REVISTA RIDING
Revista de Investigaciones, Desarrollo e Innovación en Ingenierías
Barrancabermeja - Colombia
Revista para la difusión y divulgación de avances de Investigación e Innovación
ISSN 2590-5929

vol. 08, No. 01, enero-junio de 2024 páginas 01-06.
ISSN 2590-5929

Design of a dust suppression system us a control method to prevent the risk generated in the workers for the use of explosives in the underground traditional mining.

Diseño de un sistema de supresión de polvos como medida de control para los riesgos generados a los trabajadores por el uso de explosivos en la actividad minera subterránea tradicional

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Recibido: marzo 18 de 2024 – Aceptado: junio 19 de 2024

Abstract

In a small village in the municipality of Santa Rosa del Sur of Bolívar whose population is mainly dedicated to mining, the implementation of a dust suppression system is proposed as a control measure to prevent or mitigate effects on the health and integrity of the workers who work on underground mine fronts, and who are exposed to contaminants that remain suspended in the environment after the detonation of explosives for underground progress, in an activity known in the sector as "burning". Traditionally these contaminants are removed with a ventilation system that requires approximately 3 hours for the air quality to be acceptable in the workplace. With the implementation of the dust suppression system, waiting time was reduced to only 18.33% of the time required with the traditional method. Another important finding is that the presence of contaminants with the potential to cause harm to worker's health was also reduced compared to the traditional method. The health conditions of the miners improved in the short term. The health symptoms that are mistakenly called by the miners as flu decreased by 40%. This investigative article arose from the interest of two students from the Manuela Beltran University in controlling and mitigating latent health conditions in a mine in the South of Bolivar.

Keywords: Dust suppression system, underground mining, control measure.

Resumen

En una pequeña vereda del municipio de Santa Rosa del Sur de Bolívar cuya población se dedica principalmente a la minería, se propone la implementación de un sistema de supresión de polvos como medida de control para prevenir o mitigar afectaciones sobre la salud y la integridad de los trabajadores que desempeñan labores en los frentes de minas subterráneos, y que están expuestos a los contaminantes que quedan suspendidos en el ambiente tras la detonación de explosivos para el avance subterráneo, en una actividad conocida en el sector como "quema". Tradicionalmente estos contaminantes son retirados con un sistema de ventilación que requiere de aproximadamente 3 horas para que la calidad del aire sea aceptable en el lugar de trabajo. Con la implementación del sistema de supresión de polvos se logró reducir el tiempo de espera a tan solo un 18.33% del tiempo requerido con el método tradicional. Otro importante hallazgo es que la presencia de contaminantes con potencial para causar daño en la salud de los trabajadores también se redujo en comparación con el método tradicional. Las condiciones de salud de los mineros mejoraron a corto plazo, Las sintomatologías de salud que son llamados por los mineros erróneamente como gripas disminuyeron en un 40%. El presente artículo investigativo surgió del interés de dos estudiantes de la Universidad Manuela Beltrán por controlar y mitigar las condiciones de salud latentes en una mina del Sur de Bolívar

Palabras clave: Sistema de supresión de polvos, minería subterránea, medida de control.

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INTRODUCCIÓN

In certain regions of Colombia, Mining continues to be developed informally, without the safety conditions that are currently required for the legally constituted mining sector. The quality of the air inside underground mines is a parameter that must be taken into account when referring to safety in underground work in accordance with decree 1886 of 2015, specifically in its title II where it contains everything related to ventilation characteristics. According to the Safety Guide for Ventilation of Underground Mines, published by the National Mining Agency, Sena, Ministry of Labor and Ministry of Mines and Energy in 2017, ventilation inside the underground mine must meet certain characteristics to avoid discomfort in health. The atmosphere of the mine must have an optimal composition, temperature, degree of humidity, among others, to carry out work safely and healthily and to obtain high performance from the workers.

Due to the use of explosives for underground advancement, contaminants are generated that remain suspended in the air and without optimal removal these can cause serious damage to the health of the workers who carry out their duties inside the work fronts and can also generate delays due to the time it takes to re-establish the necessary conditions to be able to resume work.

To complement the ventilation system traditionally used in these mining regions of Colombian to remove contaminants suspended in the air, this research proposes the implementation of a dust suppression system that functions as a water curtain that covers the entire exit area of the contaminant from the work front, this curtain is achieved by the implementation of a water pumping system and the installation of nozzles that determine the way in which the water is released. The objective is to achieve the largest contact surface to be able to trap the particles suspended in the atmosphere, so that, due to the action of gravity, they precipitate to the bottom of the work front, accumulating in a tank in order to drain the contaminants later.

This investigation was developed because it was important to achieve the largest contact surface to be able to trap the particles suspended in the atmosphere, so that, due to the action of gravity, they precipitate to the bottom of the work front, accumulating in a tank in order to drain the contaminants later, it was mandatory to do a previous bibliography revision to choose the most appropriated materials to develop a prototype related to the conditions of the mine, as we are going to explain in this document.

Furthermore, what is intended with this scientific article is to formulate bases for the possible implementation of the dust suppression system in a mine in La Vereda La Fortuna in the South of Bolívar as an engineering control measure for prevention of accidents and occupational diseases, and that these types of measures spread through the surrounding communities that make up the mining sector of the San Lucas mountain range.

ARTICLE CONTENT

A. MATERIALS AND METHODS

This study was based on the compilation of data referring to dust suppression systems, bibliographic sources of academic origin were used, coming from databases of scientific documents, where important parameters could be evidenced to take into account in the choice of the system, such as: efficiency, cost, reliability and complexity. after exhaustive review of the scientific article A Review of Physical and Chemical Methods to Improve the Performance of Water for Dust Reduction, Process Safety and Environmental Protection (Zhang et al., 2022, P.87), where the physical and chemical methods that can be implemented as a dust suppression system are presented, it is concluded that the best alternative in terms of economy and practicality is the physical method, either with air atomization or ultrasonic atomization. These two systems are also characterized, according to the table taken from this article, by their high level of reliability and moderate efficiency. Table I. describes the different types of physical methods in terms of efficiency, costs, reliability and complexity, being Low (L), Moderate (M) and High (H).

TABLE I

THE CONTRAST OF PHYSICAL METHODS [1].

Contrast between different physical methods				
Types	**Efficiency**	**Cost**	**Reliability**	**Complexity**
Air Atomization	M	L	H	L
ultrasonic atomización	M	L	H	L
Magnetic Water	H	M	M	M
Water mist charge	H	M	M	M

Taken from A review of physical and chemical methods to improve the performance of water for dust reduction, Process Safety and Environmental Protection. Zhang, Q. Fan, L. Wang, H. Han, H. Zhu, Z. Zhao, X. Wang, Y. (2022). (P.91)

TABLE II

THE CONTRAST OF CHEMICAL METHODS [2].

Contrast between different chemical methods					
Types		**Efficiency**	**Cost**	**Reliability**	**Complexity**
Single Liquid Phase Dust Suppressant	**Humectants**	M	M	M	L
	Agglomerate	M	H	M	H
	Coagulant	M	M	M	L
	Compound	H	H	M	H
Gas-liquid two-phase dust suppression foam		H	M	M	M

Taken from A review of physical and chemical methods to improve the performance of water for dust reduction, Process Safety and Environmental Protection. Zhang, Q. Fan, L. Wang, H. Han, H. Zhu, Z. Zhao, X. Wang, Y. (2022). (P.95)

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Regarding the choice between this pair of physical systems, we can rely on the document called Experimental characterization of the ultrasonic atomization of liquids with particles in suspension (Ranz, A. 2014, P.13), which in turn compiles the conclusions of the study by Berger in 1984 where conventional (pressure) atomizers are compared with ultrasonic ones and as a result it is obtained that:

In surface coating applications, high-speed atomizers are ineffective, as the strong impact of droplets on surfaces causes erosion of the coating materials themselves and loss of material.

Pressure atomizers present clogging problems in the narrowing of the orifices that generate high pressures. Impurities or suspended matter can clog the channels through which the atomized liquid circulates. When the obstruction occurs partially, it affects the deformation of the aerosol and the deformation of the atomized droplets, which no longer have the desired size. The limiting case is a total obstruction, with which the atomizer becomes unusable.

Conventional atomizers are subject to abrasion and corrosion due to possible particles present in the liquid to be atomized. Carbon and aluminium oxide are two of the main culprits of this negative effect. These limitations do not exist in an ultrasonic atomizer since the operating principle is based on the generation of capillary waves on the surface of the liquid as a result of the ultrasonic vibrations of a piezoelectric material.

With all of the above, it is determined that the method to be used, after the analysis of all the bibliographic material found, is in theory, the dust suppression system through ultrasonic atomization. This decision was made after relating the disadvantages of the conventional method (by pressure) with the particularities of the case, mainly due to the risk of erosion or weakening of a structure due to the impact of water inside a tunnel, which could cause fatal situations, in addition, clogging problems that can cause failures in operation or even render the atomizer unusable after total obstruction, the latter is very important because the location of the system will most likely not allow continuous monitoring during its operation because these places must be evicted due to the fires, which makes even more relevant the fact that the system presents any of these types of failures. Several experimental analyses were carried out to reach certain conclusions, in which mathematical models were carried out where the thicknesses of the bubble cutters were decreased or increased and their reaction to these modifications (Balaga et al. 2021b) they found that the production of droplets of Small diameter under the same volume of water increases its total surface area, improving dust particle capture efficiency. As mentioned (Wang et al., 2019 b; Zuo et al., 2017). (Xie, J et al., 2022, P. 493)

A. DATA COLLECTION TECHNIQUES AND INSTRUMENTS

During the analytical process, the three variables of interest will have to be quantitatively assessed, such as waiting times, environmental conditions and health effects. The instruments and techniques that will be used for their evaluation will be stated in the table III.

TABLE III
DATA COLLECTION TECHNIQUES. [3].

Data Collection Techniques	
Variable	**measuring tool**
Waiting time	Stopwatch, three timed measurements on different days will be measured in present time. After the application of the new methodology, three timed time measurements will be taken to verify the average and determine if the method is effective in reducing waiting times during the burning process in an underground gold extraction mine.
Environmental conditions	Table of environmental measurements through multidetector, 3 shots will be taken during 3 different descents to carry out burning tasks before the implementation of the method and then the same procedure will be carried out post implementation to average whether the method is effective or not.
Health effects	Survey, staff will be interviewed looking forward their opinions in terms of feelings of discomfort or well-being when descending into the mine. This will be done before and after the method is executed. It is suggested that periodic medical examinations be carried out to verify the physical conditions of the workers.

B. DATA PROCESSING AND ANALYSIS TECHNIQUES

For the first two variables, waiting times and environmental conditions, the data will be tabulated and an average will be taken where the efficiency of the method will be determined. For the third variable, the opinion of the workers will be taken into account to be able to show if there are possible improvements in environmental conditions during descents.

C. MATERIALS

The following illustration is a 3D model of the dust suppressor prototype implemented in the gold extraction mine, located in the La Fortuna village in the South of Bolívar.

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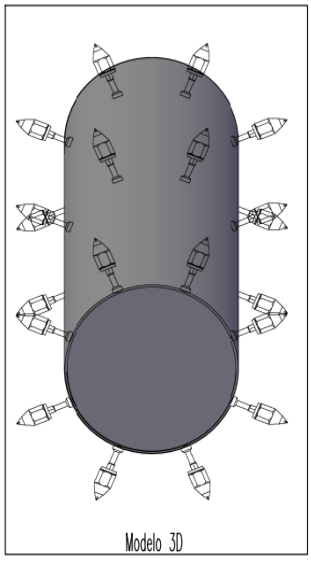
Figure 1. 3D Model of the Dust Suppressor Prototype



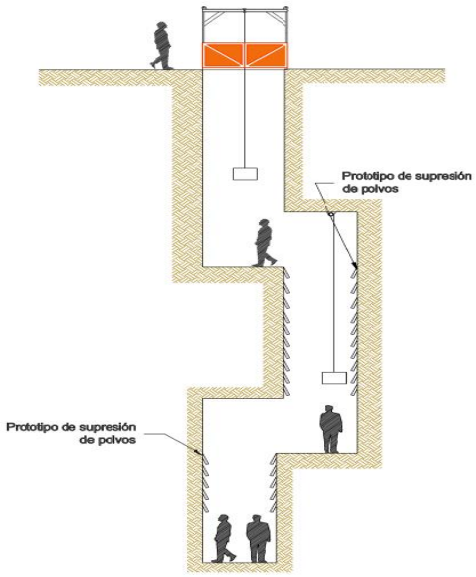
The device to be used consists of a series of stainless steel tubes that were adapted to the walls of the mine mouth along with the ventilation system and that are interconnected with each other to drag the water through flexible hoses, it is important It should be noted that this device works at the same time as the air force system because together a better result is obtained in terms of normalization of working atmospheres. Table 4. Describes the characteristics of the materials used in the dust suppression system.

TABLE IV

CHARACTERISTICS OF THE MATERIALS USED FOR THE DESIGN OF THE DUST SUPPRESSOR [4].

Name	**Dust Control Ultrasonic Air Atomizing Nozzle**
Reference	*SK508*
Materials	Stainless steel, brass
Quantity	24 units for device
Name	**Stainless Steel tuve**
Tube dimensions	Internal diameter 4in: Length 50cm
Quantity	4 units in total
Name	**Flexible hose with quick couplings**
Dimension	5.5 meters per section
Quantity	2 units

The Figure 2. Graphically describes the positioning of the dust suppression system inside the mine.



In order to cover a larger intervention area inside the mine mouth, four prototypes were installed along the descent, in places where the dust is mostly concentrated. In the first section of the mine mouth, no installation was carried out because the dust and gases do not reach to the surface. The dust suppression system works intermittently to prevent inappropriate use of water resources in a rural area where there is no drinking water and water for use and consumption is limited. This is why every two minutes an operator outside the mine will activate the device that will be connected to a compressor and that will release the mist-type water inside the mine.

RESULTS

This study was based on the compilation of data referring to dust suppression systems, bibliographic sources of academic origin were used, coming from databases of scientific documents, where important parameters could be evidenced to take into account in the choice of the system, such as: efficiency, cost, reliability and complexity.

Within the analysis of results, the three variables to be evaluated were taken into account: waiting times, environmental conditions and health conditions, obtaining the following results:

For the assessment of variable #1, it was demonstrated that the values in terms of waiting time are possible to reduce when implementing new technologies in an economic activity that carries out extractive work by traditional methods with cultural roots. With a depth greater than 180m and with the installation of 4 devices, it was possible to minimize waiting times to only 18.33% of the time used with the traditional

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methodology, which is equivalent to 33 min. This waiting time improves the productivity of the company, minimizing extended and strenuous hours as well as avoiding work pressure from senior management when workers are detained for long periods of time.

By analysing variable #2 that corresponds to Environmental conditions, it was possible to manage and convince senior management people to acquire the multi-gas detector equipment, a device that according to Decree 1886 of 2015 is essential to carry out gas monitoring inside the sinkhole. To compare the values, some measurements were taken prior to the implementation of the dust suppression design to have a base reference. The data obtained from taking the Environmental measurements yielded better results, this ones adjust to the Permissible Limit Values according to OSHAS and have levels that generate minor reactions in the health of the workers immediately, showing stable values according to regulations, values that in in the past were not within the minimum work standards for mining atmospheres and generated immediate discomfort to workers, with symptoms such as headache, dizziness, eye irritation, discomfort and burning in the throat, among others, symptoms that sometimes long term can develop occupational diseases such as pneumoconiosis.

What is more, variable #3, the information provided by the workers in terms of their health conditions through a survey, several factors could be interpreted, firstly the workers who have greater work experience, who are also the oldest. age have generated greater resistance to the variables that generate health discomfort, these workers cannot easily identify if they do present symptoms and consider that there are no better ways to do the job. Countering this argument, it was evident that younger workers and less experienced workers were much more sensitive to identifying symptoms and had discomfort at the level of wanting to leave their jobs, a situation that could lead to poor living conditions due to not having economic support in a community where they are mainly dedicated to mining.

CONCLUSIONS

Mining in the South of Bolívar develops its extractive activities with traditional methodologies that give productive results but that generate a high risk for the workers who carried out work there. Although cultural roots are part of the artisanal DNA that the activity imprints on it as added value, a dust suppression system as a measure to control the risks generated by explosives in underground mining activity is an effective strategy to mitigate dusts, fumes and vapors that are generated as a result of blasting in an underground mine in the Vereda la Fortuna and that is presented as a proposal capable of providing tangible results without subtracting that indigenous and ancestral potential that is of such importance for the inhabitants of the sector.

With a depth greater than 180m and with the installation of 4 devices, it was possible to minimize waiting times to only 18.33% of the time used with the traditional methodology, which is equivalent to 33 min. This waiting time improves the productivity of the company, minimizing extended and strenuous hours as well as avoiding work pressure from senior management when workers are detained for long periods of time.

In terms of atmospheric measurements, Gas monitoring showed that the Permissible Limit Values are within the OSHAS standards, the levels of Oxygen and Carbon Dioxide were stabilized, the other gases in turn decreased their levels, and are within the established margins where its presence does not cause harm to workers.

The health conditions of the miners improved in the short term, because although many already have medical discomfort, a risk was eliminated by implementing a dust suppression system that works in conjunction with the traditional air forge system. Health symptoms that are mistakenly called flu by miners decreased by 40%. Likewise, 86.7% of the workers considered that they no longer presented symptoms such as severe migraines, hallucinations and insomnia as a result of the labour demand in high seasons for gold mining (more than five burnings per week).

SPECIAL THANKS

The authors recognize the contributions of Arevalo, Walter, for his hard work and advice as thesis director of the specialization in occupational health and safety at the Manuela Beltran University, a document that resulted in this scientific article. Furthermore, they also deeply thank the mine workers who supported this research.

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ISSN 2590-5929

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