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Conventional Chimney Safety Management Tools for Risk Control at Buenaventura Mining Company - Mallay Unit – Lima

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Mining is the most significant economic activity for the growth of our country; however, economic growth does not necessarily equate to national development.

The mining industry, in all its operational aspects, is regarded as a high-risk undertaking, encompassing a range of inherent risks. The inherent risks associated with its operational activities. A review of the database provided by the Ministry of Energy and Mines reveals that from 2010 to 2023, a total of 582 fatal accidents occurred in the mining sector. Of these, 71 employees died due to exposure or contact by inhalation with toxic or asphyxiating gases (poor ventilation). Notably, two fatal accidents occurred in the U.E.A. Mallay due to gassing in chimneys.

This thesis aims to identify potential weaknesses and opportunities for continuous improvement in the prevention of accidents in conventional chimneys. It seeks to establish standards and procedures for the optimal filling of continuous IPERC, as well as to determine the most suitable rock type and support structure, and to select appropriate drilling meshes for control. The aforementioned areas of focus include labor section, gas monitoring, labor ventilation, work at height, empty spaces, and so forth. These will be addressed through the implementation of management tools and innovative control measures for each activity within the aforementioned mining process. This approach will facilitate the safe execution of operations while aligning with the objectives of our organization.

It is noteworthy that this research serves as a reference for mining companies seeking to develop safe and accident-free operations in chimneys and to ensure the safe return of their employees to their families.
Keywords: mining, safety management, chimney.

1. Introduction

Conventional mining in Peru, as in other parts of the world, employs the use of conventional chimneys in accordance with the specific characteristics of the mineralization, particularly in instances where the mineral deposits are narrow veins of high grade. These operations are inherently associated with a heightened level of risk. Underground works, including conventional chimneys in development and shafts in development or deepening, are classified as confined spaces (D.S. N°024-2016-EM; modified by D.S. N.º 023-2017-EM and D.S. N°034-2023-EM).

It is not uncommon for accidents associated with high-risk activities to result in significant injuries, disabilities, and, in some cases, even fatalities.

The Ministry of Energy and Mines has published statistical data from 2010 to 2023, which reveals a total of 582 fatal accidents. Of particular concern is the observation that, in recent years, the number of fatal accidents in the mining sector has not decreased but, rather, has increased. In 2019, for instance, there were four such accidents. The number of deaths decreased slightly in 2020, with 19 fatalities, and increased in 2021, with 63 deaths. There was a slight decline in 2022, with 39 deaths, and a similar number in 2023.

Table 1 National mining fatalities, from 2010 to 2023.

Cuadro Estadístico de Accidentes Mortales 2010 - 2023													
AÑO	ENE.	FEB.	MAR.	ABR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.	Total
2023	2	1	1	1	27	2	0	5	0	0	0	0	39
2022	2	3	5	3	2	0	2	5	8	4	1	4	39
2021	1	1	1	0	1	28	2	19	2	2	5	1	63
2020	2	5	3	0	2	1	1	0	0	0	0	5	19
2019	4	2	1	4	4	3	3	3	3	1	6	6	40
2018	2	1	2	5	3	2	1	3	2	2	3	1	27
2017	5	5	3	2	6	1	3	4	2	8	0	2	41
2016	4	3	3	1	6	2	2	3	4	1	2	3	34
2015	5	2	7	2	0	2	1	2	2	3	3	0	29
2014	6	1	1	1	1	3	7	2	2	0	1	7	32
2013	4	6	5	6	1	4	4	4	5	2	4	2	47
2012	2	6	9	2	4	2	5	5	3	8	4	4	54
2011	4	8	2	5	6	5	4	5	4	5	1	3	52
2010	5	13	1	6	5	9	6	4	3	4	4	6	66
Total	48	57	44	38	68	64	41	64	40	40	34	44	582

Source: Statistics Ministry of Energy and Mines, 2023.

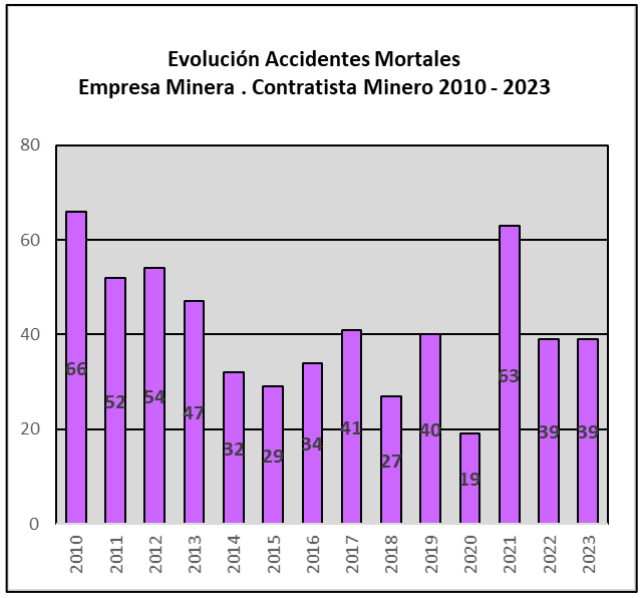


Figure 1. Evolution of fatal accidents 2010 - 2023.

Source: Own elaboration.

Within these statistics, Cia. de Minas Buenaventura in its Mallay production unit has 02 fatal accidents due to gassing or inhalation of toxic substances in conventional chimneys. For this reason there is a concern for Minera Buenaventura and all its workers in general, the senior management proposed to give a renewed impetus to the safety management system, aiming to involve employees and provide adequate physical conditions in which the worker must perform and comply with the safety management tools and controls established to prevent its occurrence.

Table 2. Fatal accidents at U.E.A. Mallay, by gassing

FAX COYUNTURAL DE ACCIDENTES MORTALES

Año de Accidente : 2012 Y 2016

FECHA ACCIDENTE	TITULAR MINERO	CONCESIÓN / UEA	VICTIMA	EMPRESA	TIPO EMPRESA	CLASIFICACIÓN SEGÚN TIPO
01/03/2012	COMPAÑIA DE MINAS BUENAVENTURA S.A.A.	MALLAY	ESPINOZA AYALA, ABRAHAM	SERMINAS SOCIEDAD ANONIMA CERRADA - SERMINAS S.A.C.	Contratista Minero	INTOXICACIÓN - ASFIXIA - ABSORCIÓN - RADIACIONES
27/09/2016	COMPAÑÍA DE MINAS BUENAVENTURA S.A.A.	MALLAY	CHIRIBOGA RODRIGUEZ, WINSTON EDMUNDO	JCB CONTRATISTAS S.R.L.	Contratista Minero	CONTACTO POR INHALACIÓN, POR INGESTIÓN O POR ABSORCIÓN CON SUSTANCIAS NOCIVAS

Source: MEM 2012 and MEM 2016.

The objective of this research is to reduce the incidence of serious disabling and fatal accidents, property damage (equipment and facilities), and process stoppages or losses through the implementation of safety management tools within the Mallay Administrative Economic Unit of Compañía de Minas Buenaventura S.A. These tools have been developed in response to incidents generated by the unit operations of conventional chimney cycling.

As a consequence of these factors, the fatal accidents that occurred in the Mallay E.A.U. were primarily attributable to the elevated risk of inhalation, ingestion, or absorption of harmful substances (gassing) in conventional chimneys. Consequently, this research has been undertaken to identify a range of solution options, employing a variety of safety management tools to mitigate risks associated with worker behavior, leadership, and the commitment of first-line supervisors, as well as the potential failure or absence of a comprehensive management plan in the context of unit operations involving chimney cycling.

The objective is to ascertain the extent to which the conventional chimney safety management tools impacted risk control in the Buenaventura Mining Company Mallay Unit in Lima between 2017 and 2018.

The objective was to demonstrate the importance and performance of conventional chimney safety management tools in risk control at the Buenaventura Mining Company Mallay Unit in Lima between 2017 and 2018.

2. Methodology

The research is explanatory in nature, as it seeks to elucidate the manner by which management tools facilitate the control of risks inherent to chimney operations. Explanatory research aims to reach conclusions and provide explanations that contribute to the development of theories and the understanding of specific phenomena. The study was correlational in nature and sought to demonstrate that the implementation of safety management tools in conventional chimneys would effectively contribute to risk control within the Buenaventura Mining Company Mallay Unit in Lima between the years 2017 and 2018.

The unit of analysis is comprised of mining collaborators from the Administrative Economic Unit Mallay (Lima) of the Buenaventura Mining Company. Specifically, this includes mining collaborators who are engaged in the development of various conventional subway chimneys within the aforementioned unit. A total of 210 mining collaborators were included in the study.

- Exploration and development workings: Four workings.
- Four workings were identified in the preparation stacks.

The research techniques employed were as follows:

A. Observation.

The objective was to identify the risks associated with the conventional chimney of the Mallay Mining Unit (Lima) and to determine the most effective methods for their control, taking into account the use of safety tools.

B. Interview

Through dialogue, three types of response will be elicited: personal consultation with workers, institutional consultation with those responsible for safety, and broad consultation

with workers in the conventional chimney area.

Instruments applied

A. Observation sheet. The check list establishes the safety conditions in the conventional chimney area and the application of tools for this purpose.

B. Questionnaire. To know and understand the workers' opinion about safety, their conditions and particular situations regarding safety in the conventional chimney area.

3. Results

Study área

At the beginning of the 20th century, the recognition of the territory received a new impetus thanks to the promulgation of the first mining code in 1901 and the explorations that were conducted on horseback with the limited technical conditions that were available at the time. At that time, this area was recognized by the inaugural cohort of Peruvian engineers involved in that effort. A number of significant documents have survived from that period, including the first issue of the Bulletin of the Corps of Mining Engineers of Peru, published in 1901. It was during the course of this research that the existence of the Mallay mine was identified. The mine is situated 200 km northeast of Lima, in the province of Oyón, in close proximity to Uchucchacua within the Huaura river basin at an altitude of 4250 meters above sea level. Prior to this, the area had been the subject of exploration by the United States Geological Survey. The institution identified twelve occurrences, yet concluded that none possessed sufficient potential for mining development. However, this assessment was ultimately erroneous, as this is the location of four significant mining enterprises: Uchucchacua, Raura, Iscaycruz, and Mallay, where the following events transpired:

1st. At the end of 2003, Buenaventura carried out mapping and surface sampling works on the isguiz mantle, obtaining good results to develop explorations through diamond drilling.

2nd. In 2004, an opportunity arose to acquire 7000 h of the mining concession owned by Isaac Rios, where polymetallic minerals were found to be outcropping in sedimentary rock.

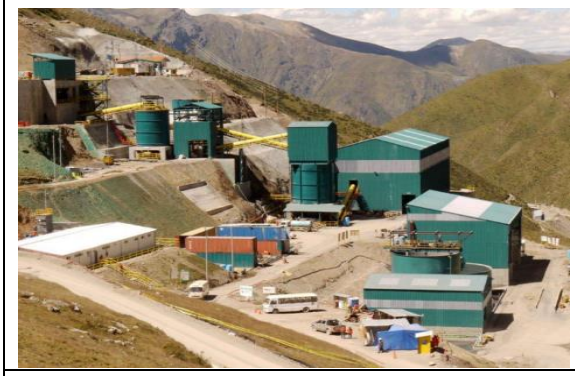
3rd. In 2005, Mallay was listed as a Brownfield project of Uchucchacua due to its proximity to this mine, where the drilling campaign was completed with positive results, starting exploration work by means of a 300 m cruise to the Isguiz mantle, continuing exploration until 2011. At the same time, metallurgical tests were carried out which demonstrated that the Mallay ore is docile to selective flotation, starting the construction of the concentrator plant with a capacity to treat 500 tons/day.

4th. In July 2010, Buenaventura began the construction and preparation stage of the Mallay Mining Unit, executing various surface and underground works.

5th. On April 13, 2012, the Mallay Unit started operations with an initial production of 450 TCS/DIA, with the use of thermal energy (generator set), the extraction method being a subway mine, is the up-fill cut with detrital backfill. Currently 450 TCS/DIA are produced,

with an average grade of 7.06 Oz Ag, 4.91% Pb and 6.43% Zn, working with energy coming from the interconnected network.

Image view of the area

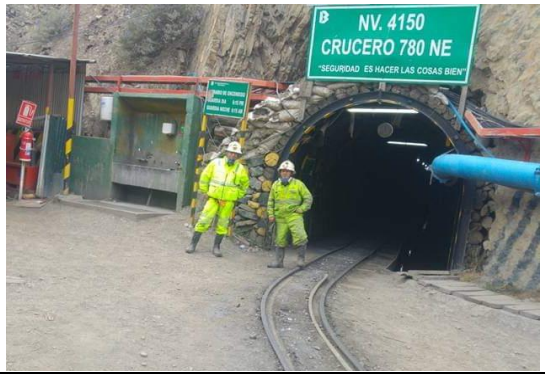


Picture 1. Metallurgical Plant View U.E.A Mallay.

Source: Own elaboration

Picture 2. View of U.E.A Mallay Offices.

Source: Own elaboration



Picture 3. View Nv.4150 of mineral extraction U.E.A Mallay.

Source: Own elaboration

Picture 4. Panoramic view of Mallay Mining Unit.

Source: Own elaboration

Located in the Mallay Mining Unit of Compañía de Minas Buenaventura S.A.A., it is located in Mallay, district of Oyón, province of Oyón, department of Lima, at an elevation between 4,090 and 4,470 meters above sea level, on the western slope of the Andes Mountains, in the Huaura river basin, southwest of the city of the same name.

UTM coordinates

North : 296,814.607 m

East : 8,817,403.860 m

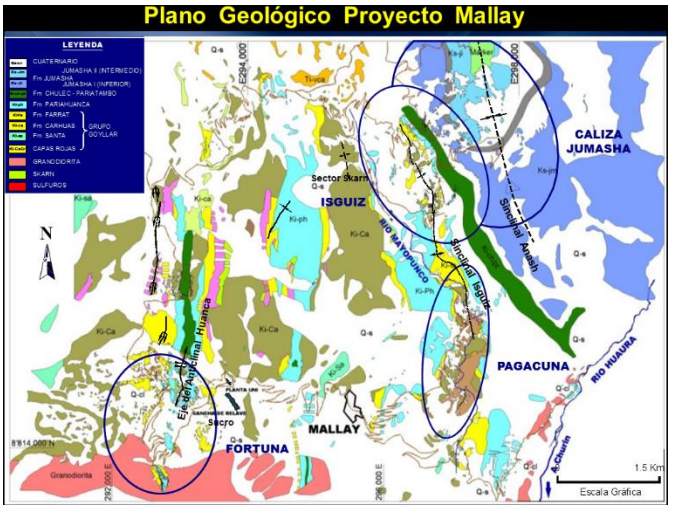


Figure: Geological map of U.E.A. Mallay.

Source: U.E.A. Mallay Geology Area.

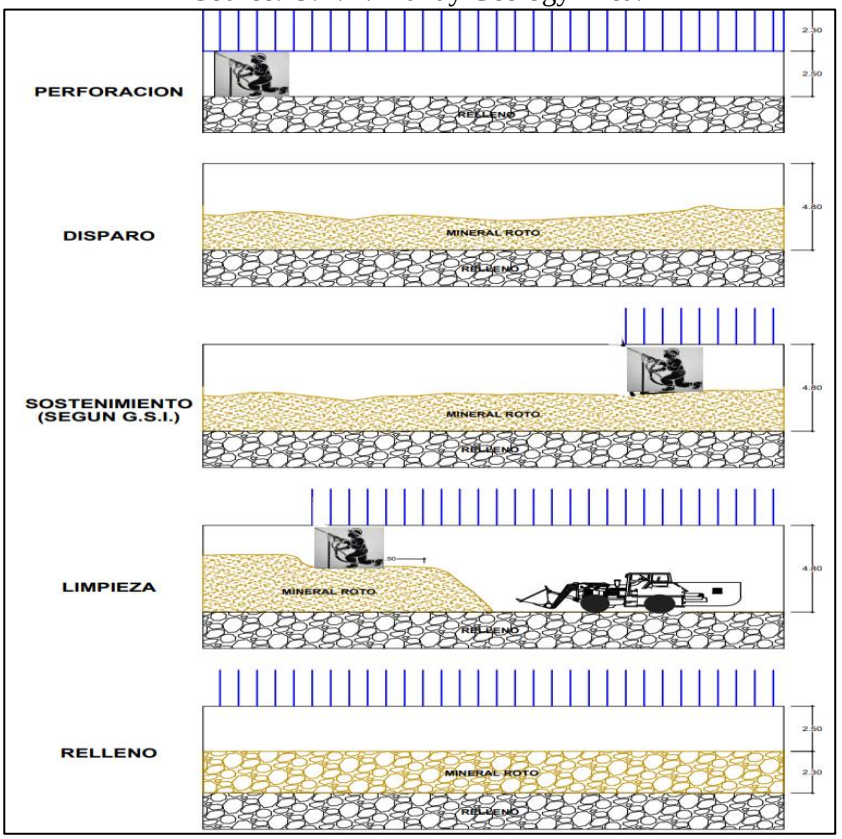


Figure: Exploitation of pits in enhancement with Jack Leg cleaning with Scoop.

Source: Mallay Unit pit standards

The mine is projected to produce in the medium and long term 450 TCS/day and 1000 TCS/day respectively, having planned to develop 13 levels from level 4470 to level 3800, with a distance between levels of 50 meters, the mining method is upward cut and fill, extracting silver, lead, zinc in a conventional way, having as predominant rock for the mineralization of type IIIA and IIIB for the encasing rock.

Given these characteristics, the air demand inside the mine was calculated according to the provisions of the Regulation of Occupational Safety and Health in Mining (D.S N°024-2016-EM; modified by D.S N°023-2017-EM and D.S N°034-2023-EM).

Table 1: Indoor air requirement for the mine interior

Appearance	Altitude	Air requirement	
Personal	0 to 1 500 msnm	3m^3/min	105.9 cfm
	1 500 to 3 000 msnm	4m^3/min	141.3 cfm
	3 000 to 4 000 msnm	5m^3/min	176.6 cfm
	More than 4 000 msnm	5 m^3/min	211.9 cfm
Diesel		3m^3/min/HP	105.9 cfm/HP

Source: D.S N°024-2016-EM

Projected medium-term air requirement (400 TS/d).

To calculate the air balance, the maximum amount of equipment that could be operating simultaneously in the medium term was estimated. A total of 70,707 cfm is required.

Table 1. Air flow rate required for 400 Tm/d

Appearance	Quantity in operation	Power (HP)	Total (HP)	Consumption of cfm per HP	Air required (cfm)
Scooptram of 2.2. yd^3	2	117	234	105.9	24,781
Persons per shift	150			211.9	31,785
Subtotal					56,666
Safety factor 25%					14,141
Total					70,707

Figure 6: Air flow rate required for 400 TS/D.

Source: Mallay Unit Ventilation Area

Long-term projected air requirement 1000 TSD.

To calculate the air balance, twice the number of workers per guard was considered, and two additional 2.2 yd³ scooptrams and a 100 HP service equipment were included. The resulting required flow rate is 154,652 cfm.

Table 1. Air flow rate required for 1000 Tm/d

Appearance	Quantity in operation	Power (HP)	Total (HP)	Consumption of cfm per HP	Air required (cfm)
Service equipment	1	100	100	105.9	10,590

Scooptram of 2.2. yd^3	2	117	234	105.9	49,561
Persons per shift	300			211.9	63,570
Subtotal					123,721
Safety factor 25%					30,930
Total					154,652

Source: Mallay Unit Ventilation Area

Two surface chimneys for stale air extraction

For the ventilation system, the required air balance is 168,300 cfm and meets the established requirement.

Table 1. Stale air capacity

Appearance	Labor	Level	Simulated flow rate (cfm)
Fresh air intake	Bocamina Nv 4150	Nv 4150	26,600
	Crucero N° 4250	Nv 4250	36,200
	Bocamina N° 4250	Nv 4250	30,200
	Bocamina N° 4310	Nv 4310	20,700
	Bocamina N° 4370	Nv 4370	12,900
	Bocamina N° 4420	Nv 4420	9,100
	Chim 800	Nv 4420	5,600
	Bocamina Nv 4470	Nv 4470	27,000
Stale air outlet	Chim Norte (7´ x 7´)	Nv 4770	76,600
	Proy RC 8410 N (7´ x 7´)	Nv 4770	99,000
Balance	Total intake (fresh air)		168,300
	Total output (stale air)		176,500
	Power consumption 162 HP		
	Ratio (HP/cfm) x 103 0.96		

Source: Ventilation area. Mallay Unit

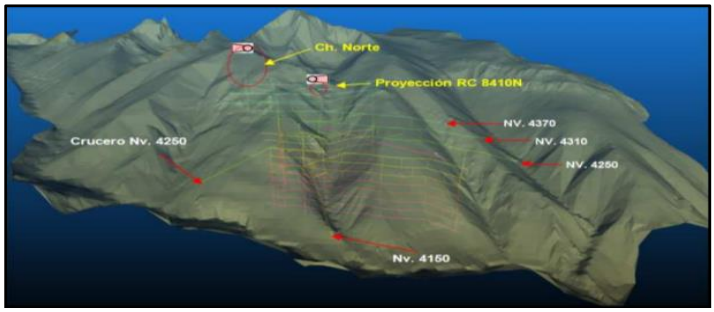


Figure 11: Exhaust stacks for foul air extraction

Source: Mallay unit ventilation area.

Fan dimensions.

For the selection of the fans, parameters such as: total pressure (in. H2O), required flow (cfm), power (HP) and blade angle (°) were taken into consideration.

Two fans were determined, which will be located at the top of the North chimney and in the projection of the RC 8410 N.

Table 1. Fans for stale air extraction

Chimenea	Flow rate (cfm)	Total pressure (in H2O	Power HP	Ventilation series	Blade Angle (°)
North Chim	76,600	4.4	72.4	VAV-54-26.5-1750-I-A	50
North Chim	76,600	4.4	72.4	VAV-60-26.5-1750-I-A	50

Source: Mallay unit ventilation area.

Chimney operation cycle.

Chimney inspection and monitoring

It is the first activity after a cycle, it is a process of direct observation that collects data on the work area, its processes, conditions, protective measures and compliance with legal provisions on occupational safety and health. SUPREME DECREE N°024-2016-EM; modified by D.S N.º 023-2017-EM and D.S N°034-2023-EM.

Order and cleanliness

Activity that is performed to maintain the accesses, stockpiles and floors must always be free of oil, grease, water and all kinds of obstacles in order to facilitate the safe movement of collaborators in their activities and/or emergencies. SUPREME DECREE N°024-2016-EM; modified by D.S N.º 023-2017-EM and D.S N°034-2023-EM ARTICLE 398.

Chimney ventilation

This activity consists of supplying clean air with 15” diameter ventilation sleeves under the flange and compressed air (third line) at the top of the work, the objective is to evacuate gases, dusts, suspended fumes that could affect the worker's health and maintain comfortable environmental conditions.

The chimneys are blind subway works with only one access and at the beginning of the shift the supervisor or shift manager must take measurements of the following gases:

- Carbon monoxide
- Nitrogen monoxide
- Carbon dioxide
- Nitrogen dioxide
- Oxygen and others.

The work sites must have at least 19.5% oxygen (SUPREME DECREE N°024-2016-EM; modified by D.S N.º 023-2017-EM and D.S N°034-2023-EM - EM Article 246).

The minimum necessary amount of fresh air per man shall be 6m3/min, given that the Mallay mining unit passes 4000 m.a.s.l. (D.S N°024-2016-EM; modified by D.S N.º 023-2017-EM and D.S N°034-2023-EM, Article-247).

The air speed shall not be less than 20m/min or more than 250m/min. (D.S N°024-2016-EM; modified by D.S N.º 023-2017-EM and D.S N°034-2023-EM Article-248).

If the chimney works are temporarily abandoned for more than 15 days, proactive measures shall be taken to place red ribbons prohibiting the entrance of the chimney.

Chimney watering

This activity is performed with pressurized water after each shot 5 meters before the top of the work, in order to minimize dust, identify fractures or loose rocks for a better untying of rocks. product of the shot.

The watering will start from the crown or roof to the gables and finish at the load.

Untied from chimney rocks

This activity is performed to avoid the detachment of loose rocks as a result of blasting, being this risk the main cause of accidents in mines, all collaborators before entering their work to start this activity must comply with the following established work rules. (SUPREME DECREE N°024-2016-EM; modified by D.S N.º 023-2017-EM and D.S N°034-2023-EM)

- If gases and fumes still persist, the chimney will be ventilated for at least one hour using the third line (compressed air).
- The 1" knotted rope must be moved to make any rock fragments loose in the chimney path fall.
- Set the traffic light to red when going up to untie the rocks.
- Climb up inspecting the chimney until you reach the top, verify the condition of the rocks. The anchor line must be secured to the anchor point.
- The collaborators will secure two boards on the last advancing prop, as a platform for untying.

Untie loose rocks from the roof and gables always using your E.P.P. and the appropriate barrette. Choose the right length of barrette, according to the chimney section, so that the unbolter can move easily. Lower the chimney by untying loose rocks from the gables and cleaning the load accumulated on the boards. Untie in chimneys is done from top to bottom, constantly verifying the stability of the rock massif with the sound emitted by the blow of the barretilla against the rock.

Picture 6. Inspection and monitoring of Chimney 1360-2

Source: Own elaboration

Picture 7. Chimney Order and Cleaning

Source: Own elaboration

Picture 8. Ventilation with sleeve and third line in chimney.

Source: Own elaboration

Picture 9. Watering of crown load in Chimney

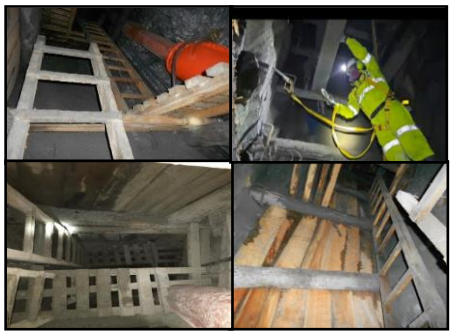
Source: Own elaboration.

Picture 10. Untying of rocks in Chimney

Source: Own elaboration

Picture 11. Supporting with over frames and mesh plus Split set in Chimney.

Source: Own elaboration



Picture 12. Woodwork, stairway, landing, mailbox lining, in-line props and ranfla.

Source: Own elaboration

Picture 13. Chimney perforation

Source: Own elaboration

Picture 14. Loading and blasting in chimney

Source: Own elaboration

Chimney support

In order to choose the type of support, the geomechanical table should be used, which indicates the type of rock and the section of the work.

For a better support the following parameters will be complied with:

- The worker will verify the area to be supported must have a clean floor and an adequate height to place the support with electrowelded mesh plus bolts or wooden frames.
- The Supervisor must guarantee the painting of the perforation mesh for the placement and distribution of the systematic support with bolts, the support will be in advanced from a supported point.
- The worker will take into account that the drill holes to be drilled must be perpendicular to the discontinuities (faults and fractures) and be in the range of drill diameter must be 36 mm (minimum) to 38 mm (maximum).

- To place the Split set bolt the Driller will always drill half a foot more than the total length of the bolt. For example, to place a 5 foot split set, drill 5 and a half feet, then drill the first hole from the supported side. Always start holding at the crown and continue towards the gables, drill drilled split set.

- The sequence of support will be "Drill Drilled, Bolt in place". Comply with the re-tying during the support according to the Rock Untying Frequency chart.

- The Driller shall note that the split set bolt shall be presented and pressed in with the slot down using the split set adapter.

- The Driller will take into account that the split set plate must be stuck and in full contact with the rock, and the work will be held up to the top before continuing with its advance, complying with the policy "advanced section, sustained section".

Chimney woodwork

This activity will be executed having the whole area supported, the wood works will be carried out as follows:

- Before climbing the chimney, verify that the valve of the third line is open at all times, place the traffic light and delimit the work area. Place the red traffic lights (no climbing), Green (accessible, warn with the third line closing and opening the valve) The props will be removed, the advancing props and the groove will be removed.

- The workers will place the props in line at 1.10 m of distance between props and securing it on the 2 inches pin, then proceed to nail the 2" thick boards that will serve as a platform for drilling without leaving open spaces. To perform this step you must remain with the harness secured to the anchor point.

- The workers will have to take the measurement of the section, cut the props and the boards on the floor according to the measurements taken.

- The workers will place aligned 6" x 6" props every 1.10 m. for the division of the chimney and the lining with 2" x 8" x 10' boards, taking into account that the road compartment must be on the exit side and must be completely lined towards the laydown area.

- The workers will place the landings every 2.40 m, they will be made with 2" x 3" slats and spaced 2" between slats leaving an opening for the access of personnel and transfer of materials 80 cm x 70 cm.

- The workers will place stairs on the road that will be 3.40 mts. long, with 03 steps passing (1 meter) from the landings and placed alternately to the left and right, supported in the same direction with a maximum angle of inclination of 80° with respect to the horizontal.

- Install the grill, with 30 lbs rail, with a span of 8", which must be secured with nails to the line prop.

- Lastly, place the slot on the road side with 2" boards and they must be secured with 5" nails.

Chimney drilling

The drilling activity is executed after all the wood works, for the above mentioned cycle it is necessary to place advance props that serve as platform or drilling floor with a height of 1.50 m from the floor to the crown edge.

The cycle of drilling in chimneys is important to consider the following aspects:

- Bleed the hoses and install the drilling machine, securing with the clamp, having all the valves of the drilling machine closed to prevent the machine from lifting violently.
- Anchor to the anchor point and mark 1 meter above the last strut, where you will proceed to punch the 2" dowels, using the jackleg machine. Proceed to square the dowel using the disc points and the combo.
- Measure the length of the struts and boards to be used. Cut the props and boards on the floor on the jackleg. Then they will need to raise the materials using the stocking rope.
- Place and secure the advancing props on the legs and nail the boards to secure the drilling platform.
- Center the grain and/or take out the direction point (direction and inclination), proceed to paint the drilling mesh according to the standard drilling mesh.
- Drill 2 anchor holes of 3 feet at 1.2 meters from the last prop. Always start the drilling using the set of holes with the kicker (2'), follower (4').
- In case of double compartment chimneys, the jackleg machine will be left under the groove; in case of single compartment chimneys, it must be secured to the penultimate prop protected with boards. The machine must be properly cleaned and with its hood.

Loading and blasting

The blastholes are usually mechanically charged with ANFO or emulsion explosive. The blasts are timed to cut downward, with the wall drills being the last to fire. Blasting, in mining, is the action of fragmenting rock using gases at high pressures and temperatures from explosive mixtures, to perform different types of workings or exploit the ore body. Remigio Palomino, G. C. (2020). Estudio geomecánico para diseñar mallas de perforación y voladura en chimeneas - Mina San Andrés - Minera Aurífera Retamas S.A.

Within this activity it is important to consider the following steps:

- The Driller and Assistant Driller will have the internal authorization of work at height, the (PETAR), SUCAMEC, then verify the order and cleanliness of the work area, identify its hazards in the IP book and take control measures, to perform this work must use mandatory full PPE and fall protection equipment.
- The Driller will request the explosive material to the supervisor, who will authorize in writing the amount of explosives according to the calculation made.
- Raise the materials in buckets and separately for the preparation of the primers and explosive charge, it will be done in a safe area (stopes or chimney level).

- The Driller and Assistant Driller, before loading, will obligatorily make a re-drawing of the work zone according to the type of rock and cleaning of the drill holes using a spoon.

- The Driller in coordination with the Helper will first place the bait pushing with a wooden striker in a soft way, then they will introduce the amount of dynamite cartridges according to the length of the drill hole and type of rock, they will carry out the attack starting with the second cartridge if necessary to achieve the adequate confinement and will use clay blocks in all the loaded drill holes.

- The Driller will proceed to tie connectors according to the exit sequence and will perform a final check of the tie splices (connectors - quick fuse and/or detonating cord). In the case of chimneys with double compartments, the quick fuse must reach at least to the last break in the road. In the case of chimneys without double compartments, the fast fuse must reach the horizontal work.

- The Assistant Driller will return the leftover explosive and/or accessories to the auxiliary powder magazine drawers.

- Before firing, the Driller will coordinate with the nearby workings, then place the lookouts and proceed with the firing complying with the firing schedule established by the mine owner, obligatorily place the firing warning sign “Work Fired” and leave the work ventilation with third line, making sure that the third line of air must be placed on two props below the top, secure and point the hose to the front.

Evaluation of security management tools

Table 6 Implementation of security management tools

It	Appearance or detail	R	P	N
1.	Updated Occupational Health and Safety Plan	1		
2.	Joint Occupational Health and Safety Committee formed.	1		
3.	Permanent dissemination of Law No. 29783 and its regulation D.S 034-2023-EM.		1	
4.	Safety protocols published		1	
5.	Prevention and safety training schedule.	1		
6.	Occupational Health and Safety supervision and monitoring.		1	
7.	Risk maps in the work areas according to the designated tasks.		1	
8.	Contingency and emergency plan disseminated, implemented and put into practice.		1	
9.	Base IPERC matrix	1		
10.	Continuous IPERC	1		
11.	Evidence of preparation of CHECK LIST	1		
12.	Evidence of elaboration of Safe Work Order (STO)	1		
13.	Evidence of elaboration of procedures and standards	1		
14.	Evidence of elaboration of High Risk Work Permit (PETAR)	1		

15.	Geomechanical Evaluation (GSI Table)	1		
16.	Signage implemented	1		
17.	Permanent control of compliance with management tools	1		
Total		12	5	0

Source: Observation sheet applied

Comment

Of the 17 security management tools, 12 are completed or being implemented and 5 are in progress.

Table 7. Evaluation of the condition of security management tools

Score	Situation	Personal	Percentage
15	Unsatisfactory	0	0,00
12 a 14	Critical	5	20,83
10 a 13	Acceptable	14	58,33
6 a 9	Satisfactory	3	12,50
0 a 5	Very satisfactory	2	8,33
Totales		24	100,00

Source: Survey applied to workers.

It can be seen that they respond about the conditions of the management tools in general, for 3 workers they are in Critical condition, for 15 workers they are in Acceptable condition, for 4 workers they are in Satisfactory condition and for 2 workers they are in Very Satisfactory condition.

Evaluation of risk conditions

According to the study, the following results were obtained:

1st. The description of risks and hazards is correct in 67% of cases, incorrect in 17% of cases, and in 16% of cases it has not been done. This is favorable to management.

2nd. Regarding the use of equipment, it could be seen that in 67% of cases the correct use is made, in 21% of cases the correct use is not made and in 12% of cases it has not been made. This is favorable to management.

3rd. With respect to the identification of hazards and risks, it can be seen that it is correct in 67% of cases, 21% of cases it is incorrect and in 12% of cases it has not been done. This is favorable to management.

Perception of security

With respect to the perception of security by the surveyed workers, the following results were obtained:

1st. Regarding knowledge of occupational health and safety management, 54% have good knowledge, 25% have knowledge, 13% are indifferent or not interested, and 8% have no knowledge. This is favorable to the management, since the majority affirms to have knowledge.

2nd. On the need for occupational health and safety management, 50% indicate that they strongly agree and 29% agree, 17% are indifferent and 4% do not agree. This is favorable to the management, since the majority affirms to have knowledge.

3rd. Regarding the knowledge of the hazards and risks in their task, 75% have good knowledge, 12% have knowledge, 8% are indifferent to the information, and 4% do not consider it necessary. This is favorable to the management, since the majority affirms to have knowledge.

4th. Regarding training on Occupational Health and Safety Management, 83% of workers accept having been trained, 13% consider that they have had some training and 4% are indifferent, no one denies having been trained. This is favorable to the management, since the majority affirms that they have been trained.

5th. Regarding the need for Occupational Health and Safety Management Tools, it can be seen that 83% consider it very necessary, 13% that it is necessary and 4% are indifferent to having the tools. This is favorable to management, since the majority affirms that it is necessary.

6th. Regarding the need for a risk map in the work environment, it can be seen that 92% consider it very necessary, 4% consider it necessary and 4% say they are indifferent. This is favorable to the management, since the majority affirms that it is necessary.

7th. Regarding the perception that the work is safe in the establishment, 46% consider that it is very safe, 42% consider that it is safe and for 12% it is not safe. With 88% agreeing that it is very safe or safe, it can be indicated that the response is favorable for the management.

8th. Regarding the safety inspections carried out, 46% consider that they are always carried out, 50% that they are carried out and 4% do not recognize that they are carried out, being 96% those who carry them out, it is considered to be favorable.

9th. On the use of a Safe Work Order and the answers coincide in very necessary with 88% and necessary with 12%, i.e. 100% recognize the need, the answer is favorable.

10th. On the use of a Planned Work Observation and the answers are very necessary for 79% and necessary for 17% and only 4% are not necessary, therefore, the answer is favorable.

11th. Regarding the determination to apply a sanction for substandard conduct, 58% strongly agree, 38% agree and 4% do not agree, therefore, the answer is favorable.

12th. However, regarding the auxiliary elements of safety and health at work, between totally agree and agree, 12% are in agreement, 8% are indifferent and 80% are in disagreement. This aspect is not favorable.

13th. Regarding the need for Written Permission for High-Risk Work, 71% consider it very necessary, 25% consider it necessary, only 4% do not consider it necessary, therefore the PETAR is favorable.

14th. Regarding the registration of Adverse Events in the last semester, 71% also consider it very necessary, 25% consider it necessary and only 4% do not consider it necessary. Therefore, the response is favorable for the management.

15th. Regarding the most used management tool, and it can be seen that the answers are diverse, being the Safe Work Observation at 38%, the Written Permit for High-Risk Works at 25% and the continuous IPER at 21%, it implies considering that there is interest in safety management, but also which would be the most necessary tools to strengthen its implementation.

Table 26 Relationship between security assessment and management tools

Rating	Perception	Reason	Percentage	HHG evaluation	Percentage
Unsatisfactory	8	0.12	0.60	0	0.00
Critical	58	0.87	4.37	3	12.50
Acceptable	60	0.90	4.52	15	62.50
Satisfactory	292	4.40	21.99	4	16.67
Very satisfactory	910	13.70	68.52	2	8.33
	1328	20.00	100.00	24.00	100.00

Source: Tables processed from N° 11 to 24.

Comment

It can be seen that they respond on the Relationship of Management Tools is 0.60 to 0 understood as Unsatisfactory, for the Critical condition it is 4.37 to 12.50, for Acceptable it is 4.52 to 62.50 and for Satisfactory it is 21.99 to 16.67 and for Very Satisfactory it is 68.52 to 8.33. Considering more consistency in the Satisfactory.

Table 27 Situation of risks by chimney evaluated

Risk	Chimney 1		Chimney 2	
	f	p	f	p
High	5	38.46	3	11.11
Medium	8	61.54	9	33.33
Low	0	0.00	15	55.56
Total	13	100.00	27	100.00

Source: IPERC Matrix Observation - Chimneys

Comment

It can be seen that in the case of Chimney 1 there are 5 high risks, 8 medium risks and 0 low risks, it is a critical risk chimney; for Chimney 2 there are 3 high risks, 9 medium risks and 15 low risks, it is a moderate risk chimney.

Table 28 Chimney risk severity assessed

Risk	Chimney 1		Chimney 2	
	f	p	f	p
Critical	3	23.08	3	11.11
Moderate	9	69.23	8	29.63
Low	1	7.69	16	59.26
Total	13	100.00	27	100.00

Source: IPERC Matrix Observation – Chimneys

Comment

It can be seen that in the case of Chimney 1 there are 3 critical risks, 9 moderate risks and 1 low risk, it is a chimney of critical severity; for Chimney 2 there are 3 critical risks, 9 moderate risks and 16 low risks, it is a chimney of moderate severity.

Table 29 Frequency of risk by Chimney evaluated

Probability	Chimney 1		Chimney 2	
	f	p	f	p
High	4	23.08	2	11.11
Moderate	9	69.23	13	29.63
Low	0	7.69	24	59.26
Total	13	100.00	27	100.00

Source: IPERC Matrix Observation - Chimneys

Comment

It can be seen that in the case of Chimney 1 there are 4 risks of high probability of occurrence, 9 of moderate probability of occurrence and 0 of low probability, it is a chimney of moderate frequency of accidents, for Chimney 2 there are 2 of high probability of occurrence, 13 of moderate probability and 24 of low probability of occurrence, it is a chimney of moderate to low frequency of accidents.

4. DISCUSSION OF RESULTS

A. Perez and Beatncourth (2019) in their study identify a series of problems and risks, mainly due to the fact that, in safety management, personnel protective equipment is not requested, there is no proper signage, and training is not met and there is no budget for occupational safety and health.

Comment:

In direct controversy with what was observed in this thesis, the study has considered the use of personal protective equipment according to Table 8 and has complied with training according to table 13 in both cases, unlike the cited thesis, the results were favorable, since the thesis consulted indicated these facts as critical.

B. Álvarez (2021) in his study appreciated a series of risks and problems as a result of the lack of prevention, training and timely medical attention.

Comment:

Table 11 indicates that occupational health and safety management is the most important factor and, as mentioned in Table 13, that it is considered important, but does not indicate anything about timely medical care.

C. Cedeño (2022) expresses in his study the need for a comprehensive improvement of the system that prevents accidents or occupational diseases, there is a high risk in workers of mortality or permanent disability, apply control measures or risk suppression, with training measures on critical aspects such as: working at heights, timely work permit, use of lifelines and personal protective equipment, which Table 26

Comment:

Table 23 specifies the risks or hazards that exist and that adverse events can be prevented by taking them into account. According to Table 25, the safety tools are considered satisfactory.

D. Florez Salas et al. (2022) in their article indicate determining the need to better manage occupational safety and health and that this is better planned in such a way that it is executed in a consistent, timely and relevant way, which helps to reduce accidents, are also identified as direct management tools: Personal Protective Equipment, Hazard Identification, Risk Assessment and Control Measures (IPERC), Safe Work Standard Procedures (PETS), Occupational Safety and Health Signage and High Risk Work Analysis, with this a high standard of safety at work would be achieved.

Comment:

Table 14 indicates the need for management tools and the need to implement them, then tables 15 to 19 and 22 consider that management tools are necessary, and Table 23 considers that all the HHGG are necessary, but especially the Safe Work Observation with the highest acceptance.

E. Sosa (2021), in his thesis there is a direct relationship in risk control tools and innovation, is that it is important human talent management and teamwork, therefore it was determined that the main asset is the workers, that there is leadership to develop risk management and that workers require more involvement with the work they develop and the culture of safety.

Comment:

That all of the above should be considered with respect to these facts, according to Table 14, 83% consider their implementation necessary.

F. Aguilar (2022), to establish occupational health and safety management tools to prevent accidents, considering that the IPERC matrix defined the major risks, that it is important to align with the standards in order to establish all the control and precisely when the management tools are applied everything was simpler.

Comment:

It considers that Table 24 indicates how important it is that the management tool is satisfactory as Table 6 indicated that the conditions of these were acceptable, that Tables 25 to 27 consider the situation, severity and frequency as a reference to evaluate the IPERC matrix of both stacks.

G. Quispe (2019), in his study considered that it is positive the safety system in relation to the drilling of the chimneys, that the safety plan is important for the system and safety in the activities of the company and that training is mainly the strength to obtain favorable results in meeting the goals proposed for the safety system in relation to the chimneys.

Comment:

Tables 25 to 27 imply that the matrix is important, but it is important because, as indicated above, it establishes the critical situation, the frequency of the risks and their severity.

5. Conclusions

In the research conducted with workers in Conventional Chimneys at the Buenaventura Mining Company Mallay - Lima Unit, the general conclusion was reached that safety management tools will contribute to risk control in the different activities within the cycle.

- According to the studies carried out on the conditions or status of the Safety Management Tools in Conventional Chimneys, it is determined that, out of a total of 24 employees, 21 employees consider that they are acceptable, satisfactory and/or very satisfactory, since they are classified as favorable.

- Given the studies in the evaluation of risk conditions in Compañía Minera Buenaventura Mallay Unit - Lima, according to Table 7, 66.66 % of the workers describe correctly the risks and hazards related to their activities in the chimney are clearly established as favorable.

- The study shows in Table 20 sanction for substandard conduct or act of non-compliance with management tools that 58.3% totally agree and 37.5% agree, this will lead us to a better use of management tools.

- The importance and performance of the Conventional Chimney Safety Management Tools in Risk Control at the Buenaventura Mining Company - Mallay Unit - Lima implied that they are necessary according to the workers' criteria, but also from the IPERC matrix the situation of the workers is identified, but it is also considered in view of the need established in the study regarding the management tools.

RECOMMENDATIONS

After corroborating that the application of the safety management tools in conventional chimneys will effectively contribute to risk control at the Buenaventura Mining Company Mallay - Lima Unit, the first recommendation is to provide training at all levels to employees on the importance, use, filling and evaluation of the aforementioned tools.

- Within the study conducted in the evaluation of the conditions of the management tools, for 3 workers they are in critical condition (it is not very important and the filling is

done by commitment without making the evaluations), It is necessary to train, evaluate, train and update the Management Tools for the control of risks in the chimneys and with the possibility of replicating in other realities.

- In the study conducted in the evaluation of risk conditions, 16.67% described incorrectly and 16.67% did not describe the risks. It is recommended to select workers with at least 3 years of experience for the job profile and to avoid constant movement or rotation of employees in conventional chimneys, given that these activities are considered high risk.

- It is recommended that before applying sanctions for substandard behavior or acts that do not comply with the management tools, a psychology department be set up to check the worker's emotional state, given that most accidents are caused by the workers' own actions.

- Raise awareness of workers in a culture of prevention of accidents and incidents making the correct use of management tools and be trained, trained, updated permanently.

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