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# Assessing the impact of climate change on Ha Tu coal mine, Quang Ninh province



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### ABSTRACT

*Climate change has been affecting the socio-economic life of Quang Ninh province in general, and the coal mining activities of many companies, including Ha Tu Coal Joint Stock Company in particular. By the methods of collection, synthesis, statistics, field survey, and public consultation, this study has evaluated the climate condition of the study region and the impact of climate change on the coal mines in the past. The environmental incident of landslides caused by heavy rain in 2015 has filled rivers and streams and destroyed infrastructure. According to the scenario of climate change for Quang Ninh province by 2100 (B2), the regional temperature will increase by 2.5°C, and the rainfall will increase by 7.3% compared to the period 1980÷1999. The study predicted the potential impacts of climate change on mining operations in the future such as the increased risk of landslides, floods, geological hazards, the drawdown of groundwater levels, and subsidence of the ground surface at the mining site. By the forecast results, the larger the mining depth is, the higher the radius affected by the lowering of the groundwater level will become, which can be up to 2.4 km compared to the mining area. In addition, the increase in temperature will be one of the factors that cause difficulties for production activities, affect the health of workers, slow down the process of reclamation and restoration of the mine environment, and increase electricity and water costs, etc. The study also proposed several technical and management solutions to reduce the risk and respond to environmental incidents before the impact of climate change on the Ha Tu coal mine towards sustainable development.*

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## 1. Introduction

Quang Ninh is a coastal province affected by climate change and sea-level rise, therefore it has paid great attention to its economic development and has been oriented sustainably, to adapt to the risks of climate change, including coal mining

activities. The energy and water intensity of large-scale mining may make this sector particularly vulnerable (Odell et al., 2018). The Ha Tu Coal Joint Stock Company is one of the major coal enterprises in Ha Long, Quang Ninh with modern mining technology, leading the Vietnam National Coal-Mineral Industries Group Holding Corporation Limited (Vinacomin) and in the region. The climate change issues in the area have had a significant impact on coal mining activities, environmental ecology, and people's lives around the mine area.

Therefore, studying the impact of climate change on Ha Tu coal mine in order to assess and forecast the potential risks of mining activities, as well as develop a plan to respond to environmental risks and incidents suitable to current conditions is very necessary to ensure economic benefits and sustainable development for the study.

## 2. Study methods

### 2.1. Data collection method

The data used in this study were collected from the monitoring of meteorology, hydrology, the environmental incidents occurring due to climate change in the locality, the environmental treatment systems, and the management and response reports to climate change in the Ha Tu mining area.

### 2.2. Field survey method

The field survey method was applied to the measurement of environmental quality (soil, water, air) in the mining area and the residential area around mining.

The current status of mining activities, protection works, and response to environmental incidents that can occur in the mine area was surveyed and assessed. Public consultations for the worker and resident on incidents and environmental impacts caused by climate change in the Ha Tu coal mine was carried out to determine the cause and evaluate the losses that the business is paying to solve these problems.

### 2.3. Synthesize and processing data

The data from the collection, field survey, and community consultation were synthesized and analyzed in order to assess the impacts of climate change on Ha Tu coal mine area, and forecast impacts on mining activities. The solutions for management, control, and minimization of the impact of climate change were proposed to orient the construction, development, and mining safety and sustainability.

## 3. Results and discussion

### 3.1. Climatic conditions in Ha Tu coal mine area

Ha Tu coal mine is located in Ha Long city, Quang Ninh province. This area is affected by the tropical climate, monsoon, hot and humid climate in the Northeast region. The rainy season is from May to October every year. The humidity is from 60÷80%, the temperature is from 25÷30°C, and heavy rainfall is concentrated in July and August every year. The dry season is from November to April next year, the humidity is from 30÷40%, and the temperature is from 15÷18°C. The average temperature of the year is 23.6°C. The hottest time is in June with a temperature up to 32.2°C and the coldest is in January with a temperature of 10.1°C. The total of sunshine hours in a year is from 1,600÷1,800 hours. In the past time, the monitoring data showed that the Ha Tu mine area has about 30 heavy rains with a rainfall of 10÷60 mm/hour and the highest number of rainy days in a year is 151 days. Moreover, the Quang Ninh province also received heavy rain with a total rainfall amount of 1,000÷1,300 mm (July 23 to August 4 in 2015). This rain greatly affected the mining activities of coal mines and caused environmental disasters in the area. This result comes from the reason with the number of strong storms and super typhoons appearing in the East Sea area increased by 1.5 times compared to the last decade (General Statistics Office, 2020). The heavy rains in the area, the sudden increase of water level in rivers and streams, floods, erosion, and landslides have affected socio-economic activities and caused significant damage to Quang Ninh province.

Figure 1 shows the trend and changes in temperature and rainfall over the past 10 years in the whole area of Quang Ninh province. In recent years, the temperature and the rainfall have a

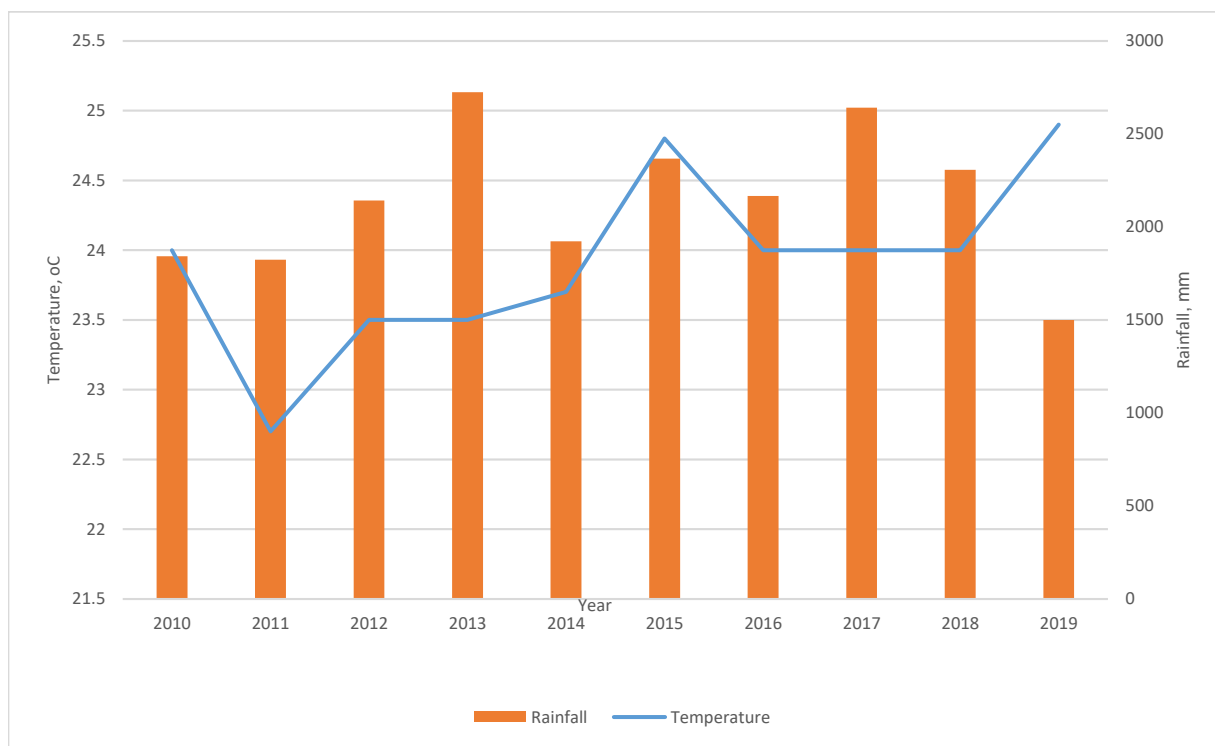


Figure 1. Evolution of temperature and rainfall in Ha Long area (General Statistics office, 2020).

trended to increase. In the period from 2010 to 2020, the temperature increased by 1.0÷1.5°C compared with the period 2000 - 2010, and the average rainfall of 2,355 mm was higher than that in the period 2000 - 2010 of 1,768 mm. However, the study also showed that there is an uneven distribution of rainfall throughout the year and in regions. This matter has led to an increase in extreme weather events in each region and caused difficulties for production and mining activities as well as planting work and environmental rehabilitation. In the rainy season, the rainfall accounts for 80%, causing flooding, landslides in many places, and making transportation more difficult. In the dry season, the water level of rivers and lakes is drawdown, causing a drought situation, lacking water for production and living activities, and also reducing groundwater reserves.

**3.2. Forecast of climate change in the study region**

According to research results from the National Center for Hydro-meteorological Forecasting, the average temperature in Quang Ninh province has increased by about 0.1°C in the

last decade. The periods of heat tend to occur earlier and end later. The number of heat waves occur more frequently, more locally, and more complexly. Under the Climate Change Scenario of Quang Ninh Province with average emissions (B2), the average temperature in 2100 will increase about 2.5°C compared to the period from 1980÷1999 (Table 1).

Table 1. The increasing of annual temperature (°C) compared to the period 1980÷1999 according to the average emission scenario (B2) of Quang Ninh province (Ministry of Natural Resources and Environment, 2016).

N <sup>o</sup>	Year	The increasing of temperature (°C)
1	2030	0.7
2	2040	1.0
3	2050	1.2
4	2060	1,6
5	2070	1.8
6	2080	2.1
7	2090	2.3
8	2100	2.5

In the past years, the rains have occurred erratically and are different from the previous period. Flood season and the flood peak usually appear later. According to scenario B2, at the end of the 21st century, the average annual rainfall in the province will increase by 7÷8%, and it will reach over 2,000 mm in 2,100 (Table 1). Facing the situations of long rains, late floods combined with the bad drainage systems, environmental protection measures were not paid attention, etc. This fact leads to an increase in inundation, the risk of pollution, geological hazards, environmental incidents, and stalled mining activities, causing economic and social losses for people in this area.

*Table 2. The changing of rainfall compared to the period 1980÷1999 according to the average emission scenario (B2) of Quang Ninh province (Ministry of Natural Resources and Environment, 2016).*

Order	Year	The changing of rainfall (%)	Precipitation (mm)
1	2030	2.1	1,916.7
2	2040	3.0	1,933.6
3	2050	3.8	1,948.6
4	2060	4.7	1,966.5
5	2070	5.4	1,978.7
6	2080	6.1	1,991.8
7	2090	6.8	2,004.9
8	2100	7.3	2,014.3

### **3.3. Impacts of the climate change on the Ha Tu coal mine area**

#### **3.3.1. The status impacts of climate change on Ha Tu coal mine**

The statistics of the environmental incidents occurring in the Ha Tu mine area by the climate change and natural disasters such as rain, flood, storm, whirlwind, flash floods, etc. showed that the mining activities, properties, and the lives of people around the mining area were seriously affected. In the many years such as 2005, 2007, and 2008, thunderstorms and heavy rains caused landslides in the whole Hon Gai area, obstructing

traffic, and affecting the waste dump area and coal mining activities of the Ha Tu coal mine.

With the rainfall twice times higher than the record rain 40 years ago, the rain in July 2015 was considered as the biggest environmental incident in the coal industry. Waste rock and coal slag in the waste dumps have been washed away by water, creating a stream of mud and rock flowing down to below residential areas, which caused the sedimentation of rivers and streams, obstructed the flow, and destroyed roads, technical infrastructure, and polluted environments. At Ha Tu coal mine, this rain flooded the mining pit at the coal seam 16, in which an estimation of about 6.7 million cubic meters of water and 3 million cubic meters of soil and rock flew into it.

Waste rock covering the entire system of roads went down to the seam, destroyed the entire transporting railway from Ha Tu mine to Lang Khanh port, separated machinery and equipment, and destroyed the retaining wall of coal depot 9. This incident caused coal to be washed out and filled many lakes, streams, rivers, drainage canals, and surrounding residential areas, etc. Causing economic damage and environmental pollution in the study region. Many machines, equipment, and properties of the company were badly damaged, and the electricity pole system in the mine was broken. The company's troubleshooting cost was estimated to be 300 billion VND. (Vinacom, 2021).

Besides, the environmental incidents, the frequent impacts of the climate change have affected the mining activities and the environment of the Ha Tu coal mine as follows:

- The storm caused water stagnation in the pit, increased the risk of the water flowing into the pit below, hindered the mining process, reduced labor productivity, and stalled coal processing. According to the Company's assessment, when heavy rain occurs, coal mining output will decrease 20÷30% and increase the cost of drainage water pumping.

- Flooding increased the risk of landslides, subsidence of the ground surface in the mining areas, and dumps such as the dumps of seam coal 7 and 8. Besides that, the topography and the direction of surface flow in the area have changed. It increased annual costs for

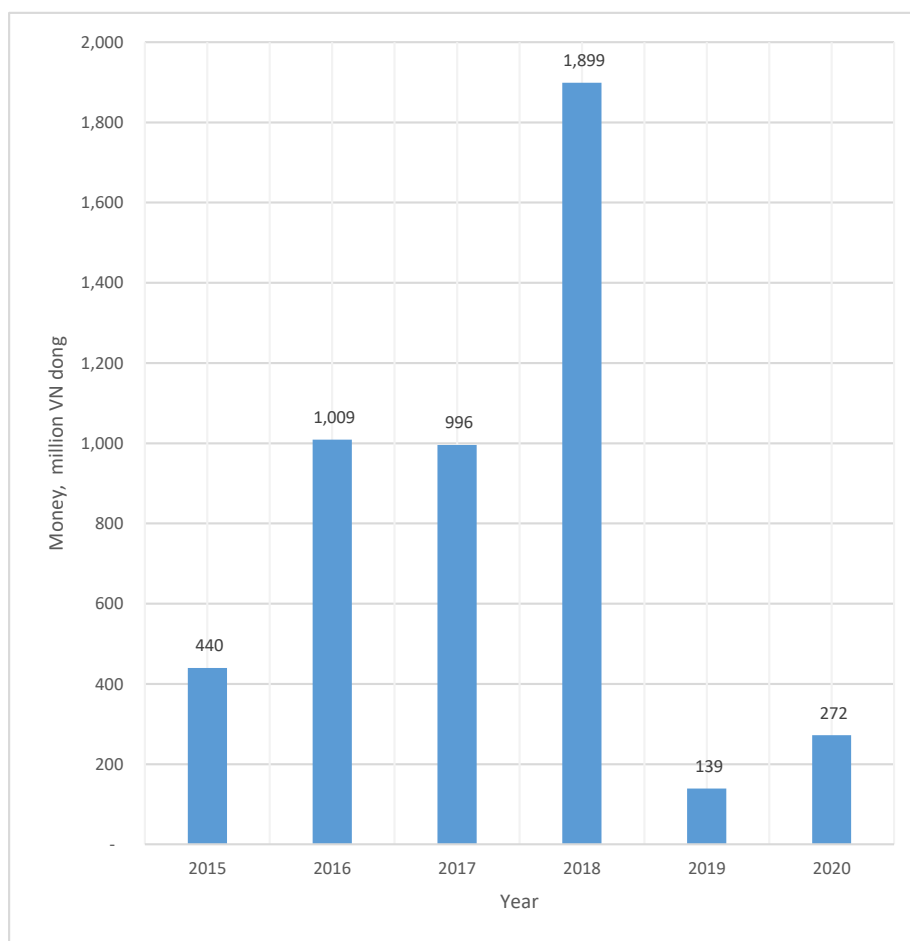


Figure 2. Annual cost for reinforcement embankment of Ha Tu coal mine (Ha Tu Coal Mine Joint Stock Company, 2021).

monitoring, reclamation, and reinforcement to limit the risk of landslides of dumps.

- Climate change increases the risk of landslides on transportation routes, so the Company must always have a plan for maintenance, repair and reinforcement embankment before and after the rainy season with the cost is shown in the Figure 2.

- The increase in temperature causes many difficulties for the production process, especially for outdoor activities such as planting trees, renovating, and restoring the environment because the heat affects the health of workers. Hot weather increases the electricity demand, causes overload, damages power supply equipment, and reduces labor efficiency. It also increases the water demand for domestic purposes and production activities, which increases the cost of water exploitation and

supply. It led to drawdown groundwater levels, increased risk of land surface subsidence, salinity intrusion, degradation, depletion, pollution of aquifers, and regional ecology. Besides that, the risk of dust and gas emissions from transport vehicles, machinery, equipment, drilling, blasting activities, etc. to the environment was increased. To overcome these problems, the enterprise had to invest and build more works to treat and reduce dust such as sprinkler systems, dust nets, car wash stations, tarpaulins for vehicles and outdoor coal storage, and rebuilding of storage and coal processing areas. (Vinacomin, 2020).

- Climate change also affects the soil surface temperature, hydrological regime, and soil moisture in the mine area. The increase in rainfall and temperature contributes to accelerating the weathering of waste soil, polluting soil and water, and increasing the amount of wastewater that has

acidic properties and contains many heavy metals. These factors will reduce the ability to prevent contamination of soil, surface water, and groundwater as well as harm the species, habitats, and ecosystems of the mining area.

### 3.3.2. Forecasting the potential impacts of climate change on Ha Tu coal mine

Currently, the Ha Tu coal mine is mined by the open-pit method in the Bac Bang Danh area under license No. 2575/GP-BTNMT of the Ministry of Natural Resources and Environment for a period of 10 years with a mining capacity of 20,354,365 tons (Ha Tu Coal Mine Joint Stock Company, 2020). With current mining technology, to produce one ton of coal, it is necessary to excavate from 8÷10 cubic meters of soil and rock and discharge from 1÷3 cubic meters of mine wastewater. It will be a danger to the environment, with the risk of landslides in residential areas around the foot of dumpsites, especially in the rainy season. Therefore, forecasting the impacts of climate change is very necessary, in order to give out synchronous management solutions, and avoid pollution and environmental incidents. Some risks to the Ha Tu coal mine during the mining period are determined as follows:

- Prolonged floods and storms will cause severe damage to infrastructures such as landslides and road damage.

- Electrical systems, construction with great altitudes, the operators, the warehouses for products, and raw materials can be destroyed by lightning and storms.

- Climate change has increased the temperature and extreme weather events that affect workers' health, blood pressure, circulatory, cardiovascular, respiratory, and neurological disorders, feelings of suffocation, breathing difficulty, fatigue, dizziness, etc. Prolonged hot weather makes it difficult to work outdoor. With low rainfall in the dry season, the dust will increase, spread further and affect the health of workers.

- Climate change in the region will increase temperature, prolonged rain, and flood that will make unstable soil and rock and water infiltration, leading to the risk of landslides in rock waste dumping at the Tru seam pit and

North Bang Danh field, filling the moongs, affecting the drainage of the mine, reducing the quality of surface water burying equipment, effecting the topographical and landscape of the area. During heavy rains, if the pump doesn't immediately drain, it will be damaged. Time to pump and drain water from 3 to 5 days can disrupt the exploitation, and losses economic and affect the life and income of the workers. In addition, the pumping of water to dry the mining also increases the flow of water on the Lo Phong stream and leading to a risk of flooding in this area.

- There are 2 faults, one of which is inversely distributed in the south of mining with the Northeast - Southwest direction extending about 3,800 m (Ha Tu Coal Mine Joint Stock Company, 2020). The machinery and equipment blasting, and transporting waste rock during heavy and prolonged rains affected the slopes, dumps, roads, drainage ditches, etc. leading to cracks, slippage and environmental disaster.

- The increasing demand for water exploitation leads to the risk of lowering the groundwater level in the dry season. According to the calculations, when the exploitation goes down to -250 m deep, the coal is exploited below the groundwater level and pumped out regularly (quantity is 2,070 cubic meters per day in the dry season and is 493,799 cubic meters per day in the rainy season), which leads to the lowering of the groundwater level (Ha Tu Coal Mine Joint Stock Company, 2020). The decline and lowering of the groundwater level occur gradually and lasts until the end of exploitation. By the forecast results, the larger the mining depth is, the higher the radius affected by the lowering of the groundwater level becomes, which can be up to 2.4 km compared to the mining area, thereby increasing the risk (Table 3). This is the cause of surface subsidence in the Ha Tu coal mine, affecting production activities and the life of people around the mining area.

- According to the calculation and forecast results of mining activities of Ha Tu mining in the future, the mining will exploit the seam coal 7 and 8 from +30 m to -250 m, rock waste dumping at the Tru seam pit of the mining site and a part of North Bang Danh field to +110 m

Table 3. Radius of influence of the lower groundwater level belong to the year of exploitation (Ha Tu Coal Mine Joint Stock Company, 2020).

Year of exploitation	Mining bottom	Square of mining bottom (m <sup>2</sup> )	Radius of well (m)	Depth of groundwater level (m)	Radius of influence (m)
2 <sup>nd</sup> year	+ 45	70,168	149	68	191
3 <sup>rd</sup> year	+ 30	76,200	156	83	258
4 <sup>th</sup> year	± 0	69,079	148	113	409
8 <sup>th</sup> year	- 250	33,589	103	363	2,356
End of exploitation	- 250	47,652	123	363	2,356

will change the landscape of this area, forming high mountains - deep moongs. To minimize the change in surface structure, it is necessary to carry out activities to strengthen the mining pit, plant trees on the surface and slopes, improving the ground to plant trees. However, climate change with an increase in temperature, longer rainfall, floods, etc will also slow down and cause more difficulties in planting trees and restoring the environment each year.

Mining activities with the increasing the extreme weather conditions such as longer rains and floods with heavy rainfall intensity, and increased drought will affect the region's ecology, reducing the number of species, and habitats, slowing down the regeneration and afforestation, etc. Floods also lead to landslides, washing away soil and rocks in the waste rock dumps into the streams that make sedimentation of flows and change the living conditions of aquatic organisms.

### 3.4. Proposing solutions to respond to climate change in Ha Tu mining

#### 3.4.1. Technical Solutions

The plans to respond to climate change are given to enhance the efficiency of production and business of the Company and minimize the risk of accidents and incidents such as:

At the beginning of the dry season, deep excavation is carried out to form a mining system with inclined pit bottom or a mining system with 2-level pit bottom to reduce the flood and mud. The drainage pumping system with a large capacity and high thrust (Hong Ha, 2014) is strengthened. Belong to the actual water flow, the mining has to have a reasonable

pump operation to ensure water drainage in the rainy season.

With the expansion of mining activities in the North Bang Danh area, waste dumps are formed with slopes up to 350 m; the land is often stripped of fertile soil, easily eroded, and unsuitable for re-greening forests, etc (Vietnam National Coal-Mineral Industries Holding Corporation Limited, 2020). Therefore, the company needs to carry out reasonable waste disposal technology, and stable stratification of dumps to ensure the safety of surrounding works and minimize environmental pollution. It is necessary to upgrade and renovate transport works, solidify the slopes, build dikes, dams, and drainage around the foot of the waste rock dumps, renovate and restore the environment, and plant trees, etc. to both ensure stability and prevent the waste rock dumps from slipping, and restore the environmental landscape (Nguyen Thi Hue, 2016).

Large-capacity vehicles with modern technologies and using economical fuel such as hydraulic excavator capacity 12 cubic meters per bucket, trucks transporting waste rock from 90 to 130 tons need to be invested. Vehicles should be covered during transportation. There is a need to continue using the dust suppression misting system and invest in more specialized irrigation water trucks of specialized 50 cubic meters. In addition, transportation routes need to be diked at the foot to prevent slipping, and trees and grass need to be planted to strengthen the base of floors.

It is necessary to review areas that have a risk of flooding or distributing the abnormal flow and affecting residential areas for control measures. It is also important to carry out research and

coordinate with Ha Lam mining to build a database on environmental resources; automatic monitoring and warning system of natural disasters (flash floods and landslides, etc.) in high-risk areas such as waste dumps to forecast, and reduce risks. The hydro-meteorological observation stations in mining to monitor the change of temperature, rainfall, etc. to prevent the risks of rain and flood should be built. Cleaner production in mining activities in order to minimize energy loss, waste generation, and greenhouse gas emissions shall be applied.

#### 3.4.2. Management Solutions

It is necessary to build the flexible response plans suitable for reality such as Plans to respond to strong storms and super storms; Developing the map of flash floods and landslides for Ha Long areas; Plans for storm prevention concurrently with the implementation of mining drainage, dredging the system of ditches and streams and plans to relocate and resettle residential areas located in weak geological and landslides, etc.

The recovery for those that are affected by climate change should be increased. There is a need of using cost-effective human resources (Yun-jia et al., 2009). In order to comply with the Environmental Policies of the Government and Quang Ninh Province such as Resolution No. 24-NQ/TW of the Central Committee to respond to climate change, the management of resources and environment protection, implementation of the National Strategy on Green Growth, etc need to be enhanced.

It is necessary to have plans to save clean energy such as saving water, growing trees, protecting forests and the environment, building a green lifestyle, etc. (Vu Phong Cam, 2021). The documents of incident response with climate change for the Ha Tu coal mine and refer with Quang Ninh Province scenario to disseminate for officials and workers shall be established. It is also vital to arrange resources for incident response, and have training courses to improve the qualifications of workers who play important roles in Plans for Climate change and sea-level rise response. It is important to set up disaster insurance funds and implement livelihood support policies for officials and

people living around the mining area when environmental incidents happen.

There is a need to improve the inspection and supervision of mining fields such as drainage systems, transportation, electricity, factories, waste dump area, mining – pit, etc. to take timely response measures. It is necessary to regularly review and supplement plans for natural disaster control, immediate prevention of the risks, ensuring the safety of people and equipment, workshops, and warehouse systems. The spirit of "Discipline and Concentricity" of miners in the action plan as well as in the issues of incident response, remedial consequences, and production restoration when the mining process is affected by natural disasters and the climate change should continue to be promoted.

#### 4. Conclusion

By using a field survey and public consultations method, the study assessed the impacts of climate change on mines over time, in which the biggest environmental incident in 2015 was caused by floods that made landslides, destruction of roads, technical infrastructure, damaged machinery, and equipment, coal drifted out, disrupted production and heavy economic losses.

The climate change scenario B2 by the Ministry of Natural Resources and Environment was used to forecast the impact of climate change on mining activities in the future. The research results showed that the risk of landslides, flooding incidents, geological hazards, lowering groundwater levels, and surface subsidence is increasing in this area. In addition, the increase in temperature leads to difficulties for production, affects the health of workers, slows down renovation and restoration of the environment, and increases the cost of electricity.

The study also proposed the technical method and management solutions to cope with risks and environmental incidents under the impact of climate change to build "Green - Clean - Modern" Ha Tu coal mine following sustainable environmental development.



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## Contribution of authors

Tran Thi Thanh Thuy – Building the structure of the article, field surveys, assessing the impact of climate change on the Ha Tu coal mine, and editing the article; Pham Khanh Huy – Collecting, synthesizing documents, and assessing the impacts of climate conditions on the Ha Tu coal mine; Nguyen Mai Hoa – Synthesizing documents and writing the proposals for management solutions, environmental protection, and response to climate change for the Ha Tu coal mine.

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