MINING INDUSTRY
OCCUPATIONAL
SAFETY & HEALTH

MINERALS COUNCIL
SOUTH AFRICA

IMPROVED UNDERGROUND WORKFACE VISIBILITY

Northam Platinum – Eland

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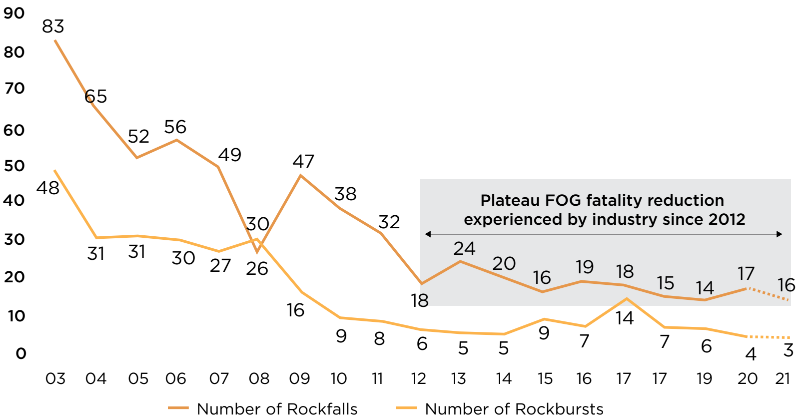
1 INTRODUCTION AND BACKGROUND

In July 2021, the Minerals Council South Africa, through the mandate of the CEO Zero Harm Forum and the guidance of internal stakeholders, developed the Elimination of Falls-of-Ground Fatalities Action Plan (FOGAP) in working towards the improvement of fall-of-ground (FOG) safety in the South African mining industry.

Figure 1 shows a steep decline in fall-of-ground fatalities for the period 2003 to 2011. The diagram also shows that this decline is followed by a plateau in the same indicator for the period 2012 to 2020. This observation is important because it shows that the rate of improvement of FOG fatalities has reduced over time. Although there is still a decline in the numbers, there has been a reduction in the acceleration (or pace) of working towards the zero-harm goal. This slow rate works against the timelines set by the CEO Zero Harm Forum.

The FOGAP was designed to assist the South African mining industry (SAMI) to break through this plateau. It complements the continuing work of the Minerals Council South Africa and other external stakeholders to enable the SAMI to work towards the goal of zero harm.

Figure 1: Plateau in reduction of FOG fatalities (2003 - 2021)



The FOGAP identifies six key areas (referred to as the six pillars) that need to be addressed to accelerate the industry's journey towards zero harm. The first of the six pillars is the adoption of leading practices. This pillar identifies potential leading practices, and amongst them is the "improvement of underground visibility to an appropriate standard". The FOGAP identified this as a quick win project that can be investigated, documented, and adopted in the short term. As a result, a recommendation was made to the MOSH FOG team for this initiative to be investigated as a potential leading practice. The investigation is documented in this report.

"The rate of improvement of FOG fatalities has reduced over time. This indicates a reduction in the pace of working towards the zero-harm goal."

Gold Fields – South Deep

Ivanplats – Ivanhoe Mines

1.1 Background

The Department of Mineral Resources and Energy (DMRE) South African Mines Reportable Accidents Statistical Systems (SAMRASS) for the years 2015 to 2019 shows that most of the Falls of Ground accidents occur at the stope working face. This observation was made from the analysis of 1,198 serious accidents and 108 fatalities. The analyses in Figure 2 and Figure 3 show the following for the period of 2015 to 2019[1].

63%

(759) of serious FOG injuries occurred at the stope working face

56%

(61) of FOG fatalities, occurred at the stope working face

Figure 2: Location of most FOG injuries (2015- 2019)

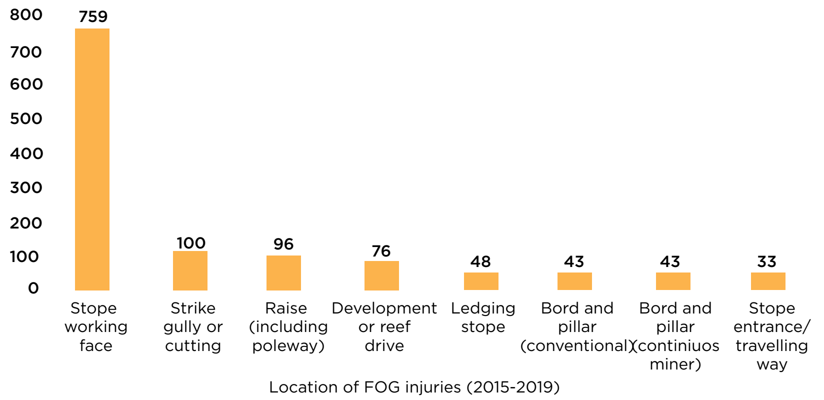
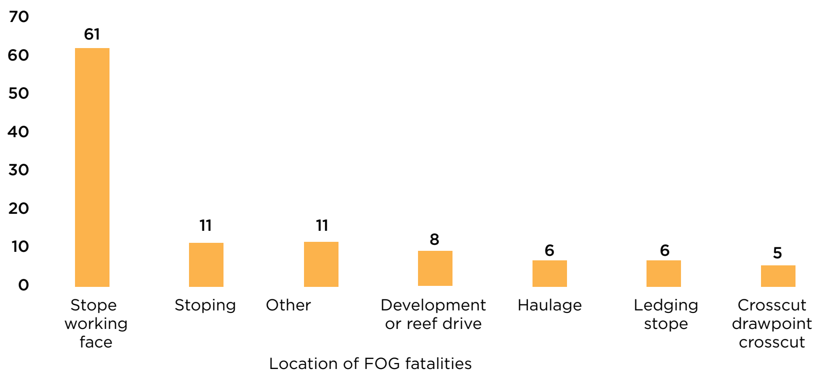


Figure 3: Location of most FOG fatalities (2015- 2019)



The information in these figures shows that FOG injuries and fatalities mainly occur at the working faces of conventional stopes. This is because these areas have the highest concentration of employees during the shift compared to other excavations. The fall-of-ground hazards in this area, and exposure of personnel to these hazards combine to make this the most high-risk working area underground. It is because of these reasons that this investigation focuses specifically on the illumination of the conventional stope working face[2]. It is important to note that this also includes the illumination of the development faces of conventional mines.

Underground working faces are dark, and where conventional mining methods are used; employees primarily rely only on cap lamps for illumination. Although the cap lamps provide enough illumination for one to navigate through a stope or working face, the lighting is not sufficient for hazard identification. There is anecdotal evidence that proper in-stope illumination will improve the identification of rockfall hazards (and other ancillary excavations).

[1] The data analysis was limited to the year 2019 because it was not possible for the MOSH FOG team to retrieve the SAMRASS data for 2020 and 2021 from the DMRE.

[2] This also covers hybrid mines that have sections that use conventional mining methods. The intervention is less applicable to excavations that use mechanised mining methods because in such cases sufficient illumination provided by the Trackless Mobile Machinery (TMM) that is used.

"Underground working faces are dark and, where conventional mining methods are used, employees primarily rely only on cap lamps for illumination."

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Petra Diamonds – Finsch

1.1.1 Selection of strip lighting for case studies

There are several illumination units and systems that are available for the underground mining environment. However, very few are suitable for providing sufficient illumination for the stoping environment and other production faces. Table 1 shows the various options that are available for underground illumination, and it provides the selection criterion that was used to narrow down these options to those that are suitable for a dynamic production face.

Table 1: Evaluation criteria used for the selection of the LED (Light-emitting diode) strip lights[3]

	Selection Criteria										
Light type	**Handing during EEMS**	**Portability**	**Power source / Maintenance**	**Light intensity adjustability**	**Durability**	**Even light distribution**	**Glaring**	**Cost**	**Security**	**Sum**	**Weighted Performance**
Compact florescent bulb	2	2,5	2	2	1	2	2	5	5	23,5	44,0%
Stick LED Light	5	5	5	3	4	2	2	2	1	29	60,0%
LED Strip	4	2,5	3	3	3	5	5	3	5	33,5	65,0%

In the evaluation criteria, the MOSH Falls of Ground team considered three forms of lighting, i.e., compact fluorescent bulbs which are commonly used underground, glow stick LED lights, and strip LED lights which were identified during the investigation of this project. The team assigned a weighted average to each light type based on the criteria. This process found that the compact florescent bulb is the least favourable for the illumination of the underground working face, and the LED strip light is the most favourable. In the opinion of the MOSH FOG team, the LED strip light outperformed the LED glow stick because it produces a more even distribution of light, it produces less glare, it is much cheaper , and it is less of a security risk (meaning that it cannot be stolen or sold to illegal miners underground because it is not battery powered). It is because of these reasons that this report focuses specifically on the LED strip light.

[3] The following scoring was used: Poor = 1, Bad = 2; Good = 3; Very good = 4; Best = 5. In Table 1, security risk refers to the risk of the light being stolen or sold to illegal miners.

" The LED strip light outperformed the LED glow stick because it produces a more even distribution of light, it produces less glare, it is cheaper, and it is less of a security risk."

1.2 Aim and objectives

The aim of this report is to document how mines use LED strip lights to improve visibility in conventional stopes. The objectives of the investigation are as follows:

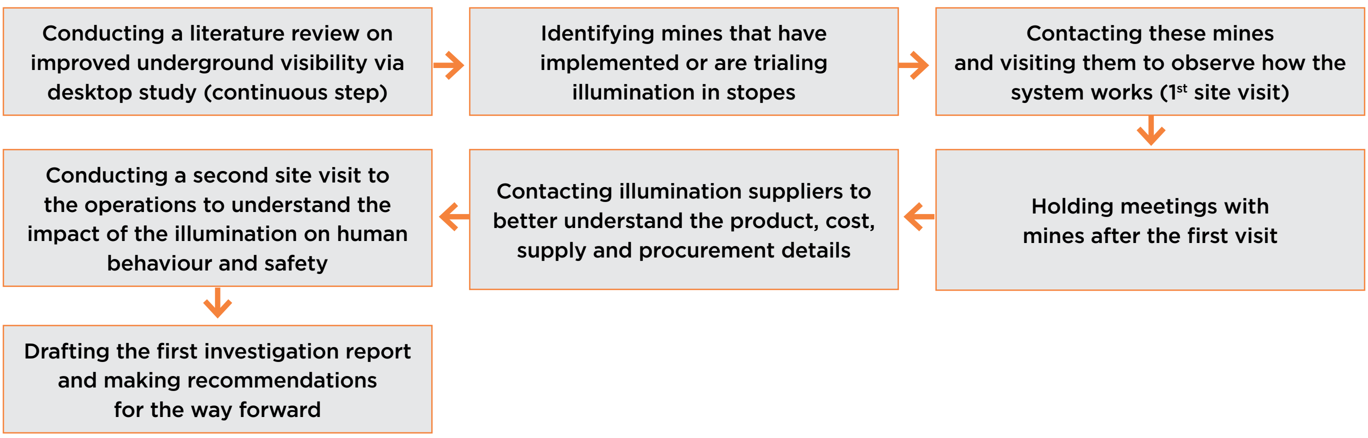
i. To understand the importance of improved visibility in the underground working environment;

ii. To document case studies that have implemented illumination in narrow tabular stoping and identify learnings from these case studies;

iii. To recommend the way forward for the South African mining industry in the adoption of this initiative.

1.3 Investigation methodology

Figure 4: Summary of methodology followed in investigation



2 LITERATURE REVIEW

2.1 The challenges of illuminating the underground working environment

Underground mines are regarded as some of the most difficult environments to illuminate. This is a significant challenge because adequate lighting is important for people to work safely. It is difficult to illuminate underground workings because of the following reasons:

- The active mining environment is constantly changing (especially with narrow tabular orebodies).
- Some areas are narrow, confined, and far from the main power source making them harder to illuminate, while other areas are larger and open.
- Underground surfaces reflect light poorly, and they offer low visual contrasts.
- Some operations may have strict lighting or electricity regulations, while other mines might be looking to curb electricity costs and manage the load on the power grid.

Because of these difficulties, people who work underground often depend on visual cues to see, identify, and communicate various hazards.

Some of the largest employers in the South African mining industry are the gold and platinum mines. A large percentage of these mines extract ore from narrow tabular stopes. In almost all the cases the only source of illumination in a stope is a cap lamp, which is a point light source. Although cap lamps are useful, they do not match the visibility of a good general lighting system. Some cap lamps create glare from the spot beam which can affect the ability to see. The lack of peripheral vision also causes a tunnel vision effect. Working safely, and hazard identification depends on the ability to see properly, and lighting plays an integral part in this.

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2.2 The occupational health hazards of poor lighting

Studies show that a dark environment increases fatigue. The body and mind naturally depend on the night and day cycle of light to function properly. Poor or no lighting affects the body's natural way of functioning because it disrupts the circadian rhythm[5]. There are indications that a disrupted circadian rhythm can lead to short-term problems such as insomnia, sleep deprivation, depression, and a weakened immune system. It can also cause more severe long-term health consequences such as cancer, diabetes, and obesity. Working in an underground environment with insufficient or no lighting for extended periods of time makes one more vulnerable to issues such as fatigue, eye strain and light sensitivity. Insufficient lighting can reduce one's alertness, productivity, reaction time, and cognitive function. The reduction of these abilities increases the risk of accidents.

"Underground mines are regarded as some of the most difficult environments to illuminate."

2.3 The application of illumination in underground mines and narrow tabular stopes

During the investigation and documentation of this leading practice, there was no literature available on the application of illumination in conventional stopes. However, there was literature on the illumination of the general underground working environment in the South African Mining Industry. The literature identified to be relevant to this study is shown in Table 2.

[5] *The natural cycle of physical, mental, and behaviour changes that the body goes through in a 24-hour cycle. Circadian rhythms are mostly affected by light and darkness and are controlled by a small area in the middle of the brain (National Cancer Institute 2022).*

Sibanye-Stillwater – SA PGM Operations

Table 2: Literature about underground illumination in the South African mining industry

Project or report name	Description	Recommendations / findings
GAP 804: The role of illumination in reducing risk to health and safety in South African gold and platinum mines.	**Aim:** To make recommendations on how to improve the visual environment in underground gold and platinum mines to enable the better identification of potential hazards.	• The study recommended the improvement of visibility in three areas, one of which was the dynamic mining environment (i.e., production and development areas). The study recommended the installation of temporary, semiportable lights which can be mounted on machines or other equipment. • This study also made recommendations on the selection, positioning, and maintenance of lighting equipment in gold and platinum mines.
SIM 160701: Proposed illumination guidelines for equipment operating in the SAMI	**Main intent:** To improve the visual environment on mines in its totality by developing a guideline on minimum illumination standards, practices, and principles for mobile equipment operating in South African open pit and underground mines	The study proposed minimum illumination levels based on current global best practices on mines. According to the report, these levels should not be considered as the "be-all" of mine illumination. This study also recommended illumination practices and principles. The study produced the following findings: • Measuring illumination levels with illuminance metres is complex due to the increased use of LED luminaires. • A recommendation of a minimum of 50 lux in at least 3 points of measurement. The measurement should be taken 1m off the ground (measured horizontally and vertically), at points of potential interaction between man and fixed equipment.

As shown in Table 2, the literature that is most relevant to this study is GAP 804 (The role of illumination in reducing risk to health and safety in South African gold and platinum mines). Before the investigation of this leading practice, there had not been any formal documentation of the application of illumination in stope working faces.

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3 CASE STUDIES

Following the identification of the in-stope illumination as a potential leading practice, the MOSH Falls of Ground team was tasked with visiting mines that were conducting trials of this initiative. In November 2021 and March 2022, the FOG team conducted site visits to two mines to observe the performance of the illumination in the stopes, and to engage with the employees that were working in these stopes. This section of the report documents the observations that were made at the two mines. The information was sourced from the site visits, engagements with employees, reports that were written by the companies and information from product suppliers.

3.1 Eland mine case study

3.1.1 Background

Eland mine is located 20km west of Pretoria, and it forms part of the Northam Platinum Limited Group. Eland mines the UG2 reef at a shallow depth of about 150m below surface. Eland is a hybrid mine that uses flexible off-reef mechanized mining methods to access the ore reserves, and conventional mining methods (i.e., narrow tabular stoping) on-reef. According to the mine, the narrow tabular orebody dips at 25 to 28 degrees.

One of the significant challenges that Eland mine experiences is the geotechnical complexity of the ground. Mining activity is complicated by prominent clay-filled shear zones which exists in the hanging wall. This prominent hanging wall shear zone has resulted in the mine focusing more on hanging wall support and rockfall hazard detection and identification.

Source: Eland Mine (2022)

Figure 5: Strip lights installed in haulage at Eland mine

Source: Eland Mine (2022)

3.1.2 Findings

At the time of the visit, Eland mine was using strip LED lights in the stopes. Prior to these lights the mine had considered 5 other different lighting options which raged from yellow lights to white LED lights. The operation eventually settled on the LED strip lights due to the following reasons:

- The LED strip lights have a low energy consumption[6];
- The lights have low running and maintenance costs; and
- The lights are robust, durable, flexible, and easy to cut, repair and install.

At the time of the visit, strip LED lights were installed in the main decline (as shown in Figure 5). In the panel the lights were installed along the travelling way, into the centre gulley (including the winch area[7]), into the Advanced Strike Gulley (ASG) (along the siding), and across the entire face length of the panel. The lights are powered from the winch gulley box using a 46-volt converter and 50m cable sections. The main connection to the winch box is done by an artisan, while crew members link the light strips to each other using a connector.

In the panels the operation installs one continuous strip light across the entire length of the stope face (30m). At the time of the visit, the lighting unit was located about 1m to 2m from the face, behind the last line of permanent support as shown in Figure 6[8]. The mine aims to illuminate the 0 to 4m face area across the entire panel.

During the visit, the MOSH FOG team observed the lighting to be sufficient for rockfall hazard identification across the entire panel length. The lighting in the panel also had an even distribution, there was no dark spots or glare observed.

Eland mine has separate crews for support installation, drilling, and cleaning the stopes because of a shift rotation system[9]. The lights along the panel face are installed by the supporting crew at the start of the shift, during the process of Entry Examination and Making Safe (EEMS), and they are removed by the drilling crew before the blast is taken. Like the installation of permanent support, the light installation moves forward with every blast. The low weight strip lights are connected to the diamond mesh in the hanging wall with clips and cable ties. The installation process that was demonstrated by the mining crew appeared to be simple and quick.

The strip lights at the Eland stope working face contain 72 LEDs per metre. The mine and the product supplier indicated that the brightness of the strips can be adjusted by increasing or reducing the LEDs per metre. The strips have connection points that can be cut and joined to control units to extend or shorten the light strips. The supplier indicated that the DC version of the strip lights allows for the connection of a power supply at both ends of the run.

3.1.3 Costs

According to Eland mine and the product supplier, the cost of illuminating a stope at the time that this report was written was R571.65 per metre. The mine indicated that initial capital costs are high, however the running costs are very low. All the lights that are in use are imported and supplied to the mine by local distributors.

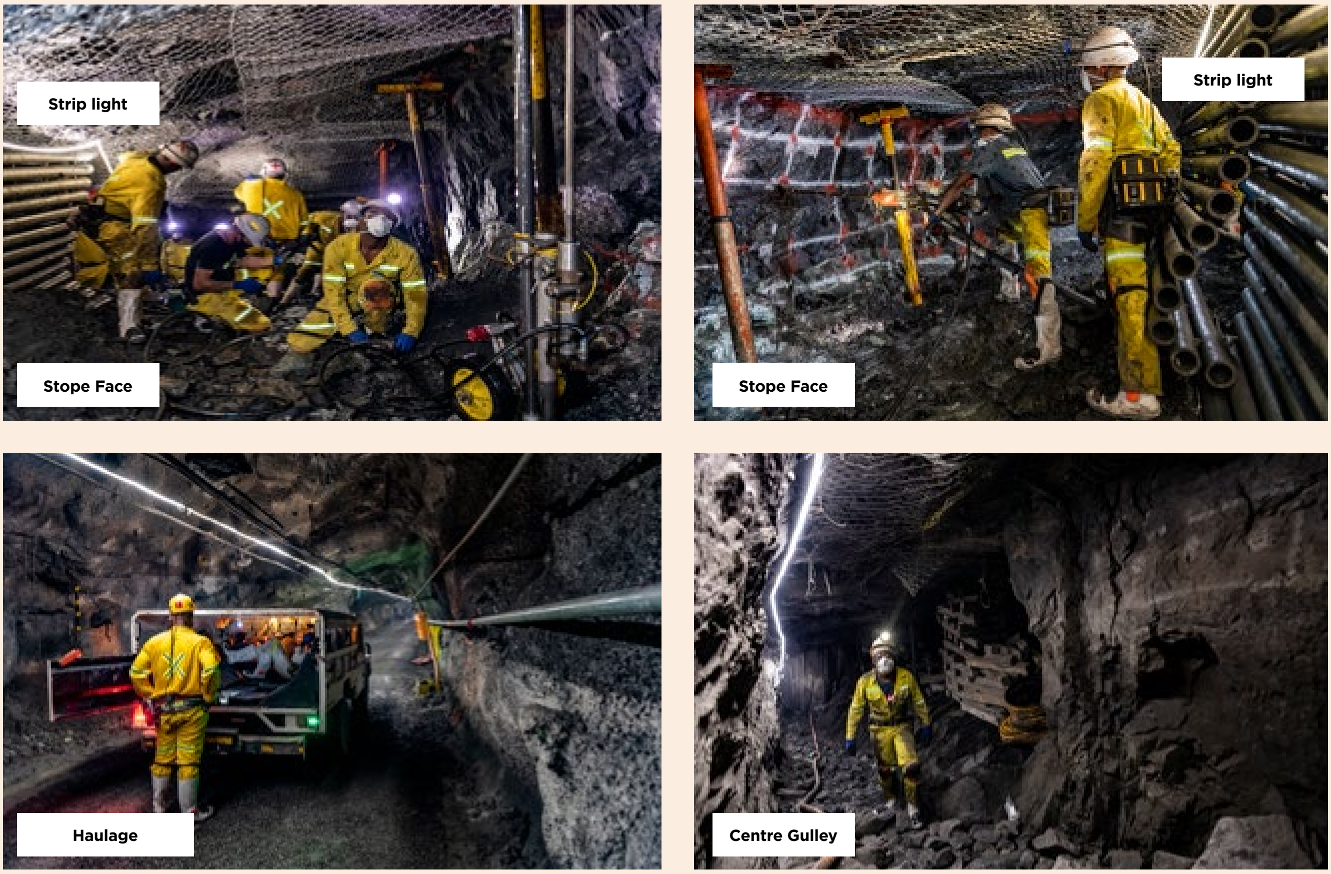
[6] According to the supplier, the 72 LED per metre strip consumes 14 watts per metre, and the 60 LED per strip consumes 9w/M.

[7] The lights are installed in the winch area because the mine perceives this area as high-risk.

[8] The mine indicated that the lights in the panel that was visited had been installed for 5 to 6 months.

[9] Eland mine runs on a fixed 5-day shift cycle that averages 45 hours per week on double rotation shifts.

Figure 6: Strip lights installed on reef at Eland mine



Source: Eland Mine (2022)

3.2 Dishaba mine case study

3.2.1 Background

Dishaba mine is located 40km South of the mining town of Thabazimbi. The mine forms part of the operations within Anglo American's Amandelbult Complex. Dishaba is a conventional mine that uses scattered breast mining to mine both the UG2 and Merensky reefs. The observation of the in-stope illumination took place in the UG2 workings. The case study area was located 400m below surface, and the reef dipped at 20 degrees.

Figure 7: LED strip lights attached to safety net at Dishaba

Source: Anglo American Platinum (2017)

3.2.2 Findings

Anglo American Platinum (Amplats) has conducted a well-documented trial of the LED strip lights. The mine has been involved in this process since July 2018. According to information provided by the mine, the installation of in-stope illumination at Anglo American Platinum began with a proof-of-concept study that was conducted at Tumela mine. This study was then followed by a production trial at Dishaba.

During the proof-of-concept stage, the project used 10m long light strips. However, the longer strip lights were found to be costly because any small damage to the strip would require the entire 10m length to be replaced. To manage this challenge, the project introduced the Halo daisy chain. This daisy chain consists of shorter (525mm) intervals of LED strips, that are interconnected by male and female plugs (on either sides) which extend for 290mm. The total length of one daisy chain unit is just over 1.1m. With this unit, if one link fails it can be removed and replaced with another one without compromising the entire light. The accessories that accompany the daisy chain for 1 panel are: two LED light extension connector and cables; one step-down transformer; a t-shaped plug, a 4mm (1m long) cable; and LED clip and a gulley stand. According to the mine, 18 daisy chains are required to illuminate a 20m face length.

The in-stope lights are connected to the mains voltage using a step-down transformer and with cables that run for a length of 20m. The connections to the mains voltage and step-down transformer are conducted by the stope artisan, while the production crews are responsible for installing the lights at the start of the shift and removing the lights at the end of the shift.

"The production crews are responsible for installing the lights at the start of the shift and removing the lights at the end of the shift."

Actual versus intended use of the strip lights at Dishaba mine

The LED daisy chain lights at Dishaba are designed to be attached to permanent support units (for EEMS), and then moved to the safety nets (as shown in Figure 7) to provide general illumination for drilling and other work activities. According to the trial report, the strip lights at Amandelbult were intended to be used during Entry Examination and Making Safe (EEMS) as well as during the main activities of the mining cycle (such as support installation, marking, drilling, and charging) to improve visibility. However, according to the mining team, and the mine's standard operating procedure on illumination, the strip lights are not used during EEMS[9]. The mine indicated that they intend to use the glow stick light during EEMS because it is more portable and more practical to use during EEMS compared to the strip light[10]. They further added that this intention was still in the trial phase. In this current phase, Dishaba mine installs the strip lights after EEMS for the face preparation (drilling and supporting).

During the underground visit, the daisy chain lights were observed to provide good illumination. Figure 8 shows the differences between a conventional stope with the LED strip lights and one that only relies on cap lamps at Amandelbult. In this case study dark spots were observed between the LED strips, creating an uneven light distribution. This was caused by the interconnecting male and female plugs.

Like the units used at Eland, the Dishaba strip lights are designed to be durable and water resistant. These lights are also adaptable, meaning that they can be designed to meet specific voltage and illumination requirements. The latter can be achieved by adjusting the LED spacing or intervals to increase or decrease illumination.

3.2.3 Costs

When the in-stope LED strip lights were introduced in 2019, Anglo American Platinum calculated the costs of the lights to be R 14 307 for a 20m long panel (including the ASG). This amount worked out to R 715.35 per metre. During the documentation of the in-stope lighting initiative (in 2022), it was indicated that the cost of illumination had increased significantly to R 42 351 for a 28m long panel, which amounted to about R 1 512.54 per metre.

[9] The lights are used more to provide general stope illumination for drilling verses identifying possible ground control hazards

[10] Dishaba mine added that there are practical reasons why the mine cannot install the strip LED lights during EEMS and hence they had to find an alternative solution.

Figure 8: Demonstration of effectiveness of LED strip lights in a conventional stope at Dishaba mine

Source: Anglo American Platinum (2017)

4 FACTORS TO CONSIDERS WHEN ADOPTING WORKFACE ILLUMINATION

4.1 The product specifications

The workface illumination needs to meet a specific set of minimum requirements for it to achieve the desired end goal. Table 3 provides the specifications that should be used to guide mines in the selection of the lighting units for a production environment. These specifications were obtained from information provided by the case studies, approved product suppliers and industry experts

Table 3: Specifications to guide the selection of workface illumination

Feature	Description
1. Product testing and certification	• All the lighting products that are brought to the mine should be intrinsically safe, and they should be designed to operate safety. • The products should be independently tested and certified and they should be accompanied by these reports and certificates. • All lights and their connection components should comply to the product specifications of the mines (e.g., they should have the correct SABS test reports, IA Certificates and other certificates required for fiery and non-fiery mines). • The lights should comply to the MHSA and the OHSA.
2. Product robustness and durability	• The lights including all the accompanying connection points and accessories should be dust and water ingress resistant. • The system should be robust and durable. It should be able to work reliably, and last under tough working conditions (e.g., in underground stopes). • In the case of coal mines, the lights and its connection components should be able to function safely in an area with coal dust (see product specifications column). The dust should not affect the durability of the connection components. • The lights should have an increased ability to withstand vibration, impact, and shock.
3. LED lifespan	• The expected life span of the LED lights should be at least 30,000 hours.
4. Product reliability	• The product should be highly reliable. This means that if one component of the light is entirely disconnected or damaged, or if one light fails, the severed portion should be easily and quickly replaced or repaired.
5. Product flexibility and adaptability	• The lights need to be flexible or adaptable. • The lights should have the ability to be managed and installed with ease by one or two people. • The lights should be easy to install and remove. They should have the ability to be secured of fastened to nets, bolts and other forms of support using cable ties or straps. • The lights should have a variable and long run length.
6. Light intensity	• The minimum light intensity for these excavations should be 20 lux within 1.5m radius of the light source[12]. The light intensity should be sufficient to allow proper Fall of Ground and geological hazard identification from a safe distance. • The correct instrumentation should be used to measure the light intensity (i.e., an LED illumination compatible lux meter).
7. Power requirements	• The lighting unit should have the ability to be powered by either a winch or a power source that is in the vicinity of the working face. • It should not exceed the typical underground voltage for lamps which is 110V so that it is not usable outside the underground setting. • The light should be powered in such a way that discourages theft.
8. Energy efficiency and costs	• The lights should have a low energy consumption and low maintenance costs.

[12] *It is important to note that this minimum value is a starting point that can be changed in the future. More work needs to be done to determine the most practical minimum light intensity for underground working faces that use LEDs.*

4.2 The human behaviour and leadership aspects

In addition to investigating the technical aspects of in-stope illumination, the MOSH Falls of Ground team examined the behaviours that are required (from the leaders and the followers) to ensure successful adoption, and sustainability of this initiative. Table 4 shows the leadership and behavioural attributes that are to ensure that the illumination initiative is well implemented.

Table 4: The required leadership and behavioural attributes for the adoption of workface illumination

Requirement	Description
Rationale and support	• The importance of, and rationale behind the illumination should be very clear, well understood and well communicated with all the relevant stakeholders. It should align with the intention behind this document which is: **To improve workface visibility for better hazard identification, better safety performance, and higher working efficiency.** • Senior management should create an urgency for this initiative. • There should be support and complete buy-in from all stakeholders (top-down and bottom-up). • There should be financial provision for the initiative, meaning that it should be included in the budget. • There should be enough human resource support (e.g., enough artisans) for this initiative. • There should be systems in place to ensure constant availability of the lighting material at the mine.
Communication	• The following should be communicated with the relevant stakeholders in a timely manner: - The importance of in-stope or workface illumination. - The processes to be followed when setting up the infrastructure. - The process of maintaining the infrastructure and keeping it in good working condition. - The roles and responsibilities of the various stakeholders involved in setting up and maintaining the illumination. • Communication should be clear and preferably take the form of: - A standard operating procedure for the installation of the lights along the ASG and the stope working face as part of Entry Examination and Making Safe. This procedure should also cover the removal and storage of the lights at the end of the shift - Updating the existing procedures (such as EEMS) to include the illumination
Training	• Training and induction material should be updated to include workface illumination. The material should cover the lighting installation, use, and removal. • There should be PTOs on the installation, use and removal of the in-stope lights.
Other factors	• QA/QC processes should be put in place underground and in the surface areas where the lights are stored. These storage areas should be inspected frequently. • The installation of the lights in the face area should also be inspected to ensure that the illumination is enough for proper hazard identification.

It is important for each role player to understand their roles and responsibilities in this initiative. These roles and responsibilities need to be agreed in advance to establish the accountability at the different levels. Table 4 lists the recommended roles and responsibilities for the adoption of workface illumination.

Table 5: Roles and responsibilities

Role	Responsibility in the in-stope illumination initiative
Senior management	• Taking ownership of the initiative and securing buy-in from the top and the bottom stakeholders. • Commitment of financial and other resources. • Establishing and communicating the rationale and urgency for the lighting.
Engineering supervisor/foreman	• Giving installation instructions to the artisans to install lighting systems in the required areas. • Ensuring that the lights are installed safely, and the people don't get injured by poor installations.
Engineering artisans	• Connecting the lighting system to the mains power source and maintaining this connection and ensuring that the installation does not lead to injuries or fatalities. • Ensuring that the lights work well. • Working with the crew to ensure that all non-functional components of the lighting unit are replaced. • Maintaining the lights.
Production supervisor and mine overseer	• Ensuring that the lights and their accessories are supplied to the crews in a timely manner. • Ensuring that the lights are in good condition, they are well maintained, and they provide the required illumination. • Ensuring that the lights fulfil their intended purpose. • Putting in measures to discourage the misuse and damaging of the lights. • Ensuring that the lights are stored correctly.
Production team (Miner, team leader and crew members)	• Inspecting the lights to ensure that they work. • Extending the lights from the main connection into the stope working face. • Ensuring that the lights are installed in areas where they will not get damaged (for example in the stick side). • Removing the lights and storing them safely before the blast. • Reporting any faults to the supervisors and engineering. • Storing the lights properly and ensuring their longevity.
Ventilation/ Environmental/ Occupational Health	• QA/QC of the lights and the conditions of storage. • Conducting illumination surveys to ensure that the lights provide the correct level of illumination.
Product supplier	• Understanding the requirements of the mine and supplying an affordable product that meets the mines' needs and standards. • Ensuring that there is enough supply to meet the product demand.

4.3 The development of a Standard Operating Procedure (SOP)

It is important for all mines that intend to use the workface illumination to create a Standard Operating Procedure for these lights. This procedure should not be generic. It should be designed specifically for the lights used in the workface. The SOP should cover the following technical, behavioural, and leadership factors:

- The intention or purpose of the illumination, and the desired outcome (e.g., to improve workface visibility to enable hazard identification).
- A clear indication of the roles and responsibilities of all parties involved in the installation, removal, and maintenance of the lights.
- A description of how the lights should be installed (during EEMS), extended and removed at the end of the shift.
- Specification of the distance the lights should be installed from the face.
- Details on how the lights should be handled and stored.
- Description of the replacement of dysfunctional lights and lighting components. Details on how and where the non-functional lights should be discarded.
- QA/QC information for light storage underground and on surface.
- Information about how the lights will be inspected by OHS and engineering personnel?
- Information about the process of replacing or exchanging the light.

4.4 The installation, positioning, and the removal of the lights

The following guidelines should be followed in connection to the installation, removal, and positioning of the workface illumination:

- The main purpose of these lights should be to provide sufficient illumination to enable the identification of rockfall hazards, during EEMS and during the shift. To fulfil the primary function, the lights must be installed by the mining crew, at the start of the shift as part of the EEMS process.
- The secondary purpose should be to provide sufficient illumination to aid the marking, drilling, and support process. This means that they are left in the stope for the remainder for the shift.
- The lights should be removed at the end of the shift. The removal and storage of the lights should be carried out correctly (as per the SOP) to preserve the longevity of the light.
- The light should be installed at a position that will allow the face area to be well illuminated (i.e., area located 0-4m from that face). It is recommended that the lights be installed at least 1.5m from the face (i.e., behind the last line of permanent support or the starting point of the safety net. The light should not be placed in a manner that causes direct glare (i.e., in a way that causes the light to shine straight into one's eye). The light should not be in the direct line of sight of individuals.

4.5 Assessing the risks associated with LED lights

It is important for mines conduct a risk assessment prior to the installation of the LED lights. The purpose of the risk assessment would be to evaluate the hazards that are associated to the LED lights and then to remove the hazard or minimise the level of its risk by adding control measures, thereby creating a safer and healthier work environment.

The following should be considered when evaluating the hazards associated with the LED lights: Fire hazards, emission of additional heat, electrical hazards, toxicity hazards, over exposure of people to blue LED lights which may result in health problems, and impact on the eyes.

Implats – Impala Rustenburg operations

"It is important for all mines that intend to use the workface illumination to create a Standard Operating Procedure."

5 OCCUPATIONAL HEALTH FACTORS

In introducing increased lighting into the working stope to improve safety, it needs to be considered that such improvements may bring about another occupational risk such a health hazards into the working environment.

Assessing the effects of light on health, there are three areas that stand out, being the effects on skin, eyes and mental health through sleep, mood and circadian rhythm. With this report focusing on artificial lighting sources in underground workings, the effects on skin will not be considered as studies have showed UV and IR produced by artificial light are very low to cause any long-time damage to the skin (SCENIHR, 2012).

The use of lighting needs consideration and too much or too little (intensity and exposure periods) can be detrimental. Too much light can result in strain to the eyes (glare) and circadian disruptions leading to possible health conditions (decreased melatonin). Too little light can result in strain to the eye (focusing and headache) and circadian disruptions leading to mental health such as Seasonal Affective Disorder (SAD)[13] . The latter might be the current state in underground mine workers who are exposed to very little lighting, both natural and artificial. Therefore, the focus is in increasing the light from the current state.

(SCENIHR, 2012) indicated that the only effect artificial lighting can have on the eyes is glare and it is empirically divided into two, discomfort glare and disability glare. Discomfort glare does not impair visibility but causes an uncomfortable sensation that causes the observer to look away from the glaring source. This could have a direct bearing on observations of rock conditions. It increases when the light source is facing the observer. Disability glare is due to the light scattering within the ocular media which creates a veil that lowers any contrast and renders viewing impossible. In GAP 804, (2001) the issue of glare was briefly covered with some suggestions made on how to manage glare. One of the relevant recommendations from GAP 804, (2001) was to have low-intensity lights with small distances between them rather than high-intensity lights farther apart. This can be compared to a stick light source versus a continuous strip LED light source.

Increasing the light amount in the working place might be beneficial to underground workers who are deprived of light due to long underground shift. In many cases the behaviour of workers has been sighted as a major contributor to safety. However, the workers state of mind is hardly considered or probably the reference thereof is already impacted by the working environment that is conducive for SAD. According to (SCENIHR, 2012) several studies have shown that light therapy may be an efficient treatment for SAD. Increased light for night shift workers presents different benefits and challenges as opposed to day shift mine workers who work in low light. Although this is good for alertness for night-shift workers, it must be understood that alertness at night is achieved though the disruption of the circadian rhythm.

[13] *Seasonal Affective Disorder (SAD) is a mood syndrome or depression, particularly occurring in people living in areas with significant differences in exposure to natural light during summer and winter.*

Northam Platinum – Eland

6 OPPORTUNITIES FOR IMPROVEMENT OR FURTHER WORK REQUIRED FOR THE ADEQUATE ILLUMINATION OF UNDERGROUND WORKFACES

It should be noted that until the launch of this initiative, there had never been a collective approach (across the entire South African Mining Industry) to working towards the full illumination of workfaces.

The only efforts that exist have been attempts by individual mines, and these projects have been done in isolation. This joint approach has brought the realisation that there are several opportunities to improve on this initiative, which are listed as follows:

a) **Specifying minimum illumination levels for production faces:** The industry needs to a set minimum light intensity for the LED lights for the underground workfaces. In addition to providing sufficient illumination for drilling, these minimum values should be sufficient to allow the proper identification of rockfall and other mining-related hazards in the production environment.

b) **Developing a standardised way of conducting illumination surveys at workfaces:** The SAMI needs to agree on and develop a standardised method of measuring illumination at the workface.

c) **The development of equipment that can adequately measure LED light intensity and colour temperature:** According to the industry experts, one of the challenges of the LED lights is that the current instruments provide a low reading when the intensity of these lights it measured. It important to ensure that the devices that are used to measure provide accurate values.

"Until the launch of this initiative there has never been a collective approach to working towards the full illumination of workfaces."

Northam Platinum – Eland

7 SWOT AND PESTEL ANALYSES

Table 6: LED striplight SWOT analysis

Strengths	Weaknesses
• Energy efficient- LED lights use 75% less energy than the incandescent lights and 50% less than Compact fluorescent lights. • Easy installation process • Non-Toxic- do not contain toxic chemicals like mercury found in fluorescent lights • Low costs in the long term due to their low maintenance, long life, and high durability • Low Temperature, easy to handle, robust, dust and waterproof. • Lights powered by specific voltage making them difficult to steal.	• Supply constraints- No local manufacturer • High initial cost • No standardised form of measuring illumination across the SAMI • No standardised values for minimum illumination required in workfaces.
Opportunities	**Threats**
• Local manufacturing: - The creation of several job opportunities (increasing local employment). - The reduction of the price of the lighting units. • Safe and productive mining	• Cheap substitutes with poor quality • Supply not being able to meet the demand because of importation • In the case that rechargeable LED lights are used for the working face, there is a risk of the rechargeable lights being stolen for outside use and use by illegal miners.

Table 7: PESTLE analysis (mining industry environment readiness)

Political	Economic	Social	Technology	Legal	Environment
MHSA – requires that Mining companies guarantee the health and safety of their employees as part of their operating license	Investors are now looking to invest in mining companies that have a sound health and safety performance. The adoption of in-stope lighting has the potential to reignite the lighting industry and create much-needed quality jobs	There is a perception that mining companies do not invest enough in OHS initiatives. The adoption of in-stope lighting will assist in minimising this perception.	The SAMI has embarked on the modernisation path. The industry has been investing in some modernisation projects that are intended to transform the SAMI into a modern industry embracing innovative technology. This bodes well for the adoption of in-stope lighting	There are no legal concerns identified that can be barriers to the adoption of the in-stope lighting. The only perceived risk is that of security. If the mines adopt battery powered illumination there is a risk of theft, and the units being sold to illegal miners.	The National Environment Management Act deals with how the waste should be handled and disposed. The SAMI has a history of compliance as this is part of the license conditions

9 CONCLUSION

The statistics provided in this report show that most of the FOG fatalities in the South African Mining Industry occur at the stope working face. This means that mines need to take more effort into making this area safe. There is anecdotal evidence that adequate illumination at the working face reduces safety risks. The case studies documented in this report show that good workface illumination improves cognitive function as well as the productivity of workers. These are some of the reasons why the South African Mining Industry should invest adequately in this initiative.

The two case studies from Eland and Dishaba mines gave an insight on how adequate in-stope lighting can improve the working condition and reduce the FOG risks. The case studies also revealed that adequate in-stope lighting increase employee morale and productivity. In addition to this all the employees received this initiative very well without any noticeable resistance.

It is important to note that even though this report highly recommends the LED strip light, the mines are at liberty to install any efficient illumination for the working faces. However, the light must be an aid to Entry Examination and Making Safe. The mines should also use the specifications and factors to consider shown in section 4 of this document to guide the selection of a suitable light.

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