A HANDBOOK ON

OCCUPATIONAL HEALTH PRACTICE IN THE SOUTH AFRICAN MINING INDUSTRY

CHAPTER 19

Author
Dr Johan Schoeman

Copyright © MHSC
First edition,
first impression 2001
Second edition 2026

© All rights reserved. Apart from any fair dealing for the purpose of research, criticism, or review as permitted under the Copyright Act, no part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying and recording, without permission in writing from MHSC.

Chapter 19

Illumination

The aim of workplace illumination (i.e. providing a suitable visual environment) is to improve safety and maintain visual health, as both contribute to a productive work environment. Specifically in terms of safety, illumination must increase the visibility of hazards, allow early detection of hazards by increasing the field of vision, improve visibility for performance of tasks and for visual health, increase general comfort, and reduce visual fatigue. A poorly designed visual environment can cause errors due to an inability to see properly, which might cause confusion, illusion, disorientation, discomfort, and headaches. Knowledge of the basic characteristics of light and light source is necessary for understanding the illumination conditions and requirements in a mining environment. This chapter describes the basic characteristics of light and light sources, discusses methods of improving lighting conditions underground, and provides a self-contained source of information and guidance, specifically for the mining sector.

Dr Johan Schoeman
Occupational Hygienist

19.1 Introduction

The provision of adequate illumination to ensure a safe visual working environment is a challenge faced across all industries, but it is particularly difficult in mining. The general objectives of lighting and illumination are to improve safety, maintain visual health, and increase productivity. Since most information is processed visually, the quality and quantity of illumination is critical for safe and efficient performance.

The provision of lighting is particularly important in the underground mining environment, where there is an absence of natural light and potentially hazardous tasks, often involving the use of large mobile machines, are conducted in confined spaces (1). According to the Illuminating Engineering Society (IES), the mining environment presents the most challenging lighting environment in the world (2).

Light is defined as part of the electromagnetic spectrum, or energy transmitted through space, or a material medium in the form of electromagnetic waves (3). Light is defined further by electrical engineers as visually radiant energy, the part of the electromagnetic spectrum that is visible to the human eye.

From a visual health perspective, it is important to note that the amount of light reflected from the surface of an object will influence the detail observed and the visual strain experienced by the observer. **Figure 19.1** shows a visual representation of the wavelength of light, through the electromagnetic spectrum.

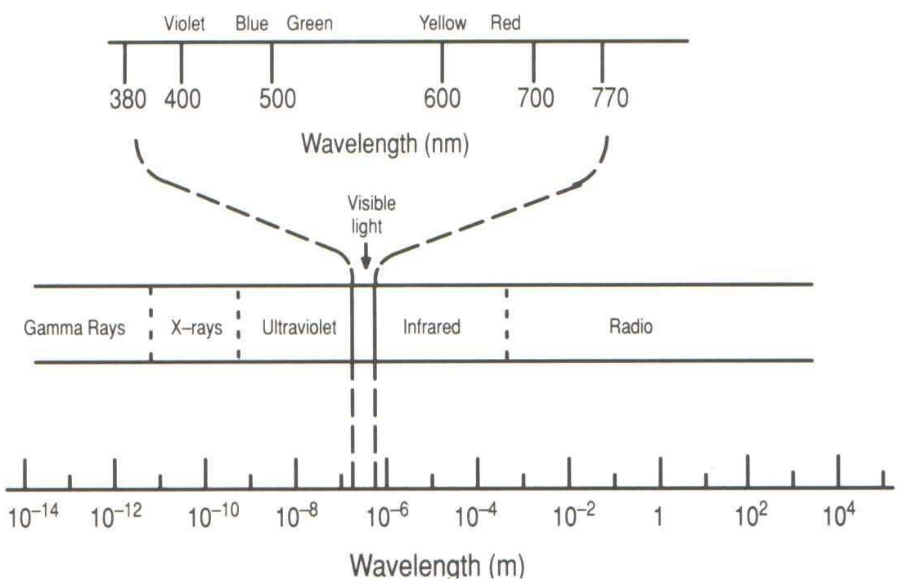


Figure 19.1. Visible light as part of the electromagnetic spectrum

Source: Zwinkels (2015) (4)

The Safety in Mines Research Advisory Committee (SIMRAC) undertook project No. COL 451 to produce general guidance and recommendations for a wide range of underground coal mining locations and activities, to assist mine operators in improving standards of illumination and visibility, thereby improving health and safety (5). A review of relevant illumination Standards and guidelines used in coal mining industries worldwide was conducted, along with an assessment of their applicability to conditions in the South African coal mining industry.

The review also included an assessment of the available literature to identify those factors that must be considered to ensure a safe visual working environment. Studies with regards to various underground machines and workplaces identified critical visual task requirements, and recommendations were formulated on standards for the improvement of both illumination and visibility under specific conditions. The project also made recommendations on improving the visual environment to reduce specifically identified hazards, and produced guidance for the selection, siting, and maintenance of lighting equipment. A follow-up project No. GAP 804 built on the work of COL 451 and, using the same proven approaches and methodology, expanded the recommendations and guidance developed for the coal sector to embrace the needs of gold and platinum mines (6).

The accident reports recorded on the South African Mines Reportable Accidents Statistical System (SAMRASS) database rarely cite 'lack of illumination/visibility' as a primary cause of accidents in gold and platinum mines. The quality of the visual environment may, however, make a far more significant contribution to accidents than the records indicate. Although 'lack of illumination/visibility' is seldom reported as the direct cause of an accident, it can often be a contributing factor.

There are several studies that have been conducted to support the generally held belief that an increased level of illumination reduces mining accidents.

Van Graan and Schutte (1977) (7) refer to a study in the former Union of Soviet Socialist Republics (USSR) where, following the introduction of fluorescent lighting on a coal face, production increased by 3.5% and the number of accidents diminished by 40%. Sammarco et al. (2012) (8), conducted a study that showed that underground coal mineworkers wear cap lamps on their hard hats, as their primary light source to illuminate nearby areas where their vision is directed. Proper illumination may improve miner safety by improving their slips, trips, and fall hazard recognition and balance. Trotter (1983) referred to an Indian study that found that 35% of all minor accidents in coal mines could be attributed to poor lighting (9). A retrospective study of mining industry accidents by Rahimi et al. (2022) revealed that poor lighting contributes significantly to injuries (10).

Subsequent research in South Africa by Odendaal (1996) (11), Franz, Ashworth and Mthombeni [GAP 203] (1998) (12), and Kielblock et al. [SIMRISK 401] (1997) (13), also supports the general theory that improved illumination reduces accident potential.

19.2 Human Health Effects

Medical research on the effects of excessive light on the human body suggests that a variety of adverse health effects may be caused by light pollution or excessive light exposure, and some lighting design textbooks use human health as an explicit criterion for proper lighting. Health effects of over-illumination or improper spectral composition of light may include increased headache incidence, worker fatigue, medically defined stress, and an increase in anxiety.

Common levels of fluorescent lighting in offices are sufficient to elevate blood pressure by about eight points (14). Specifically, within the USA, there is evidence that levels of light in most office environments lead to increased stress, as well as increased errors. The case against light pollution is strengthened by a range of studies on health effects, suggesting that insufficient and excess light may induce loss in visual acuity, hypertension, headaches, and increased incidence of carcinoma (15).

Illumination is essential at all places where personnel are required to travel or work. The levels of illumination required are dependent on the type of work being conducted, task detail to be observed, as well as the presence of any special aspects, such as safety hazards. Proper illumination allows the human eye to discern objects, form, colour and brightness. This is mainly achieved by the amount and quality of light reflected from the surface of the object of interest. Insufficient illumination further pose an increased risk of safety hazards. Low-level illumination, for example, increases the risk of a worker tripping over obstacles, being unable to discern approaching objects, and falling into cavities.

Another safety hazard associated with artificial lighting is known as the stroboscopic effect. This occurs when the flicker speed or frequency at which light is being emitted from certain types of lamps (fluorescent) matches the rotational speed of rotating objects, such as pulleys and prop-shafts, by creating an impression or illusion that the rotating objects are stationary. When designing lighting systems, it is important to consider this effect in areas where people work or move near rotating equipment. Either the illumination source should be adjusted or, if possible, the speed of the equipment should be modified.

Until the beginning of the twentieth century, miners commonly suffered from the eye condition called miners' nystagmus, for which there was no known cure. Miners' nystagmus produced uncontrollable oscillation of the eyeballs, headaches, dizziness, and loss of night vision. It was believed that working under very low light levels over long periods caused the symptoms. Coal miners were particularly susceptible, because coal reflects very little light. These miners often had to lie on their sides when working low coal seams, and this may have contributed to the development of the condition. With the introduction of the electric cap lamps in mines, miners' nystagmus has disappeared, eliminating a significant health impact associated with underground lighting.

A particular hazard associated with over-illuminated situations, involving strong contrast between the background and the illumination source, and reflection from surfaces, is glare. There are different types of glare, including (16):

- Relative glare, caused by contrasts in brightness, which may either cause discomfort in the eye or an inability to discern objects
- Absolute glare, such as too bright for the eye to adapt
- Adaptive glare, which is temporary and to which the eyes can adapt

However, illumination engineering distinguishes between two types of glare, namely: **disability glare** and **discomfort glare** (17). **Disability glare** is defined as glare resulting in decreased visual performance and visibility (18). The cause is stray light that enters the eye and scatters within it, producing a veiling luminance over the retina, with the effect of reducing the perceived contrast of objects being viewed. **Discomfort glare** causes fatigue and pain, as a result of non-uniform distributions of very bright light in the observer's field of view (19).

Glare is often a major concern in the mining industry. To reduce this, Deng et al. (2018) (20) suggest that it is better to have low-power lights with small distances between them, than high-power lights further apart. For example, in an underground roadway the former provides even illumination, while the latter produces repetitive transitions between bright glaring light and darkness. Uniform lighting makes for better hazard perception, as dark patches and shadows act to camouflage obstacles and hazards. Reducing glare and enhancing visibility in the mining industry requires a combination of strategies such as proper lighting design, appropriate personal protective equipment (PPE), proper light placement, and uniform lighting (2, 19).

Based on the South African National Standards (SANS) 10114-1:2020, the following guidelines to reduce glare are suggested for the mining industry (21):

- Move illuminance sources out of the direct field of view
- Shield sources from direct view
- Use prismatic lenses, filters, or cross polarisers
- Minimise luminance differences between visible sources and background
- Increase background or overall illuminance
- Ensure favourable luminaire positioning, relative to work tasks
- Eliminate or reduce polished surfaces

- Provide light with the correct level, colour balance, and distribution

It should also be noted that glare is relative. For example, in an un-illuminated area underground, the cap lamp can give a blinding glare; but at a well-lit shaft bottom, it is entirely tolerable, and on the surface in daylight, it may not even be noticed.

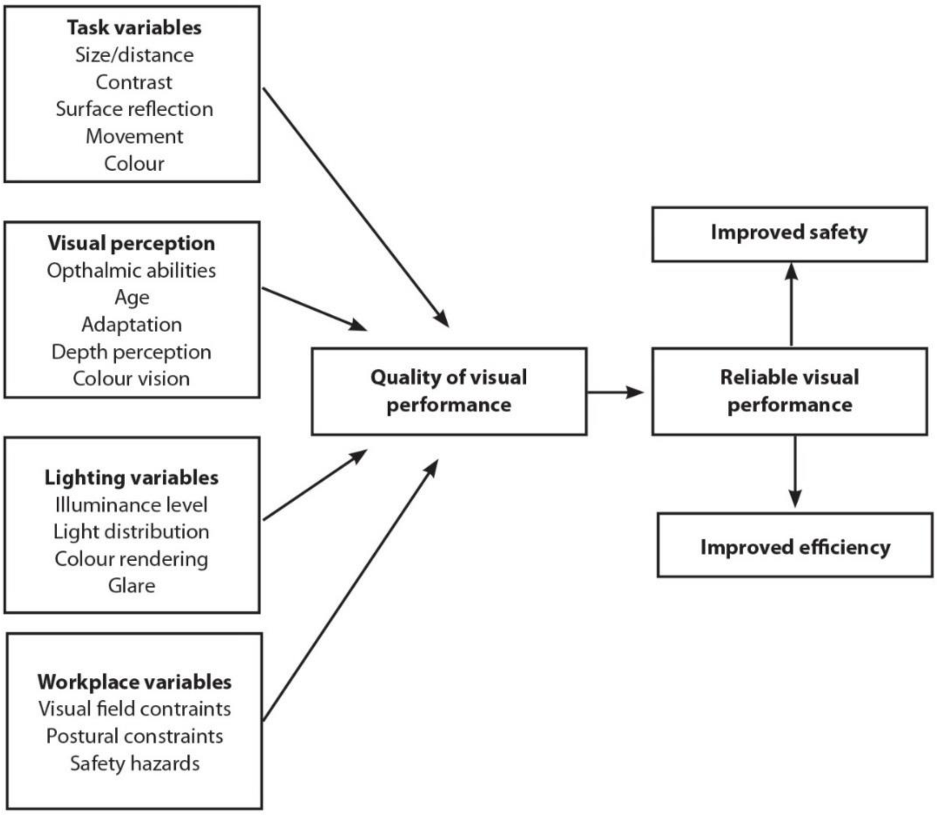
With recent technological advances in new light sources, the interest in lighting and health has been revived. It is now possible to have lighting levels in mines that would have been extremely difficult to achieve in the past. Besides the main concern about glare, normally associated with increased illuminance levels, a concern has also been expressed about the radiometric energy given off by lights, notably arc lights. A high-intensity discharge (HID) light source can still operate if the glass envelope containing the source is cracked or broken. Workers can then be in danger of receiving doses beyond threshold limit values (TLVs), particularly as these light sources often cannot be mounted very high. Damage to the structures of the eye (such as retina or macula) may occur as a result of overexposure to light, such as from the sun or arc lights. See also Chapter 13 of this Handbook (Health Effects of Radiation).

19.2.1 Factors affecting a visual environment

The level of illumination is only one of the factors that determine the quality and, hence, the safety of a visual environment. The ability to see clearly is crucial, as it enables workers to navigate the hazards within the mining environment, as well as operate machinery safely and assess geological conditions (1). In mining, other identified factors that affect the overall quality of the visual environment include:

- Mounting height restrictions and task requirements often place luminaires in the worker's direct line of sight, causing glare.
- Mounting positions restrict the size, location, and light distribution of luminaires.
- Luminaires must meet safety requirements for use in explosive atmospheres.
- Inherent vision deficiencies of the workforce population
- Low surface reflectance of rough, darkly coloured rock, which severely limits secondary reflections and indirect lighting.
- Suspended dust and water vapour cause back-scattering, which reduces apparent illuminance, and dust deposits on brightly painted, potentially hazardous machinery, decrease surface reflectance and reduces visibility.
- Reduction of effective illuminance by protective eyewear

The range of factors that can influence the visual environment is summarised in **Figure 19.2**.



19

Figure 19.2. Factors influencing the visual environment and performance.

Source: Adapted from Ladeira et al. (2019) (22)

To ensure the quality and reliability of visual performance and, hence, safety, all these factors must be taken into consideration. It is required that workers should undergo initial screening programmes and periodic testing, to ensure that they have sufficient visual abilities to undertake their work in a safe manner. However, efforts should be directed at tailoring the visual environment to meet the needs of workers and their tasks, rather than selecting individuals to cope with poor conditions.

19.3 Recommended Controls

When light enters the eyes, numerous receptors sensitive to different wavelengths of light are being triggered. Action potentials are generated and relayed to the visual cortex, where they are integrated to produce vision. Without light, vision is impossible, regardless of how well the eye functions. The way in which light is used determines the way in which the eye can function. The delicate sense of sight can be weakened or damaged if it is misused.

Recommendations on the setting of illumination and visibility Standards in coal mines have been derived from the results of the SIMRAC project No. COL 451: 'Assessment of world-wide illumination and visibility standards in coal mines' (5).

Past accident records rarely indicate poor illumination or visibility as the primary cause of accidents. However, there is little doubt that visual conditions will have a significant impact on accident potential. For example, past studies have shown accident rates decreasing by as much as 60% when the overall illumination levels were increased (25, 2, 26).

Whilst it is easy to assume that visibility can be improved by simply increasing surrounding illumination levels, this is often not the case. Levels of illumination are only one of the many factors that determine the quality (and safety) of a visual working environment. To ensure a safe visual environment, the factors shown in **Table 19.1** must be considered:

Table 19.1. Factors influencing safe visual environment.

Generic variables	
Lighting variables	Workplace variables
Illuminance level	Visual field constraints
Light distribution	Postural constraints
Colour rendering	Safety hazards
Glare	
Task variables	**Visual perception variables**
Size and distance	Ophthalmic abilities
Contrast	Age
Surface reflectance	Adaptation
Movement	Depth perception
Colour	Colour vision

The wide range of interacting variables shown in **Table 19.1** has led to the setting of a diverse range of illumination Standards for underground coal mining, by various countries throughout the world. However, compliance with any prescribed lighting Standard will not necessarily ensure a safe visual working environment. Given the wide range of variables that needs to be considered, providing a prescriptive approach to alleviating visual problems underground is impractical. In addition, attempting to use a prescriptive approach does not fit with the risk assessment philosophy enshrined in the Mine Health and Safety Act No. 29 of 1996 (MHSA) (23).

The purpose of these recommendations is to help identify potential hazards that can result from poor visual environments, across a comprehensive range of the operational situations most frequently encountered in South African coal mines. Recommendations are made for improving the visual environment to reduce the risks identified, and guidance is included for the provision, siting, and maintenance of lighting equipment.

Information about workplace illumination allows direct and effective action to be taken, at both corporate and individual mine levels, to enhance the visual working environment. This should lead to improved safety and a reduction in the number of accidents arising from poor visual environments and lighting standards. It is important to keep in mind that the recommendations are not prescriptive, and that each situation must be subjected to a specific risk assessment. The recommendations must be used as a guide to good practice, and the information is presented in a form designed to act as an aid to all members of the coal mining community, when conducting such risk assessments for specific situations.

The recommendations are divided into three sections that address specific operational environments:

- **Static locations** include areas of the mine that are of a long-term, fixed nature. Hence, it is likely to be practical to recommend the installation of comprehensive, permanent lighting fixtures and other aids to improve the visual environment in these locations.

- **Dynamic locations** are primarily production areas that, by their very nature, are likely to move on an almost daily basis. Hence, it is less practical to provide fixed lighting installations in these locations.

- **Mobile machines** include a broad sample of typical mining machines. The visual environment of both the operators and the workers in areas where the machines typically operate is addressed.

Each of the entries in the above sections are divided into sub-sections that follow the logical progress of a typical risk assessment process. The sub-sections used, and the objectives of each, are:

- **Tasks considered** – provides an indication of the scope of the recommendations made and, hence, indicates the likely validity of the section in relation to the risk assessment being conducted.

- **Critical visual requirements** – identifies the visual elements that must be clearly visible to ensure a safe and productive environment (this clarity not only enhances safety, but also boosts efficiency)

- **Potential visual limitations** – indicates those limitations most frequently encountered in typical coal mining environments that impact on the critical visual requirements.

- **Potential hazards** – lists the significant hazards that are likely to result from the visual limitations and, hence, may need to be addressed to ensure that a suitable and sufficient risk assessment is conducted.

- **Recommendations** – provides an indication of the range of control measures that should be considered, if reasonably practicable, to eliminate or mitigate the risks arising from the potential hazards
- **Additional considerations** – identifies measures, beyond the recommendations that relate directly to the quality of the visual environment, that can be taken to mitigate hazards, giving typical examples.

19.4 Measuring and Evaluating Illumination

19.4.1 Lighting instruments

Instruments are used to evaluate lighting systems and components. The field of light measurement is called *photometry*, and the instruments used to measure lighting are called photometers. A wide range of photometers is available to measure various light energy and related quantities, including illumination, luminance, luminous intensity, luminous flux, contrast, colour, and visibility.

The main types of photometers are spectrophotometers, which measure light intensity across a range of wavelengths, and filter photometers, which use optical filters to isolate specific wavelengths. Other common types include benchtop photometers, flame photometers, and imaging photometers.

Photometers are amongst the most important tools for illumination system design and evaluation. Specific uses for underground mine illumination measurements are:
- Verifying compliance with illumination and luminance specifications outlined in the Regulations.
- Evaluating illumination system design options
- Calculating reflectance of mine and mine simulator surface
- Assessing light distribution
- Monitoring illumination reduction over time
- Evaluating discomfort and disability glare

In the underground mine lighting application, the photometer is used to verify compliance with the MHSA lighting Regulations, and in the design and evaluation of lighting systems. Before taking measurements with a photometer, care must be taken to ensure that the luminaire or illumination system is in proper condition to satisfy the purpose of measurements.

The principles of good lighting are:
- Average illumination on the floor level, within 5 m of a task, is restricted to at least one fifth of the average illumination on the task.
- Glare is reduced to a level that does not decrease vision.
- Good housekeeping is maintained, ensuring armature and lamps are kept clean and, when defective, are immediately repaired or replaced (good housekeeping also increases the lifetime and illumination of source by 30%)

Optimum illumination ratio conditions should be designed for:
- Task: surrounding ratio of 3:1
- Task: further away ratio of 5:1
- Task: window ratio of 1:5

Preferably, Illumination levels should be measured at night to:
- Avoid possible influence of natural light on recordings.
- Obtain the worst-case scenario.
- Establish a reference value for illumination to compare future illumination levels against, and to establish the degree of deterioration or improvement.

Perimeter lux levels at night can be used to develop a specification for surveillance security cameras, in terms of minimum lux required to operate.

19.4.2 Basic concepts of lighting and measurements

To measure light, the basics of illumination and physics associated with light need to be understood. Similar to sound, light has speed and wavelength characteristics and, as such, all measurements and formulae are based on these two simple physical characteristics. Illuminance is defined as the quantity of luminous flux (LF) density present on a specific surface, and is represented as 'lux' (24). Additionally, the measurements for interior and artificial lighting provided in SANS 10114-1:2020 are recommended for the South African mining industry (SAMI) (21).

South African mining Regulations and Standards recommend minimum illuminance levels for various underground locations, to ensure safety and visibility. The minimum illuminance levels recommended are 20 lux for haulage roads, 50 lux for loading and tipping points, and 100 lux for work areas where visual tasks are performed (5, 6). The Standards further recommend higher levels of illuminance for emergency areas and areas where safety-related tasks are performed.

However, specific illuminance requirements may vary based on mine size, layout, and the type of mining operation. The lux levels required in underground mining vary significantly, based on the specific use and conditions of the mine. Generally, the lux level must be sufficient to ensure the safety and productivity of workers, while also meeting relevant health and safety regulations

19.4.2.1 Photometry

The measurement of light (photometry) plays an important role in the design of a lighting system. All the data required to design lighting comes from the photometry laboratory or from the occupational hygienist or from the ventilation and occupation hygiene engineers who use a research radiometer in the workplace to obtain accurate illumination levels.

Illumination standards used today are based on the old unit of 1 candlepower (a non-SI unit). For example, if a source of 1 candlepower is placed in the middle of a hollow sphere with a unit radius, then the inside surface of the sphere is calculated based on the formula $4\pi r^2$. If the sphere has a radius of one meter, then the surface will be:

$$4 \times \pi \times 1^2 = 12.57 \text{ m}^2$$

The *luminous flux* is the flow of light energy per time unit measuring how much light is emitted by a source, and the unit of measurement is called 'lumen (lm)' (the Latin word for light). To summarise, one candela or one candlepower, in a unit sphere, radiates 1lm.

19.4.2.2 Photometry performance

In occupational hygiene, luminaires are not measured by physical size, but by their photometric performance, because that determines compliance, visibility, safety, and comfort. **Table 19.2** lists the measurements, instruments used, what is assessed and the importance of the measurement. **Table 19.2. Luminary measurements**

#	Measurement	Instrument Used	What Is Assessed	Why It Matters
1	Illuminance (lux)	Lux meter (Goldilux, Konica Minolta)	Light on a surface	Legal compliance (SANS 10114-1)
2	Luminance (cd/m²)	spot luminance meter	Perceived brightness	Ensuring visibility, safety and for compliance
3	Uniformity	Lux meter + grid layout	Evenness of lighting	Prevents shadows, improves safety
4	Unified Glare Rating	Luminance meter + software	Discomfort glare	Reduces discomfort and eye strain
5	Colour Rendering Index	Spectral light meter	Colour accuracy	Critical for inspection tasks
6	Correlated Colour Temperature	Spectral light meter	Light colour	Comfort, alertness, task suitability
7	Flicker	Flicker meter	Light stability	Safety around moving machinery
8	Spectral distribution	Spectroradiometer	Wavelength output	Suitability for harsh environments
9	Emergency Lighting	Lux meter + emergency tester	Safety lighting performance	Life safety compliance

19.4.2.3 The lumen

The lumen (lm) is the photometric equivalent of the watt **(1 watt at 555 nm = 683 lumens)**, weighted to align with the eye's response of the 'standard observer'. Yellowish-green light receives the highest weight, because it stimulates the human visual system more than blue or red light of equal radiometric power.

To ensure proper supply of lighting in the workplace, the occupational hygienist must refer to engineering specifications with information on the lighting properties of a *fixture* or *luminaire.* In these technical sheets, the light distribution at various angles is indicated graphically or in tabular format, and is known as the *candle-power distribution curve.*

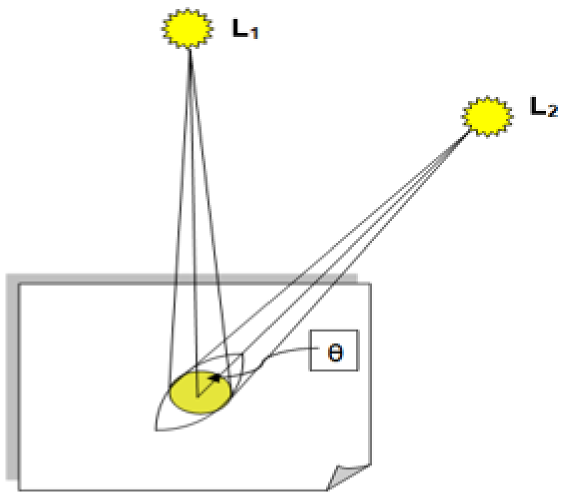


Figure 19.3. The difference in lighting from two identical sources of light, one perpendicular and the other at an angle to the plane

Note:
L_1 and L_2 = light sources L_1 intensity = L_2 intensity
Illumination on surface from L_2 = illumination from L_1 x cos θ

Source: Adapted from Jiao et al. (2024) (24)

Brightness or luminance occurs in a workspace as a result of:
- Light-giving source (e.g. the sun or a local lamp)
- Energy transmitted through an object (glass)
- By reflection

The common unit for luminance is 1 lm/m^2/sr (lumens per square meter per steradian) and in the imperial system 1 lm/m^2/sr is equal to 1 candela/m^2 or 9.290 x 10^{-2} cd/ft^2.

The *reflection factor* of a colour is given in terms of the percentage of light that is reflected from a coloured plane, when compared with the reflection from a matt white plane, e.g. magnesium oxide.

19.4.3 Benefits of good lighting

19.4.3.1 Preservation of human energy

Workers require adequate lighting to perform their daily tasks. The level of illumination that is available is related to how much energy they use when completing the task. If workers are in a dark environment, then they will become more stressed and spend more energy trying to see what they are doing.

19.4.3.2 Decreased risk of accidents

Good lighting helps reduce the frequency of workplace accidents. Workers who cannot see objects because they are too dark, or cannot drive a forklift to see where to place the load, can cause serious damage to equipment, buildings, and processes, which in turn results in financial loss.

Therefore, it is important to maintain adequate illumination whenever possible, to minimise the risk of lighting-related incidents.

19.4.3.3 Increased production

In many South African workplaces, lighting is accepted as an expense and installed with little or no planning. By increasing lighting and choosing the correct illumination system for a specific workplace, worker morale and productivity can be improved. This finding has been documented in many workplaces around the world, such as Canada, the USA, and Asia (3). Worker productivity in some garment industries in Asia increased by 25%, while in Canada and the USA, the efficiency levels of welders and automobile workers was improved by 12–15%.

19.4.3.4 Better working conditions

The overall working space inside a factory can be increased greatly by proper illumination. Housekeeping can be controlled better, since all areas of the work floor are lit and there are no areas where waste or unused material can be stored.

Final product quality and engineering are also improved when welders can see their welds, or fitters can see the work they are doing more clearly.

19.4.3.5 Decreased waste

It has also been shown that there is less waste of raw products when the efficiency and morale of workers improves and, therefore, the economic status of the company increases (25).

19.4.3.6 Other advantages

The benefits listed above on good lighting not only increase safety in the workplace, but also productivity. The logistics and management of workers at a work site is very important, in South Africa and worldwide, and it has been clearly shown that where companies follow proper logistics and cause less waste, they are more profitable and successful and have a work force that is loyal to the company.

19.4.4 Principles of good lighting

Legislation requires that the quality and quantity of the lighting in a workspace need to be assessed. Complying with the principles of good lighting is also important to overall health and safety.

19.4.4.1 Quantity of lighting

The quantity of light in the workplace must be enough to allow the worker to see well, without straining their eyes. The volume of jobs/tasks that a worker completes depends on:

- Size or detail of the work being completed
- Brightness or luminance of the workspace and the point of work
- Contrast of light
- Available time to make observation.

19

The Environmental Regulations for Workplaces, 2003 (ERW) (26), under the Occupational Health and Safety Act No. 85 of 1993 (OHSA) (27), state that employers must provide lighting in compliance with the prescribed values in every workplace. Care must be taken to ensure that:

- Average illumination on any floor level in a workplace within 5 m of a task is at least one fifth of the average illumination on that task.
- Glare in any workshop is reduced to a level that does not impair vision.
- Lighting on rotating machines should be such that the danger of the stroboscopic effect is eliminated.
- Armatures and lamps are kept clean and, when defective, repaired or replaced immediately.

Table 19.2 shows the recommended minimum intensity levels of illumination stipulated under the ERW.

Table 19.2. Recommended minimum average illumination intensity levels for office tasks

Location or industry	Place or type of activity	Recommended lighting (lux)	Glare index (minimum)
Offices	Entrance halls and reception areas	100	22
	Conference, general, typing and filing	300	19
	Computer and business machine operators	500	19
	Drawing	500	16

19.4.5 Practical applications for lighting

Availability of daylight:

- It is generally assumed that the sky has a certain luminance distribution. In the past, technicians assumed that daylight was equivalent to the light that occurs under an overcast sky. In South Africa, however, it has been admitted that the sky is often much brighter. Daylight at a point indoors is generally expressed as a percentage of the available light outdoors, and is known as the daylight factor.

Influence of obstructions:

- Inside any workplace, objects may reflect, refract, or disperse light through window frames, beams, ventilation ducts, cranes, and glass in daylight designs, and these must be taken into consideration.

Layout of the production floor:

- Space constraints on the work floor may position workers in areas with limited access to natural sunlight. In the case of metal workers who operate lathes, computer numerised control (CNC) machines, and turning or boring machines, it is expedient if the main axis is perpendicular to the windows. If workers complain about the presence of glare in the workspace, then it is better to either glaze the windows or rely on artificial illumination.

Distribution of daylight:

- The intensity of daylight can be 3 000–4 000 lux or more. Where sunbeams pass through (or enter) the work site, it is important to prevent high glare or stroboscopic effects in the workspace.
- In a saw-tooth (serrated) window or roof design, the distribution of light over the machines comes mainly from one direction. The light distribution can be enhanced, firstly, by using rows of smaller windows rather than large, widespread windows and, secondly, by improving the lighting at the back of the room through the use of light colours in the interior roof surface or ceiling. Light is usually better distributed with skylights, although this depends on the diffusion characteristics of the glazing material and the position of the windows.

Exclusion of direct sunlight:

- The infiltration of direct sunlight into work areas can result in an atmosphere of warmth and brightness, but it can also cause severe contrasts in luminance, which may pose a particular problem if the worker is unable to change their position. Thus, it is essential to eliminate direct sunlight in work areas by considering the orientation of the building, the installation of special glass and other material, blinds, overhangs, and/or louvres. The elimination of sunlight can also add to improved thermal conditions.
- The implementation of designs that eliminate sunlight can be simplified by making use of sunlight diagrams and shadow models.

Maintenance of glazing material:

- Glazing materials are commonly used in the workplace and are now present in every vehicle on the South African roads. Tinted windscreens and windows in a car reduce the amount of glare a driver experiences (either from the sun during the day or from headlights of other vehicles at night). However, the accumulation of dust and dirt on glazing material can be detrimental to daylight illumination, causing a decrease of up to 50% in daylight. It is recommended that a regular cleaning routine should be followed.

19.4.6 Use of colour in factory buildings

The colour of ceilings, walls, floors, machines, and furniture and work surfaces is very important for comfort, efficiency, vision, and good housekeeping. A few basic principles to consider include:

- Light colours reflect lighter and, therefore, contribute to the lighting of the area. Ceilings, window frames, and walls should be painted in a very light colour, preferably a matt white, to reduce contrasts.
- Dark-coloured surroundings create a gloomy and depressing atmosphere, and may strain the eyes due to the contrast with brightly illuminated surfaces being too severe. In contrast, pleasant and colourful environments tend to lead to a happier workplace atmosphere. Walls should preferably be painted in a colour having a reflection factor of between 60–70%. The lower sections of walls should not be dark; colours having reflection factors of between 29-40% should be applied instead.
- Floors should not be overly dark. They should preferably have a reflection factor of 30%, which also contributes to good housekeeping practices.
- In many industries, machinery and equipment are painted black or dark grey and have shiny handles and attachments. This is an unhealthy custom. Careful use of colour on machines and in the background can create a much more pleasant working environment. Dangerous moving parts, safety handles, and control levers should be painted in clear, recognisable colours.
- Colour can also be used to indicate various types of piping. The South African Bureau of Standards (SABS) has compiled a user code for this purpose.
- Colour and colour symbols can be used as warnings, e.g. to highlight dangerous areas, and to identify safety equipment and escape routes.

19.4.7 Types of lamps

As they are the primary source of artificial light, lamps are crucial for illuminance, enabling visibility and functionality in various environments. Proper illumination, achieved through lamps, is essential for visual performance, safety, and creating desired ambiance. There are several types of lamps with different properties of construction, appearance, and luminous efficacy. The UK Health and Safety Executive (HSE) highlights the following types of lamps (28):

- **Tungsten lamps**, also known as incandescent lamps, utilise a tungsten filament, which is a thin wire that heats up and emits light when electricity passes through it. They are a common light source, especially in photography and microscopy, due to their stable and broad-spectrum output of light. They are mainly used for commercial interiors and emergency lighting and hand lamps.

- **Fluorescent lamps** are low-pressure mercury-vapour gas-discharge lamps that produces light through fluorescence. They consist of glass tubes coated with a phosphor material, filled with a gas mixture (including mercury vapour and a noble gas), and are equipped with electrodes at each end. When electricity is applied, the electrodes heat up and emit electrons that excite the gas, causing them to emit ultraviolet (UV) radiation. The phosphor coating then absorbs this UV radiation and re-emits it as visible light. They are mainly used for industrial and commercial lighting.

- **Light-emitting diode (LED) lamps** are semiconductor devices that emit light when an electric current passes through them. They are known for their energy efficiency, long lifespan, and durability compared to traditional incandescent and fluorescent bulbs. Light-emitting diode lamps are applied across many industries for residential, commercial, industrial, automotive, street, and appliance lighting.

- **Mercury vapour lamps** are a type of gas-discharge lamp that produce light by passing an electric arc through vapourised mercury. They are known for their bright, long-lasting light and are commonly used for illuminating large areas like streets, sports arenas, and industrial spaces. A mercury lamp typically consists of an inner quartz tube containing the mercury vapour, enclosed in an outer glass bulb that filters out harmful UV radiation. These can be high-, medium-, or low-pressure mercury vapour lamps for different applications.

- **Metal halide lamps** are a type of high-intensity discharge (HID) lamp that produce light by passing an electric current through a mixture of mercury vapour and metal halides. These lamps are known for their high luminous efficacy, producing a bright white light, and are commonly used for applications requiring high-intensity illumination like sports stadiums, parking lots, and large indoor spaces.

- **Sodium vapour lamps** rely on the excitation of sodium vapour to produce light, and their long lifespan and energy efficiency make them suitable for outdoor applications. The sodium vapour can be either high pressured or low pressured. High-pressured lamps emit a broader, more orange light, while low-pressured lamps emit a characteristic yellow light that is very efficient, but limits colour perception.

19.5 References

1. Li J, Qin Y, Guan C, Xin Y, Wang Z, Qi R. Lighting for work: a study on the effect of underground low-light environment on miners' physiology. Environmental Science and Pollution Research. 2022 Feb 1:1-0.
2. Mayton AG, Demich B, Nasarwanji MF. Investigation of machine-mounted area lighting to reduce risk of injury from slips-trips-falls for operators of mobile surface mining equipment. Mining, metallurgy & exploration. 2020 Dec;37(6):1919-30.
3. Mills W, Martin K and Cathey J. Light and Lighting Basics for OSH Professionals. Professional Safety, 2020. 65(07), pp.22-30.
4. Zwinkels J. Light, electromagnetic spectrum. Encyclopedia of color science and technology, 2015 Jan. 8071:1-8.
5. Mine Health and Safety Council SIMRAC COL 451. Assessment of World-wide Illumination and Visibility Standards in Coal Mines. [Online] [Cited: 16 April 2025.] https://mhsc.org.za/sites/default/files/public/research_documents/2.%20COL%20451%20Final%20Report.pdf.
6. Mine Health and Safety Council SIMRAC GAP 804 . The Role of Illumination in Reducing Risk to Health and Safety in South African Gold and Platinum Mines. [Online] [Cited: 16 April 2025.] https://researchspace.csir.co.za/server/api/core/bitstreams/a6f22837-6445-4c5e-98cd-09506f6ed9a3/content.
7. Van Graan CH and Schutte PC. Underground Illumination and the selection of heavy vehicle drivers. De Beers Consolidated mines, 1977.
8. Sammarco JJ, Pollard JP, Porter WL, Dempsey PG, Moore CT. The effect of cap lamp lighting on postural control and stability. International journal of industrial ergonomics, 2012 Jul 1. 42(4):377-83.
9. Trotter DA. The lighting of underground mines. Mines Accident Prevention Association, 1983.
10. Rahimi E, Shekarian Y, Shekarian N, Roghanchi P. Accident Analysis of Mining Industry in the United States–A retrospective study for 36 years. Journal of Sustainable Mining. 2022;21(1):27-44.
11. Odendaal EP. The consequences of poor illumination on underground mine workers and the subsequent effects on productivity and safety. Unpublished doctoral thesis, University of the Witwatersrand, Johannesburg, South Africa, 1996.
12. Franz RM, Ashworth SG, Mthombeni IS. Investigate the role of environmental factors in causing or contributing to underground accidents in gold and platinum mines. 1998.
13. Kielblock AJ, Franz RM, Unsted AD, van der Linde A, Ashworth SGE. Quantification of occupational health risks in the South African mining industry and assessment of the sources of uncertainty in the estimates. Final report, SIMRISK 401, SIMRAC, 1997.
14. Tang L, Zhang X, Zhou X, Gu X, Fan S, Liu M. Study of heart rate and blood pressure subject to pulsed LED lighting. Leukos, 2022 Apr 3. 18(2):145-53.
15. Dorn L. Stress, Health, and the Office Environment. Human Stress and the Environment. 2022 Mar 23:161-80.
16. Suk JY, Schiler M, Kensek K. Absolute glare factor and relative glare factor based metric: Predicting and quantifying levels of daylight glare in office space. Energy and buildings. 2016 Oct 15;130:8-19.
17. Tyukhova Y. Discomfort glare in outdoor environments after dark–a review of methods, measures, and models. Building and Environment. 2024 Jul 17:111850.
18. Mehri A, Aliabadi M, Golmohammadi R, Zakerian SA. An empirical investigation of disability glare and visibility level during driving inside very long road tunnels: A case study. Tunnelling and Underground Space Technology. 2022 Jul 1;125:104496.
19. Sen A, Khamaj A, Karmakar S. Design intervention for addressing the safety and health risks of discomfort glare and UV radiation associated with BIPV installation and maintenance. Energy and Buildings. 2024 Sep 1;318:114479.
20. Deng M, Chan AH, Wu F, Sun L. Depth perception, dark adaptation, vigilance and accident proneness of Chinese coal mine workers. International journal of occupational safety and ergonomics. 2018 Jul 3;24(3):450-6.
21. SANS 10114-1:2020 Ed 4. Interior lighting - Artificial lighting of interiors. Pretoria. South African National Standards, 2020.
22. Ladeira WJ, Nardi VA, Santini FD, Jardim WC. Factors influencing visual attention: A meta-analysis. Journal of Marketing Management. 2019 Nov 22;35(17-18):1710-40.
23. South Africa. Mine Health and Safety Act No. 29 of 1996 as amended. Pretoria, Government Printers.
24. Jiao Y, Chen S, Jie Z, Chen J, Ma L, Jiang YG. Lumen: Unleashing versatile vision-centric capabilities of large multimodal models. arXiv preprint arXiv:2403.07304. 2024 Mar 12.
25. Katabaro JM, Yan Y. Effects of Lighting Quality on Working Efficiency of Workers in Office Building in Tanzania. J Environ Public Health. 2019 Nov 14;2019:3476490.
26. Department of Employment and Labour. Environmental Regulations for Workplaces. Pretoria : Government

Printers, 2003.
27. South Africa. Occupational Health and Safety Act No. 85 of 1993. Pretoria, Government Printers.
28. Health and Safety Executive. Lighting at Work . [Online] [Cited: 19 June 2025.] https://www.hse.gov.uk/pubns/books/hsg38.htm.