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Identification and assessment of OSH risks in small-capacity quarrying activities of construction materials in Vietnam

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Abstract - The quarries of construction materials are widely distributed throughout Vietnam, mainly supplying stone for local construction needs. They have a small capacity, simple mining technology, and always have potential risks of unsafety. The process of proactively identifying the existence and potential of hazards related to occupational safety, determining their characteristics, nature and origin, so that risk control can be assessed by the right measure is very important. The study aims to provide a process to identify potential occupational safety hazards in production activities on construction material quarries, thereby qualitatively and quantitatively assessing the level of occupational safety risks. Through a quantitative assessment method that scores points for the criteria of risk frequency, severity and risk recognition ability, to determine the level of risk, the level of potential risk and assign risk levels to classify and assess risks from which specific control measures can be taken. Research results at small-capacity construction material quarries in Vietnam with high risk of occupational safety and health (OSH), the authors have classified the risk levels in the technological and production stages of the mine. The research results are a reference document to quickly assess the dangerous and harmful levels of OSH hazards at quarries in Vietnam. With this identification process, it is possible to develop algorithms to create loops to help control OSH better and improve safety work efficiency.

Keywords - identification, hazards, risks, occupational safety and health (OSH), construction materials.

1. INTRODUCTION

In the world, there have been many studies on occupational safety in mining in general and quarrying of construction materials in particular, including studies on occupational safety risks in quarrying activities and research algorithms to support risk assessment, identify the risks of occupational safety in mining (Hermanus M.A., 2007; Occupational health and safety in mining - Status, new developments and concerns, pp 531-538.; Wanjiku M. W. ,2015;), typically, studies on risk assessment in the mining sector as well as guidance documents on risk assessment for mines (Russian Ministry of Health, 2004, P 2.2.1766-03; The University of Queensland, 2007; website:https://oshwiki.eu/wiki/Occupational_safety_and_health_risk_a ssessment_methodologies.). In addition, there are a number of documents on risk assessment, such as: Handbook on risk assessment in metal mines, open pit mines and quarries. These studies only stop at the mere study of risk assessment, occupational safety risks for each job and working position, but have not provided an overall identification and assessment process. In 2014, Assoc.Prof.Dr. Bui Xuan Nam has published the textbook "Occupational safety and health in the Mining Industry" providing specialized knowledge and necessary safety techniques related to the main technological stages in surface mining, underground mining, mineral processing, electromechanical, mine mechanics in Vietnam(Bui Xuan Nam et al, 2014, P.43). The issue of OSH risk assessment and proposals for the application of an appropriate management system in stone mining and processing establishments as well as in the field of state management of OSH in construction stone mining enterprises in Vietnam has also been studied (Ha Tat Thang, 2016; Nguyen Thang Loi et al, 2019).

In Vietnam, these quarries usually have a design capacity from 10.000 m^3/year to 50.000 m^3/year, and the common range is 25.000 m^3/năm to 100.000 m^3/năm (Nguyen Anh Tho, 2020). The quarries of construction materials are often located on high rocky terrain, the mining area is small, and the terrain is not favorable for mining. Because the value of ordinary building material stone is not high, according to the local demand, and the capacity of the investor, the usual construction material quarries have a small production scale, and the mining technology is not seriously invested. Especially in recent years, with the outbreak of mining and processing of common stone and building materials in localities across the country, some investors have only focused on profits, shortening the capital recovery time and not fully complied with regulations and safety regulations in mining. The phenomenon of small-scale sloping mining being transformed into smooth slanting layer mining has almost become common in small-scale quarrying areas, that has formed mining "troughs" with great steep slope, or to reduce the cost of loosening the mined rock down the slide of the rock layer. This mining has potential risks in mining such as mountain landslide (Len Co mountain landslide - Nghe An province, rock slide in zone D of Trai Son mine - Hai Phong city, ect.). In addition, it also causes the impact of blasting activities to the surrounding environment such as flying rocks, falling rocks, and dust. Although there have been quite a few studies in the world and in Vietnam on risk assessment and OSHA system in the field of construction materials quarrying, there has not been any assessment for the quarries of construction materials with medium and small capacity and applying mining system like in Vietnam. The quantification of occupational safety risks for each technological stage, each equipment, each working area, the experience and working attitude of employees, etc., all of these factors will be integrated into the process of risk identification and assessment, thereby yielding more accurate results.

2. EXPLOITATION STATUS OF SMALL CAPACITY CONSTRUCTION MATERIAL QUARRIES IN VIETNAM

Mainly, the quarries for quarrying construction materials usually use manual mining methods by vertical layer, conveying by blasting (also known as free-cutting or free-cutting technology).. Applying this mining technology, people use a hand drill, drill holes with a small diameter from 34÷42 mm, load mines into the borehole. Rocks after blasting will splash down the mountainside and gather at the foot of the mountain. Here, hydraulic excavators are used to shovel rocks and dump them into trucks which transport them to crushing and screening stations to produce all kinds of stones. The bucket capacity of the excavator is usually E ≤ 0,5m³ combined with trucks with a load of 5÷7 tons (Fomin S.I., Tran Dinh Bao, Do Ngoc Hoan, 2019, P.345-359). Small capacity stone mining enterprises have not focused on training mining techniques, equipping workers with means and equipment of labor protection, on the other hand, the awareness of workers themselves about the role of OSH, and accident prevention for themselves are still limited. Due to lack of awareness, many workers have ignored safety and scientific principles in the mining process, as long as they can exploit many products to get high income.

a) b)

Fig 1. Application of free mining method in some quarries

a- Bu Hem construction stone quarry; b- Quarrying area in Banh village, Chau Quang, Quy Hop

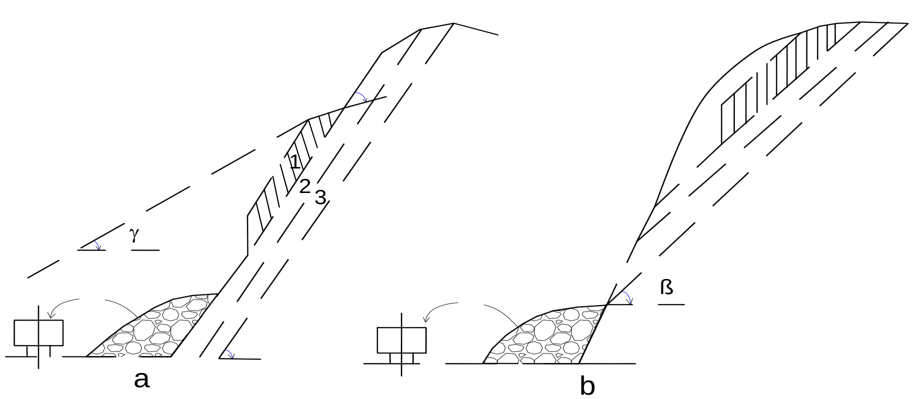

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Fig 2. Sequence of ridge-type deposits exploitation by Exploitation technology

a) When $\gamma \leq 40^o$; b) When $\gamma > 40^o$; 1, 2, 3 - sequence of exploiting the serial layers

Figure 2. Sequence of ridge-type mining by exploitation technology (Fig. 1.3) is widely applied in Vietnam with a mine capacity of less than 100,000 m^3/year.. The mining technology diagram is shown in Fig.3.

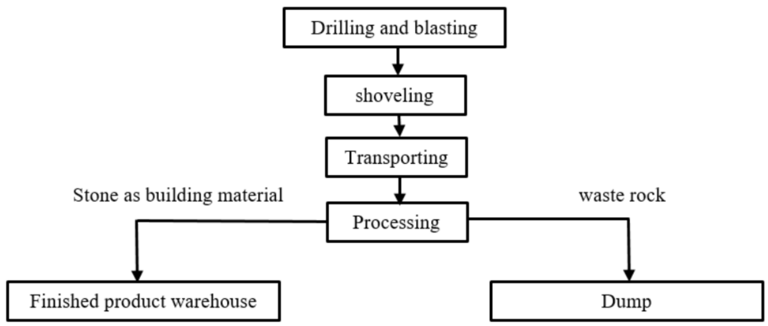
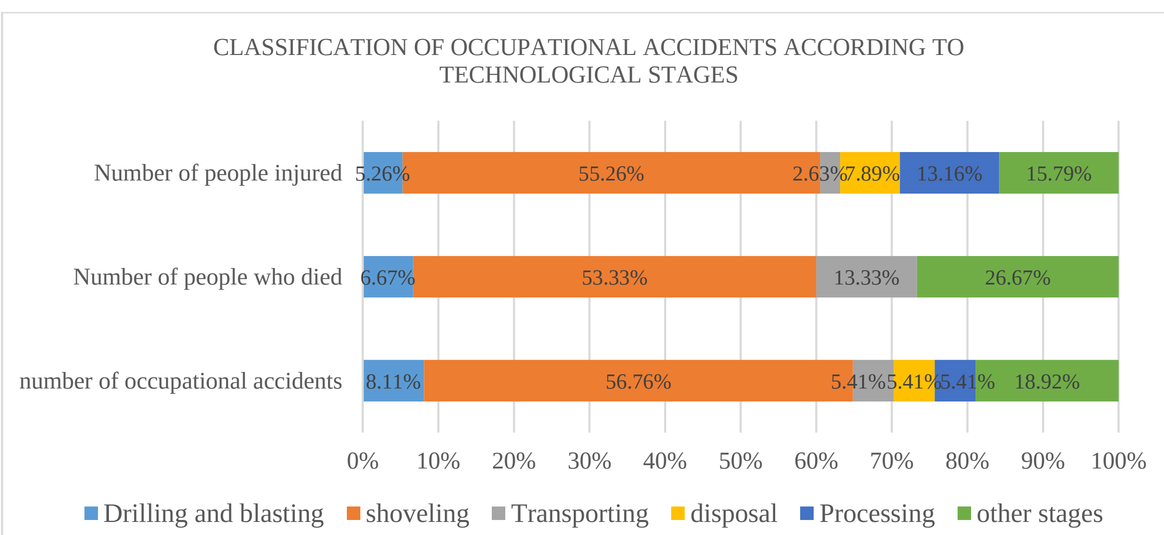


Fig 3. Diagram of vertical layer mining technology conveyed by blasting

* *Advantages:* The mining technology is simple, the investment is not large, the price is low, suitable for businesses with limited financial conditions and the required mining area is not large.

* *Disadvantages:* Mining is not safe, with many potential risks of unsafety occurring during the mining process, causing great loss and waste of resources.

In recent years, the situation of occupational accidents has become increasingly serious, affecting the socio-economic development of the country. In 2021, there were 5,797 occupational accidents nationwide, causing 5,910 victims of which: the number of fatal occupational accidents was 574; the death toll is 602 people; the number of people seriously injured is 1,226 people. Accordingly, the mining and mineral extraction sectors accounted for 13.27% of the total number of occupational accidents and 12.82% of the total number of deaths (IONOS Startupguide. Retrieved 2021-12-23.), and the mining industry is ranked as one of 11 occupations with high risk of OSH. Mining of construction materials which is a small-scale field of mining, with limited mining technology, many hidden risks, is being carried out on a scale from South to North. According to statistics in the field of stone mining for construction materials in 2021, there were 52 cases of occupational accidents, killing 49 people and injuring 33 others. To assess the level of unsafety by each stage of mining technology, we classify occupational accidents according to the technological stages in the production line: drilling and blasting; loading, unloading, transportation, stone discharging, processing and in other stages. The assessment is made according to classification based on data on occupational accidents in the period from 2015 to 2021 shown in Figure 4. (Do Ngoc Hoan, 2021, p.16-19; Dao Phu Cuong et al, 2016, P.58).

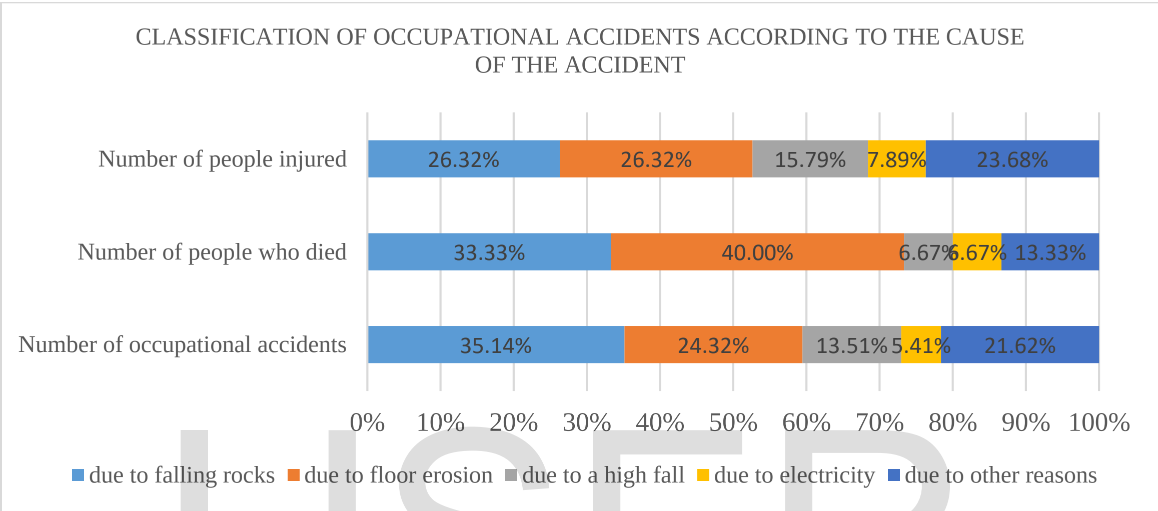


(Source: Department of Occupational Safety - Ministry of Labor, Invalids and Social Affairs, 2022)

Fig 4. Classification of accidents by technological stages

Looking at the chart, we can see that occupational accidents often focus on loading and unloading with over 50% of cases and deaths due to occupational accidents. High-risk stages are drilling, blasting, transportation, processing and other ancillary stages.

Understanding the causes of occupational accidents is also an important basis for assessing the severity of occupational safety. The number of occupational accidents classified by groups of causes of occupational accidents include: falling rocks; floor erosion; high fall; electrocution; other causes, shown in Figure 5.

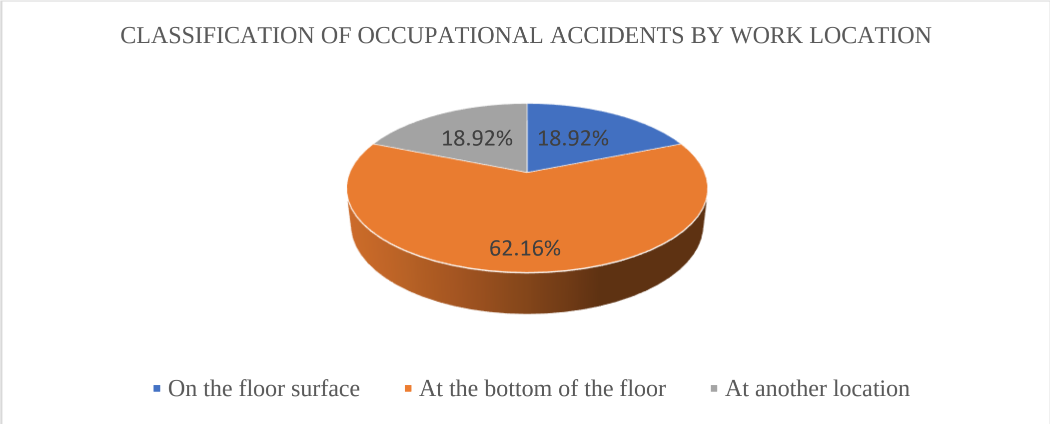


(Source: Department of Occupational Safety - Ministry of Labor, Invalids and Social Affairs, 2022)

Fig 5. Classification of occupational accidents by cause of accident

Figure 5 shows that the group of causes of falling rocks, landslides and high falls are the main causes of occupational accidents, the number of deaths and injuries also falls into this group of causes.

When identifying occupational safety risks, we often concern about the working space and location to classify and come to an accurate assessment. Classification of occupational accidents by working location on mines based on data collected from 2015 to 2021 shown in Figure 6.

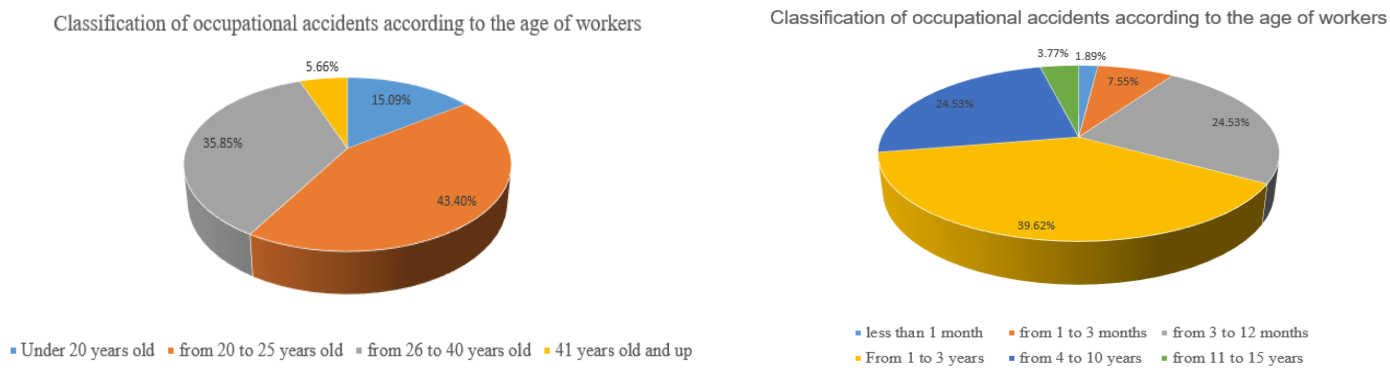


(Source: Department of Occupational Safety - Ministry of Labor, Invalids and Social Affairs, 2022)

Fig 6. Classification of occupational accidents by working location

The location on the floor often occurs occupational accidents due to high falls or incidents due to drilling and blasting work, this group of causes accounts for a low proportion compared to the location at the bottom of the floor because this is where the loading and unloading activities take place. Occupational accidents caused by landslides and falling rocks are the cause of the majority of occupational accidents, mainly in this working place. 18.92% of the accidents occurred at other locations, including accidents caused by electric shock, or accidents in processing, dumping, mechanics, etc.

One cause of occupational accidents is the carelessness and lack of experience and skills of workers. To assess occupational accidents, we classify them according to the working age and seniority of the employees. According to statistics from 2015 to 2021, the structure of working age and seniority of employees working on quarries of construction materials in Vietnam are shown in Figure 7.



(Source: Department of Occupational Safety - Ministry of Labor, Invalids and Social Affairs, 2022)

Fig 7. Structure of working age and seniority of employees in quarries of construction materials

The diagram on the age and seniority structure of employees shows that 43.4% of employees are aged between 20-25 years old, 35.85% of employees are aged between 26 and 40 years old, and the number of employees is over 40 years old accounted for 5.66%. Correspondingly, the majority of employees with 1-3 years of seniority accounted for 39.62%, 3-12 months of seniority accounted for 24.53%, equal to those with 4 to 10 years of experience. The number of skilled workers and long-term experience accounts for only a very small percentage of 3.77%. This is explained by the mining activities here are small, seasonal job and the employees are not attached for a long time. The number of employees with good health to stay in the profession is not much due to the harsh working conditions and contains many risks on OSH.

3. RESEARCH METHODOLOGY

3.1. Methods of identifying dangerous factors

The identification of occupational safety risks is determined through the analysis of factors such as working conditions, workers' skills, mining management, etc., the best identification is checked in practice at workplace. Fish bone Diagram method, also known as Cause-Effect diagram: is a tool used to analyze arising difficulties, helping us to understand the problem comprehensively and find the potential causes of a problem. Problem identification can be done by answering questions: Who, What, When, Where, Why, How. Writing the problem in the box to the left in the center of the paper, then drawing a horizontal line that divides the paper into two halves, are the head and backbone of the Fish bone Diagram (IONOS Startupguide. Retrieved 2021-12-23). Identifying the main cause group: For each main cause group draw a rib branch on the diagram, usually the main groups of causes include: People, Machines and Equipment, Raw Materials, Environment, System Policy, Information, Measurement, etc.

In addition, risk identification will be carried out by surveying among employees, inspecting the actual workplace, reviewing records and documents on occupational safety: minutes of occupational accident investigation, the technical problems causing loss of occupational safety; working environment monitoring data; periodic health examination results; records of self-inspection of enterprises, minutes of inspection and examination of labor safety.

3.2. Methods of risk assessment

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The risk assessment will be quantified using a scoring method based on the criteria of risk frequency (a), severity (b), level of risk (c), ability of risk identification (d), degree of potential risk (e), risk tier (f) and degree of risk (g).

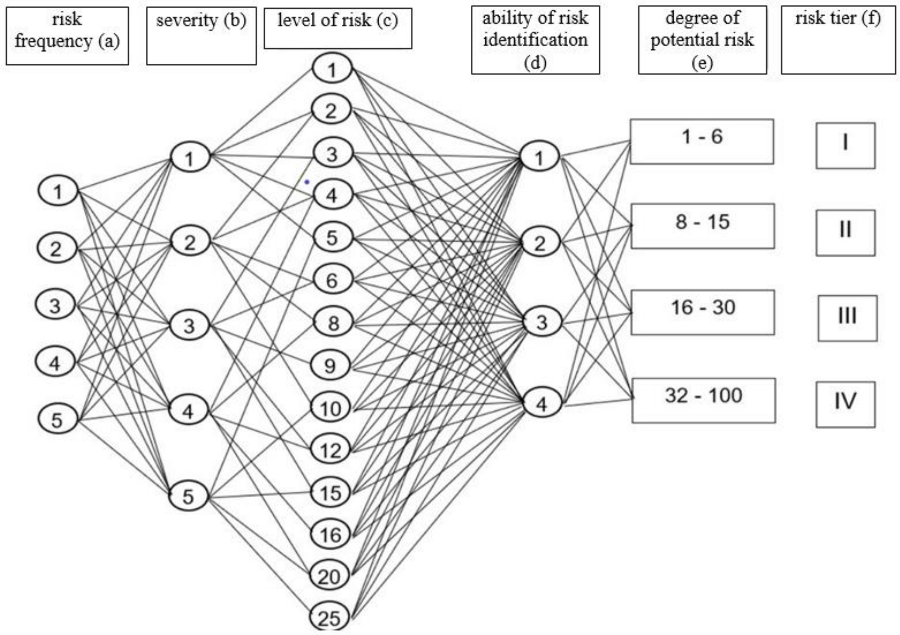

Fig 8. Classification of OSH risk assessment by identification matrix for scores

The assessment of occupational safety risks using the identification score matrix will classify the potential risk level into 100 different levels, from which to classify into 4 corresponding risk tiers. Tier I - acceptable level of risk; Tier II - Moderate risk level; Tier III – high level of risk and Tier IV – unacceptable level of risk (Ministry of Labor of Russia, 2014).

4. RESEARCH RESULT

In opencast quarrying, the risks of occupational accidents are hidden in all technological stages and production processes. The main technological stages in the exploitation of opencast quarries are currently: Drilling - blasting, loading and unloading, transportation, stone discharge and other auxiliary stages such as drainage, repair... Therefore, to assess risk, it is necessary to break down the main stages into smaller stages in the order of before - after. Some questions need to be raised during the analysis and identification of hazards according to the applied technology, the conditions related to the production process, the different possible incidents and their harmful effects, ect. Based on the accident database compiled from mines with similar conditions and the incidents that have occurred in the mine during the specified time, a risk matrix is established to determine the level of risk and the risk control measures in open pit mines. Preliminary risk assessment matrix in open pit mine see Table 1.

Table 1. Risk assessment matrix and OSH control measures in quarrying

Technological Stages	Production stages	The risks	(a)	(b)	(c)	(d)	(e)	(f)
Drilling, Blasting	Testing of Drilling machine	Electrocution	1	4	4	3	12	II
		Slipping and falling	1	3	3	2	6	I
		Gundrill dropped, drill rod collapsed	1	3	3	4	12	II
		The drill flipped	1	4	4	3	12	II
	Drilling holes for mines	Electrocution	1	4	4	3	12	II
		Falling from above	1	5	5	4	20	III
		Gundrill dropped	1	3	3	4	12	II
		Gundrill stuck	3	1	3	3	9	II

Technological Stages	Production stages	The risks	(a)	(b)	(c)	(d)	(e)	(f)
		Rockslide	2	5	10	4	40	IV
		Machine overturned	1	4	4	4	16	III
		Dust	5	2	10	1	10	II
		Noise	5	1	5	1	5	I
		Vibration	5	1	5	1	5	I
	Loading for blasting	Detonators, explosives explode while loading	2	5	10	4	40	IV
		Falling rocks, flying rocks	2	3	6	4	24	III
		Waves pounding in the air	4	1	4	2	8	II
		Hangfire	1	5	5	4	20	III
		Rockslide	3	4	12	3	36	IV
		Poisonous gas	4	3	12	1	12	II
		Shockwaves	5	1	5	3	15	II
Loading and unloading	Shoveling	Landslide	3	5	15	4	60	IV
		Machine overturned	2	4	8	4	32	III
		Device collision	2	1	2	3	6	II
		Dust	5	1	5	2	10	II
		Noise	5	1	5	2	10	II
		Vibration	5	1	5	1	5	I
	Bucket turning	Landslide	3	5	15	4	60	IV
		Collision with human	1	3	3	3	9	II
		Collision with the device	2	1	2	3	6	II
		Falling rocks, flying rocks	2	3	6	4	24	III
	Unloading	Landslide	3	5	15	4	60	IV
		Collision with the device	1	1	1	1	1	I
		Falling rocks, flying rocks	3	4	12	4	48	IV
	Moving	Working posture	4	1	4	3	12	II
		Falling	1	5	5	4	20	III
		Collision with the device	1	1	1	1	1	I
		Machine overturned	1	4	4	2	8	II
Transporting, stone discharging	Testing	Slipping and falling	5	2	10	1	10	II
		Drifting Trucks	2	3	6	4	24	III
		Truck crash	3	1	3	4	12	II
		Collision of the device	1	2	2	3	6	I
	Transporting	Collision with excavator	1	2	2	4	8	II
		Landslides, falling rocks	3	5	15	3	45	IV
		Bucket collapse	1	1	1	4	4	I

Technological Stages	Production stages	The risks	(a)	(b)	(c)	(d)	(e)	(f)
	Moving	Device on fire	1	4	4	4	16	III
		Losing control	2	5	10	4	40	IV
		Loss of brakes	2	5	10	4	40	IV
		Collision of the device	2	3	6	4	24	III
		Truck overturned	1	4	4	4	16	III
		Landslides, falling rocks	3	3	9	3	27	III
	Discharging	Collision of the device	2	2	4	4	16	III
		Truck overturned	5	1	5	4	20	III
Processing	Crush and sieve	Swept away, clamped	2	3	6	3	18	III
		Falling	2	3	6	2	12	II
		Electrocuted	3	5	15	2	30	III
		Dust	5	2	10	1	10	II
		Vibration	5	1	5	1	5	I
		Noise	5	3	15	1	15	II
Auxiliary stages	Consumption	Collision of the device	2	1	2	4	8	II
		Dust	5	1	5	1	5	I
		Traffic accident	2	2	4	3	12	II
	Mechanic factory	Fire and explosion	2	5	10	4	40	IV
		Stumbled	5	1	5	2	10	II
		Falling objects	3	4	12	2	24	III
		Splashing objects	3	2	6	2	12	II
		Electrocuted	2	4	8	3	24	III
	Storage	Explosion at fuel depot	1	5	5	4	20	III
		Slipping and falling at the fuel depot, extra grease	2	3	6	2	12	II
		Fire and explosion at explosives warehouse	1	5	5	4	20	III
	Kitchen	Fire and explosion	2	3	6	3	18	III
		Slipping and falling	5	1	5	1	5	I
		Thermal burns	5	1	5	2	10	II
		Food poisoning	5	1	5	2	10	II

From Table 1, it can be seen that out of 5 technological stages and 16 production stages on mines that are evaluated on many OSH hazards, 11 are assessed at Risk Level IV (the highest), 21 risks are assessed at level III, 30 risks are assessed at level II and 11 risks are assessed respectively at risk level I. The high risks indicated are landslides, falling rocks, fire explosion, loss of control when operating equipment. From these assessments, it is possible to propose risk control measures corresponding to their respective risk levels.

5. CONCLUSION

In order to improve the effectiveness of OSH management for small-scale construction material quarries, a process of identifying, assessing risks and controlling OSH is essential.

The process has identified hazards based on analysis of mining documents, surveys of actual working conditions, thereby providing qualitative and quantitative methods to assess risks and classify them into different risk groups and levels. After the hazards are identified and assessed, they are controlled by specific measures and tested through actual production as well as consulting employees before approval and application, enterprises can reduce occupational accidents and occupational diseases for employees.

In addition, it also opens up a direction for content development when building algorithms to create loops to check the accuracy of the process as well as being able to assess the secondary impact that harmful factors cause on the workers. Table 1. Results of horizontal coordinates of test network points.

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