting substances. For BIOX® process sodium cyanide will be used that classified as extremely hazardous chemical, entitled in “List of hazardous and dangerous chemicals restricted to use in Mongolia” confirmed under decree 95 of Government of Mongolia in 2007 and other chemicals including sodium acid, sulfuric acid, and caustic soda classified as special hazardous chemical, entitled “The classification of dangerous and harmful chemicals” confirmed under mutual decree 04/04 by ministers of MNET and MOH in 2009. Sodium acid, sulfuric acid, sodium and calcium hydroxide and other chemicals, which are classified as caustic chemicals in the fourth appendix of the latter decree, are allowed to use for the production. Sodium acid is also classified as psychotropic in the second appendix of the same decree, entitled “Classification of the chemicals based their impacts on human or animal bodies”. This section has the descriptions including physical and chemical properties, hazardous and dangerous classification, standard permissible level in workplace, potential damage, toxicant, preventative measures, mitigation, transportation, storage, neutralization, application, safety accessories, first aid, and environmental impacts of the special hazardous, caustic, and explosive chemicals.

Microorganism is the most important content and resource of the troposphere. Ecosystem stability is greatly dependent on microorganism in the troposphere. Therefore, microorganism is the important biological reserve. In 2002 the Biodiversity convention has issued the Cartagen Biosafy Protocol that internationally regulate the interrelation between countries to prevent from potential impacts on human health, ecosystem,

biological diversity and genetic fund caused by life modified organism and products generated from life modified organism. Mongolia has joined Cartagena Biosafety Protocol and approved “The law of life modified organism”. The national committee of the biosafety is established in 2008 by approval of 127<sup>th</sup> decree by minister of MNET. This committee is responsible to manage the biosafety in Mongolia. It is legally confirmed that the permission for people and organization to export, import and transit life modified organism should be authorized by state centralized administrative body under the conclusion of the Committee. The cultures of *Acidithiobacillus Ferrooxidans*, *Acidithiobacillus Thiooxidans*, *Leptospirillum Ferrooxidans* for biological oxidation will be imported, then the bio preparation shipment will be regulated under the appendix of the decree 70 of minister of Road, transportation and tourism in 2006, entitled “Transportation guideline of bio dangerous package and bio preparation”.

#### **4.1. Risk assessment of toxic and hazardous reagents**

##### **4.1.1. Impact and risk assessment of reagents**

The risk assessment of the chemicals used in BIOX® plant is classified by its properties, risk level, and selected some representing chemicals in order to determine the physical and chemical properties, impacts, and risks on human health and existing environment, define mitigation measures to be taken to avoid hazardous chemicals transfer via respiratory, skin, digestive, and eyes. It requires compliance of preventative measures, safety guidelines while importing, storing, applying, and disposing hazardous and dangerous chemicals. BIOX® plant will use different chemicals at the process stages of sulfide and transition ore flotation, biological oxidation of flotation concentration, cyanidation and gold recovery and both solid and liquid chemicals will be used annually. Chemicals for processing will be stored in the container at designated area. Besides defining chemical properties, impacts on human health and environment, risk assessment also requires to evaluate the packaging, shipment, transshipment, storage, and utilization. In addition, potential risk danger and level should be calculated for constructions and employees working at 100, 200 and 500 m distance. According to the evaluation result, it is defined as 3C level (having lower probability with severe consequence). Chemicals may cause cancer and impact on productivity. An evidence of sharp intoxication is represented with lethal dose (LD50). LD50 is average mg chemical amount per kg body weight that mortifies almost fifty percent of the experimental living organism. Danger and risk level of the chemicals determined with lethal dose. There are four different level classified based on lethal doses of chemicals while transferring via digestive system. Herein:

- ▶ Most dangerous, lower than LD50-15 mg/kg
- ▶ Dangerous LD50-15-150 mg/kg
- ▶ Moderate danger LD-151-5000 mg/kg
- ▶ Lower danger, more than LD50-5001 mg/kg

For the purpose to define the classification, following specifications are considered. Please see below table.

**Table 124. Effect level of chemicals for organism**

	Parameters	Degree			
		1	2	3	4
1	Permissible level inside work place, mg/m <sup>3</sup>	<0.1	0.1-1.0	1.1-10.0	>100.0
2	Lethal dose transferred vi stomach, mg/kg	<0.5	1.5-150	151-5000	>5000
3	Lethal dose transferred via skin, mg/g	<100	101-500	501-2500	>2500
4	Lethal dose transferred via respiratory, mg/m <sup>3</sup>	<500	501-5000	5001-50000	>50000
5	Coefficient of intoxication via atmosphere	>300	301-30	29-3	<3
6	Strongly effecting zone	<6.0	6.0-18.0	18.1-54.0	>54.0
7	Gradually effecting zone	>10.0	10.0-5.0	4.9-2.5	<2.5

A potential accident during transportation, transshipment, storage, and application is lower because chemicals have approved certification, safe packaging. Packaging, dimension, and label of chemicals are produced under international standards and technological requirements of importers and consumers. Breach of technological procedure or irresponsible handling by workers might lead to accident, which may have largest impact. Preventative measures to eliminate and mitigate should be prepared. It is suitable to transport or load when traffic is less crowded. There is a potential spill and loss hazard of chemicals caused by accidents during load/unload of trains and vehicles breaking the seal or packaging of chemicals. Dry chemical is easy to collect by shovel and restrict its spreading. However, immediate actions should be taken to prevent evaporation and spreading of liquid chemicals. Conditions should be provided to take immediate emergency response in case of spill such as detoxification and neutralization during transportation, storage and use of chemicals.

*Risk assessment of reagent storage:*

Risk and accident assessment of Boroo gold reagent storage is conducted in order to determine risk types and degree and how to store reagents and its usage. Following descriptions are used in this assessment.

**Danger:** dangerous incident, external factors (natural disaster, technical accident, disease), their degree

**Target:** Weakness and vulnerability of living or nonliving objects under external forces

**Risk:** Damages by certain accident at proper place, in the clear period (human life, health, property, livelihood, and operational delay)

**Disaster:** Many people affected, destroyed property and environment, social abnormality and serious condition exceeded internal protection measures

In this assessment, risk degree of reagent storage is evaluated during biological oxidation process.

*Risk assessment:*

Risk degree of reagent storage is evaluated with 5 different specifications by compared with sodium cyanide (6.1A) (Table 45).

1. *Life:* low damage, severe condition, rate 3
2. *Environment:* less polluted, impacts restricted around an object, rate 2
3. *Property:* limited, rate 2
4. *Probability:* low probability, once in a 100-1000 years, rate 2
5. *Risk degree:* low probability, limited consequence, rate 2

**Table 13. Risk assessment**

**Target:** Reagent storage  
**Dangerous reagent:** Sodium cyanide (6.1A)  
**Risk type:** intoxication effect

Operation	Target objects	Consequence	Risk				Probability	Danger degree	Description
			Life, health	Environment	Property	Flourishing speed			
Load/unload	<b>People:</b> Driver, Bookkeeper, Emergency officers	Toxic	3			2	2	2	damage low, severe condition
	<b>Environment:</b> Air, Soil	Contamination		2	2		2	2	low polluted, impacts around an object
	<b>Property:</b> Equipment, Machinery	Contamination			2	2	2	2	limited

Reagent storage of bio-oxidation process plant at Boroo mine site belong to 2B grade for general risk assessment of reagent storage. This grade means consequence limited; probability of accident occurrence is low. Hazard calculation for employees and local residents, caused by sodium cyanide spillage at reagent storage area, is measured as following.

**Table 14. Basic data**

Possible amount of spilled sodium cyanide	20 tone (1 container) or 1 tone
Employee at reagent storage area	Approximately 3-5 people
Truck	1
Crane	1

The loading and shipment activities are conducted at storage area. When sodium cyanide spilled, the damage estimation on employees to be poisoned, machineries, roads and concrete areas to be contaminated is illustrated below:

- Sodium cyanide is factory-built strong wrapped with low spillage condition,
- Sodium cyanide is solid, compressed and not evaporable when it spilled, not spreadable to distance, steady, storage with concrete floor and barrier keep spill spreading in minimum
- No impact on employees health, as there is no operations held within 50m
- No impact on local residents health, as there is no workplace, living house and households within 100 m
- In case of accident, 3-5 employees, one truck and one crane is exposed to contamination
- Employees are provided with self-protection equipment, decreasing potential harm rate caused by accident

As indicated in risk assessment, potential risk of accident cases at storage area are low, location of the storage is sufficient to keep harm of spillage in minimum. The safety procedures are strictly followed during loading, hauling, and storing of chemical substance.

**Sodium cyanide-NaCN:**

Code: (CAS) 143-33-9

Nomenclature: Sodium cyanide/ / /

**Table 15. Physical properties of sodium cyanide**

<b>Appearance:</b> White, crystal small ball shaped, apricot weak smell			
<b>Boiling point (BP):</b> 1496 C° Soluble in water	<b>Molecule weight (MW):</b> 49.0	<b>Low explosion limit (LEL):</b> unidentified	<b>Fire Rating (NFPA Fire Rating):</b> long combustion, 0
<b>Melting point (MLT):</b> 563,9 °	<b>Vapor pressure (VP):</b> 0 mm g (approx)	<b>Upper explosion limit (UEL):</b> unidentified	<b>Health Rating (NFPA):</b> 3
<b>Flammable point FP:</b> unidentified	<b>Vapor density (VD):</b> unidentified	<b>Special instance (NFPA Sp. Inst.):</b> unidentified	<b>Reactivity rating (NFPA):</b> 0
<b>Density (Sp. GR):</b> 1.60 gr/cm3	<b>Other properties:</b> Generates toxic gas when burn by flame force (cyan, nitrous oxide); in wet condition senile oxide dominate carbonic acid; prohibited to put together with ammonia, carbon monoxide, sodium carbonate because of readily reacting; gradually catch fire when it get hot		

**Table 16. Risk classification of sodium cyanide**



<b>Caustic :</b> 8.1 Caustic-metal corrosive	<b>Flammable:</b> 4.3 Flammable in wet	<b>Harm :</b> 6.1 (exceptional poisonous), 6.3 (skin irritator), 6.4 (eye irritator), 6.5 (allergenic), 6.9 (harmful on certain organ, system)
<b>Environment :</b> Harmful <b>9.1</b> , <b>9.2</b> , <b>9.3</b> , <b>9.4</b> .	<b>Concentration :</b> occupational permissible level 0.3mg/m <sup>3</sup> ; Drinking water permissible level 0.01mg/L; death dose approximately LD50 1.8 mg/kg; death dosage for 5 minutes: 110.0 mg	

**Protection equipment:**

*Respiration:* Use IP-4 separator and -16 filter mask, DZU, DPG-3 hat

*Skin:* Use KIX-5 separator and L-1, OP-1 protection uniform, elastic gloves and boots

*Eye:* Use glass, faceguard

*Storage:* store in a cool place in paper bag or wooden box against light and humid

- Should be sealed tightly
- Prohibited to store with other reagents

*Application:* Used to leach gold by ore cyanidation

*Measures during accident:*

- Buffer dangerous zone within at least 50 m radius area.
- Allow to enter only person with protective devices
- Provide fire safety
- Prohibit to reach spilled reagent
- Smoking prohibited or remove fire source
- Extinguish fire with water, foam and powder from distance during emergency
- Serve ambulance and first aid to victims

*Transportation:* Transport avoiding heat

*Neutralization:*

- Neutralize by spraying ammonia solution with 20-25 % concentration and ferric chloride 20% concentration or lime solution.
- Neutralize with mix of 2 volume of 10 % ferric sulfate and 1 volume of 10 % lime-milk (20 % caustic soda) solution.
- After neutralization wash out with solution of surface active substances

*Concentration detection equipment:*

- Detect 0,005-0,08 mg/L limit by IT-36 (green ringed) tube
- Detect 0,01 mg/L limit by dedicated paper or identification reaction

*Environment:* strongly pollutes soil, water, air. 9.1 (harm to aquatic organism), 9.2(soil organism), 9.3(vertebrate), 9.4(invertebrata)



**Table 17. Mitigation measures to eliminate the risk by sodium cyanide impact**

<b>Risk type</b>	<b>Preventative measures against potential risk</b>	<b>Mitigation and elimination measures, first aid</b>
Coughing, sneezing, hoarsening, head aching, respiratory organ reaction will occur during inspiratory poisoning	<ul style="list-style-type: none"> <li>-Prevent from evaporation during storage and handling of sodium cyanide</li> <li>-Install enough air conditioners and ventilators inside workplace</li> <li>-Provide employees with personal protective equipment</li> <li>-Protect from evaporation</li> <li>-Constant control, monitoring of workplace atmosphere</li> <li>-Employees that work with sodium cyanide should be involved in health examination and inspection per quarter</li> <li>-Employees should attend the training for first aid assistance</li> </ul>	<ul style="list-style-type: none"> <li>-Urgently take outside or breath oxygen</li> <li>-Do artificial respiration when unconscious</li> <li>-breath y ammonia</li> <li>-Call emergency and take to hospital</li> </ul>
Poisoning via skin, will result skin redness and irritation, burn and also same characteristics as respiratory effect	<ul style="list-style-type: none"> <li>-Use gloves, hat and apron manufactured for special use</li> <li>-Tissue, soap and etc. must be prepared</li> <li>-Store work clothes and outfit separately</li> <li>-Get familiarized with full course of first aid procedure</li> </ul>	<ul style="list-style-type: none"> <li>-Take off the outfit polluted with sodium cyanide</li> <li>-Wash the outfit or body with enough water</li> <li>-Moisten and apply a compress with sodium thiosulfate /Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>/</li> <li>-Affected skin shall kept warm</li> <li>-Receive urgent medical treatment</li> </ul>
Eye poisoning results redness, blazing up, eye disorder, blurring, alternative with optic and blindness	<ul style="list-style-type: none"> <li>-Apply protection glasses when handle</li> <li>-Apply face muzzle</li> </ul>	<ul style="list-style-type: none"> <li>-Wash immediately with enough water.</li> <li>-call doctor immediately and receive urgent medical treatment</li> </ul>
Poisoning via digestive organs result feel nausea, dyspepsia, burning, smudgy, etc.	<ul style="list-style-type: none"> <li>-Restricted to store food in substance storage</li> <li>-Restricted to eat food at work place</li> <li>-Restricted to smoke at work place</li> <li>-Clean spilled sodium cyanide with enough water</li> <li>-Use gloves and other protection accessories when cleaning</li> </ul>	<ul style="list-style-type: none"> <li>-when sodium cyanide entered to mouth, to rinse and wash loads of water</li> <li>-force to drink load of pure water, soapy water and force to be vomit</li> <li>- drink thiosulfate sodium /Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>/ 1% solution is and vomit</li> <li>-after that, wash and rinse mouth thoroughly</li> <li>-call doctor immediately</li> <li>-urgently take to hospital</li> </ul>
5. When alone, it is less flammable, but easily reacts with other substance becoming explosive and flammable	<ul style="list-style-type: none"> <li>-restricted to keep with flammable substances</li> <li>-when preparing sodium cyanide solution, water should not be added to acid abut acid into water in small amounts and should be thoroughly mixed</li> </ul>	<ul style="list-style-type: none"> <li>-to have equipments ready for preventing danger of fire</li> </ul>
“Extremely hazardous” should be label placed		

Caustic soda i.e. sodium hydrate oxide-NaOH

: (CAS) 1310-73-2

Nomenclature: Sodium hydroxide/

/

/caustic soda

**Table 18. Physical properties of caustic soda**

<b>External condition:</b> Whitish, odorless, solid (lamella, round, granular shaped)			
<b>Boiling point (BP):</b> 1390C (25 C - 100 ml water 111,1 gr dissolve)	<b>Molecule weight (MW):</b> 40.0	<b>Low explosion limit (LEL):</b> unidentified	<b>Fire rating (NFPA Fire Rating):</b> non-inflammable, 0
<b>Melting temperature (MLT):</b> 318 °	<b>Vapor pressure (VP):</b> 0 mm g(approximately)	<b>Upper explosion limit (UEL):</b> unidentified	<b>Health rating (NFPA Health Rating):</b> 3
<b>Flammable point FP:</b> unidentified	<b>Vapor density (VD):</b> unidentified	<b>Special instance (NFPA Sp. Inst.):</b> unidentified	<b>Reactivity rating (NFPA Reactivity Rating):</b> 0
<b>Density (Sp. GR):</b> 2,1 (equal to 1 in water)	<b>Other characterization:</b> immediate reaction to acids; discharge loads of heat when reacting with water; generate bases react with metals; strong hydroxide and oxidizer		

**Table 191. Hazardous degree of caustic soda**

<b>Caustic :</b> 8.1A(metal corrosive), 8.2B(skin damager), 8.3A(eye damager)	<b>Harm :</b> 6.1D
<b>Environment :</b> poisonous 9.1D, 9.3C	<b>Concentration:</b> occupational permissible level 0.2 mg/m <sup>3</sup>

**Protection equipments:**

*Respiration:* Use IP-4 separator and -16 filter mask, DZU, DPG-3 hat

*Skin:* Use KIX-5 separator and L-1 protection uniform, elastic gloves and boots

*Eye:* Use glass, faceguard

*Storage:* store in glass or iron box in a cool place avoiding light and humid

*Application:* Used to provide pH stability, against cyanide vaporization

*Measures during accident:*

- Buffer dangerous zone within at least 50 m radius area.
- Allow to enter only person with protection equipments
- Provide fire safety
- Prohibit to reach spilled reagent
- Serve ambulance and first aid to victims

*Transportation:*

- Haul out of missing water inside and spillage
- Haul with crane and trolley


*Neutralization:* Spreading sodium and thiosulfate 10-20% solution as a raining.

*Environmental impact:* pollute soil, water, air. 9.1D (harm to aquatic organism), 9.3C (vertebrate), negative influences like reducing oxygen concentration in air

**Table 52. Mitigation measures to eliminate the risk by caustic soda impact**

<b>Risk type</b>	<b>Preventative measures against potential risk</b>	<b>Mitigation and elimination measures, first aid</b>
1. Coughing, sneezing,	-full installation of conditioner, ventilator	-poisoned with sodium hydroxide

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hoarsening, headaching, respiratory organ reaction, reducing smell sensibility will occur during inspiratory poisoning	-provide employees with mask, muzzle, other protection accessories - constant control, monitoring of workplace air - Employees deal with sodium cyanide should be involved health examination and inspection per quarter -employees should be participated in first aid training	person urgently take a fresh air or breath with long time -to have drink milk and lemon acid 2-3% solution, vitellus -call ambulance urgently -urgently bring to hospital
2. skin irritation when poisoning via skin, skin redness, ulcerate, strong burning risk will occur	-use designed work clothes such as gloves, hat, apron -tissue, soap etc must be prepared -store work clothes and outfit separately -Possess fully first aid guideline	-take off the contaminated outfit -wash ulcerated body with enough water -wash acetic or lemon acid 2-3% solution -apply Vaseline jelly -affected skin shall kept warm -to receive urgent medical treatment
3. when poisoning to eye, occur redness, blazing up, eye disorder, alternative with optic and blindness	-when dealing, wear protection glass	-wash immediately with load water and weak lemon acid -call doctor immediately -to receive urgent medical treatment
4. when poisoning through digestion organ, feeling sensation, digestion organ burning, tormina and diarrhea etc	-restricted to store food in substance storage -restricted to eat food at work place -restricted to smoke at work place -keep away from strong acid -keep in cool place -clean spilled sodium cyanide with loads of water	-mouth is rinsed and washed with water -loads of water to drink -doctor called -urgently bring to hospital
5. pollute soil, water, air. negative influences like reducing oxygen concentration in air	“hydroxide” label is placed  On the label R:35 and S:2, 26, 27, 37/39 guidemarks must be written	-keep away from halogen compounds, hydrocarbonate free room. -neutralize by sprinkling with sodium 10-20% and thiosulfate solution

Sulfuric acid- $H_2SO_4$

Code: (CAS) 7664-93-9

Nomenclature: Sulfuric acid/

/

**Table 203. Physical properties of sulfuric acid**

<b>External condition:</b> Colorless, black brown, thick oilish, odorless, liquid. (Pure substance, become solid under 11°C. Mostly use as a liquid)			
<b>Boiling point (BP):</b> 290°C	<b>Boiling point (BP):</b> 290°C	<b>Boiling point (BP):</b> 290°C	<b>Fire rating (NFPA Fire Rating):</b> imflammable, 0
<b>Melting/freezing temperature (MLT):</b> FRZ: 11°C	<b>Vapor pressure (VP):</b> 0.001 mm Hg	<b>Upper explosion limit (UEL):</b> unidentified	<b>Health rating (NFPA Health Rating):</b> 3
<b>Flammable point FP:</b> unidentified	<b>Vapor density (VD):</b> unidentified	<b>Special instancy (NFPA Sp. Inst.):</b> waterless	<b>Reactivity rating (NFPA Reactivity Rating):</b> 2
<b>Density (Sp.)</b>	<b>Other characterization:</b> 60% solution is extra harmful oxidizer, oxidize and release		

<b>GR):</b> 1.84 (96-98% acid)	reaction with various absorbent substances; generate strong burning, 100% sulfuric acid is called monohydrate; well humidify when it has concentration; generates smoke as “smoky acid” or “oleum” when dissolving sulfuric anhydride into sulfuric acid.
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**Table 214. Hazardous degree of sulfuric acid**

<b>Caustic :</b> 8.1A(metal corrosive), 8.2B(skin damager), 8.3A(eye damager)	<b>Harm:</b> 6.1D(Extra harm), 6.7A(Cancer initiator), 6.9A(certain organ, system harmful)
<b>Environment :</b> 9.1D(aquatic organisms)	<b>Concentration:</b> occupational permissible level: 1.0 mg/cm <sup>3</sup>

**Protection equipments:**

*Respiration:* Use IP-4 separator and -16 filter mask, DZU, DPG-3 hat

*Skin:* Use KIX-5 separator and L-1 protection uniform, elastic gloves and boots

*Eye:* Use glass, faceguard

*Storage:* prohibited to store with flammable substances store in glass or iron box in a cool place avoiding light and humid

*Application:* Used to provide pH stability, against cyanide evaporation

*Storage:* keep away from flammable substances. Label as “poisonous”, “caustic”, “oxidizing” signs.

*Usage:* use for separating or purifying gold absorbed coal from organic and non-organic elements, compounds and for bio-oxidizing operation.

*Provision during accident:*

- Set danger zone at least at 50 m
- Only personnel with personal protective equipment shall work in danger zone.
- Spilled sulfuric acid absorbed by sand or foam
- Serve ambulance and first aid to victims

*Transportation:*

- Transport avoiding entrance and spill of water
- Haul with crane and trolley


*Neutralization method:* Neutralize with technical sodium solution when spilled in large quantity, then wash with large amount of

*Environmental impact:* pollute soil, water, air. 9.1D (harm to aquatic organism)

**Table 55. Mitigation measures to eliminate the risk by sulfuric acid impact**

<b>Risk type</b>	<b>Preventative measures against potential risk</b>	<b>First aid during mitigation and elimination measures</b>
1. Coughing, sneezing, hoarsening, sore throat, head	-prevent from evaporation when dealing with sulfuric acid, its storage	-poisoned with sulfuric acid person should be urgently taken to fresh air and

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aching, wheezing, stifle will occur during inspiratory poisoning	-full install conditioner, ventilator at workplace -provide employees with mask, muzzle, other protection accessories - permanent control, monitoring on workplace air -employees working with sulfuric acid should be included in medical checkup once in a quarter -employees should attend first aid training	breath well -do artificial respiration when fainted - ammonia spirit smelt -to have drink warm milk with sodium and warm spring water -to have breath with spirit steam -call doctor urgently -urgently take medical treatment
2. skin irritation when poisoning via skin, is skin itches, redness, ulcerate, strong burning risks will occur	-use designed work clothes such as gloves, hat, apron -tissue, soap etc. must be prepared -store work clothes and outfit separately -Familiarize with first aid guideline	-take off the outfit which polluted with sulfuric acid -wash spillage touched clothes or body with enough water -wash with ammonia solution and rinse with more water again thoroughly -affected skin shall kept warm, apply cream -to receive urgent medical treatment urgently
3. when poisoning to eye, occur redness, blazing up, eye disorder, alternative to optic and get blindness	-wear protection glass when dealing with sulfuric acid -use face protection	If sulfuric acid touched to eye, apply loads of water thoroughly -call doctor immediately -urgently take medical treatment
4. When poisoning through digestion organ, feeling nausea, sensitive, digestion organ burning, etc.	-restricted to store food in substance storage -restricted to eat food in work place -restricted to smoke in work place -keep away from other agents and keep in cool place -clean with loads of water after neutralization	-mouth is rinsed and washed with water thoroughly -mouth is rinsed and washed with sodium water - drink a lot of water and force to vomit -call doctor immediately -urgently bring to hospital
5. sulfuric acid is flammable and explosive 6. Sulfuric acid has a danger of explosion when pouring water on it. 7. pollutes environment	Never pour water on acid!!! Gradually pour acid on water and stir well. Also need to choose thermo stable box for sulfuric acid solution preparation	Must not keep with flammable substances!!! R:35, S: 26-30 signs attached. “Poisonous”, “caustic”, “oxidizing” signs attached. 

**Reagents:**

Chemical and physical properties of the reagents like flotation promoter, flotation frother, flocculent, and defoamer are evaluated in the following table.

**Table 56. Risk assessment of the reagents**

	<b>Reagent name, chemical formula, CAS number</b>	<b>Physical and chemical character, usage</b>	<b>Hazardous and dangerous grade</b>
1.	potassium amylxanthate $C_6H_{12}OS_2K$ CAS: 2720-73-2	White pellet with yellowish ray. Active completion more than 90%, free alkali 0,2%, water, non-volatile 4,0%, dissolve into alcohol. Weight 0,94 g/cm <sup>3</sup>	Self-heated -4,2 . hazardous-6,1 , skin harm-6,3 , eye-6,4 . Easy dissolve with acidic impact or heat. Discharge fatal hydro sulfuric acid, carbonic disulfide. Wide use of sulfide ore for flotation.

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2.	Sodium Isobutyl Xanthate, (CH <sub>3</sub> ) <sub>2</sub> CHCH <sub>2</sub> -O-(C=S)SNa CAS: 25306-75-6	Yellowish powder. Active completion more than 85%, free alkali 0,5%, water, non-volatile 10%, dissolves in water. Melts at 150-250 °.	skin harm-6,3 , eye-6,4 . Easy dissolve with heating. Discharge fatal sulfuric gas. Used for sulfur ore and gold flotation.
3.	Propylene Glycol Ethers (Dowfrost-250), this product consist of 3 reagents. propylene glycol -CAS: 57-55-6: distilled water-CAS: 7732-18-55: potassic hydro phosphate-CAS:1-4	Colorless, weight: 1,05 g/cm <sup>3</sup> , flame bursting in air: 2,6-12,5% (100-130 °, propylene glycol), vapor pressure:0,7mm Hg 20 °, vapor density: 2,6 g/cm <sup>2</sup> , boil at 162 °, freeze at -51 °. pH9-11 at 5% water solution.	Harmless to aquatic organisms. (LD <sub>50</sub> /EC <sub>50</sub> >100 mg/l), potential shock to respiratory and optical organ.
4.	2-Mercaptobenzothiazole solution, sodium salt – Senko(NaMBT 50), C <sub>7</sub> H <sub>4</sub> NS <sub>2</sub> Na6 CAS: 2492-26-4	Yellowish liquid, pH =10, weight 1,27 g/cm <sup>3</sup> .	Metal rust-8,1 . Skin irritator - 8,2 . Eye irritator -8,3 . Sulfide ore used for floatation as a lathering.
5.	Flocculent cationic-High Molecular Weight Cationic Polyacrylamide (Powder), Accepta 4211-4224	White pellet (powder), solution (5g/l) pH 2,5-4,5 stable at normal state. Discharge heat during reaction with oxidizer.	Gulp : LD <sub>50</sub> >5000 mg/kg, no reaction to skin and eye. NO <sub>x</sub> , CO, CO <sub>2</sub> will be formed by its dissolution. Hydrolysis product is harmless to aquatic organism. Use for filtering, flotation thickening, flotation at mine site.
6.	Antiscalant 97 or 98, this product consist of potassic acrylate and phosphate.	Soft odor liquid. Acidic. complete dissolve in water. Weight: 1.16-1.27 g/cm <sup>3</sup> . Boil at 212 °F. inflammable. stable at normal state.	Burning harm to skin (8.2B), eye (8.3A). potential formation of CO <sub>x</sub> , NO <sub>x</sub> , NH <sub>3</sub> , P <sub>2</sub> O <sub>5</sub> by its dissolution. Shall store strong alkali reagent separate.
7.	Corrosion inhibitor (Accepta 3532) – Sodium nitrite (NaNO <sub>2</sub> ), CAS: 7632-00-0	White or pale flavescent, hard powder. Dissolve in water, acidic characterized. Water magnifier, dissolve at 320 °C. Discharge azotic oxide.	Oxidization : 5.1.1C, Harmful : 6.1C, eye irritator: 6.4A, heritage: 6.6B, harmful to certain organ system: 6.9B, harmful to aquatic organism. 9.1A, harmful to vertebrate: 9.3B

**Table 58. The risk from poisoning of flotation substances, its mitigation, elimination procedures.**

Risk character	Safety rules	First aid to mitigate, eliminate risk
<b>1. Potassium amylxanthate</b>		
1. Dust reacts to nose, throat and respiration organ. Dissolution product reacts to central nervous system or risks of loss of memory.	<ul style="list-style-type: none"> <li>- prevent from Potassium amylxanthate dust and discompose during storage and handling.</li> <li>-installation on conditioner, ventilator at workplace</li> <li>-provide employees with mask, muzzle, other protection accessories</li> <li>-constant monitoring of workplace air</li> <li>- employees who deal with this substance shall see a dispensary and keep them in control yearly</li> <li>-possess first aid and guideline during potassium amylxanthate dust and dissolution product poisoning</li> </ul>	<ul style="list-style-type: none"> <li>-poisoned with respiratory poisoned person urgently take a fresh air and breath well</li> <li>-do artificial respiration when fainted</li> <li>-call doctor urgently</li> <li>-urgently take medical treatment</li> </ul>
2. Risk when poisoning through skin, react shock,	-use designed work clothes such as gloves, hat and apron	-take off the outfit which polluted with potassium amylxanthate



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poisonous components infiltrate through skin.	-tissue, soap etc. must be prepared -store work clothes and outfit separately -Possess fully first aid guideline	-wash spillage touched clothes or body with enough water, soap -to receive urgent medical treatment urgently
3. When poisoning to eye, occur redness, blazing up, eye ache.	-Wear eye protection glass, face protection when dealing with potassium amylxanthate	-If potassium amylxanthate touched to eye, apply loads of water thoroughly -call doctor immediately -urgently take medical treatment
4. Harmful, when poisoning through digestion organ. Feeling nausea, smudgy, burning of throat, digestion organ burning, etc. risks will occur.	-Restricted to store food in substance storage -Restricted to dine in work place -Restricted to smoke in work place -Keep away from other agents and keep in cool place -Clean with loads of water after neutralization	-Mouth is rinsed and washed with water thoroughly -If not fainted, drink water Do not force to vomit -Call doctor immediately -Bring to hospital
5. potassium amylxanthate is flammable when combining with water	-Store dry, cool place with water proof package. -Haul with train, car or ship	-Store out of heating source with signs. -Store separate from oxidizer, acid or flammable substance. -Sign as “ <b>xanthate</b> ” hazardous goods, grade 4.2C attached when hauling.
<b>2. Sodium Isobutyl Xanthate</b>		
1. Dust reacts to nose, throat and respiration organ when poisoned.	-Sodium Isobutyl Xanthate prevent to get dusty, dissolve during storage and handling. -install conditioner, ventilator at workplace provide employees with mask, muzzle, other protection accessories -constant monitoring of workplace air - employees working with the substance should be included in medical checkup on annual basis -Familiarize with first aid guideline of working sodium isobutyl xanthate dust and dissolution product poisoning	-poisoned with respiratory poisoned person urgently take a fresh air and stay warm in comfortable area -do artificial respiration when fainted -call doctor urgently -urgently take medical treatment
2. Risk, when poisoning through skin, react shock and carbonic disulfide infiltrate through skin.	-use designed work clothes such as gloves, hat and apron -tissue, soap etc. must be prepared -store work clothes and outfit separately -Possess first aid guideline method	-take off the contaminated outfit, stick with sodium isobutyl xanthate -wash hair, body or clothes with enough water, soap -to receive urgent medical treatment when skin redness or blisters
3. when poisoning to eye, occur redness, blazing up, eye ache.	-Wear eye protection glass, face protection when dealing with sodium isobutyl xanthate	-Eye contact with sodium isobutyl xanthate, apply loads of water thoroughly -call doctor immediately, urgently take medical treatment
4. Harmful, when poisoning through digestion organ. Affect shock to digestion organ.	-Restricted to store food in substance storage -Restricted to eat in work place -Restricted to smoke in work place -Keep away from other agents and keep	-Mouth is rinsed and washed with water thoroughly -If not fainted, drink water -Do not force to vomit -Call doctor immediately

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	<ul style="list-style-type: none"> <li>in cool place</li> <li>-Clean with large amounts of water after neutralization</li> </ul>	-Bring to hospital
5. sodium isobutyl xanthate is emit with flammable gas when combining with water 6.Hauling 7.Potential pollution to natural water	<ul style="list-style-type: none"> <li>-Store in dry, cool place with water proof package.</li> <li>-Haul with train, car or ship</li> <li>-When spilled, avoid entrance of water.</li> </ul>	<ul style="list-style-type: none"> <li>-Store out of heating source with signs.</li> <li>-Store separate from oxidizer, acid or flammable substance.</li> <li>-Sign as “ksantagenat” hazardous goods, grade 4.2C attached when hauling.</li> <li>-If missing sodium isobutyl xanthate to water source, immediately inform related authorities.</li> </ul>
<b>3. Propylene Glycol Ethers</b>		
1. Nose, throat shocked via respiratory organ.	<ul style="list-style-type: none"> <li>-prevent from evaporation during storage and handling.</li> <li>-install conditioner, ventilator at workplace</li> <li>-provide employees with mask, muzzle, other protection accessories</li> <li>-constant monitoring of workplace air</li> <li>-employees working with the substance should be included in medical checkup on annual basis</li> <li>-possess first aid guideline</li> </ul>	-take to fresh air, call doctor, take medical treatment
2. Eye shocking risk will occur.	<ul style="list-style-type: none"> <li>-Wear eye protection glass when dealing with this substance</li> <li>-Wear face protection</li> </ul>	<ul style="list-style-type: none"> <li>-in case of eye contact, wash with large amount of water.</li> <li>-Take a medical treatment.</li> </ul>
3. Burst fire	-Use muzzle and fire resistant cloth	<ul style="list-style-type: none"> <li>-Take people out of fire center</li> <li>-Use water curtain, foam,</li> <li>-Water cloud with carbon dioxide and chemical dry eliminator.</li> </ul>
4. Risks from inappropriate storage	<ul style="list-style-type: none"> <li>-Store under 121<sup>0</sup>C temperature.</li> <li>-Do not store steel container covered by electrical chemical method.</li> </ul>	<ul style="list-style-type: none"> <li>-Store with label</li> <li>-Do not store with strong acid, alkali and oxidizer substances.</li> </ul>
<b>4. 2- Mercaptobenzothiazole solution, sodium salt (Senkol)</b>		
1. When poisoning through respiration organ, coughing, headache will occur.	<ul style="list-style-type: none"> <li>-prevent from evaporation during storage and handling.</li> <li>-install conditioner, ventilator at workplace</li> <li>-provide employees with mask, muzzle, other protection accessories</li> <li>-constant monitoring of workplace air</li> <li>-possess first aid guideline</li> </ul>	<ul style="list-style-type: none"> <li>-urgently take a fresh air</li> <li>-do artificial respiration when breathing difficulty occurs</li> <li>-urgently take medical treatment</li> </ul>
2. Risk, when poisoning through skin, react itchy and skin redness.	<ul style="list-style-type: none"> <li>-use designed work clothes such as gloves, hat and apron</li> <li>-tissue, soap etc. must be prepared</li> <li>-store work clothes and outfit separately</li> <li>-Possess first aid guideline method</li> </ul>	<ul style="list-style-type: none"> <li>-Take off the contaminated outfit. Wash before reuse.</li> <li>-wash body parts or clothes with enough water and soap</li> <li>- receive medical treatment when skin redness or blisters</li> </ul>
3. eye redness, blazing up etc. will occur	-Wear eye protection glass when dealing with senkol	-Wash eyes thoroughly with enough water
4. Digestion organ in risk	<ul style="list-style-type: none"> <li>-Restricted to store food in substance storage</li> <li>-Restricted to eat in work place</li> <li>-Restricted to smoke in work place</li> </ul>	<ul style="list-style-type: none"> <li>-Mouth is rinsed and washed with water thoroughly</li> <li>-If not fainted, drink water</li> <li>-Do not force to vomit</li> </ul>

	-Keep away from other agents and keep in cool place -Clean with loads of water after neutralization	-Call doctor immediately -Bring to hospital
5. Risks from inappropriate storage.	-Store in a cool, dry, conditioned storage. Under 2 years.	-Store with label -Do not store with strong acid, alkali and oxidizer substances.
6. Risks from spillage, loss	-Use protection clothes, mask -Do not use water to remove spillage	-Spillage should be absorbed in inactive matter and leave it in sealed container.
<b>5. Flocculent cationic</b>		
1. Risk to skin	-use designed work clothes such as gloves, hat and apron -tissue, soap etc. must be prepared -store work clothes and outfit separately -Possess first aid guideline method	-wash the substance spilled body part or clothes with enough water, soap -to receive medical advice when skin reaction got increased
2. Risk to eye	-Wear protection glasses when dealing with this substance	-Wash eyes thoroughly with enough water, when this substance touched to eye -to receive medical treatment when eye redness increased
3. Risks from inappropriate storage	When putting this substance in and out of storage, use gloves, glasses, muzzle and prevent from raising dust. Wash hands after.	-Store in a cool (0-35°C) dry storage.
4. Risk of spillage	-Prevent from loss of substance to water source.	-Do not wash. Suck by pipe. Store in a sealed container. Can be washed by water on substance spilled trace.
5. Impact to nature	Over 70% is hydrolysis in 28 days in nature. The hydrolysis products are harmless to aquatic organisms. No accumulation in nature. Poison grade to fish LD <sub>50</sub> /96 hour >10-100mg/l.	The impact of this substance to aquatic organism reduces with carbon in solution in short term.
<b>6. Antiscalant</b>		
1. When poisoning through respiration organ, wheezing, stifle will occur.	-prevent from dusting during storage and handling with antiscalant -install conditioner, ventilator at workplace -provide employees with mask, muzzle, other protection accessories -constant monitoring of workplace air -possess first aid and guideline during Antiscalant poisoning	-poisoned with respiratory organ urgently take a fresh air, breath well -do artificial respiration when difficulty poisoned -take medical treatment
2. Risk, when poisoning through skin, react skin redness, blaze up, ulcerate, burn etc. occur.	-use designed work clothes such as gloves, hat and apron -tissue, soap etc. must be prepared -store work clothes and outfit separately	-wash antiscalant spilled body part or clothes with enough water, soap -receive medical treatment urgently
3. when poisoning to eye, occur redness, blazing up, eye ache, eye blur etc.	-Wear eye protection glass when dealing with antiscalant -Wear face protection	-Wash eyes thoroughly with enough water, when this substance touched to eye -Call doctor urgently to receive medical treatment
4. Digestion organ in risk	-Restricted to store food in substance	-Mouth is rinsed and washed with

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	storage -Restricted to dine in work place -Restricted to smoke in work place -Keep away from other agents and keep in cool place -Clean with loads of water after neutralization	water thoroughly -If not fainted, drink water or milk -Do not force to vomit -Call doctor immediately -Bring to hospital
5. Activity when spilled	-Use protection uniform -Use ventilator -Store in a room temperature	Spillage has to absorb to inactive matter and leaves it in sealed container. Spilled trace is neutralized with soft alkaline liquid and wash with enough water. Acknowledge to related organization.
<b>7. Corrosion inhibitor: Sodium nitrite</b>		
1. When poisoning through respiration organ, coughing, hoarsening, sore throat, headache, wheezing, stifle will occur.	-prevent from dust generation during storage and handling with sodium nitrite -install conditioner, ventilator at workplace -provide employees with mask, muzzle, other protection accessories -constant monitoring of workplace air -possess first aid guideline during	-urgently take a fresh air, breath well -do artificial respiration when fainted -victims stay warm and calm -call ambulance -take medical treatment
2. Risk, when poisoning through skin, react itching, skin redness, blaze up, ulcerate, burn etc. occur.	-use designed work clothes such as gloves, hat and apron -tissue, soap etc. must be prepared -store work clothes and outfit separately	-Take a victim out of substance origin, take off the outfit immediately and leave it away from body. -wash with sodium nitrite body parts or clothes with enough water and soap -receive medical treatment immediately
3. Contac with eye, occur redness, blazing up, eye ache, eye blur, burn etc.	-Wear eye protection glass when dealing with sodium nitrite -Wear face protection	-Wash eyes thoroughly with enough water -Call doctor urgently when illness continue
4. Harmful, when poisoning through digestion organ. Feeling nausea, burning of digestion organ, diarrhea etc risks will occur.	-Restricted to store food in substance storage -Restricted to eat in work place -Restricted to smoke in work place -Keep away from other agents and keep in cool place -Clean with loads of water after neutralization	-Mouth is rinsed well -Never let drink water or force to vomit of fainted person -Call doctor urgently -Bring to hospital
5. Activity when spilled	-Do not touch to the spilled substance -Use respiratory protection muzzle, mask -Use plastic or rubber gloves, glasses, face protection -Wear especial clothes	-Spilled substance should be absorbed by vermikupit, dry sand -cover spilled trace with soda and mix then wash with water -Leave it in container with water and neutralize with hydrochloric acid -Neutralize with calcium hypochlorite -Put preventive action to avoid entrance into water source

6. Storage and hauling	-Store in a cool, dry, ventilated area in sealed container. -Protect from direct sun light	-Store with label -Do not store with wet, humid, acid, organic acid, strong oxidizer, and flammable matter.
7.harm impact to the nature		-Haul with train, car or ship. Hauling grade: 5.1 (oxidizer) -Strong impact to aquatic organ

#### **4.1.2. Risk assessment of the bacteria**

Tailings from BIOX® process might have chemical contents such as acidic reactor, cyanide, caustic, and nutrient of bacteria culture. Biological oxidation process emphasizes tailings management mostly to mitigate the environmental impacts during sulfide ore oxidation process. As well as there are potential risks of accidents during chemical use, transportation, load/unload, storage, dissolution and disposals. Much attention is paid to oxidation of sulfide ore and tailings management. Industrial water requires treatment and neutralization before supplied to tailings pond or transmitted to other facilities, as well as to organize prevention management and monitoring programs to prevent from potential accidents and loss of hazardous wastes. Organic CO provides regeneration energy of most microorganisms, however, specific of microorganisms used in bio metallurgy is non-organic compounds provide regeneration energy. Sulfur bacteria is widely spread in soil, mine drainage water and ore, with asexual reproduction, 0.5-2  $\mu\text{m}$  size and gets energy from  $\text{S}^0$ ,  $\text{S}^{2-}$ ,  $\text{S}_2\text{O}_3^{2-}$ ,  $\text{SO}_3^{2-}$  and  $\text{Fe}^{2+}$  and oxidation of sulfur minerals. Main indicator to define amount of bio-dissolution of sulfuric minerals is number of bacteria in solution volume (in 1 ml) after oxidation and normal dissolving condition number of bacteria reaches  $10^8$ - $10^{10}$ . Kh.Sereendorj opened *Thiobacillus ferrooxidans* and defined its chemical and physical characteristics, as well as developed a method to breed its culture.

#### Control and Management of bacteria used in the BIOX® process:

The autotrophic, mesophilic, acidophilic bacteria used in the BIOX® process are common in nature and thrive in iron rich, wet, warm, acidic, and oxidized environments. Autotrophic bacteria use inorganic carbon for cell growth, mesophilic bacteria have a normal temperature range for growth of 8 to 45 °C (Rittman and McCarty, 2001), and acidophilic bacteria are active under acidic conditions. *Acidithiobacillus ferrooxidans* are the most important of the bacteria to the BIOX process, but *Thiobacillus thiooxidans* and *Leptosperillum ferrooxidans* are also used. In aerobic conditions, these bacteria oxidize ferrous iron to ferric iron and sulfide to sulfuric acid. The bacteria are found in nature and developed environments, abundant where sulfide rocks are exposed near stream banks, on corroding metals and concrete in municipal wastewater treatment plants, and from

leaching tailings and waste rock piles. They are strict aerobes, and are inactive in dry and cold environments. The biological oxidation strategy is selected based on the mineralogy of the ore. BIOX® process is developed and granted by Gold Fields Limited and already in operation. The bacteria are grown in the reactor from inoculums, a nutrient rich cocktail of the bacteria used to start the reactor with a suitably high number of active bacteria. A period of several days to weeks may be needed to establish the conditions needed for effective oxidation. While the BIOX® process maintains a very high retention of bacteria in each reactor, some bacteria also flow out of the reactor with the processed solids. However, follow-up steps of washing and cyanidation kill the bacteria. Beyond containment strategies to avoid spills and to provide secondary containment, spills can also be effectively managed with neutralization and other simple cleanup measures used to manage spills of slurries. In general, the bacteria are not pathogenic, or otherwise harmful in nature, other than playing a significant role in acid rock drainage (ARD) and corrosion. More cautious measures to isolate the bacteria are not necessary, because they are already ubiquitous in nature. However, acids and metals, and other chemical products of the sulfide oxidation reactions that are either created or promoted by the bacteria, may be harmful to human health and the environment. Therefore, controls to prevent and contain spills should be in place to limit exposures or accidental discharges of the untreated byproducts. Overall, focus is given to proper engineering and management processes, such as the selection of appropriate materials for tank construction and regular monitoring practices.

Some aspects of the BIOX Process are critical to effective biological operations, primarily agitation and aeration. The bacteria are sensitive to interruptions, especially to the dissolved oxygen concentration. Measures to prevent interruptions include regular maintenance of sparge rings, a backup generator to deal with power outages, and checking the cooling coils for corrosion or leaks since biocides in the coolant can shut down the reactor. Shut downs can last for a week or more, so regular monitoring and contingency measures are in place to maintain a high level of operation.

*Monitoring and risk mitigation measures for bacteria in BIOX® process:*

Risks for accidental release of water suspensions containing high counts of bacteria from the BIOX Process should be controlled by a spill prevention plan for the mine site. Regular measures should suffice, such as checking fluid levels, monitoring seals around the base of the tanks, and monitoring transfer piping and pumps. Focus should be on spill prevention to control risks to a low level. While risks may be kept low from an effective



spill prevention plan, active monitoring may be needed to test whether an accidental release of bacteria has occurred. In order to determine whether there has been significant discharge of the bacteria used in the BIOX Process, rapid and modern monitoring methods can be put in place at the project site. A method based on polymerase chain reaction (PCR) has been developed to provide rapid and specific detection of *Acidithiobacillus ferrooxidans* and *Leptospirillum ferrooxidans* (Escobar, et al, 2008). The detection limit of the method was reported as 100,000 cells per milliliter (mL), but environmental samples with lower cell counts might be prepared through culture enrichment techniques. One difficulty with environmental sampling is that the bacteria are ubiquitous in nature and the method development for the analysis of environmental samples should be based on effective background control. A more rapid, but less specific way for monitoring the acidophilic bacteria from the BIOX reactors is to monitor pH and metals concentrations of water and soil near suspected spill or accidental discharge areas. The source for these bacteria would likely be the BIOX reactors, which have low (acidic) pH and elevated concentrations of heavy metals. Since spills containing the bacteria would contain elevated ferric iron concentrations, the solutions would tend to oxidize reduced iron present in the soil, visible, orange-stained soils, and sediment may be evident near spill sites. Monitoring of pH, heavy metals concentrations in site soils, surface water, and sediments can help to focus the spots for environmental sampling for bacteria, if this sampling was deemed necessary. As mentioned above, the activity of the bacteria is expected to drop precipitously when dissolved oxygen is depleted, carbon dioxide is limited, or the pH is neutralized. Therefore, mitigation methods for spills should include pH neutralization and reducing atmospheric exposure with a cover, measures that might be similar to treating acid spills. Soils affected by spills may also be excavated, neutralized with lime amendment, and placed in the lined tailings management facility. Several factors influence increase of bacteria activity that could be divided into main categories such as physical and chemical, biological and technological. Physical and chemical factor includes mineral composition of ore, ratio of sulfur minerals, acidity, gas composition, temperature; biological factors include concentration of biomass, activation, adaptability, amount of nutrients; technological factors include aeration and water regime, particle size of ore, duration of dissolution process. Maximum activation of sulfur bacteria is at 28-30°C, in temperatures higher than 50°C protein gathers and ferments become inactive and the cell dies. In temperature less than 10°C oxidation of  $\text{Fe}^{2+}$ ,  $\text{S}^0$  and  $\text{S}^{2-}$  slows down, therefore number of bacteria ( $2.5 \times 10^1$ ) decreases and becomes inactive. Appropriate pH for bacteria generation is 1.7-2.4. Bacteria die when pH is less than 1.2.

Although microorganisms are found in pH=7-7.6, they become inactive. When pH is above 9, bacteria dies. Ratio of nutrient material is important in increasing or decreasing number of bacteria in processing solution. Bacteria is inactive when ratio of phosphorus and nitrogen is 1:10 or 1:30 and very active when is 1:20.

*Control of metals liberated from BIOX® process:*

One of the specifics of bacteria used in processing is its quick adaptation to heavy metals.  $\text{Fe}^{3+}$  and  $\text{H}^+$  protect entrance of other metal ions to bacteria. Some organic compounds of carbon (hydrocarbonate and peptone), as well as ions of  $\text{Cl}^+$  and  $\text{NO}_3^-$  and ultra violet ray decreases activity of bacteria.  $\text{SO}_3^{2-}$ ,  $\text{Ag}^+$ ,  $\text{Hg}^{2+}$ ,  $\text{Au}^+$ ,  $\text{As}^{3+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Mo}^{2+}$ ,  $\text{Co}^{2+}$ ,  $\text{Cu}^{2+}$  are toxic to growth and oxidation of bacteria. However, as the effluent water pH is neutralized by crushed limestone, iron and other metals precipitate out of solution. Arsenic, in particular, can be a concern if there is not ample iron to scavenge it from the solution. In the case of pyritic ore, however, iron is abundant and arsenic removal and other oxyanions are effectively scavenged by iron precipitation. Most other metals are also effectively removed by neutralization and precipitation. Scale control in the neutralization tanks may be required 2 to 3 times per year. Carryover of fine solids from the washing and thickening process may lead to minor loss of bacteria associated with fine solids to effluent neutralization, but the bacteria are not viable at the more neutral pH and without significant sulfide concentrations. In addition, the washing process leads to some precipitation, and coagulants and flocculents can be used to reduce the carryover of fine solids to effluent neutralization. Precipitation sludge should be dewatered and managed according to a solid and hazardous waste management plan for the site. Regular monitoring and process control on the neutralization and precipitation process is typical. Effluent water can be reused for the flotation circuit or other processes, to reduce the amount of fresh makeup water needed.

*Condition of tailings:*

Washed and sulfide-depleted tailings may, in general, pose a minor environmental threat as compared to other sulfide-rich tailings. Reactive metals and conditions that would lead to production of acid-rock drainage are generally muted by the processing of the BIOX process, compared to other, sulfide-rich tailings. However, tailings are managed in a HDPE lined pond, with a compacted clay barrier underneath and a network of monitoring wells placed to monitor site underground water. These measures should minimize seepage. Other isolation measures for the tailings include construction of a vegetative cover layer from oxidized tailings that have considerably lower rates of metals leaching

characteristics than sulfide tailings. The tailings are expected to be managed in an expanded tailings facility, and further details are discussed in the section addressing tailings disposal.

## **4.2. Assessment of potential hazards and accidents**

### **4.2.1. Industrial accident**

Potential industrial accidents can occur during an operation and mostly it affects by human activities. The industrial potential accident caused by human activity means the direct connection with construction phase, choosing other engineering construction base, design, installation of construction machinery and dealing with machinery during operation. In other words, breach of operational procedure, technological procedure, and machineries operation control causes not only potential accidents like environmental pollution, normal operation of facilities, machinery breakage, it also may cause economical loss and cause fatality, disability to work. Potential accidents may occur due to:

- Loss of normal technological regime, damage and malfunction of machinery
- Loss of normal technological regime due to false signs and information caused by broken equipment
- Attempt to fix damages and work on electric equipment by untrained employee
- Untrained employee work on equipment without management authorization
- Breach safety procedures working without safety glasses, muzzle, gloves, earmuffs, mask for dust, gas or dealing with electricity without personal protection equipment.
- Start fire by creating short-circuit in wet area
- Electric shock caused maintenance work conducted when the equipment is still plugged to power
- Breach of electric equipment guideline and safety procedure
- Breach of health & safety guideline
- Rush to start work when actions on safety operation has not been taken yet
- Inaccurate control or not full extinction over fire extinguish, high pressure, temperature, voltage caused by themselves indiscretion
- Inattentive over barrier or slippery on path, area and steps
- Electrical connecting defect is not discovered on time

In order to avoid similar accidents in future technical and economic actions should be taken such as thorough investigation, finding person responsible for accident.

#### **4.2.2. Fuel and lubricants risk assessment**

The most dangerous accidents that might happen while receive, store, distribute fuel and lubricants are spillage, fire and explosion. The main sources of these accidents are damages of steel frameworks, pumps, connectors, and operational deficiency.

##### Steel frameworks (gate, bolt etc.)

- Loss of seal of steel frame, valve and flange, valve base worn out
- Crack of steel frame
- Fuel spillage caused by base hardness loss due to weathering, corrosion and pollution with solid particles
- Improper work of valves due to bad housekeeping, damage and freezing
- Improper work of worn out valve, sudden opening and closing
- Valve jam, caused by contamination or frozen water inside

Some larger steel frameworks have serpentine gears, which cause more breakdowns. Valves equipped with motor also have various breakdowns and mechanical or automated steel frameworks do same as.

- Engine damage caused by valve over tighten or jamming
- To be lost the isolation of electric motor, broken caused vibration, brush and bearing worn out, broken ventilator or no blowing caused by dust, generate short electric circuit caused by put inside water or unusual object
- Valve to open incompletely or not open due to on or off mode of motor
- Initiator to be broken which might lead damages and bending of other equipments

Beside above problems, some accidents might happen comparatively rare that should be controlled or diagnosed during preparatory examination and technical inspection.

- Steel frameworks to be assembled incorrectly, which might be difficult to detect in initial inspection and cause to corrode or vibrate the valve
- To be not suitable for technological flow
- Select incorrect inventory or design
- Assembled broken steel framework or design and carrying capacity of receiver pipes are incompatible with technology

*Fuel pipelines:*

Damages of fuel pipelines are to be lumped, fuel spillage or leakage. The lump mostly settled inside that caused by collected mechanical impurities, sedimentation, settled water to be frozen, lose its regulation and breaking. Sometimes the lump might be caused by internal corrosion. Mechanical damages like twist or collapse could settle the lump. The reasons to spill fuel or break are:

- Corrosion and weathering
- Cracked cap or pieces
- Overloaded
- Broke while assembling
- Pipes to be disjoined when jamming occurred around soft joints
- Dislocation the base
- Installation of pipes underground in insufficient depth
- To be over pressured both inside and outside of the pipes which might cause explosion
- Pumping pipes to become soft
- Disjoin not separable joints of the pipes caused by over loading

*Flanges (joints):*

Major damages of flange causes spill of fuel or lost the seal of the hardiness.

- Flange and bolts tightened loosely or over heated, overloaded
- Bolts to be loosen or widen caused by mechanical application or vibration
- Bolts to be over tighten
- Surface holes of flange hardiness are defiled or get in small particles
- Assembled incorrectly, incompatible bolts, seals used, and reinforced with less bolts
- Corrosion on surface of hardiness
- Bolts corrosion, broken caused by overpressure or breaking

*Reservoir (storage tank):* major damages are caused by fuel spillage and lump settlement inside pipes. The reasons are:

- Cracks and holes in storage tank, its bottom, cap and welded joints
- In or out pipes are overflowing, use for other substances or not assembled stably

Irregular fuel spillage could be caused by overused reservoir, not determined utilization reserve and corroded or worn out storage tank, its bottom and cap. There also happen damage not adjusted the speed regularly while pouring or filling the storage. If protective and exhaling valves don't operate while filling the reservoir, there will be overloading or over scarce. So storage tank or cap of the reservoir will be deformed or bored inside. The reasons to fire, explode, emergency or fuel overflow while receiving fuel, are failure of level gauge or incorrect calculation and measurement.

Safety valves (protective valves): If flange bolts are loosen, sense pressure rate incompletely. A valve will be weathered easily if it is assembled in part of continuously opened or closed section.

Signal system: All signal system has alignments of assembling and operating conditions. Following measures should be considered during assembling. Herein:

- Provide the condition to be assembled right sequence and show correct measurements for a long term
- It is required signals to be protected against other equipments affect, vibration and temperature change
- Assemble the gauges (electric connection) correctly and reliable
- Complete under correctly selected procedure and alignment of operating condition

Flow signal (consumption regulator): It provides incorrect data when it is broken. Reasons are:

- Adjusted the signal intervals incorrectly
- Signal spaces are filled by impurities
- Flanges between signals are get flow.

Temperature signal: The most common signal is thermocouples. The thermocouples are broken due to corrosion, outside pressure, mechanical damage, and deformation affect. It also shows incorrect numbers when connected incompletely, incorrectly and had short electric circuit

Pressure signal:

- Spill mellifluence from gauge pipe
- Gauge to be jammed by outside affect



- Open or short electric circuit
- Joints to be lumped

**Fuel spillage and leakage:**

Fuel spillage will be happen when pipelines technological flow, infiltration, frames, and bottom of reservoir are cracked or bored. Fuel loss will depend on damage extent of storage tank, location height, fill amount and pressure inside reservoir. There fuel spill from the joints of pump, flange and steel frameworks. Spilled fuel will evaporate and pollute the atmosphere.

**Fire:** Potential fire accidents of BGC operations are:

- Fire in the parking areas of reservoir and overpasses caused by spilled fuel
- Fire tracking spilled fuel
- Blocked fire inside building or warehouse

Fist Sir. Tomas (1963) has proved that the correlation of spilled fuel amount and height of the fire flame could be evaluated with a formula.

$$L/D=42 \times (M / P)^{0.61}$$

Herein,            L– height of fire flame;            M–burning coefficient of ditch-fuel  
                          D–diameter of ditch-fuel;    M= 2.54 x 10<sup>-4</sup> m/sec;    –Air density

Burning condition of small ditch with D=3 m is calculated as L= 5.43 m. Which means small ditch-fuel spilled for few seconds could fire acutely. As P.Taulor (1994) calculated, flame temperature is about 630-720<sup>0</sup>C for ditch-fuel with medium diameters. Fire caused by spilling fuel have much more strong movement and generate much heat all around. Wertenbach (1971) formulated flame height of fuel fire as below.

$$q = 0.0006785 \times L^{2.5}$$

Here:    q–mass of spilled fuel;            L– flame height.

If there is a depletion in the reservoir wall with 0,05 mm diameter, flow rate of spilling fuel as follows:

$$V= 2gH \quad 11.7 \text{ m/sec}$$

and spilled fuel volume for thirty seconds is  $V_q = 165.3 \text{ m}^3$  and fire flame will be reached 111 m high. Heat amount of fire evolved is indicated by Stephan-Boltzmann theory.

$$E = k \cdot T^4$$

Here,  $E$ –Emitted energy;  $k$ –Boltzmann constant,  $k=6$ ;  
 $T$ –Absolute temperature.

By using calculation with above formula, an effect of emission intensity is classified as shown in the table.

**Table 22. Effect of emission intensity**

$w / \text{m}^2$	Effect (impact)
7	After 8 seconds, start to feel burning pain on naked parts of the body like face, hand and arm
7	After 20 seconds, start to blister naked parts of the body
14	Wood will fire
21	Die if stay for 20 seconds
36	Fire cellulose after 20 seconds
36	50 % probability to die if stay for 20 seconds

There also get flash fire when permanent foginess mixed fuel evaporation and air. Sir P.Taulor defined the fire volume and continuance.

$$D = 57 \cdot M^{0.32} ; \quad T = 3.9 \cdot M^{0.32}$$

Here:  $D$ –Fire diameter,  $T$ –duration

If  $M = 1.5$  then  $D = 31 \text{ m}$  and  $T = 2.1 \text{ sec}$ .

It is possible to fire next fuel storage because flash fire heat much energy and airwaves.

#### Explosions of reservoir, pump pipelines and constructions:

There are three situations to explode:

- Large amount of fuel evaporation which could have dangerous mixture to explode
- Atmosphere of over concentrated with dangerous mixture to explode
- Side effect to fire or explode

Potential fire generators

- Collect static electric charge
- Abrasion fire from moving parts or fault of cable lines and electric gauges
- Heating from adiabatic constringency of mining
- Open fire
- Failure during welding operation
- Fire from reagents reaction

- Surface overheat of reservoir and process pipelines

Blocked explosion have much more pressure than as open explosion do.

Wave distribution from explosion and its damage:

Explosion damage will depend on its wave pressure. The formula of the pressure is as follows:

$$P = C \cdot 0.5 p \cdot U^2$$

Here: C–Coefficient of air resistance, U–Rate of airwave

By using above formula, effect caused by pressure is shown in table 57.

**Table 23. Damage of explosion wave**

<b>Pressure (10<sup>5</sup> )</b>	<b>Effect (impact)</b>
0.01-0.03	Brake window glass
0.03	Destroy building wall a little
0.08	Destroy some parts of the process plant
0.2	Steel frame bend, ruin building walls

Small particles from explosion are thrown miles. Blocked fire will cause to destroy buildings or facilities causing much damage. Probability small particles to be thrown R distance are:

If there **R = 5 m**, **M = 0.15 t**, **=0.1 kg**, and **P = 67 %** while exploding neighboring tanks may be destroyed or exploded. The probability employee of fuel station to be affected by explosion is:

$$P = N \cdot P \cdot A \cdot (2 - r)$$

Here: N–Amount of particles, P–Probability,

A–Area, r–Distance from explosion center to employee.

If **A=0.8 m<sup>2</sup>**, there are **N=3** and **P'=5 %**. Sir Miyamoto (1979) have studied an occurrence small particle to enter into the barriers and formulated.

$$E = 2.9 \cdot 10^9 \cdot t^{1.5} \cdot d^{1.5}$$

Here: d–Diameter of particle 5 cm,  $d = t \cdot (1 + 2.9 (\tan^{2.1} (b/2)))$ ;

b- Spike angel, t-Thick of colliding material.

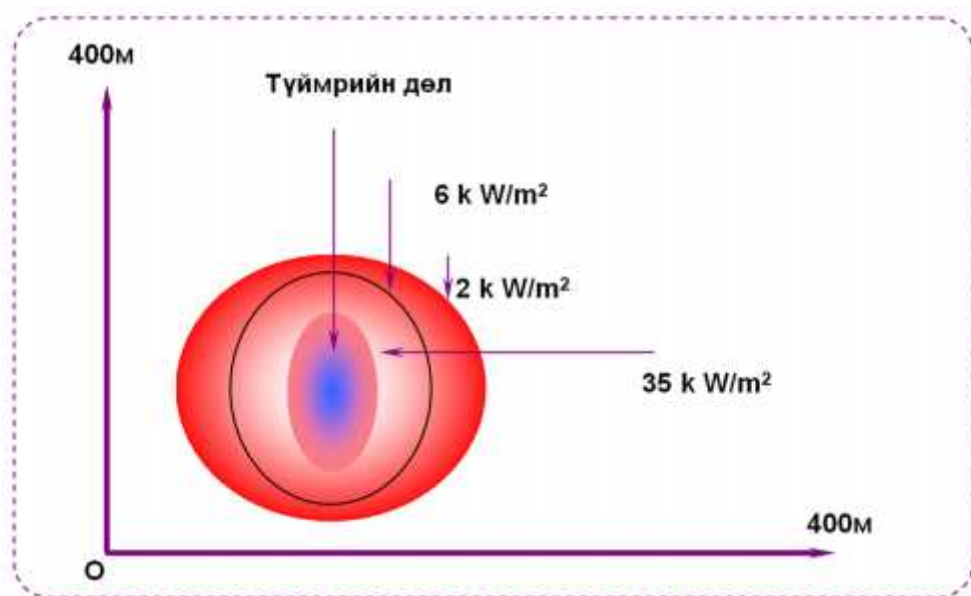
$$P = 0.38 \cdot (R / R_{max})^{-0.62}$$

Here:  $R_{max}$ – Relatively high radius of small particles

$$R_{max} = (0.4 \cdot M \cdot H / m)^{-0.62} / 2 \text{ gr as formulated.}$$

If diameter of small particle is 5 cm, entrance rate into the reservoir is 3.5 m/sec. For BGC operation, main sources of fire or explosion are fuel spillage around storage tank, transmission pipe and other parts of the reservoirs. When spilled fuel evaporates in the air with certain concentration (which depends from air humidity, temperature, wind speed and

so on) and may sparkle or flame consequently explode. If there not exhausted residues in bottom of transmission pipelines or empty spaces inside top of reservoir might cause to be explode. As presented above, the main factor to fire or explode is fuel spillage. A correlation graph (R.Taylor, 1994) that described the energy level of thermal radiation and distance for fire caused by fuel spillage is illustrated below. The intensity of thermal radiation is 35 k W/m<sup>2</sup> and 2 k W/m<sup>2</sup> per square meter at 15 m and 45 m distance respectively. There might be happen mistake during fuel station operation by people irresponsibility. By mistakes of operators, there happen overpressure, overflow, fire, explosion, spillage and signal malfunction.



**Figure 34. Correlation between radiation energy and distance while firing spilled fuel**

Factors of managing accidents:

- Check design quality
- Check execution quality
- Check the defect of the process parts and gauges
- Check the defect of the installation
- Detail the operating procedure
- Observe the training and workout
- Introduce the layout documents of fuel station and keep
- Emergency plan of dangers (accident)

**4.2.3. Labor safety**

General requirements of labor safety:

- Provide general safety requirements for the processing phases, mechanics and equipments
- Electrical equipment and instruments should be assembled in accordance with design, provide safety requirements for the electric consumption, “MNS 5151:2002, Electrical safety”
- Identify quality requirements and usage interim for work clothes according to UST0012.4.015.89 standard
- Train and practice employees to ensure fire safety, maintain internal regulation and save fire equipments regular situation, “MNS 4244:94, Safety against fire and general requirement”
- To conduct three-phase inspection for labor safety,
  - 1. Shift team
  - 2. Departments or units of organization
  - 3. Entire organization
- Prohibit using new substances and materials for processing equipments not produced under instruction or not verified under clear conditions of labor safety and health
- Assemble accessories for automatic electric power off or withhold under emergency and contingency condition that occurred caused by process malfunction
- Prevent to be occur any accidents for the components, accessories of equipments caused by power-cut or electric current change (electric current or gas), electrical equipment assembled with the additional equipments not power on automatically

*Employees health:*

Preventative condition against industrial accident is to hire people who could pass preliminary health examination; to diagnose inherent or acquired disease, which might conflict or satisfy occupational requirements. Therefore, need to follow the selected disease, which belongs to the mining production and chemical laboratory, from guidelines 5<sup>th</sup> appendix of 137<sup>th</sup> decree in 1982 by Ministry of Health protection, entitled “List of incompatible diseases to employ new employees”.

4.2.3. Accident and natural disasters

*Fire:* Project area is located in the forest-steppe region that is called zone of fire hazard. Weak regards for equipment and structures, can be source of human induced fire

danger. However, fire dangers caused with lightning or thunders can be tide over less damage or environmental pollution. To prevent against fire accident, fire equipments should be prepared and preventative measures taken.

*Thunder & lightning:* During summer seasons, heavy rain lightning and thunder occur almost 20 times. During a lightning, there comes 3-5 times thunder at 1 km square area for 30-80 minutes. These may cause temporary delay for mining production, human activities, and labor condition. A protector should be installed at the highest elevation to protect against lightning, until mine closure.

*Storm flood:* Processing plant is located comparatively at high elevation in mountainside. For TMF and HLP, flood protection dams are constructed that not happen operation accident. Storm water diversion dams should be constructed around processing plant, camp, and infrastructure facilities including bore fields.

*Earthquake:* Almost eighty percent of Mongolian territory belongs to the seismic zone and Kharaa, Eruu, Boroo river basin is located in the seismic area with 7<sup>th</sup> grade according to Mongolian general seismic zones (JEMR 2000). According to seismic map illustration, none of acute origin is recorded around the Boroo mine site but there are surrounded epicenters with low intensity. Purposed structures will be constructed with steel footing and soft walls, which is out of seismic dangers. Should consider any unexpected accidents because if there have an earthquake, open pits can collapse and damage human life or machineries. Risk assessment on TMF, HLF, open pits and waste rocks are determined in the previous reports.



## **Section 5. Closure, Reclamation and Ecological and economical Evaluation**

### **5.1. Project closure and reclamation**

A Closure and Reclamation Plan will be prepared to address procedures necessary to gain closure of the operations and to reclaim site conditions to a target state. The target state should include quantitative and aesthetic (qualitative) goals for restoration of potential impacts to socio-economic conditions, water resources, soil resources, flora and fauna, and air quality. The Closure and Reclamation Plan will be consistent with the plan include in the Boroo Gold Project Environmental Assessment. Primary components will include:

- Reclamation will provide for future public health and safety and beneficial and sustainable long-term use of the site and surrounding environment.
- Return the site to a condition, which will support land uses similar to those which existed prior to the onset of mining activities.
- The reclamation plan will mitigate the short-term impacts on topography.
- At selected points, soil sampling should be carried out to monitor whether there is soil contamination, and to identify changes in heavy metal content in the soil at reclaimed and non-reclaimed areas.
- Reduce or eliminate potential environmental impacts such as ARD or mining related underground water impacts.
- Control infiltration, erosion, sedimentation, and related degradation of existing drainages in an effort to minimize off-site impacts; and
- Employ reclamation practices using proven methods, which do not require ongoing maintenance.

#### **Biological reclamation:**

Biological reclamation is measure that taken to minimize impacts caused by loose earth blown away and air pollution. Reclamation will be completed in order to return the areas to productive land utilization as pastureland, agriculture and other specification and bring close to former natural prospect. The most important requirement for biological reclamation is providing reclamation potential of natural its own.

- Biological reclamation should follow by MNS 4918:2000. Technical requirement, Vegetation of disturbed area.

- In the beginning, it is better to use organic fertilizers to support growth and increase soil fertility and convenient to dung, peat or mineral fertilizer in our country practice. A dose of organic, potassic, nitrogenous and phosphoric fertilizer is 20-30, 40-60, 60-80 and 40-60 kg per a hectare respectively.

Soil erosion and sediment control during project construction operations and reclamation will accomplish the following environmental protection and mitigation goals for the project:

- Prevent sediment erosion into nearby wetlands and streams.
- Maintain topsoil removed during project construction for later use in reclamation activities.

For the reclamation work on disturbed area by construction should be selected a local species what are adapted in that ecosystem like, Medicago sp, Bromus sp, Elymus sp, Psatricostachys sp, Onobrychus, Melilotus and plant them as a mixture, Poplar and willow trees what are the dominant species. Preferred plant mixture and amount are illustrated in below table.

**Table 24. Plant species and seed amount**

	<b>Plant species</b>	<b>Seed mixture, kg/ha</b>
<b>1</b>	Medicago sp	12-14
<b>2</b>	Melilotus	20
<b>3</b>	Onobrychus	15
<b>4</b>	Bromus	22
<b>5</b>	Elymus	25
<b>6</b>	Psatricostachys	20

In the case of planting by mixtures of some different species, the amount of seed should be estimated by 50 percent lower. Depending on how many species are in mixture, seed rate will vary, if two species are in mixture 50-70 percent will come from each specie. If four species are in mixture, first dominant specie seed 60%; second dominant specie 20; third one is 10 and fourth specie seed will be 10 percent. Best rate of grass and legumes is 60:40. In order to estimate the needed seed level for planting we should calculate the economical quality of seed /A %/.

$$1. \quad \% = \frac{G \cdot P}{100};$$

% - Seed quality  
P - Seed purity  
G - Germination rate

2. Seed amount:

$$= \frac{B}{100};$$

- Seed amount  
B- Seed amount for 100 % quality

**A - Seed quality**

Sowing time is the end of May and beginning of June. Sowing depth for Bromus, Elymus, Agropyron, and Psatricostachys is 2.5-4 cm; for small seed of Medicago, Melilotus is 1.0-2.0 cm. If the seed mixtures contain different size of seed, it is recommended to sow the bigger seeds in first and then continue with the smaller seeds.

## **5.2. Ecological and economical evaluation**

Ecological and economical evaluation could be classified into two categories direct and indirect.

*Direct method of calculating the damage:*

- These costs include separately or in sum: environmental reclamation, expenses to eliminate pollution, paying for compensation etc.
- Cost for reducing adverse impact by establishing new engineering controls or introducing technological improvements.
- Cost relating to compensating individuals for environmental adverse impact
- Cost for arranging projects/work relating to natural resource's reclamation, amelioration, repair and maintenance (as is the market price).

By using the direct way to assess the adverse impact level, it becomes necessary to prepare, enter, and analyze a large number of data. This method can be complicated and be limited to economic calculations only.

*Indirect method of calculating the damage*

It is impossible to use only the direct way of calculating losses and costs generated to the environment. It is when improvements and amelioration actions to the impacted environment are not possible; the indirect method for calculation is used. The indirect method of calculation is based on assessing the indirect impacts on the environment and norm and normative built on this notion. In addition, it is based on assessing the environmental pollution, ecological risk payment.

### **5.2.1. Ecological and economical evaluation on land resource**

Impacted area by Boroo expansion project will be 6,32 ha and the Boroo mine project's licensed area falls into the Khangai, Khentii mountainous belt and agriculturally pastureland, the base rate for 1 ha land is 548.2 MNT. Therefore, the total cost of direct adverse impact on land is:

$$6,32 \text{ ha} * 548,2 \text{ thous.MNT} = 3'464'624 \text{ MNT}$$

### 5.2.2. Ecological and economical evaluation on land surface

Assessment on soil is divided into ecological assessment and economic assessment. According to ecological assessment, soil nutrients and mechanic properties are identified. Then, using the economic method, a money value is calculated. Both assessment methods are closely inter-related. Specifically, soil ecological assessment includes assessment on particular area's soil erosion level, humus, nutrients and organic matter, salinity, physical properties etc. In addition, soil surface slope, landform, rocks, vegetation cover and other factors are considered. The easiest and yet comprehensive way of carrying out ecological assessment is assess the soil quality/value based on humus content. Soil profiles are identified, as well as the vegetation distribution, depth of organic matter in A, B, C layers etc. C.Dorjgotov (1976) developed Mongolian regional soil classification chart, according to which the Boroo mine's soil falls into Khangai soil region and Orkhon-Selenge belt's small mountainous region's dark, mountain chernozem soil category. However, if changes to the depth of humus level in the eroded soil have been taken into account, then it would not be necessary to use the modification coefficient. In this report, we have calculated humus depth layers in connection with humus reserve. For 1 m<sup>3</sup> soil with medium-content of nutrients or 5 % humus, the market price is 3,000 MNT. Therefore, if we calculate that there is 0.06 tons or 60kg of humus, then the price of 1 kg of actual humus will be around 50 MNT. 1 kg pure humus price will vary depending on monetary fluctuation and influenced by other factors. As the result of estimation 6,32 ha of area will be degraded and humus amount to be lost is:

$$6,32 \text{ ha} * 58,5 \text{ ha/t} = 369,72 \text{ tons and evaluation is:}$$

$$369720 \text{ kg} * 50 \text{ MNT} = 18'486'000 \text{ MNT}$$

### 5.2.3. Ecological and economical evaluation on water resource

The calculation below attempts to assess the water resource depletion amount in the process of mineral resource excavation and processing. Processing water and household use water needs will be subtracted from the total water usage requirements. Totally, **13'104 thous. 3** (7200 m<sup>3</sup> \* 5 years \* 364 days) of underground water will be used for processing and domestic consumption. Water resource depletion amount calculated with current market price. Let us calculate the ecological and economic evaluation of using underground water and surface water resources:

$$Y = Y (1 + K_i) H_i$$

Herein:

Y- Ecological and economic evaluation of water, MNT

Y - Water unit resource evaluation, MNT.

K<sub>i</sub>– Required multiplier /taken from table/

H<sub>i</sub>– Water amount, m3

$$Y = 2000(1+0,42) 46035.6 \text{ m3} = 1'329'220'000 \text{ MNT.}$$

To minimize the use of additional fresh water, water from the TMF is pumped back to the mill for reuse. During warm seasons, it is anticipated that underground water consumption could be reduced until 150 m3/h or almost fifty percent.

#### 5.2.4. Ecological and economical evaluation on vegetation

Ecological and economical evaluation on vegetation should consider the daily forage amount eaten by a livestock, grazing days, forage nutrients, vegetation cover and economical outputs. Market price of grazing forage is 7000 tugriks per package with 25 kg and 280 tugriks per kilogram forage.

$$b = \text{St} * \% * \text{unit} = 13 \text{ c/ha} * 6,32 \text{ ha} * 85 \% * 280 \text{ MNT} * 5 \text{ years} = 9'777'040 \text{ MNT}$$

b – pastureland vegetation ecology-economic evaluation, thous.MNT

– pastureland crop, /

% - vegetation cover percentage, %

unit – value per pastureland crop, MNT

#### 5.2.5. Total of ecological and economical evaluation

Ecological and economic costs assessment on mineral resource use includes an assessment of the activity's impact on the natural environment, including sum of compensation on water, soil, land surface, vegetation cover etc. in monetary form. The equation for estimated the total impact cost resulting from mine operations is listed below:

$$\text{total} = \text{water} + \text{soil} + \text{land} + \text{veg cov}$$

*Y<sub>total</sub> – the total impact cost resulting from mine activity throughout its operations on the natural environment, thousand MNT;*

$Y_{water}$  – cost of adverse impact on water reserve/resource, thousand MNT;

$Y_{soil}$  – cost of adverse impact on the ground soil, thousand MNT;

$Y_{land}$  – cost of adverse impact on land impacted by mine operations, thousand MNTs;

$Y_{veg\ cov}$  – cost of adverse impact on vegetation cover, thousand MNT;

Therefore, the total ecological economic impact cost is calculated at:

$$total = 3,464,624 + 18,486,000 + 1,329,220,000 + 9,777,040 = 1'360'947'664 \text{ MNT}$$

Cost for producing 1 tons of final products was calculated below:

$$unit = total / \cdot = 1'360'947'664 \text{ MNT} / 5 \text{ years} * 1,750,000 \text{ tons} = 155 \text{ MNT}$$

Herein, – Annual production capacity

– Operation period , years

**Table 25. Total estimation of ecological and economical evaluation**

	<b>Ecological damages</b>	<b>Total, MNT</b>	<b>Value per ha are, MNT/ha</b>	<b>Value per kg product, kg/MNT</b>
1.	Damage assessment on land reserve	3,464,624	548,200	124,2
2.	Damage assessment on soil surface erosion	18,486,000	2,925,000	662,5
3.	Damage assessment on water resource	1,329,220,000	210,319,620.3	47,650
4.	Damage assessment on vegetation	9,777,040	1,547,000	3,5
	<b>Total</b>	<b>1,360,947,664</b>	<b>215,339,820</b>	<b>47,650</b>

It has been calculated that the total cost of Boroo plant expansion and biological oxidation process to which the environment is adversely affected, will be **1,360,947,664 MNT**.



## Section 6. Environmental Protection Plan

Environmental protection plan (EPP) is an official document about environmental friendly use, environmental impact mitigation, and elimination. In the environmental protection plan demonstrated the complex of Boroo ore plant expansion for construction of “bio-oxidizing BIOX® technology of oxidizing sulfide ore concentration with cyanide project,” and other procedure environmental impact mitigation event, estimated cost, rules for compliance and standards. EPP is the brief definition of environmental protection processes and requires renovation and improvement annually. To do so, make it improved compliance of connecting with more efficient use of the situation that are the results of environmental monitoring programs.

Table 26. Environmental protection plan

1. <u>Soil, vegetation cover protection, disturbed land reclamation</u>	
<b>Impact brief definition</b>	The planned project area that 6,32 he is impacted by mining operations in a ways of erosion and disturbance. The construction buildings will be placed onto approximately 4 ha area, also it pollutes as soil and vegetation cover, disturbance, deterioration, dust, industry and household solid and liquid waste and petroleum products according to the increasing vehicular movement at a surrounding area.
<b>Impact source</b>	Ore loading, transportation, waste dump, dam building, chemical, fuel and oil material storage, vehicular movement, plant technology, household waste and its facility.
<b>Object to be impacted</b>	Mine site and surrounding soil, vegetation, impact on human health, livestock, and water
<b>Standard permissible level</b>	<ul style="list-style-type: none"> <li>-Soil quality, soil pollutant elements and substances, permissible levels MNS 5850:2008</li> <li>-General requirements for assessment of soil erosion and degradation of vegetation cover in pasture lands. MNS5546:2005</li> <li>-Mongolian national standard MNS3297:91, Environmental protection, soil, urban settlement land sanitation assessment indicator norms</li> <li>-Environment. Definitions and Terminology for reclamation on destroyed land MNS5914:2008</li> <li>-Environment. Classification of land destroyed due to mining activities. MNS5915:2008</li> <li>-Reclamation of land destroyed due to mining activities. General technical requirements MNS5917:2008</li> <li>-Requirements for fertile soil removing and its temporary storage during the earth excavation. MNS5916:2008</li> <li>-Environment. Technical requirements for disturbed land vegetation. MNS5918:2008</li> </ul>
<b>Monitoring and observation requirements</b>	National and international laboratories will determine soil pollution level and write conclusion and provide graphs as guidance for selecting soil quality monitoring and sampling points (attached map) and select analyses type, methods by Boroo monitoring project.
<b>Budget for mitigation and removal of environmental impact</b>	<ul style="list-style-type: none"> <li>-Smoothing construction building, machinery site and apply it with 0.2m fertile soil (6,32 he = 63200m<sup>2</sup> 0,2m 1131,5 tugriks = 14' 302' 160tugrug)</li> <li>-Perennial plant seed scattering (6,32he 60000tugriks = 379' 200tugriks)</li> <li>-Perennial plant seed acquisition(20kg per 1he, 6,32he 20kg 5000tugrug=632' 000 tugrug)</li> <li>-Irrigation (6,32 he 400 m<sup>3</sup> 100 tugriks = 252' 800 tugrug)</li> <li>-Put signs and boards to prohibit vehicular on non-roads. (budget will be included in mining internal planning)</li> <li>-Routine the measures not throwing wastes unselected area and distracting soil etc. (budget will be included in mining internal planning)</li> <li>-Preventive measures against fire (budget will be included in mine internal planning)</li> </ul>

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	<p>-Take samples two times/year from 5 sampling locations mentioned in the report and analyze.(5 locations 2 times year 400'000 tugrug = 20'000'000 tugrug)</p> <p><b>Total budget: 34'940'480 tugrug</b> (Annual budget will be included in environmental protection plan).</p>
<b>Regulation documents to be compliance</b>	<p>Law in land:  ...50.1.1. to take measures at their expense to store land characteristics and quality, to prevent deterioration of soil fertility, deterioration of flora, soil erosion, degradation, soil infertility, extra hydration, soil salinization, its pollution and poisoning(chemical pollution) due to natural causes and human factors;  Laws on minerals:  ...39.1.3. the environmental protection plan shall contain measures to ensure that mining operations are conducted in the least damaging way to the environment. The plan shall also identify preventive, comprehensive measures to protect air and water, humans, animals and plants from the adverse effects of mining operations;</p>
<b>2. <u>Air quality control</u></b>	
<b>Impact summary</b>	<p>There will be impact on air quality from blasting, rock mining and hauling particularly during construction and industry mill operation. There will be toxic gases released and physical noise pollution generated from mine heavy duty machinery and ancillary equipments movement and noise. Several activities such as blasting, evaporation of gases and oil materials, release of toxic chemicals from vehicle exhaust, chemical and household wastes will have multiplying impact on air quality. (means of multiplying impact is multi dusty during toxic gas)</p>
<b>Impact source</b>	<p>Earth excavation during construction, construction material, hauling and loading of ore, transportation road, mine heavy machinery, crushing and grinding facility of ore, reagents, chemical reagents, flotation, thickening facility, waste disposal dam facility, petrol station.</p>
<b>Objects to be impacted</b>	<p>Site soil, vegetation, livestock</p>
<b>Standard permissible level</b>	<p>-Mongolian air quality standard MNS4585:2007 “Permissible levels of air pollution”  -“Air quality. Exhaust from diesel motor vehicle: permissible levels and identification method” MNS0017,5,1,20-92  -Air quality indicator, general requirements, MNS4585-98  - “Permissible levels of polluting sources in air in urban settlements” State hygiene inspector order  -Workplace air quality, Hygiene requirements MNS0012-013:91</p>
<b>Monitoring and observation requirements</b>	<p>Continue operations considered in Boroo mining monitoring project, write conclusion and provide graphs as guidance for sampling analysis type considered in environmental monitoring project at a time, related operations shall took if necessary.</p>
<b>Mitigation of environmental impact and budget</b>	<p>-Monitoring and analysis of site and other location's dust level and background air quality at 2 points (2 points 4 times 180'000 tugrug 5 years = 7'200'000 tugrug)  -Regular inspection and maintenance on mine heavy machinery, transportation equipment, Maintain vehicular air emission within permissible levels (budget will be included in mining internal planning)  -Keep site location's air quality within permissible level (budget will be included in mining internal planning)  <b>Total cost: 7'200'000 tug</b> (budget will be included in annual environmental protection plan)</p>
<b>Regulation documents to be compliance</b>	<p>Law on air and air pollution. Law on labor safety and hygiene.</p>
<b>3. <u>Water quality control</u></b>	
<b>Impact summary</b>	<p>Underground water pollution can expand through soil medium and negatively impact on soil, human health, livestock and vegetation.</p>
<b>Impact source</b>	<p>Seepage of waste dam, dam failure, failure of wastewater treatment facility, excess pressure, chemical substance, reagent, petroleum product storage, transportation failure, failure of bio-</p>

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	oxidizing facility tailings and household wastewater sewage.
<b>Objects to be impacted</b>	River, underground water, soil, vegetation, impact on human health, livestock and wild life, aquatic organisms as a result of lack of underground water source as a result of excessive use for human, vegetation, livestock. Aquatic organisms pollution as a result of chemical substances, reagents and possible polluted water containing bacteria spilled on ground.
<b>Standard permissible level</b>	-MNS4586:1998. Water environment quality: general requirements -MNS900:2005. Drinking water quality standard -MNS4943:2000. Water quality. Waste water; general technical requirements -MNS4288:1995. Wastewater treatment facility: basic requirement for technology -Water use payment (Government 2005 July order)
<b>Monitoring and observation requirements</b>	Heavy metal, cyanide, and other pollution monitoring will be done according to wells, monitoring bore holes. Monitoring will be also analyzed according to graphic schedule and provide results of Boroo mining land water during project operation. If there is pollution detected in water body, will collaborate with professional organizations to remove impacts.
<b>Mitigation of environmental impact and budget</b>	-Permanent control over industrial and household water, tailings in waste disposal facility, waste water lines and their facilities to prevent from wear, tear and failure. (budget will be included in mining internal planning) -Construct flood protection dam during construction phase. (budget will be included in mining internal planning) -Protect mine area and river basin from solid and liquid wastes and fuel wastes. (budget will be included in mining internal planning) -Permanent water level monitoring over water supply facilities. (budget will be included in mining internal planning) -Water monitoring (5 points 12 times 300'000 tug 5 years = 90'000'000 tug) <b>Total budget : 90'000'000 tug</b> (budget will be included in annual environmental protection plan)
<b>Regulation documents to be compliance</b>	Law on water, ...31.1. A water user shall maintain a volume of water resource required to sustain its natural and ecological balance. Law on fees for the use of water and mineral water.
<b>4. Labor safety and workforce hygiene</b>	
<b>Impact summary</b>	Most mine employees work under rather harsh labor condition of physical and chemical pollution, where often dust, noise, vibration and temperature levels fluctuate and number of work sections has an upstanding work conditions. This condition might obtain common afflict able professional disease such as asthma, varicose veins and laboratory condition may obtain coronary disease, hepatopathy, biliousness, pulmonary, bronchitis and ophthalmic, also it is possible to take effect temporal work abilities losing or to become disabled. In that manner, not delivering full set of labor safety accessories and work uniforms or not considering regular application has more probability to be afflicted by an accident. All these are impacts on mine operation and socioeconomic.
<b>Impact source</b>	Inside and outside dustiness, sounds and vibration from vehicle and equipment, accident and damage, workplace hygiene measures (temperature, warm, room air damp, light, noise, vibration, chemical substances evaporation, stink and toxic gas) lower than standard, norm and machine, equipment damage/accident, electricity break/trouble, delayed water and food supply.
<b>Objects to be impacted</b>	Employees
<b>Standard permissible level</b>	-MNS4585:1998. Air quality standard. General requirements. -MNS5002:2000. Noise. Labor safety and hygiene, noise norms and safety requirements. -MNS5003:2000. Noise-labor safety, hygiene. Noise measurement. -MNS0012-013:1991. Workplace air, workplace air zone. -MNS0012-0131:1991. Workplace air, micro environment measurement method -MNS0017-5.1.21:92.Vehicle noise, permissible level, measurement. -MNS0012-0105:94. Vibration safety general requirements -Blanket rule of blasting safety 1992 -MNS4990:2000. Workplace. Hygiene requirements -MNS4991:2000. Requirement for air toxic concentration measurement method
<b>Monitoring and</b>	Permit lateral institutions measure and control of workplace hygienic conditions, employees be

<b>observation requirements</b>	involved medical examination and prevent from disability to work temporarily or professional disease and provide employees with work clothes, labor safety accessories (muzzle, earmuffs, glasses and helmet)
<b>Mitigation of environmental impact and budget</b>	-Provide all employees with labor safety clothes and accessories. (budget will be included in mining internal planning) -Training employees for developing measures against potential accidents and labor safety, planning for emergency procedure during an accident and relating for clarification to the seasonable situations. (budget will be included in mining internal planning) -Workplace air, temperature and noise measurement, provide milk for employees norm (budget will be included in mining internal planning) -Employees medical examination once per year by professional doctor. (65 people 30'000 tug 5 years = 9'750'000 tug) <b>Total budget: 9'750'000 tug</b> (budget will be included in annual environmental protection plan)
<b>Regulation documents to be compliance</b>	Law on labor, labor safety and hygiene
<b>5. <u>Management and organization</u></b>	
<b>Implementation and budget</b>	-Develop procedures for implementing environmental management and institutional methods. (Budget will be included mining internal plan) -Report implemented annual environmental protection plan to MNET and deliver local administration of Selenge aimag. (Budget will be included mining internal plan) -Report “chemical toxic or hazardous substance storage, transport, handling, and destruction report” order by MNE, SSIA. (Budget will be included mining internal plan) -Develop short or long-term training, advertising program, protecting and preventing environmental, industrial accident, fire or flood accident, immediate undertaking actions and collaborate with professional entities. (2 times 200'000 tugrug 5 years = 2'000'000 tugrug) <b>Total budget: 2'000'000 tug</b> (budget will be included in annual environmental protection plan)
<b>Environmental protection plan estimated cost (predictive)</b>	
<b>144'516'160 tugrug</b>	

## **Section 7. Environmental Monitoring Program**

Boroo ore mining facility expansion for “oxidizing sulfide bearing ore flotation to cyanide by BIOX® technology project” construction and project activity of DEIA and EPP report reflects about mitigation of potential/ main impacts and defining challenges caused from project activity in that area, inevitable measurements for control, its definitions, schedule, regulating standard, method, budgets are implemented to environmental monitoring program (EMP). EMP is a basic document of environmental, socioeconomic value protection, its mitigation of impact implementation. Developing environmental monitoring program, which made on previous mining placement of current Boroo plant area and analyze its result and developing EPP is to prevent, protect environmental and socioeconomic possible impact may become more accurate to identify. EMP annual renovation may do on related year’s beginning and approved by MNE and implementation report to MNE on end of the year.

**Figure 27. Environmental monitoring program**

<b>1. Outdoor and indoor air pollution</b>	
<b>Required monitoring parameters</b>	-Dust ( $_{10}$ , PSM, PM <sub>25</sub> ) -Indoor and outdoor noise, vibration -Workplace hygienic measurements (dust, noise, lights, damp, physical pollution level) -Pollution point sources (SO <sub>2</sub> , NO <sub>2</sub> , CO)
<b>Standard and method</b>	MNS3113:1981. General requirements for atmosphere pollution measurement method’s MNS0017-2-3-16:1988. Atmosphere-Urban, urban settlement air pollution analyze MNS3384:1982. Atmosphere-Air sampling analyzes MNS3113:1981. General requirements for air pollution measurement MNS5061:2001. Carbon monoxide-CO <sub>2</sub> content definition method MNS0012-014:1991. Workplace air quality-micro environment measurement method MNS0012-1-015:1987. Noise-Workplace noise measurement method MNS0017.2.5.12:8988. Sulfuric gases-SO <sub>2</sub> tetrachloromercurate (TCM) measurement method MNS0017.2.5.11-1998. Nitrogen dioxide NO <sub>2</sub> testing Griss-Ilovsky method
<b>monitoring location</b>	-Plant (Outside, inside) -point source
<b>Timeline and frequency</b>	During constructing operation, 4 times a year on point sources During industry activity, 4 times a year (April, June, October, November, on 2 points)
<b>Current monitoring</b>	Boroo mine dust monitoring has been implemented since 2005 and atmosphere measurement every week in and out of mining selected points. Dust measure of average 500 mg/m <sup>3</sup> per 24 hour and average 100 mg/m <sup>3</sup> per year of air quality standard consideration have been clearly marked in guidelines developed by the World bank.
<b>Cost</b>	<b>7’200’000 tugrug</b>
<b>2. Soil pollution</b>	
<b>Required monitoring parameters</b>	-Macro and micro elements in soil -Petroleum product -Heavy metal ( b, As, Zn and other) -Agro-chemical parameters ( , humus, generating base and other)
<b>Standard and method</b>	-MNS3985-87 Soil. Index type of sanitary position -MNS3310-91 Soil. Agrochemical parameter testing -MNS2305-94 Order to accept, packing, transport, keeping -MNS(ISO)4814:1999. Chemical analyses by flame atomic absorption
<b>Monitoring location</b>	-Waste dam’s left side - Waste dam’s right side -Control point



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	-Fuel storage
<b>Timeline and frequency</b>	2 times a year at 5 points
<b>Current monitoring</b>	Sample is taken as monitoring program at selected 21 points since 2005. Monitoring result meets MNS5850:2000 standard and Boroo mining operation have not caused soil pollution.
<b>Cost</b>	<b>20'000'000 tugriks</b>
<b>3. Water pollution</b>	
<b>Required monitoring parameters</b>	-Underground water quality basic parameters -Heavy metals -Bacteriological test result
<b>Standard and method</b>	-MNS0900:1992 drinking water-drinking water monitoring -MNS3935:1986 Drinking water- common requirement for field test -MNS3936:1986 Drinking water and industrial use water. Field test method -MNS4432:1997 Drinking water- Determination method of dry residues -MNS3934:1986 Drinking and industrial use water- chemical analyses-taking sample, storage, transportation -MNS5667-10:2001 Water quality-Taking sample, part 2. Taking sample from waste water -MNS5667-2:2001 Water quality-Taking sample, part 2. Sampling method -MNS4867:1999 Water quality-Taking sample, part 3. Transportation and storage of collected sample -MNS(ISO) 5667-6:2001 Water quality-Taking sample, part 6. Taking sample from underground water -MNS5032:2001 water quality. Using Roentgen Fluorescence Analysis determine heavy metal concentration
<b>Monitoring location</b>	-Tailing dam facility -Wells
<b>Timeline and frequency</b>	-household water (every month) -Underground water (every month)
<b>Current monitoring</b>	Sampling procedure has taken from underground water, surface water and waste water at 25 points since 1999. In addition, new 4 bore hole installed to preventing seepage of TMF and HLF waste water and started control over underground water, soil from August of 2009.
<b>Cost</b>	<b>90'000'000 tugrug</b>
<b>4. Health control</b>	
<b>Required monitoring parameters</b>	- Medical examination condition before job -Medical examination-in progress -Workplace condition (air, light, dust, humidity, smell, temperature, noise, and other)
<b>Standard and method</b>	Workplace condition, health, labor condition and safety handling Mongolian standards
<b>Monitoring location</b>	-All work places
<b>Timeline and frequency</b>	Employees medical examination yearly, alternately control over workplace hygiene condition, whether or not meets the standard to be monitored, provide result by SSIA 1 time per 2 years and SIA of Selenge province 1 time per 2 years
<b>Current monitoring</b>	Constant medical examination covered employees. Provided protection accessories which helmet, glass and bright waistcoat for each employees and guests.
<b>Cost</b>	<b>9'750'000 tugrug</b>
<b>Environmental monitoring program budget (predictive)</b>	
<b>126'950'000 tugrug</b>	

Required total budget for project's environmental monitoring program, its distribution is included environmental protection plan.



## Section 8. Legal regulation

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### 8.1. Environmental laws

There are a number of environmental laws related to the expansion and usage of new bio-oxidizing industry in Boroo ore mining. Mongolian environmental management law and regulations are enacted and renewed a lot since 1994. Mongolia has enacted over 30 laws, of which relating to “environmental protection”(1995, 2005), “law on detailed environmental impact assessment ” (1998, 2002). Also most of approximately 150 additional standards are displayed relating to general issues, instructions and methodical standards. Mongolia’s environmental legislation has a five-tier hierarchical structure:

1. The Constitution, international treaties
2. General environmental law
3. The Law on Environmental Impact Assessment
4. Laws relating to natural resources
5. Fee-related laws on natural resources

Law of EIA displayed an act that broad range comprehensives and whether or not require detailed environmental assessment is determined from the result of general environmental impact assessment as an international standard. MNE (ministry of nature, environment and tourism) or local governmental organizations shall review and make decisions on projects GEIA, detailed environmental impact assessment report and summaries depend on their type, capacity and size over the project. The rest of a legislations relating to organize environmental management area zone and natural resource. The brief inevitable partisanship over environmental legislations displayed in this section.

#### Law on environmental protection:

This law contains 39 articles and chapters that general provisions, environmental assessment, environmental database, research, powers of state organizations on environmental protection, general measures on environmental protection, use and restoration of natural resources, environmental monitoring, miscellaneous. This law enacted on March 1995 and serviced on June 1995. Purpose of this law is to regulate relations between the State, citizens, business entities, and organizations in order to guarantee the human right to live in a healthy and safe environment, an ecologically balanced social and economic development, the protection of the environment for present

and future generations, the proper use of natural resources and the restoration of available resources.

*Law on Environmental Impact Assessment:*

Mongolian legislation on EIA is enacted on January 1998. In this legislation, there are two classes that general and detailed EIA and also displayed Environmental Protection Plan and Environmental Monitoring Program and expertise. Unmanageable project under environmental impact assessment caused or has caused massive damage to the health of the population or the environment, massive use of natural resource, impacts originated on thus project and required inevitable additional monitoring the assessment shall be subjected and reviewed, directed to the detailed environmental impact assessment by MNE. In legislation, project implementer shall work under the purpose of providing accomplishment of their process, resume monitoring and summary of environmental impact assessment, recommendation.

*The minerals law:*

This law is to regulate relation within the territory of Mongolia with respect to reconnaissance and mining of minerals and protection of exploration areas and areas surrounding mining tenement. Mineral related legislation consists of the Constitution of Mongolia, The Law on Land, The Law on Subsoil, Law on Environmental Protection, The national Security Law, this law, and other relevant legislative acts. Detailed descriptions provided in this project previous sections about special license holder duty by the law of article 39.1.2 “the environment impact assessment shall identify the possible adverse environmental impacts from a proposed mining operations regarding public health and environment and shall include preventive measures that avoid and minimize such adverse impacts.”

*The law on subsoil:*

This law contains 60 articles and enacted on November 1988, serviced since 1999, to regulate relations concerning the use and protection of subsoil in the interests of present and future generations. In article 29: “basic requirements on preparation of drawings of constructions and structures to be built underground for purposes other than mining or processing of mineral resources:

Drawings of constructions and structures to be built underground for purposes other than mining or processing of mineral resources should meet the following requirements, in addition to those specified in paragraph 7 of Article 28 of this law:

- 1) To use technology that enables full and complete extraction of components whose production is meaningful out of the mined raw materials;
- 2) To fully use the overburden;
- 3) To record, protect and store the industrial waste that contains components whose production is meaningful but which are not being used.

*The law on land:*

This law contains 64 articles and 7 chapters of the unified land territory of Mongolia and its basic classification, the powers of government authorities and local self-governing organizations regarding land matters, land management, land cadaster, and unified land territory report, giving land for possession or efficient and rational use of land and land protection, miscellaneous. This law enacted on April 2002 and serviced since January 2003.

The prior environmental law pursued other than beyond:

1. Law on natural plants: enacted 1995
2. Law on forest: enacted 1995
3. Law on hunting: enacted 1995
4. Law on hazardous and toxic chemicals: enacted 1995
5. Law on fees for the use of water and mineral water: enacted 1995
6. Law on land fees: enacted 1997
7. Law on sanitation: enacted 1998
8. Law on the income imposition on environmental protection and natural resource recovery from payment of fees for use of natural resource: enacted 2000
9. Law on household and industrial waste: enacted 2003
10. Law on water: enacted 2004
11. Law on plant protection: enacted 2007
12. Law on life modified organism: enacted 2007
13. Law on labor safety, health and safety: enacted 2008
14. Law on Cartagena protocol on bio-safety about convention of biological diversity: associated 2002
15. Other related laws and legislations

## **8.2. Standard and norm and normative**

Prior pursue principles for bio-oxidizing construction work and further progressing environmental standard, norm and normative. In construction process, workers health and safety shall guarantee when following normative and documents pursued.

- BNbD 12-03-04 Occupational safety in construction part 1 general safety requirements
- BNbD 40-02-06 Water supply. Outside network and facilities
- BNbD 40-01-06 Wastewater. Outside network and facilities
- BNbD 40-05-98 Water supply in construction, wastewater
- BNbd 41-03-99 Equipment and pipe heat insulation
- SNIIP. 12-01-03 Construction industry organization
- BNbD. 3.05.01-88 Internal plumber system
- BNbD.3.05.04-90 Water supply. Efficient water. Outside network, its construction
- GOST2930-62 Instruments are measuring, types and the signs
- GOST18599-86 Polyethylene pipes with pressure, technical specifications
- GOST29324-92(ISO1161/1-78) Thermoplastic pipes for the transportation of the liquids and others.

Following standard and requirements shall be guided for occupation for further permanent rules:

- MNS0012-4-006:85. Air condition system. General requirement
- MNS0012-013:82. Work area atmosphere. Hygiene requirement
- MNS0012-2-001:61. Industrial facilities. General safety requirement
- MNS0012-3-001:81. Production process. General safety requirement
- MNS0012-3-003:83. Load and shipment. General safety requirement
- MNS0012-1-018:88. XXCC. Electric safety. Highest limit of footing voltage and electric current
- MNS4234:94. XXCC. Protection against fire. Technical requirements
- MNS4284:95. XXCC. Protection against fire. General classification

Standard requirements that have to be guided during construction stages and further operation are described in previous section of this report.

## **Conclusion**

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This Boroo expansion, the project of BIOX® plant to process oxidizing sulfide ore with flotation and cyanidation, comprehensively identifies and assesses potential impacts, their severity of construction and operation stages on environment, ecosystem components, regional socio-economy, and on social issues of mine workforce.

During project implementation, it is required to be tightly guided by Mongolian laws, guidelines, legislations and company's internal order when use bacteria and reagents for sulfide ore oxidation. Therefore, there might be occurred impacts on land surface, soil, flora, fauna, ground, and surface water, particularly human health caused people irresponsibleness and unexpected natural disaster.

Protection Plan and Environmental Monitoring Plan, confirmed by MNET will be implemented annually from the commencement of construction and operation stages of the project. Potential impacts on environmental components caused by project operation especially from underground water usage that might generate impacts on ground vegetation, fauna and flora should be investigated continually and should be reported to the related administration organizations.

It assumed that preplanned and progressive technical and biological reclamation under prior studies could be possible to mitigate the main impacts. Proposed both technical and biological reclamation procedures should be implemented under Mongolian standard requirements and do field investigation for each area. If it is found bare area not planted successfully, do reclamation again in spring or autumn. It could not avoid any natural disaster or industrial accident, it is required to consider precautionary measures in the design phases of plant and other structures.

## References

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1. “Climate and geo-physical parameters for construction”, G.Namkhajantsan, UB 1994 , 149p
2. “Ecology-Sustainable development” vol 1, UB 1997
3. “Ecology-Sustainable development” vol 2, UB 1998
4. “Technical and Economic baseline study of Boroo gold mine”, BGC Co.,Ltd, 2000
5. “DEIA of Boroo gold mine”, JEMR Co.,Ltd, 2000
6. “Climate issues of continent”, G.Namkhajantsan, UB 2001
7. “DEIA of Boroo gold mine”, Gazar eco Co.,Ltd, 2003
8. “DEIA addendum report of BGC TMF reconstruction”, Gazar eco Co.,Ltd, 2004
9. “Mongolia mining sector: managing the future” WB, June 2004
10. “DEIA addendum report of Boroo gold mine”, Gazar eco Co.,Ltd, 2005
11. “Technical and Economical baseline study of Gatsuurt gold mine”, Centerra Gold Mongolia, 2006
12. “Summary of environmental sectors guidelines and regulations”, MNET, WB, 2006
13. “EPP and EMP of Boroo gold mine, 2008”, BG Co.,Ltd, 2007
14. “DEIA of Heap leaching project”, JEMR Co.,Ltd, Usnii erchim Co.,Ltd, Risk assessment center NGO, Tsakhim zurag group, 2007
15. “EPP report of Boroo gold mine”, BG Co.,Ltd, 2007
16. “Guidelines, formal claims and conclusion of SSIA and MNET”, BG Co.,Ltd, 2005-2008
17. “Climatic figure in National atlas of Mongolia”, G.Namtsajantsan, UB, 2008
18. “Investigation on biologically rehabilitated areas by BGC between 2003 and 2008”, Darkhan nogoon aral Co.,Ltd, 2008
19. “Directory of climatic, surface water and nature of Selenge aimag”, Regzedmaa and others, SB, 2008
20. “Report of TMF closure of Boroo gold mine”, Usnii erchim Co.,Ltd, 2009
21. “Boroo gold mine closure plan”, BG Co.,Ltd,, 2009
22. “Cost estimation of Boroo gold mine closure and reclamation plan”, AMC Co.,Ltd, 2009
23. “The state guarantee report of Land properties and Quality on mining licensed areas acquired by “Boroo Gold” Company in Bayangol and Mandal soums of Selenge aimag”, Geotsenoz Co.,Ltd, 2009
24. “DEIA of Boroo gold mine” BGC, 2009
25. “Guideline of ecological and economical evaluation on impacted areas by mining exploitation and operation”, MNET, Association of environmental impact assessors NGO
26. “Industrial safety and setting its control”. Sh.Boldbaatar, U.Lkhagva, UNDP, UB 2004
27. “Biological resource and wealth conservation and biosafety” WB, MNET, Insitution of biotechnology, UB 2006
28. “Environmental management-ISO14000”, P.Baigalmaa, granted by Natural reform project, UB 2006
29. “Gatsuurt Support Facilities Draft Detailed Environmental Impact Assessment”, Foth Infrastructure & Environment LLC, April 2010



30. “Methodical guideline of environmental impact assessment” MNET, Trust fund of Netherland government, Association of environmental impact assessors, UB 2010
31. “Guideline for technical and biological reclamation on disturbed areas by mining operation”, MNET, Trust fund of Netherland government, Eco sphere Co.,Ltd, S I C Co.,Ltd, UB 2010
32. “Summary of BIOX process”, Foth Infrastructure & Environment LLC, Jan 2010
33. “Design Criteria”, SNC Lavalin, Feb 2010
34. “Convention on biological diversity including Cartagena protocol on biosafety”
35. Laboratory results of waste rocks, BGC, 2006-2009
36. Laboratory results of soil, BGC, 2006-2009
37. Laboratory results of gas, BGC, 2006-2009
38. Laboratory results of dust, BGC, 2006-2009
39. Laboratory results of water levels in monitoring wells, BGC, 2006-2009