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# BUILDING A GEOENVIRONMENTAL MODEL OF MAGMATIC NI - CU SULFIDE DEPOSITS IN VIETNAM

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# INTRODUCTION

## 1. Necessity

Mining and mineral processing is an industry that contributes to the economic development of many countries. However, mineral activities are also one of the industries that cause many negative impacts on the environment. The world has recorded many mineral mines causing serious environmental pollution, even some mines have become environmental disasters [1, 2, 3]. Among the mines that pollute the environment, metal sulfide mines have the highest risk because they have the ability to generate acid discharges and accompanied by the release of heavy metals into the environment [4, 5, 6]. During mining and processing, metal sulfide minerals come into contact with water and air, are oxidized, create acid waste streams, and disperse heavy metals into surface water, groundwater, soil environment, etc. affect the health of the people around.

Environmental issues in mineral extraction at the stages before, during and after mine operation have long been a concern of scientists and management agencies [7, 8]. The study and assessment of the impact of mining and mineral processing activities on the environment is not only the determination of the situation of environmental pollution, the sources of pollution, but also a tool to predict the problems. next environmental problem in the future to have preventive solutions to reduce pollution to the lowest possible level. Geoenvironmental modeling of mineral deposits is a useful tool to solve this problem [9, 10].

In our country, in recent years, mining and mineral processing activities have been developing strongly. In fact, the problem of environmental pollution in mining and mineral processing occurs not only when the mine is in operation but also continues many years after the mine has been closed, especially sulfide mines. Meanwhile, the study of building Geoenvironmental models of mineral deposits as a tool for identification, prevention and reduction of environmental pollution has not been sufficiently concerned. Stemming from the awareness of the urgency of the problem and related to the actual conditions in Vietnam, the PhD student selected the thesis topic "Building a Geoenvironmental model of nickel-copper sulfide deposits of magma origin. In Vietnam". Nickel - copper sulfide deposits of magma origin in Vietnam have so far been discovered in two areas: the Ban Phuc nickel mine in Muong Khoa

commune, Bac Yen district, Son La province and the area of nickel mines - Suoi Cun mine is in Ngu Lao commune, Dong Chang and Phan Thanh ore points in Quang Trung commune, Ha Tri mine in Ha Tri commune, Hoa An district, Cao Bang province.

**2. Object and scope of research**

- Research object: Ban Phuc nickel mines and Suoi Cun - Ha nickel mine cluster Tri. The common point of these two mines and clusters of mines is that they belong to the same type of mine with lytic magma origin in ultramafic rocks. However, they are located in different geological structures with surrounding rocks of different composition. These mines are also in different stages of the mine life cycle : Ban Phuc has been exploited (currently suspended), while and Suoi Cun - Ha Tri mine cluster is in the exploration and exploiting preparation stage. Therefore, the selection of two objects that have both common and specific characteristics not only allows building a more general geoenvironment model, but also can directly contribute to the impact assessment. environment of Suoi Cun - Ha Tri mine cluster before the mine comes into operation.

- Scope of research: minng and surrounding areas are related in terms of geology and mine environment.

**3. Goals of the thesis**

- Built a geoenvironment model of Ban Phuc nickel mines and Suoi Cun - Ha Tri nickel mine cluster.

- Forecasting potential environmental problems and proposing measures to minimize environmental pollution at magma-derived nickel-copper sulfide mines.

**4. Research contents**

- Research on mineral composition, chemical composition and factors affecting the environment, environmental signs of mineral deposits;

- Research, calculate and experiment to forecast the possibility of generating mine acid waste stream and generating heavy metals into the environment;

- Proposing solutions to reduce environmental pollution in sulfide mineral mines in general and nickel-copper sulfide mines in particular.

**5. Defensive arguments**

Argument 1: The Ban Phuc nickel mines (Son La) and the Suoi Cun - Ha Tri nickel mine cluster (Cao Bang) both belong to the same type

of geoenvironmental model of magmatic sulfide mines, characterized by the presence of two types of dense ores and diffuse ores, related to ultramafic rocks with ore mineral compositions of Ni - Cu sulfides. However, the environmental signs in the two mines are different due to differences in specific geological features in each mine, mine operation status and some other characteristics.

Argument 2: The potential environmental problem in both Ban Phuc nickel mines (Son La) and Suoi Cun - Ha Tri nickel mines cluster (Cao Bang) is the formation of mine acid discharge, which entails the risk of pollution. heavy metal contamination, especially Cu and Ni. For Ban Phuc mine, the object that needs attention is the tailings ore waste lake, and in the Suoi Cun - Ha Tri mine cluster, these potential environmental problems need to be taken into account when planning the exploitation.

**6. New points of the thesis**

- Building a geoenvironmental model for the type of nickel-copper sulfide mineral deposits of magma origin including components that are factors affecting the environment and environmental signs.

- Researching pollution processes in mineral deposits, pointing out the root causes of environmental pollution at sulfide mineral mines. Simulating the process of weathering sulfide minerals to form mine acid flows increases the ability to disperse heavy metals from the mine to the surrounding environment.

- Forecasting potential environmental pollution problems, thereby providing mitigation solutions at magma-derived nickel-copper sulfide mines.

**7. Scientific and practical significance of the thesis**

Scientific significance:

- Research on building geoenvironmental model of Ni - Cu sulfide mine of magma origin will contribute more material for research in the field of environment, especially mining environment;

- Detailed study of geochemical characteristics and geochemical processes in magmatic Ni - Cu sulfide deposits will contribute to the development of geochemical science in general and environmental geochemistry in particular.

Practical significance:

- The results of studying and building Geoenvironmental models of Ban Phuc mines and Suoi Cun - Ha Tri mine cluster will directly

provide materials and a basis for the development of an environmental protection plan at Ban Phuc and Ha Tri mines. Suoi Cun mine cluster - Ha Tri.

- Geoenvironmental model of Ban Phuc mines and Suoi Cun - Ha Tri mine cluster can be widely applied to mines of the same type and will provide managers with a useful tool when making mining licensing decisions. Mining, providing managers, organizations and individuals operating in the field of mineral extraction and environmental protection a means to assess potential environmental problems in mineral deposits serving the environmental protection of mining in general.

# CHAPTER 1
# OVERVIEW OF RESEARCH AREA AND STUDY STATUS OF GEOENVIRONMENTAL MODELS

## 1.1. Overview of the study area

In our country, research results so far have established three areas with three types of promising supermafic - mafic magma combinations of Ni - Cu: ultramafic intrusions in structural basalt - komatite complexes. Song Da [1, 2, 3]; the subclass intrusions gabbro - peridotite of Lot - Gam structure; the intrusive lherzolite (picrite) gabbronorite of Song Hien structure [4, 5, 6].

The results of search and exploration for many years have discovered Ni - Cu sulfide deposits in the above areas: Ban Phuc nickel mine in Song Da structure, Ni - Cu mine group in Suoi Cun nickel mine area - Ha Tri in the Song Hien structure. In the area of Lo Gam structure, some manifestations of Cu - Ni ore mineralization have also been detected, but here the prospect belongs to Fe - Ti ore in Nui Chua gabbro block. Therefore, within the scope of the thesis, the PhD student focuses on Ni - Cu sulfide deposits in the two areas of Song Da structure and Song Hien structure, mainly emphasizing the geological context, mafic - ultramafic rocks. related to ore mineralization and finally the ore generation model of the mines [7, 8].

### *1.1.1. Ban Phuc nickel mine*

Ban Phuc nickel mine is located in Ta Khoa area of Song Da structural zone. According to published works on the geological structure of the Song Da zone, the vast majority of authors consider the Song Da

zone to be an inland rift zone between two uplift zones, including the Song Ma zone in the west and the Phan Xi Pang zone. in the east, separated by deep faults.

***1.1.2. Suoi Cun - Ha Tri nickel mine cluster***

Suoi Cu - Ha Tri nickel mine cluster is located in Song Hien structure, related to mafic - super mafic formations. The researchers believe that the Song Hien zone is an inland rift zone [14, 15, 16]. The evolutionary history of the Song Hien structural zone plan is shown through the development of sedimentary - magma formations.

**1.2. Study status of geoenvironmental models**

***1.2.1.* Study *of geoenvironmental models in the world***

Around the world, geoenvironmental modeling has long been the spearhead of environmental research in the Mineral Resources Program (MRP) of the United States, which was first identified by Plumlee and Nash (1995) ) [27], Over the past 25 years, much progress has been made to advance this effort on a mine-specific basis, with a focus on abandoned mine problems and, more recently, mining problems in future. The concept of geoenvironmental modeling has received widespread acclaim in the global environmental community.

***1.2.2. Study and application of geoenvironmental models of mineral deposits in Vietnam***

In Vietnam, the issue of building and applying geoenvironmental models is still very new. New scientists have access to the basic theories of geoenvironmental modeling. The studies mainly focus on assessing the effects, the process of dispersing and spreading pollutants into the environment and pollution treatment issues, but have not mentioned much about the nature of the pollutant process and potential environmental problems.

In 2010, Assoc.Prof.Dr. Nguyen Van Pho et al published the first research on geoenvironmental model of mineral deposits in Vietnam in the Journal of Earth Sciences as "Geoenvironmental model of mineral deposits and their significance in assessment prices affected by mining" [36]. In this work, the authors gave an overview of the Geoenvironmental model and its significance in state management, mineral exploitation

planning, assessment of the effects during and after the completion of mining. mining.

Then, in the years 2009-2010, the Institute of Geology chaired the State Key Project KC-08/27-06.10 "Research and assessment of the impact of mining and processing waste dumps of metal minerals. to the environment and human health and propose mitigation measures" by Assoc.Prof.Dr. Pham Tich Xuan is the chairman. This topic has mentioned the environmental geochemistry of metal mineral mine waste dumps such as: Pb - Zn Cho Dien mine (Bac Kan), Cay Cham titanium mine (Thai Nguyen), Sin Quyen copper mine (Lao Cai), Mau Due antimony mine (Ha Giang), Ky Lam tin mine (Tuyen Quang). The important conclusion of the study is that the waste dumps from mining and metal mineral processing have environmental problems.

It can be seen that the above works have made significant progress in building Geoenvironmental models in Vietnam. However, up to now, there have been no studies on Geoenvironmental models of different types of mines, not to mention the principle that mineral deposits with similar geological characteristics (of the same origin) have the same characteristics. similar environmental cues and from which these environmental signals can be predicted. This is the problem that exists and is also the direction of the topic that the researcher chooses as the topic for his thesis.

# CHAPTER 2
# THEORETICAL BASIS AND RESEARCH METHODS

## 2.1. Theoretical basis

### *2.1.5. Definition of Geoenvironmental model*

As defined by Plumlee and Nash (1995), a mine geoenvironment model is a collection of geological, geochemical, geophysical, hydrological, technical and technological information related to geochemical behavior. of geologically similar mineral deposits before and after mining and processing activities".

### 2.1.6. Components of the mineral mine model

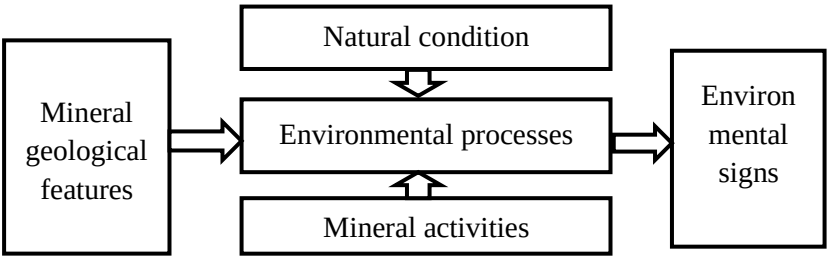


*Figure 2.1. General diagram of the geoenvironment model*

**2.2. Research Methods**

To achieve the goal of the thesis, the PhD student chooses the following research methods:

***2.2.1. Methods of synthesizing and analyzing documents***

***2.2.2. Methods of field survey, sampling***

***2.2.3. Group of methods to study mineral composition***

2.2.3.1. Thin slice lithology research method

2.2.3.2. XRD (XRD) analysis

2.2.3.3. Mineral analysis method

***2.2.4. Group of methods to study chemical composition***

2.2.4.1. Atomic absorption method (AAS)

2.2.4.2. X-ray fluorescence (XRF)

***2.2.5. Acid-base calculation method***

***2.2.6. Experimental method on the formation of mine acid***

***2.2.7. Modeling method***

## CHAPTER 3
## GEOENVIRONMENT MODEL
## BAN PHUC NICKEL DEPOSIT

**3.1. Environmental control factors of Ban Phuc nickel mine**

**3.1.1. Characteristics of Ban Phuc nickel ore mine**

- Ore body I: located in the south of the mine, is a dense nickel-copper sulfide ore body in the form of a vein plug to the northeast (20 - 25$^o$) with a slope angle of 70 - 90$^o$, the direction line extends in the northwest - southeast direction about about 900m, located on the southern edge of the Ban Phuc supermafic block. The thickness of the entire ore

body I including the inner clamping layer varies from 0.15m to 39.98m. Ore thickness is from 0.15 to 38.78m, common from 2m to 5 - 6m. Ore body I has from 1 to 5 layers of rock sandwiched inside lenticular shape, the thickness of the clamp layer is from 1 to 8.3m, which is common from 1.5 to 3m. The thickness of the ore body tends to decrease gradually with depth, to a depth of +100m is almost no longer of industrial value [9].

- Ore body II and ore body III: is an invasive Ni - Cu sulfide ore distributed in the Ban Phuc ultramafic mass. Dispersive sulfide ores in ultramafic masses are much larger in scale than dense ores. Based on the distribution of dunite and peridotite rocks, the bottom of Ban Phuc supermafic mass is southeast and slightly inclined to the southwest. In the eastern part, the intrusive mass is shaped like a depression and is oriented to the northeast [9].

***3.1.2. Mineral composition of Ban Phuc nickel ore mine***

*3.1.2.1. Mineral composition of sulfide nickel ore - dense copper*

From the analysis results of facies mineral samples, it can be seen that the ore mineral composition of nickel ore is as follows:

- Pyrotin: 66 - 92%, average 74%
- Pentlandit: 5 - 35%, average 15%
- Chalcopyrite: 5 - 18%, average 8%

Non-ore minerals include amphibol (actinolite, tremolite), albite, plagioclase, chlorite, epidot, calcite, biotite, quartz...

*3.1.2.2. Mineral composition of sulfide nickel ore - copper diffusion*

Nickel-copper sulfide ore diffuses in the bottom of the intrusive block with ore minerals accounting for about 5 - 10%, with the main composition being pentlandite, little pyrotin, violarite, valerite. Details are as follows:

Stone-forming TPKV: accounts for about 90%.

Serpentin: 85% (lizarite and antigorite)

Carbonate + chlorite + tremolite + phlogopite < 5%.

Ore deposits: account for about 10%

Magnetite + valerite + pyrotin + pentlandite + violarite.

***3.1.3. Chemical composition of Ban Phuc nickel mine***

*3.1.3.1. Chemical composition of sulfide nickel ore - dense copper*

The results of chemical composition analysis of dense Ni-Cu ore are presented in Table 3.1. From Table 3.1, it can be seen that the nickel sulfide ore - copper dense has a fairly high content of nickel, but very low in platinum and gold group elements, no or very low harmful elements.

The results of basic chemical analysis of sulfide nickel ore bodies - dense copper (TQI) with marginal content of 0.2% Ni, with average content of 1.44% Ni; 0.69% Cu; 0.05% Co; 25 ppb Au; 64 ppb Pt; 30 ppb Pd; 14.42% S; 2.28% Mg; 26.7% Fe [9].

Nickel sulfide ore - pure copper-concentrated pure copper without side-channel diffusion with an average content of metals including: 4.73% Ni; 1.84% Cu; 0.14% Co; 17.56 ppb Au; 67.55ppb Pt; 45.35ppb Pd; 0.84ppb Mg; 23.8% S; 41.45% Fe [9].

***3.1.5. Surrounding rock***

The bulkheads and pillars of the dense ore body are metamorphic sedimentary rocks of the Ban Cai Formation, which are horned, cracked mainly in layers, and contain carbonates. Because the surrounding rock contains carbonate, the ability to neutralize acids is very good.

The diffuse ore bodies are located in ultramafic blocks, so the composition of the surrounding rocks of the diffuse ore bodies is ultramafic rocks. The ultramafic rocks do not have the ability to neutralize acids as well as the carbonate sedimentary rocks of the Ban Cai Formation.

***3.1.6. Weather condition***

Ban Phuc nickel mine located in the Northwest region of Vietnam has two distinct seasons. The rainy season is from May to September, with a lot of rain from June to August, the highest temperature is 33 - 42$^{o}$C. In the dry season from October to April next year, the lowest temperature can reach 2$^{o}$C, the highest is 28$^{o}$C, the average temperature is from 12 to 14$^{o}$C. The average rainfall in the year is about 2032mm. Average humidity is about 80%. The average annual evaporation of water is about 1345 mm. This area is influenced by the northeast and southeast monsoons, with early summer westerly winds, hot and dry.

With a hot and humid climate and relatively large rainfall, it is one of the factors that cause ore to be strongly weathered. After being mined, sulfide minerals will be quickly weathered, causing acid mine discharge and dispersion of heavy metals into the environment.

***3.1.7. Topographic characteristics***

Ban Phuc nickel mine is located in an area with high mountainous terrain, steep slopes, strong cleavage, and rugged terrain. The lowest altitude is 100m, the highest is 1969m, the average height is 700m. The mountain ranges run in the northwest - southeast and are divided by a system of streams flowing in the southwest - northeast and southeast - northwest directions. The terrain is strongly dissected, with slopes from 30-40$^{o}$. V-shaped valleys are typical for strong vertical erosion. In the area, there are not many low and flat terrain.

***3.1.8. Mineral activities***

Mining activity of Ban Phuc nickel mine in recent years is mining dense ore bodies by underground method, diffuse ore bodies are still being studied.

**3.2. Environmental signs of Ban Phuc nickel mine**

***3.2.1. Environmental characteristics of Ban Phuc nickel mine surface water***

The pH of surface water in Ban Phuc mine area ranges from 3.6 to 6.7, of which 31/45 samples have pH lower than the allowable level (<5.5), accounting for ~69%. Cu content is from 0.122 mg/l to 1.98 mg/l, of which 30/45 samples have excess Cu content, accounting for 67%. Notably, surface water in Ban Phuc mine has quite high Ni content from 0.143 mg/l to 1,856 mg/l and all exceeds the allowable value according to QCVN. It can be seen that in the Ban Phuc mine area, there is an acid mine discharge that causes low pH in many samples and also shows Cu and Ni pollution in surface water.

***3.2.2. Characteristics of groundwater environment of Ban Phuc nickel mine***

The Cu content ranged from 101 to 275 mg/kg. Compared with the standard QCVN 03 - MT: 2015/BTNMT on the maximum composition

of heavy metal elements for soil used for forestry, the soil environment at some sampling points in the Ban Phuc nickel mine has a The amount of Cu exceeds the allowable level, specifically, 20/47 samples have a higher Cu content than the allowable level. Although there is no regulation on the allowed content for Ni, in the analyzed soil samples.

# CHAPTER 4
# GEOENVIRONMENT MODEL OF NICKEL SUOI CUN - HA TRI DEPOSIT

## 4.1. Factors affecting the environment of Suoi Cun - Ha Tri nickel mine cluster

### *4.1.1. Nickel mineralization of Suoi Cun - Ha Tri deposit*

Nickel - copper minerals in the Suoi Cun - Ha Tri nickel mine cluster are concentrated in three areas: Suoi Cun area has been partly exploited and is being investigated; Phan Thanh area has been explored and not yet exploited; Ha Tri area has been explored and not yet exploited.

*4.1.1.1. Mineralization of Suoi Cun area*

This ore mine is located northeast of Cao Bang city in the territory of Ngu Lao commune, Hoa An district. Characteristics of sulfide ores in ultramafic magma, depending on the type of diffusion, the main minerals are: pyrotin, pentlandite, chalcopyrite, magnetite. Ni content: 0.2 - 1.63%; Cu: 0.06 - 0.8%; Shrink: trace 0.11%; S: 0.3 - 6.91% [19].

*4.1.1.2. Mineralization in Phan Thanh area*

Nickel - copper ore in Phan Thanh block supermafic magmatic rock is placed as ore body No. 1 (TQ1). Based on the nickel content, 3 ore lenses in Phan Thanh block have been circled with the following symbols: TQ1.1, TQ1.2, TQ1.3

*4.1.1.3. Mineralization in Ha Tri 5 hamlet*

Characteristics of sulfide ores with diffuse, vascular, dense, and lenticular structure in peridotite rock. The ore mineral composition is mainly pyrotin, pyrite, chalcopyrite, secondary minerals are mainly azuzite and malachite.

Nickel - copper ore in the supermafic magmatic rock of Ha Tri block 5 is located as ore body No. 2 (TQ2). The zoning of the ore bodies to calculate the reserve is based on the identified content of 3 ore lenses

in the village block 5 Ha Tri with the following symbols: TQ2.1, TQ2.2, TQ2.3 [19].

***4.1.2. Mineral composition***

The mineralogy analysis results show that the mineral composition of the Suoi Cun - Ha Tri nickel mine has the following main components: Pyrotin, Pentlandite, Chalcopyrite, Pyrite and some other minerals.

***4.1.3. Chemical composition***

The chemical composition is one of the important factors of the mineral deposit model, which determines the environmental signs. Synthesis of research documents and results of chemical composition analysis of samples taken in Suoi Cun - Ha Tri area with average chemical compositions are: Ni from 0.563 - 2.801%, Cu from 0.238 - 0.344%, Co from 0.022 - 0.032%.

***4.1.5. Rock characteristics surrounding the nickel mine Suoi Cun - Ha Tri***

The ore bodies in the study area are mainly in the form of nests, located in ultramafic or mafic blocks, the ore bodies are located at a small depth and are lenticular. The rocks surrounding the mineral bodies are mainly ultramafic and mafic rocks, these rocks have poor acid neutralization [19, 20]. Therefore, when mining by the open-pit method, it is necessary to remove the mantle and the edge of the ore bodies. The amount of waste removed will carry sulfide minerals, which is a very serious problem for the environment.

***4.1.7. Natural condition***

*4.1.7.1. Weather condition*

The climate in the region is influenced by the climate of the Northeast region. The rainy season is from May to October, mainly from June to August, the highest rainfall can reach 200 to 300 mm, the dry season from November to April next year, the rainfall is low. The highest temperature in July to August can reach 35 to 36$^{o}$C, the lowest temperature in January to February, can be down to -1$^{o}$C, there is frost and frost. Climatic conditions in this area make sulfide minerals easily oxidized to form mine acid discharges and disperse heavy metals into the environment.

*4.1.7.2. Topographic characteristics*

Suoi Cun - Ha Tri mine area is located in a low mountainous area with gentle slopes, with an absolute height of 200 - 400m. Based on topographical characteristics, it can be divided into two types of terrain as follows:

+ Low mountain terrain: Including mountain peaks with an average height of 300 - 400m, characterized by low to medium mountain ranges, rounded peaks, and gentle slopes.

+ Topography of valleys: Distributed mainly along rivers and streams, northwest - southeast.

The characteristics of low hills and valleys create favorable conditions for the weathering process, so the weathering crust in the area is thick.

***4.2.8. Exploration activities of Suoi Cun nickel mine cluster - Ha Tri***

Mineral activities in the study area are mainly exploration activities and some mining activities in Ban Cun area, in addition, there are some locations where ore deposits are illegally exploited. Based on the characteristics of the areas, mineral activities can be divided into the following areas:

*4.2.8.1. **Exploration** activities in Ban Cun area*

Suoi Cun copper-nickel ore point has been licensed to exploit for Hoi Thang Mineral Resources One Member Company Limited with an area of 2.68 $km^2$ in the territory of Ngu Lao commune, Quang Trung commune, Hoa An district and group 9. + 10 Song Bang wards, Cao Bang city, Cao Bang province. The mine has been in operation since December 2008. The company has exploited both open-pit methods (100m long, about 60 m wide), underground mining (two lines have been exploited). kilns along the seam). Suoi Cun mine site was licensed to exploit before the 2010 Mineral Law took effect, so the issues of environmental impact assessment and environmental rehabilitation plan are still limited.

*4.2.8.2. **Exploration** activities in Quang Trung and Ha Tri areas*

Quang Trung - Ha Tri area has a lot of potential for Ni - Cu minerals, minerals here have been explored. Exploration results have

circled a number of mineral bodies with lenticular, ore-shaped concentrates. Ore mineralization includes both dense ores and diffuse ores. Exploration activities do not have much impact on the environment.

Before Tan Phat Minerals Joint Stock Company conducted exploration, there were several locations where dense Ni - Cu ores were illegally exploited, mining activities on a small scale (photo 4.16). ).

*4.2. Environmental signs of Suoi Cun nickel mine - Ha Tri*

***4.2.1. Surface water environment of Suoi Cun - Ha Tri nickel mine cluster***

Surface water in Suoi Cun - Ha Tri area has a pH ranging from 3.1 to 6.7, of which 21/52 samples have a pH lower than the allowable level (pH = 5.5), accounting for 40%. there are samples with very low pH (SCN.15, pH = 3.1). Ni content ranged from 0.259 mg/l to 2.479 mg/l and all exceeded the permissible standards. Cu content ranges from 0.206 m/l to 1,725 mg/l, of which 34/52 samples have content exceeding the allowable standard, accounting for 60% of the samples. Obviously, the surface water environment in this area has shown signs of pollution.

4.2.2. Soil environment of Suoi Cun nickel mine - Ha Tri

Compared with the standard QCVN 03 - MT: 2015/BTNMT on the maximum composition of some heavy metal elements for soil used for forestry, the soil environment at some sampling points in the Suoi Cun nickel mine cluster - Ha Tri value is within the allowable limit, there is no sign of pollution.

## CHAPTER 5
## FORECASTING POTENTIAL ENVIRONMENTAL PROBLEMS AND PROPOSING MITIGATION SOLUTIONS

### 5.1. Anticipate potential environmental problems

***5.1.1. Forecast of potential environmental problems of Ban Phuc nickel mine***

***5.1.1.1. Calculating acid production***

Based on the analysis results of tail ore samples taken at the waste lake and the potential for acid generation in the tailings ore was calculated.

*Table 5.1. Acid generating potential of tailings ore*

| **Model number** | **Sulfur content** (% Sulfur) | **NAPP** *($kgH_2SO_4/t$)* | **Ratio ANC/MPA** | **NAG** *($kgH_2SO_4/t$)* | **Acid-forming ability** |
|---|---|---|---|---|---|
| QĐBP.01 | 7,3 | 34 | 0,3 | 28 | High possibility |
| QĐBP.02 | 7,4 | 35 | 0,2 | 30 | High possibility |
| QĐBP.03 | 7,6 | 38 | 0,3 | 33 | High possibility |
| QĐBP.04 | 7,7 | 39 | 0,4 | 35 | High possibility |
| QĐBP.05 | 7,2 | 33 | 0,1 | 27 | High possibility |
| **Medium** | **7,5** | **31,8** | **0,26** | **32,6** | **High possibility** |

Calculation results show that in the waste lake area of Ban Phuc nickel mine, there is a high ability to produce acid, indicating that the oxidation of sulfide minerals has occurred to form acid.

* Formation of mine acid waste stream and heavy metal dispersion in waste rock, dump, industrial yard in pile form.

*Table 5.2. Results of determining the potential for acid generation of waste rock*

| **Model number** | **Sulfur content** (% Sulfur) | **NAPP** *($kgH_2SO_4/t$)* | **Ratio ANC/MPA** | **NAG** *($kgH_2SO_4/t$)* | **Acid-forming ability** |
|---|---|---|---|---|---|
| Samples taken at the dump | 17,1 | 126 | 0,03 | 114 | Very high |
| Sample taken at ore loading ramp | 15,7 | 122 | 0,02 | 103 | Very high |

*5.1.1.2. Experimental results on the ability to create mine acids and disperse heavy metals*

The experiment was conducted with dense nickel sulfide ores collected at the post-mining dump with the chemical composition of: 4.02% Ni; 2.16% Cu; 0.17% Co; 25.3% S; 43.21% Fe.

** pH change, Eh*

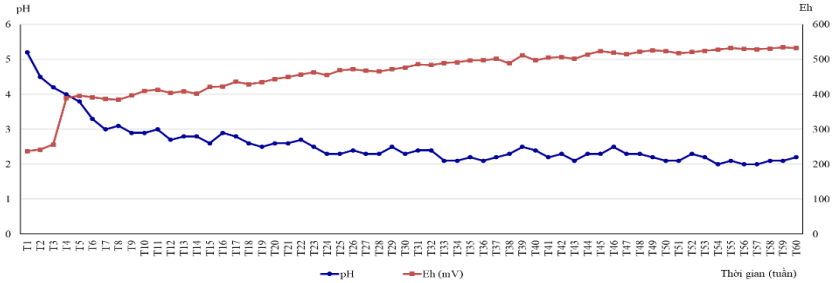


*Figure 5.1. The change of pH, Eh over time in the experiment with dense ore of Ban Phuc nickel mine*

** Generation of heavy metals*

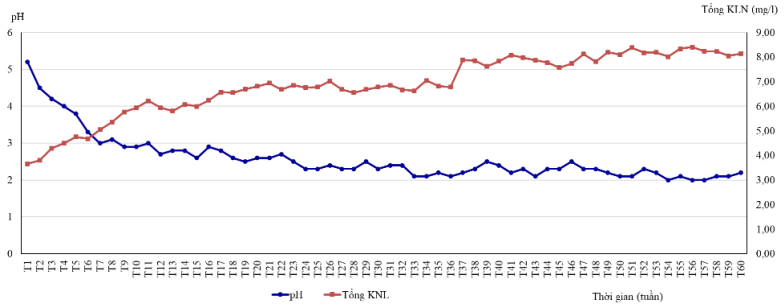


*Figure 5.2. The graph depicts the variation of total heavy metals in the experiment with dense ore of Ban Phuc nickel mine*

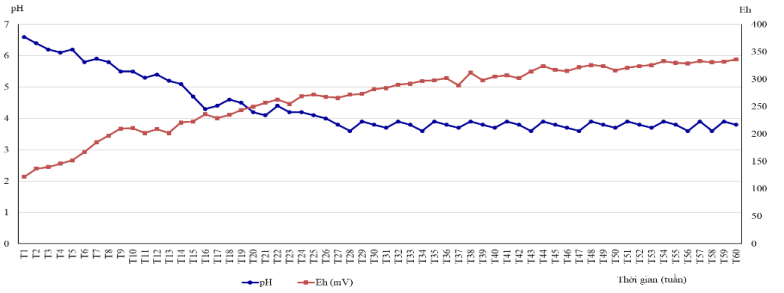


*Figure 5.4. Changes in pH, Eh in the experiment with Ban Phuc nickel mine diffusion ore*

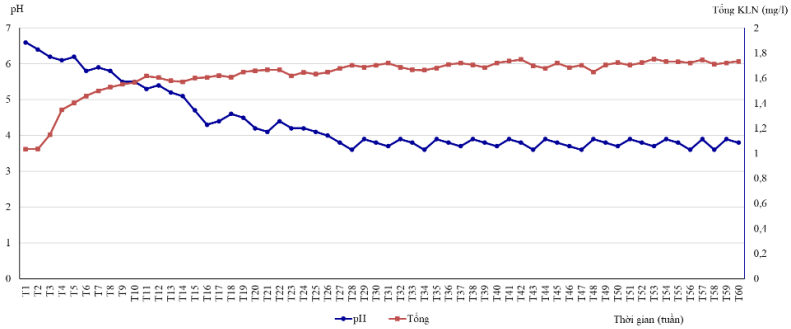


*Figure 5.5. Graph of changes in total heavy metal content in the experiment with Ban Phuc nickel mine diffusive ore*

### *5.1.2. Forecast of potential environmental problems at Suoi Cun - Ha Tri nickel mine*

*5.1.2.1. Calculating the ability to form mine acid waste stream*

*Table 5.3. Results of determining the potential for acid generation of waste rock*

| **Model number** | **Sulfur content** (% Sulfur) | **NAPP** *(kg$H_2SO_4$/t)* | **Ratio ANC/MPA** | **NAG** *(kg$H_2SO_4$/t)* | **Acid-forming ability** |
|---|---|---|---|---|---|
| Sample taken at the mining pit | 3,85 | 118 | 0,02 | 103 | Very high |
| Samples taken at the ore dump | 3,72 | 114 | 0,03 | 97 | Very high |

Calculation results show that the ability to create acid in the mining pit area and the piled ore storage area of Suoi Cun area is very large.

*5.1.2.2. Experimental results on formation of mine acid waste stream and heavy metal dispersion in Suoi Cun - Ha Tri mine*

The experiment was conducted with dense ore taken from the mining pit in Ha Tri area with the chemical composition of: 4.32% Ni; 0.12% Cu ; 0.023% Co ; 13.15% Fe ; 2.06% S.

** Change in pH, Eh*

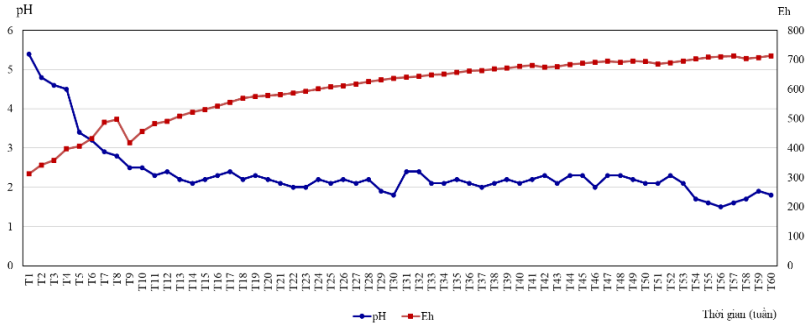


*Figure 5.7. The change of pH, Eh in the experiment with dense ore of Suoi Cun - Ha Tri area*

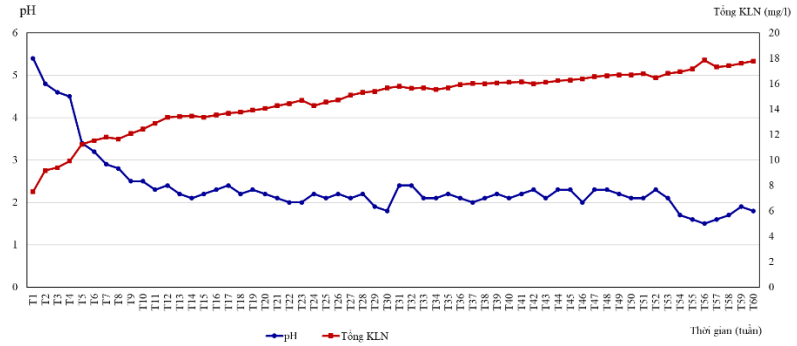


*Figure 5.8. The relationship between pH and content of heavy metals in the experiment with dense ores of Suoi Cun area*

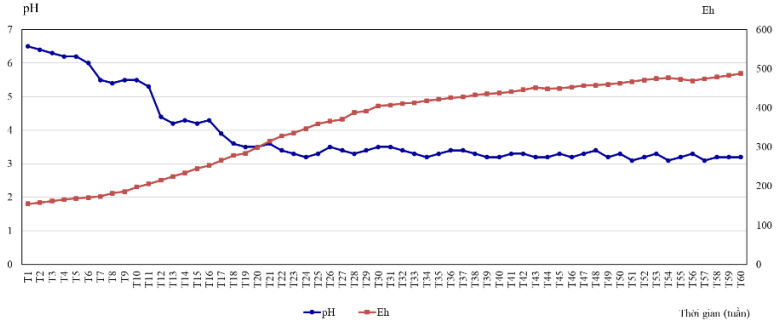


*Figure 5.10. Changes in pH, Eh in the experiment with diffuse ore of Suoi Cun - Ha Tri area*

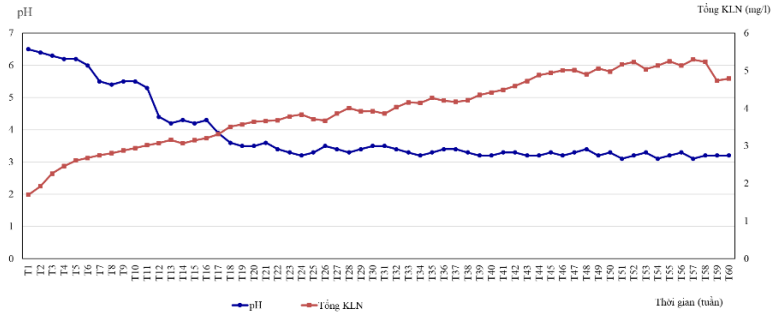


*Figure 5.11. The relationship between pH and content of heavy metals in the experiment with scattered ores of Suoi Cun - Ha Tri area*

**5.2. Proposing solutions to reduce environmental pollution**

***5.2.1. Measures to treat mine acid waste stream***

***5.2.2. Proposing solutions to reduce environmental pollution of Ban Phuc nickel mine***

The PhD student proposes some solutions to reduce environmental pollution at Ban Phuc nickel mine as follows:

- For tailing ore tailing ponds, the dam must first be kept safe to avoid dam failure by regularly checking the safety of the dam. Pumping to cover the surface of mud after mining is completed. Periodically monitor the environment of the waste lake to monitor the environment.

- For underground wastewater, rainwater overflowing through industrial yards, intra-mine transportation roads, ore storage yards, it is necessary to build water collection systems to concentrate treatment before being discharged into the environment.

***5.2.3. Proposing solutions to reduce environmental pollution at Suoi Cun - Ha Tri nickel mine***

The environmental pollution problems in Suoi Cun area are mainly due to the oxidation of sulfide minerals in the pits, storage yards, solid waste dumps, tailings waste dumps, pit wastewater, etc., which give rise to AMD. and release of heavy metals into the environment. Therefore, it is necessary to have solutions to deal with environmental pollution problems.

It is necessary to build a tailing ore waste lake and have a solution to protect the environment from tailings, you can refer to Ban Phuc nickel mine on the method of collecting and treating tail ore.

## CONCLUSIONS AND RECOMMENDATIONS

### Conclude

1. Geoenvironmental model of magmatic nickel-copper sulfide deposits is a theoretical model presented in descriptive form. The components of the Geoenvironmental model are the factors affecting the environment (mineralization characteristics, natural features, geological and mineral characteristics, hydrological characteristics, mineral activities, ...), environmental processes and environmental cues.

2. Ban Phuc nickel mine and Suoi Cun - Ha Tri nickel mine cluster have the same type of Geoenvironmental model as Ni - Cu mine of soluble magma origin, there are two types of ores: dense ore and diffuse ore with composition. ore minerals are mainly pyrotin, chalcopyrite, penlandite. The sulfide minerals present in the composition of the two mines, when weathered, will form mine acid discharges and disperse heavy metals. However, each mine has its own characteristics in terms of natural conditions, ore characteristics and mining works, so the environmental signs of the two mines are different.

3. Calculation results of acid-base balance and experimental results with ores of magmatic nickel-copper sulfide mines in the two study areas show that they are both capable of producing acid and extracting high heavy metal. Therefore, potential environmental problems in both areas are the possibility of forming acid mine discharge and the risk of heavy metal pollution to the environment, especially Cu and Ni.

4. Measures to prevent environmental pollution in sulfide mines in general and magmatic nickel sulfide mines in particular are to prevent ore's contact with the air to reduce oxidation process forming stream. mine acid discharge. At Ban Phuc nickel mine, solutions have been and are being carried out quite well. However, it is necessary to maintain environmental protection works in the following years. Solutions to reduce environmental pollution of Ban Phuc nickel mine are important

references to apply to Suoi Cun - Ha Tri nickel mine cluster. However, it is necessary to rely on the actual characteristics of the mining works of the Suoi Cun - Ha Tri nickel mine cluster to implement.

**Request**

1. The formation of mine acid discharge and dispersion of heavy metals into the environment in metal mines in general and in nickel-copper sulfide mines in particular take place for a long time during and after mining. The processes of environmental pollution in sulfide mines are very complicated, influenced by many factors, so further studies are needed to clarify, especially the role of microorganisms.

2. State management agencies, when appraising and approving projects on mining and processing sulfide minerals, should pay attention to the risks of forming mine acid discharges and the dispersion of heavy metals into the environment. At the end of mineral activities, it is necessary to strictly close the mine to ensure that it does not pollute the environment.

3. Enterprises exploiting and processing sulfide minerals should strictly comply with environmental protection measures, especially not to discharge acidic wastewater containing untreated heavy metals into the environment. Periodic environmental monitoring must be carried out to monitor potential pollution hazards.

4. Geoenvironmental solutions can be used to reduce environmental pollution due to the formation of mine acid discharges and the dispersion of heavy metals such as the planning of tailings storage areas, dam construction, construction. waste ore storage yards with acid-neutralizing materials, collecting underground wastewater and overflowing rainwater through storage areas, waste dumps, industrial yards for treatment before being discharged into the environment.

## LIST OF WORKS OF THE AUTHOR RELATED TO THE THESIS

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10. **Pham Van Chung**, Nguyen Van Pho, Nguyen Thi Thuc Anh (2022). "*forecasting potential risks of environmental pollution in the Ha Tri nickel mine*". In Proceedings "Technology in Natural Disaster Prevention and Risk Reduction" at Hanoi University of Natural Resources and Environment, Vietnam, on 31 August 2022. PUBLISHING HOUSE FOR SCIENCE AND TECHNOLOGY. ISBN: 978-604-357-070-0

11. **Pham Van Chung**, Vu Thi Hong Cam, Nguyen Thi Mai Huong (2023). "Experimental results of mine acid thimble formation and heavy metal release from nickel sulfide ore at Ban Phuc nickel mine storage". Proceedings of the National Scientific Conference "Geochemistry, environment and sustainable development" ISBN: 978-604-357-130-1.