

Evaluating the Current State of Wastewater Quality of Nui Phao Mining Company Ltd. – Dai Tu District, In Thai Nguyen Province, Vietnam

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ABSTRACT

Background: Thai Nguyen is a province in the Northeast region, also a major socio-economic center of the Northeast region, as well as the Northern Midlands and Mountains. It has significant advantages in developing metallurgical and mining industries due to plentiful natural resources. The province has attracted many businesses to invest in the mining field, including Nui Phao Mining Company Ltd., which has been licensed by Thai Nguyen Provincial People's Committee since 2004.

Since its inception, the Company has created jobs for thousands of local people, organized social activities, and developed sustainably at local. However, mining and processing activities also have certain effects on the surrounding environment, including the water environment. In particular, issues related to wastewater are always sensitive because of negative effects if not taken seriously. In order to assess the current state of the Company's wastewater quality, it is necessary to take samples and analyze them to make objective conclusions about the actual environmental situation taking place at the mine. From the above fact, the implementation of the topic: "Evaluating the current state of wastewater quality of Nui Phao Mining Company Ltd. – Dai Tu District, Thai Nguyen Province, Vietnam" is needed.

Materials and Methods: Methods of collecting documents and secondary data: Collecting documents and data on natural conditions, exploitation and processing activities, environmental state, and results of wastewater quality before and after treatment in Environment Department's reports; Researching legal documents and sub-law documents on water environment management. Sample type: Water in the reservoirs of the Project and at the discharge points. Periodic sampling type: Including the participation in sampling and evaluating of Department staff and the Institute of Environmental Science and Public Health under the supervision of government agencies such as representatives of the Department of Natural Resources and Environment and representatives of the District. Sample analysis methods: Analysis, chromatography, spectroscopy, electrochemistry. Theoretical analytical methods: Analyzing and studying different sources of documents and theories and break them down into parts to learn more about the subject. Methods of investigation and field survey: Conducting observations of reservoirs and discharge points, assessing observable sensory indicators in the area of Nui Phao Mining Company Ltd., visiting the process and production, recording, photographing, and collecting necessary information to make correct comments on the current situation. Methods of synthesis, comparison, and data processing: Synthesizing collected data to compare with Vietnamese Standards such as QCVN 40:2011/BTNMT, QCVN 08:2008/BTNMT, TCVN 6980:2011, Decision 3733/BYT to draw conclusions on the wastewater quality's current state of the Company.

Results: Wastewater is collected through a system of wastewater collection and storage facilities, then strictly treated at the Wastewater Treatment Plant. Wastewater quality shows that the water quality parameters are within the allowable limits of License 927/GP-BTNMT. The Company has closely supervised the operation of wastewater collection and treatment item works, without any problems in wastewater treatment and discharge. Although the quality of wastewater is up to standard, the issues of receiving downstream are beyond the Company's ability and responsibility to handle. The process of washing driftwood from decommissioned old waste dumps as well as existing manual mining activities, agricultural production activities, and daily activities of local people have caused downstream pollution in two streams before Nui Phao mine was operated. Besides, geochemical characteristics also contribute to the increase of some heavy metal indicators in specific weather cases. Wastewater is treated to meet column B of QCVN 40:2011/BTNMT before being discharged into the environment, so it does not have much impact on the aquatic ecosystems of Thuy Tinh stream and Cat stream.

Conclusion: The Company's wastewater quality has been controlled well, so in addition to the plans made to maintain control and prepare for incident response, recommend the Company will keep researching treatments so that wastewater can be used for domestic purposes.

Abbreviations: APT: Ammonium ParaTungstate; DP2: Discharge Point No.2; DP3: Discharge Point No.3; EIA: Environmental Impact Assessment; MONRE: Ministry of Natural Resources and Environment; NPMC: Nui Phao Mining Company Limited; NWRD: Northern Waste Rock Dump; OTC: Oxide Tailings Cell; PTP: Pit-Transferring Pond; PSRP: Plant Site Run-off Water Pond; QCVN: Vietnamese National Technical Regulation; STC: Sulphide Tailings Cell; TSS: Total Suspended Solids;TCVN: Vietnamese Standards; TSF: Tailings Storage Facilities; WWTP: Wastewater Treatment Plant; WWTP-SP: Wastewater Treatment Plant – Sediment Pond; WDSP: Waste Dump Sediment Pond.

Key Words: Evaluating,affected,discharge,wastewater quality, receiving source, mining, Nui Phao, Thai Nguyen.

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I. Introduction

In recent years, Vietnam has created obvious steps for the development process, overcome the impact of global recession, and maintained a stable annual economic growth rate along with the trend of innovation and integration along with the process of industrialization and modernization of the country. However, Vietnam is still facing many challenges, in which environmental pollution is one of the most sensitive and frustrating issues because of its unpredictable consequences. Besides air pollution, soil pollution, and noise pollution, water pollution has been the leading threat to human life.

Water pollution originates from many factors such as fertilizers and pesticides of agricultural production; wastewater from food processing; chemical wastes from industries; however, the most dangerous threats are heavy metals and toxic substances that are accumulated during industrial production. They can cause immunosuppression, reproductive failure or acute poisoning, and even death to humans and animals. Therefore, the stage of wastewater treatment in the production process should be focused on and have suitable methods for each type of wastewater.²

Thai Nguyen is located in the Northeast region, also its major socio-economic center, as well as both the Northern Midlands and Mountains with abundant natural resources. Especially, it has taken the lead in the metallurgical and mining industries. Not only that, Thai Nguyen has the second-largest coal reserve in Vietnam, including non-ferrous metals such as tin, lead, zinc, tungsten, gold, copper, nickel, etc. as well. In particular, Nui Phao mine in Dai Tu district is estimated by specialized experts that the mine has the second-largest tungsten reserve in the world after China. The mine also has the world's largest fluorine reserve of about 19.2 million tons, and a significant reserve of bismuth, copper, gold and some other metals. Of those businesses in having got attracted to invest in these fields, Nui Phao Mining Company Ltd. has been authorized by Thai Nguyen Provincial People's Committee since 2004.

Over 15 years of development, the project's activities have greatly contributed to the development of Nui Phao Mining Company Ltd. in particular and the socio-economic development of Thai Nguyen province in general. However, mining and processing activities also have certain effects on the surrounding environment, including the water environment. In order to evaluate the current state of the Company's wastewater quality, it is necessary to take samples and analyze them to make objective conclusions about the actual environmental situation taking place at the mine. From the above fact, it is essential to carry out the topic: "Evaluating the current state of wastewater quality of Nui Phao Mining Company Ltd. – Dai Tu District, Thai Nguyen Province, Vietnam". The objective is to evaluate the Company's wastewater quality in the project area and the receiving sources around 2019 and the first quarter of 2020. Thenceforth, we can propose measures to improve the water environment quality in the project area.

II. Material and Methods

Study Design:Secondary data and general information collection; Wastewater sampling and analysis; Field investigation and survey.

Study Location:Project area and wastewater receiving sources of Nui Phao Mining Company Ltd. – Dai Tu district, Thai Nguyen, Vietnam.

Study Duration:From the beginning of January, 2020 to the end of June, 2020.

Sample size:Wastewater sample.

Subject:Wastewater of Nui Phao Mining Company Ltd.

Procedure methodology:Summarizing collected data to compare with Vietnamese Standards such as QCVN 40:2011/BTNMT, QCVN 08:2008/BTNMT, TCVN 6980:2011, Decision 3733/BYT to make conclusion on the current status of wastewater quality of the Company.

Statistical analysis:The data is processed and statistical on the computer by Excel and Word.

III. Result

1. The current state of water use, wastewater and wastewater treatment process:

1.1. The Company's water balance diagram

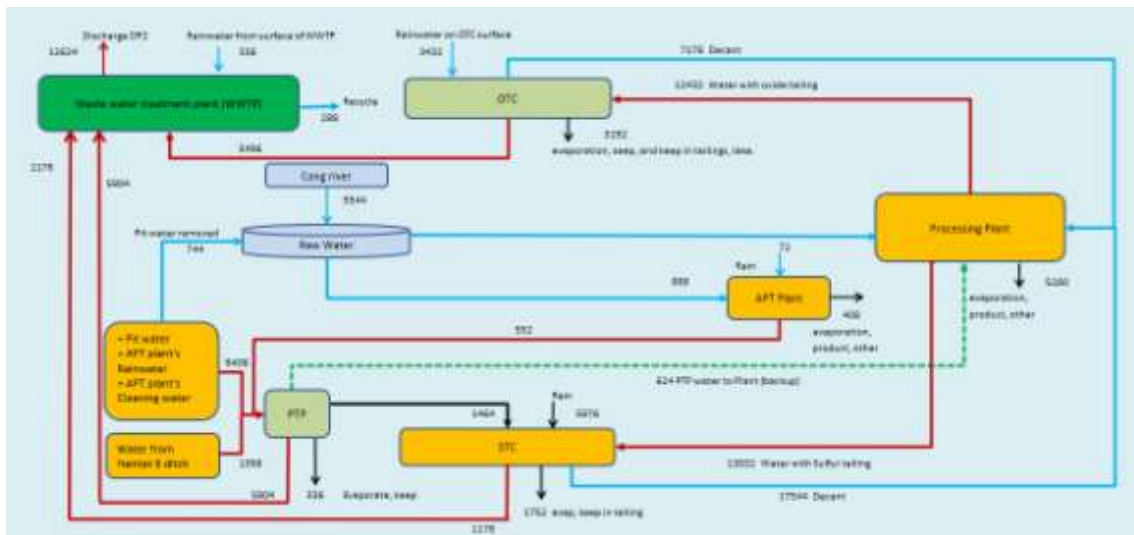


Figure 1: Company's water balance diagram.

The tailings from the processing plants are pumped to TSF including 2 separate storage cells (OTC and STC). Water from these two cells will be pumped back to the processing plant to serve production to optimize water use, a part of the non-circulating water will be pumped to WWTP for treatment and then discharged into the environment. The water from the open pit, the ore storage area, the coarse crushing area, and the APT plant will be directed to PTP. Part of the water from PTP is also pumped back to the plant for reuse in some stages, the rest is pumped to WWTP or STC.

Wastewater from mining and processing activities is stored in reservoirs of the mine, most of the water will be recycled and reused for processing activities, and the excess water will be pumped to WWTP, including wastewater from OTC, STC, and PTP. In addition to circulating water from PTP, OTC, and STC, additional water sources for the processing plant's operations also include water extracted from Cong River and underground water from drilled wells. Surface rainwater around TSF-SP is collected and led to TSF-SP before flowing to Thuy Tinh stream through DP2. Rainwater overflowing NWRD is settled and treated in WDSF before being discharged into the environment at DP3.

1.2. Features of wastewater sources

Mining and processing activities at Nui Phao polymetallic mine generate 3 main types of wastewater including domestic wastewater, industrial wastewater and overflowing rainwater. As follows:

- **Domestic wastewater:** Generally having a high concentration of TSS, organic matter content (BOD₅, COD) and nutrients (N, P) and many microorganisms, in which:

+ Domestic wastewater in the area of the refined ore processing plant and the office is collected and treated at the domestic wastewater treatment station and then discharged into PSRP adjacent to the refined ore processing plant.

+ Domestic wastewater also generated at the APT plant, with the low flow, is treated through septic tanks and then discharged into PSRP.

- **Industrial wastewater:** Including wastewater from mining and processing (at two processing plants) with high TSS content, low pH value and heavy metal content as Mn, Fe, As higher than column B of QCVN 40:2011/BTMNT:

+ Wastewater from mining: Mining at the pit is carried out by the open-pit method, so the wastewater from the mining process is drained water, including underground water flowing in the pit and surface water taken from by rainwater falling on the catching area of the pit.

+ Wastewater from processing: Including wastewater from two plants. These two waste streams will be collected and discharged to TSF area (including STC and OTC). In this area, the wastewater after settling will be pumped and circulated to serve the production.

- **Overflowing rainwater:** Divided into 3 separated areas at the mine, including rainwater overflowing the refined ore processing plant, the APT plant and NWRD:

+ Rainwater overflowing the refined ore processing plant area: Including rainwater overflowing the office,

the plant and the crushing station area. Rainwater overflowing the premises of the processing plant and the office is drained through the system of manholes and concrete open ditches along the internal roads and rainwater of the rough crushing station follows the collection ditch to PSRP. Because it washes soil, rock, and surface impurities away, TSS, Fe, and Mn concentrations are high, parameter F sometimes is higher than QCVN 40:2011/BTNMT column B, while pH is often lower than the output limit.

+ Rainwater overflowing the APT plant's area: There is no risk of pollution, rainwater is collected to PTP.

+ Rainwater overflowing NWRD: This source does not have the acid-generating capacity, so it will flow along the slope of the terrain and the ditch system constructed in NWRD and then be collected into WDSP. This overflowing rainwater is divided into 2 types of flows: The first type is rainwater which runs off the surface only when it rains and the flow is unstable, the typical component is TSS due to moving soil and rock; The second type is rainwater percolating into the bottom of NWRD: Collected by the underground-pipe system and led to the filter field in the first compartment of WDSP, the quality of this flow usually has a characteristic composition of low pH. Fe and Mn contents are higher than the allowable limit. This overflowing rainwater is directed to WDSP for sedimentation. Then the water settles into May pond and then discharges to Cat stream (through DP3).

1.3. Process and technology of wastewater treatment of the Company

No.	Work items	General information	Function	Storage time (hours)
I Biological treatment stage				
1	Air tanks	<ul style="list-style-type: none"> - Volume: 6,000m³ (50m x 60m x 2m); - The excavation tank is lined with HDPE; - Blowing-air disc system at the bottom with 5 air blowers; - Input: Pipelines from OTC, STC, and PSRP. 	Regulate flow, mix wastewater, change pH to a neutral state to support aerobic treatment.	12
2	MBBR compartments no. 1 and 2	<ul style="list-style-type: none"> - Each compartment has a volume of 1,500m³ (25m x 30m x 2m); - Digging tank, HDPE waterproof lining; - White MBBR substrate, made from virgin HDPE plastic, size 25mm*10mm; - Air disc system at the bottom from 5 air blowers; - Add Urea, H₃PO₄, sugar through the metering pump; - Automatic measurement of pH, DO, ORP; - Recirculating sludge return from biological settling tank. 	Add nutrients support aerobic microorganisms to survive and grow.	12
3	Aerobic biological compartments no. 1 and 2	<ul style="list-style-type: none"> - Each compartment has a volume of 1,500m³ (25m x 30m x 2m); - HDPE waterproofing tank; - Air disc system at the bottom from 5 air blowers with a capacity of 75kW x 10Nm³/min; - System of adding lime by metering pump; - Automatic pH measurement; - Arrange the terminal pump pit, install 3 sewage pumps with capacity of 40kW x 300m³/h. 	Continue to treat with aerobic microorganisms after the MBBR compartment.	12
4	Reactor tank	<ul style="list-style-type: none"> - Volume 15m³ (3m x 4m x 1.25m); - Steel and cylindrical tank; - Add PAC deposition aid. 	Add PAC to support biological sludge settling.	
5	Biological settling tank	<ul style="list-style-type: none"> - The volume: 1,000m³; - Steel and cylindrical tank; - The tank has 4 mud return lines (2 ways to 2 MBBR compartments, 2 ways to mud drying yard); - The water after settling flows to the physico-chemical treatment stage; - There is a way to add lime chloride into the water stream after settling to the physico-chemical treatment stage to remove the remaining biological products in the water. 	Settle then separate sludge from the wastewater stream, and support the physico-chemical treatment process.	2
6	Mud drying yard (Mud filter tank)	<ul style="list-style-type: none"> - The volume: 30m³; - The concrete tank having box shape; - Arrange gravel and sand filter layers at the bottom to separate water and mud. 	Separate the water, and dry the mud.	
II Physicochemical treatment stage				
7	System of reactor tanks	<ul style="list-style-type: none"> - Each tank has a volume of 80m³ (4.5m x 4.5m x 3.95m); - Each tank has a stirrer with a capacity of 7.5kW; - Adding-lime system to pump quantitatively into tanks; - PAC replenishment system by metering pump; - Automatic pH measuring device in tanks no. 2, 4, and 6; 	Metal precipitation and flocculation (Input wastewater is characterized by parameters Mn, F).	0,3

8	Wastewater treatment pond (WWTP – SP)	<ul style="list-style-type: none"> - Input: water from biological settling tank, PTP water. - The volume: 12,000m³ (area: 6,000m²) - HDPE waterproofing pond; - Divided into 2 concrete partitions; - At the end of the pond, there is a system of concrete drainage ditches leading to TSF-SP - the settling pond to store tailings; - Install 01 automatic wastewater monitoring station on the drainage ditch. 	Settle precipitated solids from the wastewater stream.	8
III Cleaning stage				
9	TSF-SP settling pond	<ul style="list-style-type: none"> - The volume: 41.500m³; - Dug tank, arranged additional baffles, aeration turbines, biological filter yard with plants. 	Settle the remaining. Replenish oxygen, and clean it with plants.	27,6
10	Biological filter yard	<ul style="list-style-type: none"> - The area about 2,500m², the volume about 2,500m³; - Arrange floating plant rafts; - At the end of the yard, install an automatic wastewater monitoring system at the discharge point DP2. 	Deposit sediment and clean with plants.	2

Table 1. Main work items of the wastewater treatment plant.

2. Evaluate the wastewater quality of the Company

Three reservoirs PTP, OTC, and STC have function of receiving and storing wastewater from plants, oxide and sulfide tailings, overflowing rainwater, and surface rain by area. They contain a certain quantity of chemicals, so parameters in wastewater have complicated developments. Therefore, there are almost no aquatic organisms living there.

At WDSP, water hyacinth has been used to support the absorption of heavy metals and organic compounds in the water. Besides water hyacinths, there are aquatic creatures such as snails, fish, and frogs growing in the water. Thanks to the natural settling and filtering mechanism, the water here is up to the mark. However, the turbidity of the pond changes depending on the number of rainy days and the amount of rain during the day.

Before discharging through two points DP2 and DP3, wastewater has undergone treatment and reached standards. When assessing visually, the wastewater is colorless and odorless. Not only that, there is a biological filter field where gold fish, tilapia and carp are grown well in front of DP2. The last compartment of WDSP system before discharging to May pond through DP3 also has aquatic organisms living there.

3. Assessment of wastewater quality in wastewater storage facilities before treatment in the year 2019

3.1. Wastewater quality of WDSP

WDSP system is a place to store wastewater before treatment. It receives overflowing rainwater and leachate from NWRD for storage and sedimentation before flowing to May pond through DP3. The quality of the settling pond water is monitored at the reservoir head position, named SW16B. The quality of rainwater flowing over the surface often has a characteristic composition of TSS due to the movement of soil and rock on the way. Rainwater permeating the bottom of NWRD has a characteristic composition of low pH, high Fe and Mn contents. Besides, in the rainy season (a few months of the year), it will cause parameter TSS to be unexpectedly higher compared it is to the dry season.

The input water of WDSP had a neutral pH that fluctuated unstable from about 5.92 to 8.17; however, it was still within allowable limits. Fe parameter was low, but in June 2019 exceeded the threshold about 5.5 times; Besides, TSS value spiked by 1.3 times while TSS parameter in the remaining months was quite many times lower than the allowable limit. Two parameters Fe and TSS had a similarity in that the value in June skyrocketed compared to the rest of the year. This can be explained by the June rainfall chart, which also spiked similarly because there were heavy rains in the month, with a frequency of 12 rainy days and the rainiest day was 95.4 mm. TSS and Fe content changed suddenly. Mn concentration in the first 4 months was stable and low, but got higher beyond the normative limit and fluctuates unpredictably during the last 8 months of the year from May to December, this concentration was 3-7 times higher than column B of QCVN 40:2011/BTNMT; especially in November 2019, the content was 9.9 times higher than the allowable value; The remaining indexes were all within the limit, even smaller than the allowable limit many times. Thus, although the sampling point was at the beginning of WDSP, with a large reservoir volume, the retention time was enough for natural cleaning processes to take place such as mechanical settling, decomposition, and natural precipitation. This ensures that the water overflowing through the DP3 discharge site always meets the quality standard before flowing into Cat stream.

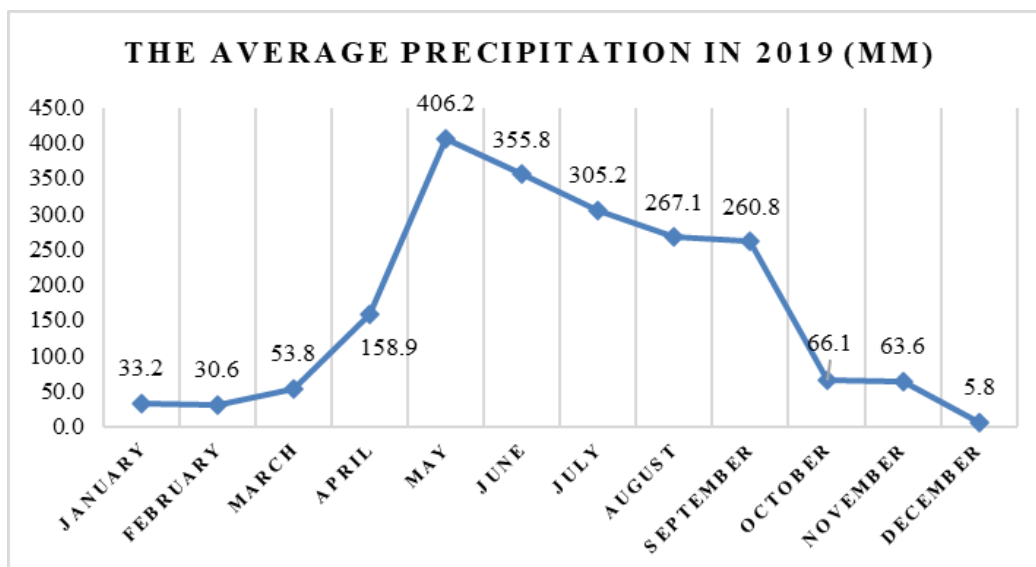


Figure 2. The average precipitation of Nui Phao mine in the year 2019 (mm)

3.2. Wastewater quality of STC in the year 2019

STC – the sulfidetailings cell is a wastewater storage facility before treatment, with the function of receiving sulfide tailings (slurry form) from the processing plant. Meanwhile, a quantity of waste rock containing high sulfide content is also transported together with rainwater collected from STC and water from PTP. After settling at STC, the tailings will be separated and circulated to the processing plant for processing. Part of the water will be pumped to WWTP before being discharged into the environment through DP2, but the water level in the cell is always maintained at a minimum height of 2m, which is to prevent the amount of oxygen from dispersed and contact with the tailings. Therefore, sulfur oxidation will not occur, then reduce the potential for acid and metal release. The quality of wastewater is characterized by parameters of BOD₅, COD, Mn, Fe and F higher than *column B of QCVN 40:2011/BTNMT* at some time points.

Params	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	QCVN 40:2011/BTNMT, Col B
pH	-	7.16	7.16	7.2	6.62	6.88	6.16	6.37	6.53	6.7	7.1	6.53	7	5.5 - 9
Cr ³⁺	mg/l	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	1
Cr ⁶⁺	mg/l	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.1
Fe	mg/l	1.96	4.58	4.92	9.2	2.66	27.6	2.45	9.22	8.39	5.79	4.55	1.67	5
Mn	mg/l	2.34	1.82	1.73	1.48	6.57	5.29	1.96	2.16	1.7	4.99	2.99	1.68	1
As	mg/l	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	0.1
Cd	mg/l	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.1
Cu	mg/l	0.023	<0.012	<0.012	<0.012	<0.012	0.021	0.014	0.012	0.031	0.013	<0.012	<0.012	2
Hg	mg/l	0.008	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.01
Ni	mg/l	<0.03	<0.03	<0.03	<0.03	0.004	0.012	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.5
Pb	mg/l	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	0.5
Zn	mg/l	0.019	0.022	<0.006	<0.006	0.014	0.093	0.009	0.009	0.007	0.016	<0.006	<0.006	3
TSS	mg/l	8	11	95	5	4	138	11	32	28	21	11	9	100
NH ₄ - N	mg/l	<0.03	<0.03	0.13	<0.03	0.27	0.41	<0.03	0.04	0.64	0.82	0.52	0.99	10
Total nitrogen	mg/l	<2	<2	<2	<2	<2	2.34	<2	<2	<2	<2	<2	<2	40
F	mg/l	5.95	6.26	6.42	5.28	0.88	8.03	6.11	7.87	8.29	7.76	6.38	7.33	10
Sulfur	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.5

(S)		2	2	2	2	2	2	2	2	2	2	2	2	
COD	mg/l	95	134	101	131	38	16	82	72	62	69	29	49	150
BOD ₅	mg/l	48	75	59	73	22	10	43	39	29	32	18	30	50

Table 2. Parameters of STC in the year 2019.

According to the data, the input water of STC had pH index that fluctuated evenly in the range of 6 - 7 compared to the upper limit of QCVN, but there was no special change. The concentration of Mn in the whole year was 1 - 3 times higher than the allowable output threshold, with an erratic tendency to rise and fall, but in May and June (the months with the highest concentration) it exceeded 5 - 6.5 times. Fe index for the months of April, August, September, and October exceeded the standard limit by 1.5 - 2 times and that of June was 5.5 times higher. TSS in March and June got higher than it was in the rest of the year, but in June it exceeded the standard by 1.3 times while the rest of the year showed lower many times more than the norm. Although the two parameters Fe and TSS had different happenings, they all had one thing in common – the highest value in June. When studying reports and the monthly precipitation data, it was significant that there was very heavy rain in June 2019, lasting up to 12 rainy days with the rainiest day being 95.4 mm, which could show that this rain partly affected the sudden increase in the concentration of these two parameters because the amount of rain from STC was considerable. COD's concentration was approximated but did not exceed the allowable limit in QCVN 40:2011/BTNMT. The BOD₅ content had quite similar changes to the COD one, but it exceeded the standard limit from February to April. The remaining parameters were within the allowable threshold, even many times smaller.⁴

STC's water quality was quite complicated when analyzing as STC receives water from PTP and the whole area's rainwater. In particular, the parameters depend on the quality of the ore tailings, while this waste stream changes in quality from day to day since factors such as chemical dosage, discharge volume and production schedule change almost continuously.

3.3. Evaluating the wastewater quality after treatment at discharge points in the year 2019

3.3.1. At the discharge point DP2

DP2 receives wastewater after treatment at WWTP to discharge to the environment through Thuy Tinh stream. Under the normal conditions (no rain), wastewater through DP2 is wastewater from both biological and physico-chemical treatment with the maximum flow of 36,000 m³/day. In case of heavy rain and floods leading to an increase in the amount of rainwater on the surface of WWTP, the Company will control the input water sources to ensure that the discharge volume at DP2 does not exceed 36,000 m³/day. Allowable water quality limits of the Company in 2019 applied QCVN 40:2011/BTNMT, value C of column B, with coefficients K_f = 0.9 and K_q = 0.9.

The concentration changes of pH, Fe and TSS parameters were quite stable; Fe content tended to decrease, Mn value fluctuated but did not exceed the allowable threshold; and F⁻, BOD₅, COD had unstable value but still lower than allowable limit many times. Overall, 14 parameters (temperature, color, Cu, Pb, Zn, Cd, Cr³⁺, Cr⁶⁺, Ni, total nitrogen, coliform, total radioactivity α and β) reached column A of QCVN 40:2011/BTNMT. For the rest of 13 parameters (pH, BOD₅, COD, TSS, As, Hg, Mn, Fe, total cyanide, S²⁻, F⁻, NH₄⁺, total phosphorus): The maximum contaminant concentration remained the same according to the Licence 927/GP-BTNMT.

The Company commits to meet QCVN 40:2011/BTNMT, column A in the year 2024.⁴

3.3.2. At the discharge point DP3

DP3 receives overflowing rainwater from NWRD, passing through WDSP and then flowing into the environment through May pond and Cat stream. The collected-water area of NWRD flowing to WDSP has changed according to the Company's development plan. The largest discharge demand at DP3 used to be 86,282 m³/day. The amount of rainwater that flows over DP3 tends to increase in rainy season months and decrease in dry season months and also gets changed according to the annual development of the normal waste-rock storage area. However, DP3 stopped discharging from August 2019 to March 2020 and just started discharging again from April 2020. Therefore, there are no analytical results for that period.⁴

According to the results of wastewater quality analysis in 2019, the water quality parameters were within the allowable limits of QCVN 40:2011/BTNMT, column B with coefficients K_f = 0.9 and K_q = 0.9. The parameters were mostly unstable. The pH value did not have much variation. The concentration of TSS tended to decrease, while the concentration of F⁻ increased. The development of Fe concentration kept going up and down unstably. BOD₅, COD and pH values had a common that in May 2019 reached the highest value in the data of the first 7 months of the year.

This can be explained by the mechanism of WDSP having enough retention time for natural cleaning processes to take place before going through DP3. Thereby ensuring that the water flowing over the discharge point met the standards before flowing into the Cat stream. During the rainy season, the peak was in May with

15 rainy days with a maximum of 185mm, which partly affected the natural cleaning process of the pond, and also affected the parameter values accordingly.

4. Evaluating the Company's wastewater quality in the first quarter of 2020

According to the *License to Discharge Wastewater into Water Sources* (first extended and amended) dated December 12, 2019, No. 3172/GP – BTNMT licensed for Nui Phao Mining Company Ltd. by MONRE, there have been some changes as follows: Periodic monitoring DP2 and DP3 with the frequency of every 3 months and not monitoring at the location of PTP, OTC, STC, and SW16B. Therefore, there was only the monitoring result of DP2 in the first quarter of the year 2020.

According to the results of the wastewater quality analysis in 2020, the water quality parameters were within the allowable limits of the latest Discharge License. This showed the efficiency of each wastewater treatment item in particular and of WWTP in general. Among the basic characteristics, the parameters that approximated the allowable limit were Mn (0.81/1 mg/l), Fe (4.05/5 mg/l), and pH (7.7/9). Parameters such as TSS, COD, and BOD were 4 to 9 times lower than the allowable limit.

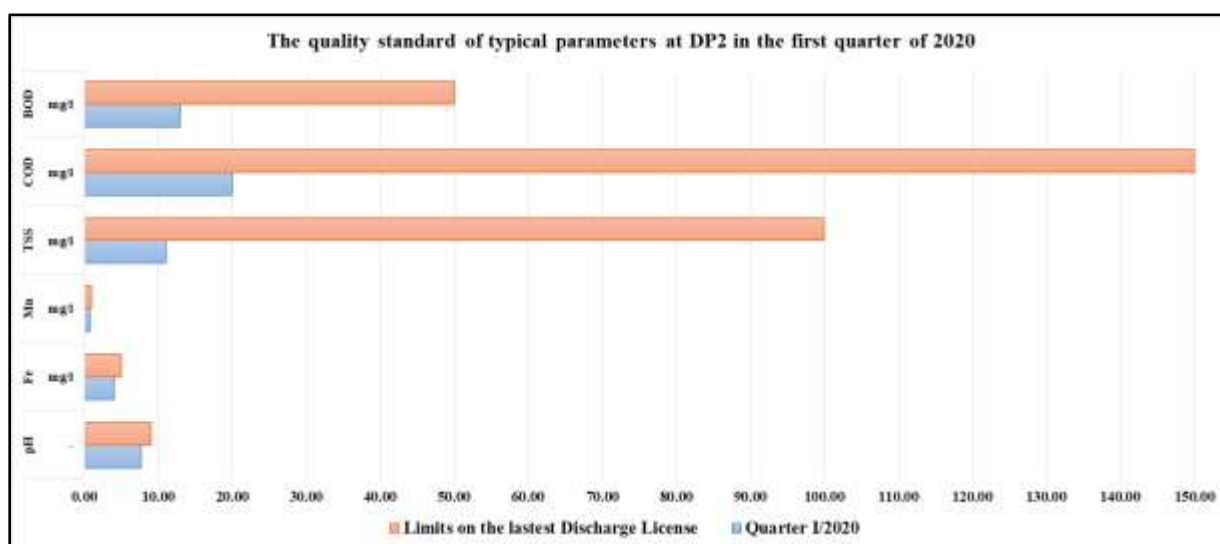


Figure 3. The quality standard of typical parameters at DP2 in Quarter 1 of the year 2020.

5. Evaluating the receiving capacity of the receiving water sources

Assessing the capacity of receiving and carrying wastewater from the water sources such as rivers and streams relies on regulations and methods in MONRE's Circular No. 76/2017/TT-BTNMT dated December 29, 2017. According to the water-quality-target-zoning map issued with Decision No. 1162/QD-UBND of Thai Nguyen Provincial People's Committee dated June 12, 2014, on approval of planning, allocation, and management of surface water resources in Thai Nguyen, the quality targets for receiving wastewater from Nui Phao mine are as follows: (1) Water from Cat stream and Thuy Tinh stream for irrigation purposes (column B1 of QCVN 08- MT:2015/BTNMT); (2) The Company's discharge area does not include sensitive areas such as national parks, conservation areas, and places where species need to be protected.

However, Cat stream and Thuy Tinh stream are also receiving sources of domestic wastewater, agricultural production, and wastewater from manufacturing bases in the area of Dai Tu district including Tan Linh, Phuc Linh, Ha Thuong communes, Cat stream, and Thuy Tinh stream. Surface water has shown polluted signs due to the process of washing driftwood from old mines and landfills that have been discontinued as well as being affected by manual mining activities and existing mines. In addition, agricultural production activities causing livestock wastewater, use of fertilizers and pesticides, and local people's daily activities also significantly affect these streams. The inspection conclusion No. 2065/KL-BTNMT dated April 27, 2017 of MONRE also stated clearly the surface water and groundwater environment in the project area as follows: "During the working time, the inspectorate had carried out taking surface water samples at all locations as well as receiving sources at different time. The results of inspection, survey, and monitoring of the surrounding environment for both surface water and groundwater had some parameters such as Mn, F, As, Cu, etc., which exceed the permitted standards and show signs of pollution. However, comparing with the background environmental monitoring results of the years 2001, 2002, and 2003 (when doing the Environmental Impact Assessment report before the project came into operation), it showed that the surrounding environment had already been polluted with the above parameters."

❖ Cat stream

The tributaries have already been affected by wastes from mining activities along both sides of the stream, which was mentioned in the 2005 EIA Report. Cat stream not only receives wastewater from DP3 but also receives wastewater from domestic and agricultural activities of the area before flowing into the canal. That is the reason why monitoring results showed that parameters NH_4^+ , and F^- in water were higher than standards in QCVN 08:2015/BTNMT. Signs of pollution do not occur frequently, mainly appear in the rainy season months (July and August). Comparing the results of the water quality analysis at DP3 with the water quality of the upstream area, the wastewater discharge does not affect the quality of the receiving source water much.

❖ **Thuy Tinh stream**

Thuy Tinh stream is the receiving source of treated wastewater from DP2. It consists of many tributaries flowing into Cat stream. Some tributaries flow through the area of some hamlets where there are some small handicraft mines of local people, Kim Son mine of Kim Son Joint Stock Company located upstream; or leachate from the old waste stone yard of a local tin factory, wastewater from a coal factory, which has increased the value of heavy metals (As, Cu, Cd, Mn, etc.). On the other hand, wastewater from domestic and livestock activities of local people makes NO_2 and F^- parameters in the stream water higher than the limitation in column B1 of QCVN 08:2015/BTNMT.

6. The impact of discharge

Thuy Tinh stream is a short and small stream branch, usually not flowing in the dry season. In addition to receiving wastewater from NPMC, Thuy Tinh stream also receives and gets affected by wastewater from adjacent areas, resulting in some water quality parameters exceeding *The standard of surface water quality for irrigation purposes*. Under natural conditions, the water hardly flows during dry-season months. Only in several months of rainy season (July, August, and September), discharged water accounts for about 13 - 23% of the natural water flow. All the above proves that the amount of water discharged on Thuy Tinh stream is superabundant and it changes the natural flow regime of this stream. The discharge of NPMC does contribute to increasing the water flow of streams in dry season.

From both the features of the aquatic ecosystem and the survey results in 2018 - 2019, it was shown that: Due to the characteristics of streams in the area, they were usually dry in dry season (from March to April), there was a small flow in the peak of rainy season (July to August), so the aquatic ecosystem in the system of Cat stream and Thuy Tinh stream was normally not as diverse as predicted in *The annual water resources management and wastewater discharge report in 2014*. The main reason was due to the water quality and aquatic ecosystems on Cat stream and Thuy Tinh stream systems, which had been affected by mining activities in the area before the time Nui Phao mine came into operation. The waste streams arising from those activities mentioned with the high content of heavy metals had caused degradation of the water environment and aquatic ecosystems in the area.

The analysis results of water quality at DP2 and DP3 showed that: Wastewater from the Company's activities has been treated to meet column B of QCVN 40:2011/BTNMT before being discharged into the environment, so it has little impact on aquatic ecosystems of Thuy Tinh stream and Cat stream.

7. Proposing measures to improve water quality in the project area

It is recommended that the Company maintains strict regulations of management environmental protection as committed through EIA and reports of environmental protection.

It is recommended that the Company maintain the plan on regulating the amount of discharge water and water in the pre-treatment wastewater storage facilities and then takes advantage of reused water source for mining and processing activities of the Company, with the target that the amount of circulating water of the Company next year will be able to be more than it would the previous year.

It is recommended that Environment Department has educational programs to raise awareness among employees as well as contractors on environmental protection in general, and have awareness of the water source's importance in particular. Since then, practical measures could be taken to protect the Company's water resources.

It is recommended that Environment Department always be ready for possible emergency cases for the system of wastewater collection, treatment, and control.

IV. Discussion

The wastewater is collected through the system of wastewater collection and storage facilities, then strictly treated at the Wastewater Treatment Plant. The wastewater quality shows that all parameters are within the allowable limits of License 927/GP-BTNMT. The Company has closely monitored the operation of collecting and treating without any problems in the treatment and discharge. Although the quality is up to standard, the issues of receiving downstream are beyond the Company's ability and responsibility to handle. As mentioned, handicraft mines had stopped working as well as agricultural activities and daily activities of local

people causing pollution downstream before Nui Phao mine was operated. Besides, the geochemical characteristics also contribute to the increase of some heavy metal indicators in specific weather cases. The wastewater is treated to meet column B of QCVN 40:2011/BTNMT before being discharged into the environment, so it does not have much impact on the aquatic ecosystems of Thuy Tinh stream and Cat stream.

V. Conclusion

The project of mining and processing tungsten, fluorspar, bismuth, copper, and gold of NPMC takes place at Nui Phao mine. During the mining operation, the Company discharges treated wastewater to Cat stream and Thuy Tinh stream system through 2 locations DP2 and DP3. The results showed that the water quality parameters are within the allowable limits of License 927/GP-BTNMT. The company has closely monitored the operation of wastewater collection and treatment works without any problems in wastewater treatment and discharge. The wastewater meets the standards before being discharged into the environment, so it does not affect much on the aquatic ecosystems of local streams.

NPMC's wastewater quality has been under well-qualified control. Besides the plans to maintain control or prepare for incident response, the Company would hopefully research treating wastewater for domestic purposes.

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