DESIGN OF ILLUMINATION SYSTEM FOR AN OPENCAST COAL MINING PROJECT – A CASE STUDY

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTERS OF TECHNOLOGY
IN
MINING ENGINEERING

BY

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UNDER THE GUIDANCE OF

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CERTIFICATE

This is to certify that the thesis entitled, **"DESIGN OF ILLUMINATION SYSTEM FOR AN OPENCAST COAL MINING PROJECT-A CASE STUDY"** submitted by OLIVE CHOWDHURY (212MN1423) in partial fulfillment of the requirements for the award of Master of Technology degree in Mining Engineering at National Institute of Technology, Rourkela (Deemed University) and is an authentic study analysis work carried out by him under my supervision. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other university/institute for the award of any Degree or Diploma.

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OLIVE CHOWDHURY

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ABSTRACT

The scientific work documented in this thesis was carried out, as a part of the research investigation, sponsored by a major coal company, to create a safe visual working environment for a large mechanized opencast coal mine by designing an effective illumination system.

The primary objectives of the project was to design an effective lighting system at different places of work to ensure safe visual working environment in an opencast coal mining project with due compliance of statutory standards. The research investigations were carried out with the following objectives:

- To conduct illumination survey and check the adequacy of lighting at vis-à-vis Directorate General of Mines Safety(DGMS) /International standards at:
    - Different places of work in the mine
    - Different Heavy Earth Moving Machineries(HEMMs)
- Design of appropriate illumination systems based on illumination requirement for:
    - Haul road
    - Overburden(OB) transport road
    - Dump yard
    - Moving Coal & OB faces

The illumination study was performed in Kusmunda opencast project (KOCP), which is located in Korba district in the Indian state of Chhattisgarh. It included an illumination survey of the existing lighting system in various working areas e.g. haul road, dump yard, coal and overburden face, followed by analysis and improvement measures. The lux meter used for the survey was a Metravi-1332. The existing illuminance levels were found inadequate in the mine dumping yard (at dump edges) and in coal face. Also, for haul road and dump road lighting the uniformity ratio of light was absent which made it appear dark although there were 400 watts HPSV lights installed on the road. Hence, an effective and modified design of the illumination system was necessary.

The illumination models for various working places in the mine were developed using DIALux software and virtual Philips luminaires were used for the design. DGMS standard for opencast mine lighting was used for both assessment and design of illumination systems. Haul road and dump road lighting design was performed as per CIE EN 13201 standard, which is internationally used for road lighting. The luminaires used for the design were 250 watts HPSV. For dump yard lighting arrangement model was obtained using 1000 watts symmetrical HPSV lamps and the design satisfied DGMS standards with a minimum illuminance of 3 lux at the dump edges. Also, designs of moving face lighting arrangements for mobile coal and overburden face have been provided. For this purpose 1000 watt symmetrical metal halide lamps were used. The design models resulted in significant improvement over the existing system and all the standards were met as per DGMS standards. Also, improvement of lux level was obtained from the results of the simulation as compared to the existing lighting system.

Based on the observations during illumination survey and design of illumination systems for the mine following recommendations have been proposed to improve the visual level in the work places and are stated below:

- Installation of 150W HPSV luminaires for roads not exceeding length of 1 km and 250W HPSV luminaires for length exceeding 1 km and other installation details should follow the given design.
- Installation of Metal Halide luminaires for coal faces and HPSV for OB faces.
- Luminaires should be die cast aluminum built.
- Truck mounted illumination system can be used instead of fixed lighting system at coal face.

KEYWORDS: Illumination; Illuminance; Uniformity ratio; Opencast Mine; DGMS.

ACRONYMS

CIE	Commission Internationale de l'éclairage
CEN	Comité Européen de Normalisation
DGMS	Directorate General of Mines Safety
HPSV	High Pressure Sodium Vapour
SIMRAC	Safety in Mines Research Advisory Committee
SAMRASS	South African Mines Reportable Accidents Statistical System
HEMM	Heavy Earth Moving Machinery
IESNA	Illuminating Engineering Society of North America
KOCP	Kusmunda Opencast Coal Mining Project
SECL	`South Eastern Coalfields Limited
CHP	Coal Handling Plant
BEML	Bharat Earth Movers Limited
OB	Overburden
ECSC	European Coal & Steel community
NIOSH	National Institute for Occupational Safety and Health

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CHAPTER: 1

INTRODUCTION

1.1. INTRODUCTION

Illumination is a very important factor to be understood properly and to be provided in the mines where activities are performed in the night shift. The provision of adequate illumination to ensure a safe visual working environment is particularly difficult to meet in coal mining. In general, vision is influenced by three main lighting design parameters: illuminance level of the surface, uniformity of light distribution and glare from sources. Luminous intensity of light source takes care of illuminance levels on visual tasks, whereas uniform distribution pattern of light depends on the technological aspects like luminaire layout, aiming angle and positioning of the light sources.

1.2. MOTIVATION FOR THE PRESENT RESEARCH WORK

In opencast coal mining where the activities are also performed in night shifts because of mass production requirements, requires effective illumination design in workplaces. The dark surrounding and low surface reflectance significantly affects productivity and safety of miners. Due to this reason it is very difficult to maintain the lighting standards specified by various regulatory bodies. Hence, a scientific approach is required to achieve better illumination standards in mines in particular. An effective lighting installation is one, which has been designed and installed so that individual may work with safety and efficiency, and with reasonable comfort. The lighting design process begins by carefully determining these needs and then practical, technical, and economic factors are considered in establishing an appropriate illumination system design. The lighting design process identifies the visual needs of coal miners and indicates in general terms what can be done to accommodate the needs. The environmental factors that affect the visibility of the surroundings are low surface reflectance, suspended dust, and water vapors that cause backscattering and reduce apparent illuminance. Hence, a suitable lighting design must account for these factors in addition to luminaire design aspects.

1.3. OBJECTIVES OF THE PROJECT

The primary objectives of the project was to design an effective lighting system at different places of work to ensure safe visual working environment in an opencast coal mining project with due compliance of statutory standards. The research investigations were carried out with the following objectives:

- To conduct illumination survey and check the adequacy of lighting at vis-à-vis Directorate General of Mines Safety(DGMS) /International standards at:
    - ✓ Different places of work in the mine
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- Design of appropriate illumination systems based on illumination requirement for:
    - ✓ Haul road
    - ✓ Overburden(OB) transport road
    - ✓ Dump yard
    - ✓ Moving Coal & OB faces.

1.4. LAYOUT OF THESIS

Chapter 1; contains the Introduction to the research work, its importance, goals of the project and Layout of the Thesis.

↓

Chapter 2; is Literature Review. Previous research studies on Illumination, basic terminologies of photometry and opencast illumination standards are discussed here.

↓

Chapter 3; presents Illumination measurement techniques and experimental and design methodology.

↓

Chapter 4; presents a case study of illumination survey performed in Kusmunda Opencast Coal Mining Project (KOCP), SECL, Chhattisgarh.

↓

Chapter 5; contains the results of the illumination survey and brief discussions of the results.

↓

Chapter 6; presents design model of illumination systems performed in the DIALux software at various workplaces in mine e.g. haul road, dump road and dump yard.

↓

Chapter 7; presents illumination design for moving faces of coal and overburden.

↓

Chapter 8; summarizes conclusions of the project work and presents the recommendations for opencast mine lighting.

CHAPTER: 2

LITERATURE REVIEW

2.1. INTRODUCTION

Good lighting is very much required for safety and production. Physiological suitability of a person to his working environment is very much important from safety point of view. Certain evidences shows that 88% of the mine accidents are attributed to unsafe acts and only 2% are attributed to unforeseen circumstances **[10]**. It is realized that if a task is performed in poor lighting for long time sign of strain appear in the individual and if not checked, can lead to physical illness. The increased mechanization demands that the lighting should be adequate and suitable in order to reduce accidents. Good lighting encourages visual performance, improves quality of work, reduces the frequency of errors and prevents fatigue, and improves visual communication with the working environment.

2.2. BASIC TERMINOLOGIES OF PHOTOMETRY

The different terminologies used in illumination are discussed below:

2.2.1. Luminous Flux

Luminous flux describes the total amount of light emitted by a light source. The amount of light emitted by a light source is the luminous flux Φ and its unit is lumen (lm) **[1]**.

2.2.2. Luminous Efficacy

Luminous efficacy is defined as the luminous flux of a lamp in relation to its power consumption and is therefore expressed in lumen per watt (lm/W). Luminous efficacy varies from light source to light source [**1**].

2.2.3. Luminous Intensity

An ideal point-source radiates luminous flux uniformly into the space in all directions. This result partly from the design of the light source and partly on the way light is intentionally directed, therefore, to have a way of presenting the spatial distribution of luminous flux, i.e. the luminous intensity distribution of the light source. The unit for measuring luminous intensity is candela (cd) **[2]**.

2.2.4. Illuminance

Illuminance is the amount of luminous flux from a light source falling on a given area and can be determined from the luminous intensity of the light source. Illuminance decreases with the square of the distance from the light source (inverse square law). The unit for measurement is lux **[2]**.

2.2.5. Luminance

Luminance is defined as the ratio of luminous intensity of a surface (cd) to the projected area of the surface (m^2) **[2]**.

2.3. LAWS OF ILLUMINATION

The cosine law and the inverse square law are two very useful lighting laws and discussed below:

2.3.1. Lambert's Cosine Law

Lambert's cosine law states that the luminous intensity observed from an ideal diffused reflecting surface is directly proportional to the cosine of the angle θ between the observer's line of sight and the surface normal. The representation of Lamberts Cosine Law is illustrated in the Fig. 2.1 **[3].**

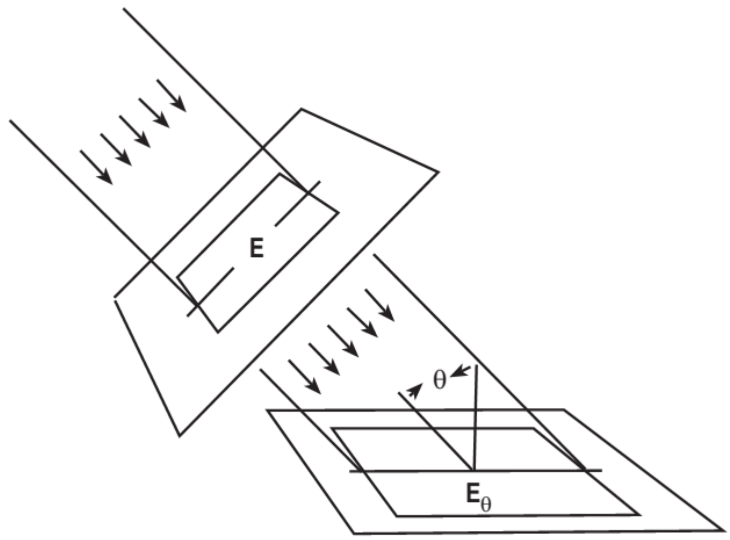

Figure 2.1: Representation of Lambert's Cosine Law [3]

2.3.2. Inverse Square Law

A problem common in lighting system design is determining the illumination on surfaces at various distances from a light source. This can be handled using the inverse square law. The equation relates illumination, intensity, and the distance between the source and light-receiving surface is known as the inverse square law, given as:

$$\mathbf{E} = I/D^2 \qquad (1)$$

Where E is illuminance, I is Luminous Intensity and D is the distance between the source and light receiving surface. It enables illumination of a surface to be calculated if the intensity of the light source and the distance between the light source and the surface are known.

The assumption made in the inverse square law is light as a point source. A second assumption inherent in the inverse square law is that the surface area is perpendicular to the direction of light flow. When this is not the case, the inverse square law can be combined with the cosine law given as follows:

$$E = E_{normal} \text{ x } \cos\theta = I \cos\theta / D^2 \qquad (2)$$

Where, cosine of the angle θ is between the observer's line of sight and the surface normal **[3]**.

2.4. TYPES OF LIGHTING

The various types of lighting used in opencast mines are presented in the Figure 2.2.

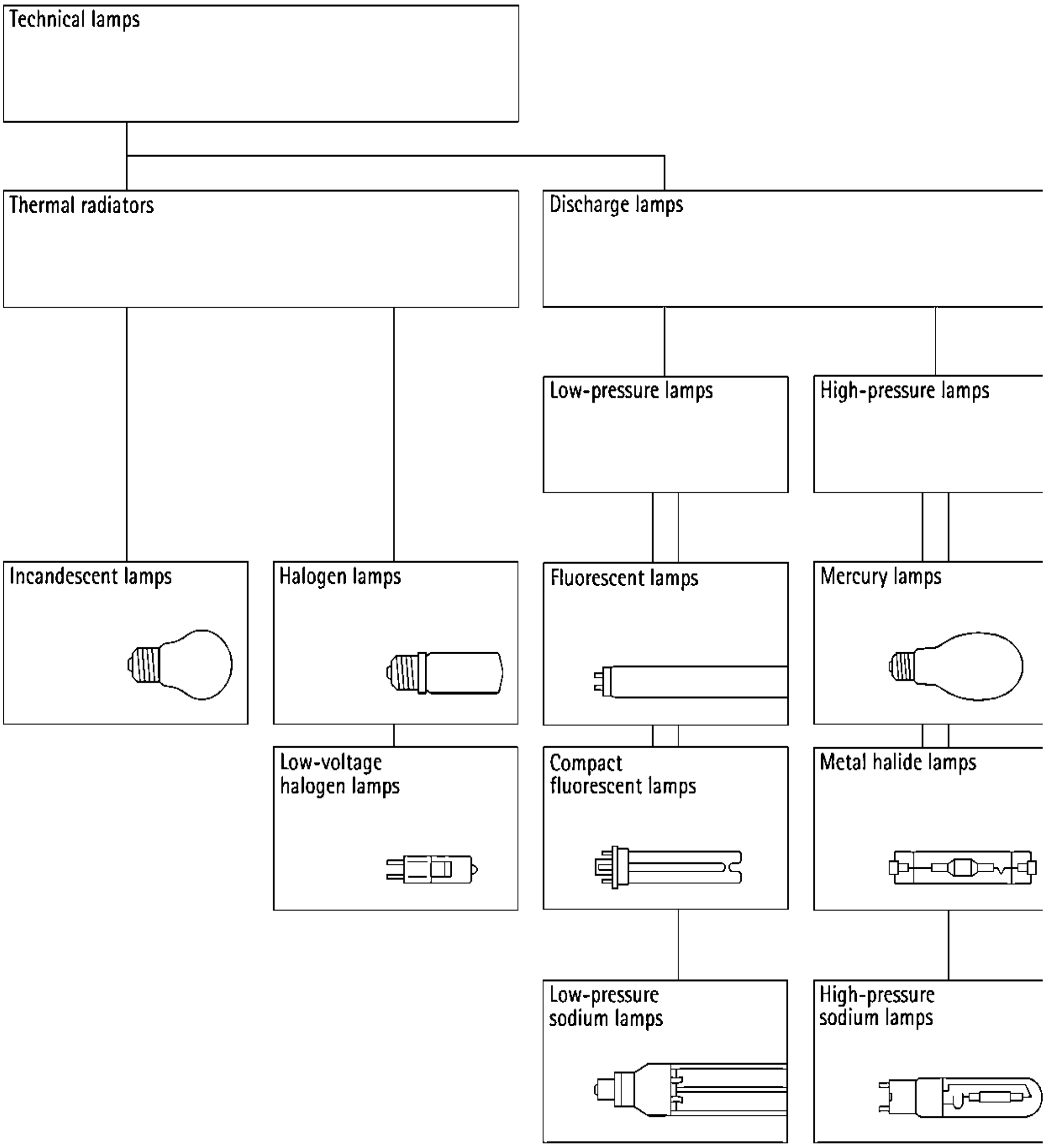

Figure 2.2: Different Types of Lighting Used in Mines [4]

The Table 2.1 summarizes some key criteria for evaluating different sources of lighting.

Table 2.1: Performance of Various Lighting Sources [5]

Type of source	Average rated lifetime (Hrs.)	Lamp efficacy (Lm/W)	Re-strike time (Min)	Color appearance	Applications
Incandescent	1000	5-15	prompt	Warm, white to yellow	General Lighting
Tungsten Halogen	2000-4000	12-35	prompt	Warm, white, slight yellow	General Lighting
Fluorescent	10000-16000	50-100	prompt	Warm, white	General Lighting
Mercury Vapor	12000	40-60	3-10	Cool, bluish	Outdoor/Road Lighting
Metal Halide	6000-12000	50-100	10-20	Cool, blue white	Outdoor/Sports Lighting
High-Pressure Sodium Vapor	12000-16000	80-100	0.5-1.0	Warm, golden colour	Outdoor/Road Lighting
Low-Pressure Sodium Vapor	6000	105-160	1-2	Warm, amber	Outdoor/Road Lighting

2.5. MINE ILLUMINATION STANDARDS IN INDIA AND ABROAD

In view of the impact that illumination and visibility can have on workers' safety and productivity, the challenges of developing appropriate standards and the practical problems of implementing them must be weighed against the potential consequences of maintaining the status quo.

Under the Constitution of India, safety, welfare and health of workers employed in mines are the concern of the Central Government (Entry 55, List-I, Schedule-7, Union, Article 246). The objective is regulated by the Mines Act, 1952 and the Rules and Regulations framed thereunder. These are administered by the Directorate-General of Mines Safety (DGMS). Apart from administering the Mines Act and the subordinate legislation there under, DGMS also administers the Mine Illumination standards and Indian Electricity Act. The minimum standard recommendations for opencast mines in India and various countries in abroad are provided in Table 2.2 and Table 2.3.

Table 2.2: DGMS Standard for Opencast Lighting [6]

Sl. No	Place/Area to be illuminated	Manner in which it is to be illuminated	Minimum standard of illumination (Lux)	Plane level in which the illumination level is to be provided
1	General working area as determined by the manager in writing	-	0.2	At the level of surface to be illuminated
2	Work place of heavy machinery	So as to cover the depth and height through which the machine works	5 10	Horizontal Vertical
3	Area where drilling rig works	So as to illuminate the full height of the rig	10	Vertical
4	Area where bulldozer or other tractor mounted machine works	-	10	At the level of crawler tracks
5	Places where manual work is done	To be provided at level of the surface on which work is done	5 10	Horizontal Vertical
6	Place where loading or unloading or transfer ,loading of dumpers ,trucks or train is carried on	-	3	Horizontal
7	Operators cabin of machines or mechanism	To be provided up to a height of 0.8m from floor level	30	Horizontal
8	At hand picking points along conveyor belt	To be provided up to a distance of not less than 1.5m from picker	50	On the surface of conveyor belt
9	Truck hauling roads	To be provided at the level of the road	0.5-3.0	Horizontal
10	Rail haulage track in the pit	To be provided at the level of the rail heads	0.5	Horizontal
11	Roadways and footpaths from bench to bench	-	3.0	Horizontal
12	Permanent paths for use of persons employed	-	1.0	Horizontal

Table 2.3: Mine Illumination Standards in Various Countries (in Lux) [7]

	Shafts	Loading	Haulages	Headings	U/G Offices	U/G Workshop	Face
Australia	20	20	-	20	100	-	-
Belgium	20-50	25	10	20	-	-	-
Canada	21-50	50	21	20	270	270	-
Czech Republic	15	20	5	20	-	-	5
Germany	30-40	40-80	15	40	-	-	-
Hungary	40-100	20-50	2-10	40-60	-	20-50	10
Poland	30-50	10-50	2-10	15-30	-	30-100	2
United Kingdom	70	30	2-5	30	60	50-100	-
European Coal & Steel Community	40-90	-	5-15	15-80	-	-	-
United states	-	-	-	-	-	-	15
South Africa	20-160	10	20	160	-	400	-

2.6. OVERVIEW OF PREVIOUS RESEARCH WORK

A limited number of studies have been undertaken on impacts of poor illumination on safety and productivity of miners. The following segment presents previous research works carried out by different investigators in India and abroad.

2.6.1 Studies on Effect of Illumination on Health, Safety and Productivity in Mines

Van Graan and Schutte (1977) reported that the introduction of fluorescent lighting on a coal face increased production by 3.5% and the number of accidents diminished by 40% **[8]**.

Mishra and Dixit (1978) reported in an Indian underground coal mines 35% of all minor accidents are attributed to the poor lighting condition **[9]**.

Trotter (1982) carried out investigations in a Hungarian mine and observed that when one part of the mine was illuminated with special purpose fixed lighting and another solely with cap lamps, the accident rate in the lighted portion decreased by 60%. In another mine study in a large West Virginia coal mine in the United States, six production sections were in operation throughout the 24-month period during which the test was carried out. Not a single major accident was reported during this time period in the only section in which mine lighting system was installed **[10]**.

Franz et al. (1995) investigated some issues which supports that illumination was the only environmental factor that could be convincingly correlated with accident occurrence. However, another finding of that work was that the accident reports studied nearly always focused on the immediate cause and failed to identify root causes, which could have included unsatisfactory lighting in many instances **[11]**.

The United States Bureau of Mines conducted a study to examine illumination levels on and about large mobile mining machinery at surface mines. Effort focused on evaluating the task lighting needs of the machinery operator. An intended outcome of the study was to supply useful data and information for efforts to establish illumination standards for the surface mining industry **[12].**

Odendaal (1996) investigated a number of factors as possible contributors to accidents in four gold and four platinum mines, including illumination, and provided a number of useful insights. It was found that approximately 74% of the occupations were solely dependent on cap lamps for illumination during more than half of the shift and accounted for 88%– 95% of reportable accidents during the 3 years considered. Odendaal also examined the relationship between work rates in combination with illumination on accident occurrence and evaluated the prevalence of judgmental errors in such events **[13]**.

Research by the U.S. National Institute for Occupational Safety and Health (NIOSH) indicated that light emitting diodes (LEDs) could be used to enhance safety by improving a miner's ability to see mining hazards **[14]** and reducing glare **[15]**. Recent National Institute for Occupational Safety and Health research focused on the spectral characteristics of light from miners’ cap lamps to improve safety. The results indicated significant gains in visual performance that could reduce pinning/striking accidents **[16]** slip/trip/fall accidents and glare-induced accidents **[17]**.

Tyson (1999) reported that lighting was a contributing factor in only 2% of opencast fatalities and also observed that in 13 separate underground fatalities between 1976 and 1985 poor lighting resulted in accidents **[18]**.

2.6.2 Experimental Studies on Mine Illumination Survey

Mayton (1991) investigated different surface mining operations in various regions of the United States using visual task evaluation, a method used by the CIE and the IES. Visibility and illumination data were collected during site visits to surface mines and quarries in 15 metal–nonmetal mines and seven coal mines. Visual tasks were identified for equipment operators on 57 types of surface mining and quarry equipment. Visibility and illumination were measured for 159 tasks. Measurements of visibility area were made with the Blackwell model 5 visual task evaluation. Existing illuminance for each task was determined with a Minolta luminance meter and a reflectance standard RS-1. He concluded that the illumination level varied from mine to mine for the same tasks and equipment and also suggested that the visibility and illumination on dozers and loaders can be improved by assuring the proper aiming of luminaires and replacing existing lamps with those of higher intensity **[19]**.

Karmakar et al. (2005) developed a computer model for design and economic analysis of lighting system in an opencast mine. The study revealed that mounting height was very important in order to achieve all the required lighting standards. With low-wattage high pressure mercury vapor lamps, the pole height was kept lowered to achieve the necessary lighting standards. HPSV lamps possessed better Isolux contour for haul road illumination. For the light sources studied in the work, 100W HPSV lamps at 12m height gave the optimum design (9737 kWh annual energy consumption), whereas at 16m height the minimum energy consumption was 7534 kWh for 150W lamps **[20]**.

Aruna and Jaralikar (2012) designed a lighting system for both mineral and overburden benches based on the minimum acceptable reflected light and the reflected uniformity ratio. For comparison of various types of lighting systems, a stretch of a 1.0 km long haul road was considered. The design was attempted with five different types of luminaires. Lamp mounting heights were varied at five steps, namely, 8, 10, 12, 14, and 16m. Design under wet conditions incurred an excess cost of 9.4% for mineral bench haul road and 50% for overburden bench haul roads. Design under wet surface conditions ensured the minimum light level even under worst condition of surface reflectivity with marginal increase in cost **[21]**.

Das and Roul (2005) performed an illumination study in a highly mechanized opencast bauxite mine of National Aluminium Company Ltd (NALCO) in which design was provided for 9m lighting tower and 18m telescopic tilt-able tower. Also, design of haul road and auxiliary haul road illumination system was performed **[22]**.

Pal et al. (2012) proposed design system of haul roads lighting for an opencast coal mine using green energy. A prototype board was also constructed and it showed fairly constant lumen output over varying input voltages **[23]**.

CHAPTER: 3

EXPERIMENTAL METHODOLOGY

3.1. INTRODUCTION

For simple lighting installations, hand calculations based on tabular data are used to provide an acceptable lighting design. More critical or optimized designs now routinely use mathematical modeling on a computer. Based on the positions and mounting heights of the fixtures and their photometric characteristics, the proposed lighting layout can be checked for uniformity and quantity of illumination (illuminance). For larger projects lighting design software can be used. Each fixture has its location entered, and then the design parameters and working environment can be entered. The computer program will then produce a set of contour charts overlaid on the project floor plan, showing the light level to be expected at the working height. More advanced programs can include the effect of light from luminaires, allowing further optimization of the operating cost of the lighting installation. The amount of artificial light received in an internal space can typically be analyzed by undertaking a daylight factor calculation **[24]**.

Computer modeling of outdoor flood lighting usually proceeds directly from photometric data. The total luminous energy of a lamp is divided into small solid angular regions. Each region is extended to the surface which is to be lit and the area calculated, giving the light power per unit of area. Where multiple lamps are used to illuminate the same area, net contribution is obtained. Again the tabulated light levels (in lux or foot-candles) can be presented as contour lines of constant lighting value, overlaid on the project plan drawing. Hand calculations might only be required at a few points, but computer calculations allow a better estimate of the uniformity and lighting level **[24]**.

3.2. ILLUMINATION MEASUREMENTS

Instruments are required to evaluate lighting systems and components. The field of light measurement is called photometry, and the instruments used to measure lighting are called photometers. Many types of photometers are available to measure light energy and related quantities, including illuminance, luminance, luminous intensity, luminous flux, contrast, color and visibility. The photometer is one of the most important tools for illumination measurement and evaluation of efficacy of illumination system.

Specific uses for mine illumination system measurements are-

- Verification of compliance with illumination and luminance specifications in the regulations;
- Evaluation of illumination system design options;
- Checking light distribution;

Photometric measurements in mines are of three types: illuminance measurement, Luminance measurement, and reflectance measurement.

3.2.1. Illuminance Measurement

This process measures the incident light (in lux) received by a surface. Most countries specify their lighting standard in lux, so this method is most widely used in mine surveys. Three different techniques can be used in mine illumination surveys:

- Direct planar measurement
- Separate measurements for direct and diffused light
- Maximum reading method **[25]**

3.2.2. Luminance Measurement

The photometer is aimed at the surface to be measured. Luminance measurements state that the photometer shall be held approximately perpendicular to the surface being measured. They also require that the sensing element be at a sufficient distance from the surface to allow the light sensing element to receive reflected light from a field not less than 3 ft^2 or more than 5 ft^2 **[25]**.

3.2.3 Reflectance Measurement

Design of mine illumination requires a thorough knowledge of reflectance of the rock surface in the mine. Four different methods are employed. These are

- Incident–reflected light comparison
- Standard chips comparison
- Reflectance standard comparison
- Sphere reflectometry **[25].**

The instrument used for the illumination survey was Metravi 1332 digital Lux-meter shown in the Figure 3.1.

Figure 3.1 Metravi 1332 Digital Lux-meter used for Illumination measurements [31]

3.3. PRINCIPLES OF ILLUMINANCE MEASUREMENT

In mine lighting, illuminance measurements are typically taken for the following purposes:

- To determine the incident luminous energy (lux) on a surface.
- To determine the light output characteristics of a luminaire.
- To determine if illuminance levels are sufficient to qualify the illumination system for DGMS approval.

The illuminance measurement in opencast mines primarily focuses on the following factors:

1. **Horizontal Illuminance:** The measure of illuminance in foot-candles or lumens, taken through a light meter's sensor at a horizontal position on a horizontal surface.
2. **Vertical Illuminance:** The measure of illuminance in foot-candles or lumens taken through a light meter's sensor at a vertical position on a vertical surface.
3. **Uniformity Ratio:** It describes the uniformity of light levels across an area. This may be expressed as a ratio of average to minimum or it may be expressed as a ratio of maximum to minimum level of illumination for a given area.

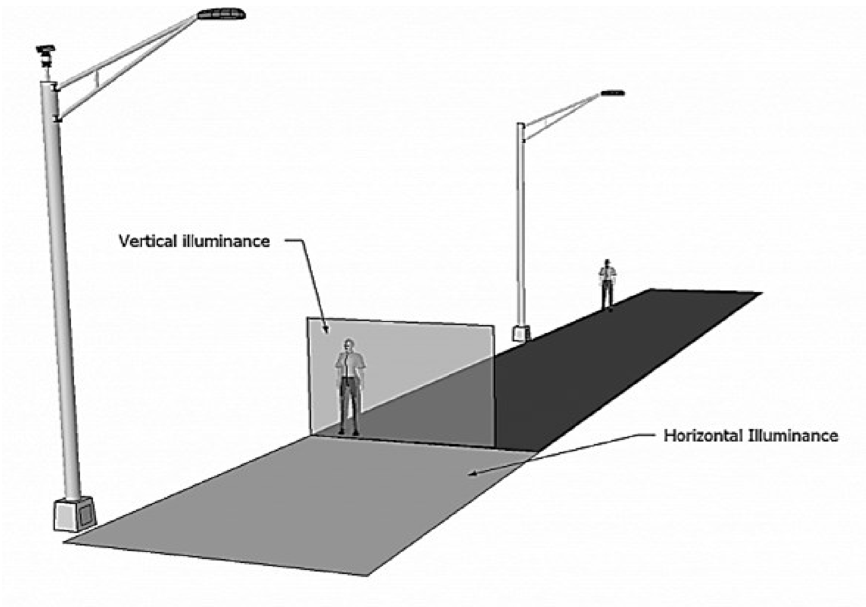

Figure 3.2 Measurement of Horizontal and Vertical Illuminance [32]

3.4. DESIGN OF LIGHTING SYSTEM FOR OPENCAST MINES

Haul roads, Dumping Yards, Moving faces of Coal & OB, within the pit are one of the critical areas in surface mines where lighting installations are not permanent due to regular advancement of the working face. Due to this reason it is very difficult to maintain the lighting standards, as specified by various regulatory bodies. Lighting in mines presents special problems because of the dark surroundings and low surface reflectance. Hence, scientific design of artificial lighting is very important to achieve the minimum required lighting standards. The parameters to be considered for designing suitable lighting system for Opencast mines are as follows:

- **Mounting Height:** Luminaire mounting height depends on the lighting arrangement and effective road width. The effective width is the horizontal distance between luminaire and the far curb. To achieve good distribution of light across the roadway, mounting height, in general, is kept equal to the road width or around it **[23]**.

- **Spacing:** Luminaire or pole spacing for a given lighting arrangement and luminaire light distribution is dependent on the mounting height and the longitudinal uniformity planned for the installation. The greater the mounting height, the larger can be the spacing for a given longitudinal uniformity. Longitudinal uniformity is the ratio of minimum to maximum illuminance along a line parallel to the road axis through the observer's position. However, in practice, excellent illumination is considered to be the one when pole spacing is not more than 8 times the mounting height **[23]**.

- **Overhang:** Poles are generally installed somewhat off-set from the road edge (curb) to provide clearance to the vehicle. Luminaire is mounted on the ranging arm to adjust the distance between it and curb. Sometimes, projection of the luminaire lies inside the road from the curb, which is known as overhang. The main purpose of overhang is to provide better uniformity of light across the road **[23]**.

- **Inclination:** Inclining or tilting the luminaires up from the horizontal is done to increase light coverage across the road width at a given mounting height. It is recommended that the angle of tilt with respect to the normal height of mounting be limited to an absolute maximum of 10°, a top limit of 5° being preferable. In general the angle varies from 10° to 15° **[23]**.

3.5. IMPORTANT PLACES TO BE ILLUMINATED FOR OPENCAST MINES

- At the Working faces of Ore/Overburden to facilitate digging and loading operation for positioning buckets during loading and unloading.
- Material to be loaded and filling level in the bucket or bowl.
- Illumination of haul roads.
- Spotting dumpers for loading and unloading at the dump yard, stack-yards etc.
- Viewing the edge and dump of the general area.
- Inside the Cabins of the machineries and along walkways.
- Below the shovels, under the carriage to identify any leakage for handling of trailing cables during relocation maneuvers.
- Over the dock of shovels and draglines for routine maintenance and inspection.
- In case of conveyor haulage system lighting is mainly needed for inspection and maintenance.
- At crusher site, bunkers, vibrators, washers and loading point.
- At maintenance shop, general repairing workshop, auto electrical shop and other places as suggested in DGMS standards.

3.6. DESIGN METHODOLOGY

The flow chart (Fig. 3.3) depicts the design methodology for the present research investigation.

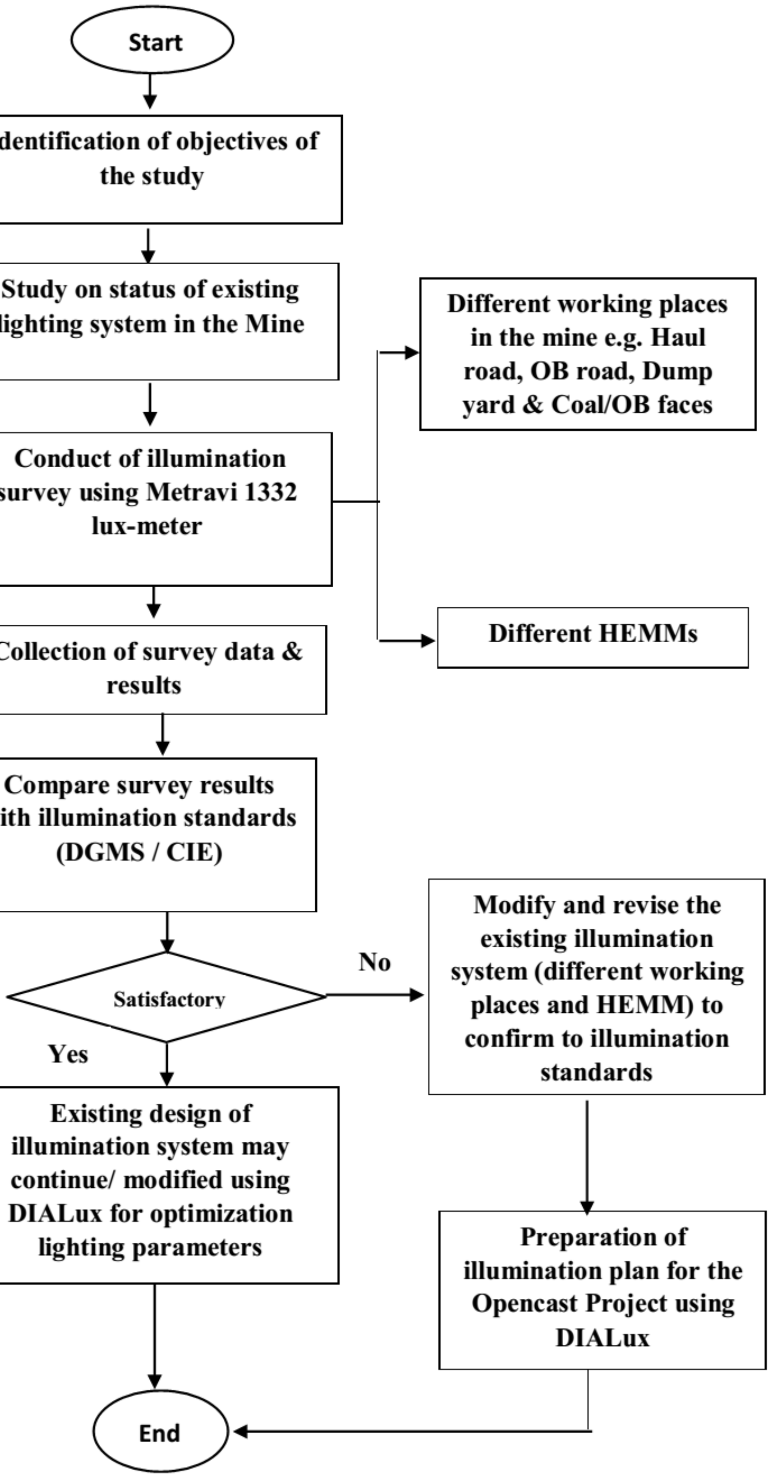

Figure 3.3 Flow chart for Illumination Design Methodology for the Project

CHAPTER: 4

ILLUMINATION SURVEY IN KUSMUNDA OPENCAST COAL PROJECT (KOCP) - A CASE STUDY

4.1. PROJECT LOCATION

Korba Coalfield is located between latitudes 22°15' N and 22°30' N and longitudes 82°15' E and 82°55' E. Korba Coalfield covers an area of about 530 square kilometers (200 sq. miles). According to Geological Survey of India, total reserves (including proved, indicated and inferred reserves) of non-coking coal (as on 1.1.2004) in Korba Coalfield was 10,074.77 million tons, out of which 7,732.87 was up to a depth of 300 m and 2,341.90 million tons was at a depth of 300–600m. Coal mined at Korba coalfield generally has the following characteristics: moisture: 4.5-7.4%, volatile matter: 27.9-39.2%, fixed carbon: 34.1-47.7%, ash content: 11.2-31.6%. Sub-areas of Korba Coalfield are: Korba, Surakachhar, Rajgamar, Manikpur, Dhelwadih, Kusmunda and Gevra. The main working coal mines are: Manikpur, Kusmunda, Gevra and Dipka (Fig 4.1). Korba Coalfield accounts for a major portion of coal mined by SECL. In 2010, coal production of SECL was 101.15 tons, out of which 73.35 tons came from Korba Coalfield alone **[33]**.

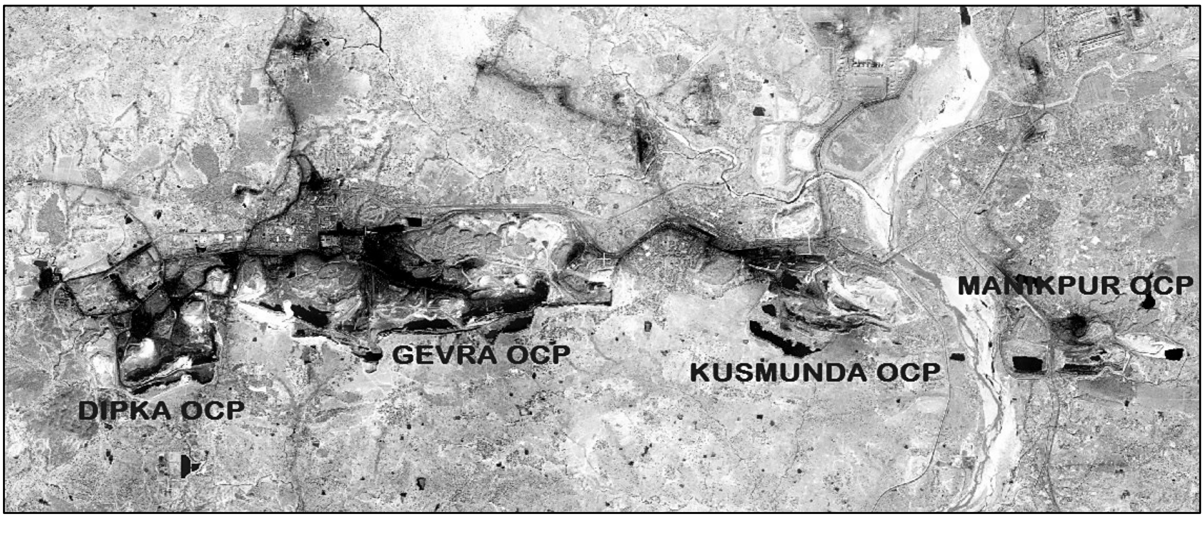

Figure 4.1 Location of Mines under SECL, Korba Area, Chhattisgarh [29]

4.2. DESCRIPTION OF THE MINE

The illumination survey was performed in Kusmunda opencast project (KOCP), which is in the Korba Coalfield, located in Korba district in the Indian state of Chhattisgarh in the basin of the Hasdeo River, a tributary of the Mahanadi. It is about 238 km by road from capital city Raipur. Kusmunda OCP Expansion, a part of Eastern Sector of Jatraj, Resdi and Sonpuri Blocks, is located in the south-central part of Korba Coalfield in Korba district of Chhattisgarh. These blocks cover an area of 25.36 sq. km. and are bounded by latitudes 22° 15’18' to 22°21'30" North and longitudes 82°38'39" to 82°42'08" East. The blocks are well connected by rail and road. 'Gevra road' and 'Korba railway stations’ on Champa-Gevra road branch line of S.E.C. railway are at a distance of 1.5 km and 5 km respectively. Bilaspur, is at a distance of about 90 km by road. Figure 4.2 depicts the physical map of Kusmunda Opencast Project **[26]**.

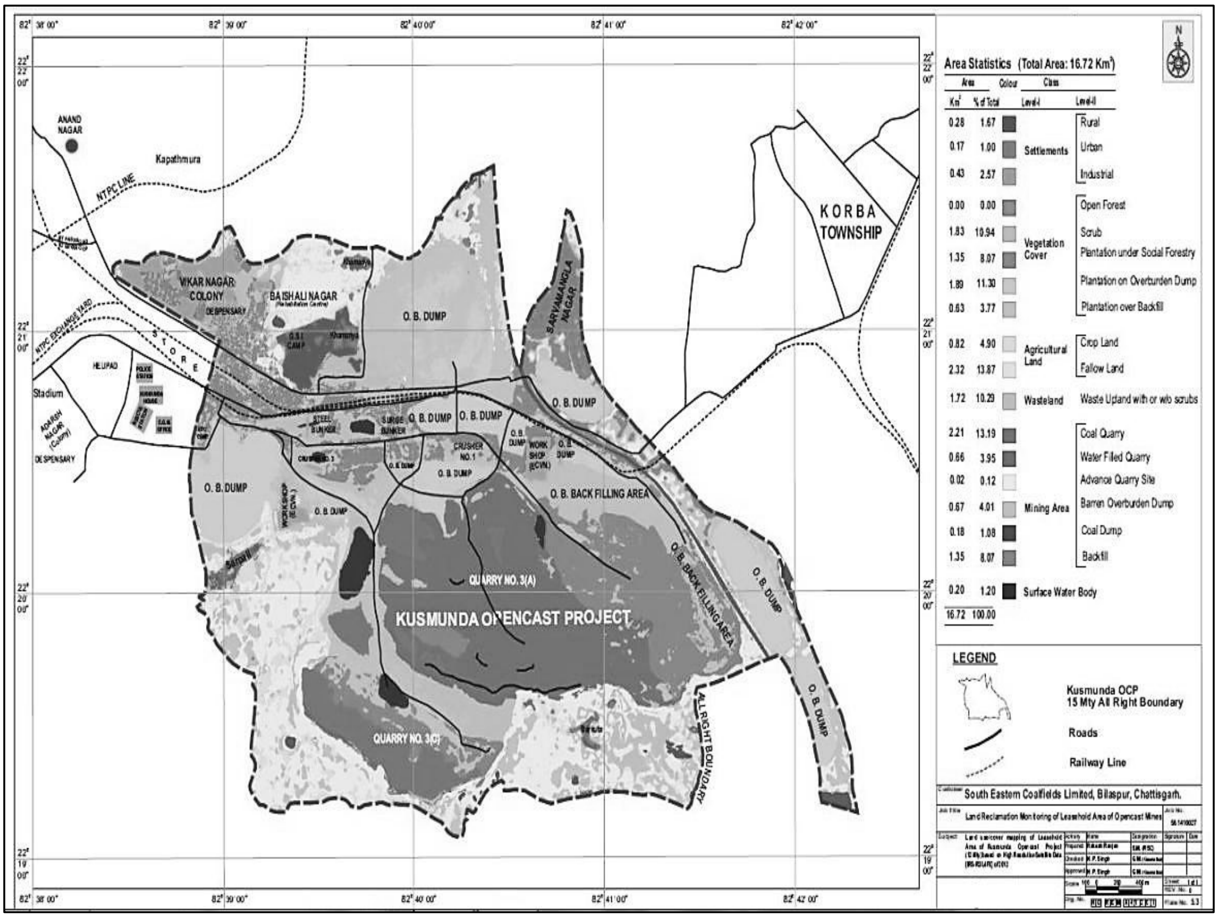

Figure 4.2 Map of Kusmunda Opencast Project, SECL, Korba, Chhattisgarh [27]

4.3. GEOLOGY & RESERVES

A Mining Block covering an area of 9.67 sq.-km has been considered in the Kusmunda Opencast Expansion Project (15MTY). The boundaries of the mining blocks are given below: -North: An arbitrary line passing north of borehole CMKK-192, 125 and NCKK-48, 81 and 56. South: An arbitrary line passing south of boreholes CMKL-101, 117, 123 CKKS-17, CMKR-53, 70, 10, 21 & CMKS-14 (corresponding to a maximum depth of 240m on lower Kusmunda Seam). East: West Bank Canal of Hasdeo River. West: An arbitrary line west of boreholes NCKK-15, 22, 21, 25, CMKL- 55, 56, 68, 114 and 184, RL 295.0 **[26]**.

4.4. GENERAL INFORMATION ABOUT KOCP [26]

Name of the Mine:	Kusmunda Opencast Project
Total Area:	2536.24 Hectare.
Total Mineable Coal Reserves:	430.03 Million tons (as on 01.04.12)
Total Overburden Reserves:	707.66 Million cubic meters (as on 01.04.12)
Life of the Mine:	29 years @ 15 MT/Year
Name of Seams:	Upper Kusmunda and Lower Kusmunda
Quality of Seams:	Grade-F
Overall Quality of the Coal:	G-11
Average Stripping Ratio:	1.42 cubic meter/ton
Thickness of the Seam:	Upper Kusmunda 9.5m to 35.73m
	Lower Kusmunda Top Split 30.02m to 43.60m
	Composite Seam 50.85m to 60.22m.
	Lower Kusmunda Bottom Split 5.18m to 16.65m
Dip of Seam:	4º to 10º.
Extent of the Mine:	2.0 km along the Strike.
	1.5 km along the Dip.
	110 to 150 m by Depth.

4.5. LOCATION OF STUDY AREAS FOR ILLUMINATION SURVEY

The details of the study areas of the mine under study are given below:

4.5.1. Haul Road

Haul roads are maintained keeping width three times of the largest plying dumper/trucks, and gradient is kept smoother than 1 in 16. At corners and curves, visibility to drivers is maintained at least 30m. At slopes separate lane is provided for up and down traffic. The length of the mine haul road is approximately 1.6km.

4.5.2. Coal Face

The method of winning coal is by pay-loader in combination with tipping trucks. Coal is being transported up to CHP and siding by tipping trucks. Surface miners are also introduced for winning of coal.The bench width for working in coal is 15m, for bench height of 5m.

4.5.3. Overburden (OB) Face

The method of overburden removal is by conventional shovel and dumper combination. At present 120Te, 100Te dumpers in combination with 10 m^3 & 4.6 m^3 shovels. Considering the average floor gradient of 5° to 10° the coal extraction and OB removal benches are made parallel to the seam floor. The benches are given suitable lateral gradient towards the main sump to avoid water logging and facilitate smooth movement of dumpers. The bench width for working in OB is 40m for bench height of 14m. The bench slopes are maintained along width towards height of the bench.

4.5.4. Dumping Road and Dump Yard

Stock piles and dumps are strategically located. Regular inspections of dumps are being done. Berms in dumps are maintained as per norms. Dumpers are maintained properly with special attention to the safety feature. 100Te and 120Te dumpers are used for dumping of overburden. There are two dumping yards; lower dumping and upper dumping. Both dumping roads are approximately 600m in length and width of 40m.

4.6. OBSERVATIONS OF ILLUMINATION SURVEY

Some observations were made during the illumination survey and are presented below:

4.6.1 Haul Road

There were luminaires tilted in left/right directions mentioned at some of the poles, due to which lux levels were reduced. Also there were drop of operating voltage on the luminaires which are at higher distance from the transformer location and hence reduced lux level. Some defective luminaires are found not working, i.e. not glowing.

4.6.2 Coal Face

There were only 2, 1000 Watt HPSV lamps installed for the coal at a height of approximately 50m from the high wall side.

4.6.3 Dumping Yard

The upper dumping yard had an approximate area of 100m x 80m and there were 5 lighting poles installed among which 4 was of 1000 Watt and the other 2x400 Watt while the lower dumping yard had an approximate area of 120m x 60m and there were 4 lighting poles installed among which 2 was of 1000 Watt and the others 2x400 Watt. There were not adequate lux levels found during the survey on the dump edges as per the DGMS guidelines but the dump edges could be identified by the heap of overburden stacked near it.

4.6.4 Dumping Road

The dump road were illuminated using 400 Watts HPSV lamps single row arrangement and hence on the pole side lux levels were much higher and at the end along road width the lux levels were significantly lower, which resulted in non-uniform light distribution. Some defective luminaires are also found on the pole that is not working, i.e. not glowing.

4.6.5 OB Face

Lamps used for illumination were 1000 and 2x400 Watts HPSV. The mine was highly mechanized with high production of OB per day, hence temporary light setup was provided. Lux levels of the machine mounted HEMMs at OB face were enough to perform the night operations, although peripheral lighting was low.

CHAPTER: 5

RESULTS AND DISCUSSION

5.1. INTRODUCTION

The illumination survey was performed in a mechanized opencast coal mine project of Coal India Limited during June, 2013 to May, 2014. The mine had a total area of 2536.24 ha and mineable coal reserves of 430 million tons **[26]**. The method of winning coal was by pay-loader in combination with tipping trucks and surface miner. The method of overburden removal was by conventional shovel and dumper combination. Coal was transported in to coal handling plants as well as to nearby stacking yards. Haul roads were generally maintained keeping the width three times of the largest plying dumpers/trucks and the gradient of the slope was kept less than 1 in 16. At corners and curves, visibility to drivers was maintained at least 30 m. At slopes a separate lane was provided for each direction of traffic.

5.2 RESULTS OF ILLUMINATION SURVEY

The illumination survey readings in various workplaces of the mine and are represented in Tables 5.1 to 5.7.

Table 5.1: Haul Road Illumination Survey Data in KOCP

Pole No.	Spacing (m)	Road width (m)	Pole height (m)	No. of lamps	Consumption (watt)	Illuminance (lux)				Remarks
						L1	L2	L3	L4	
Satarkata Chowk to Upper Loop (as on 10.06.13 @7:30-9:30 PM)										
1	-	40	11	1	400	21.4	14.7	3.3	1.9	
2	42	40	11	1	400	18.2	12.5	3.4	1.6	
3	40.40	40	11	1	400	22.5	10.7	2.4	1.9	
4	38.70	40	11	1	400	16.8	6.6	2.4	1.4	
5	38.20	40	11	1	400	0.4	0.3	0.2	0.1	Defective
6	39.80	40	11	1	400	19.4	9.4	1.4	0.6	
7	39.60	30	11	1	400	2.2	1.3	0.5	0.4	Line Drop
8	49	30	11	1	400	17.8	5	1.8	1	
9	45	20	11	1	400	16.1	11.9	1.8	1	
10	44.80	20	11	1	400	17.4	13.6	5.7	5.7	
11	44	30	11	1	400	19	8.4	3.3	0.9	
12	44.40	30	11	1	400	13	4	1.3	0.3	
13	45.20	30	11	1	400	23.4	13.5	2.4	1	
14	45.70	30	11	1	400	6.4	3	0.7	0.2	
15	44.50	30	11	1	400	0.2	0	0	0	Defective
16	45	30	11	1	400	20	8	2.8	0.8	
17	46	30	11	1	400	16.4	4.8	1.8	0.7	
18	29.30	30	11	1	400	14.7	7.6	5.4	2.2	
Upper Loop to Lower Loop via Mid Intersection(as on 12.06.13 @7:20-9:00 PM)										
19	-	22	18	2	1000	8.7	5.6	3.8	3.2	
20	58	22	11	1	400*2	1.8	1.4	1.4	1.6	Tilted
21	63	22	11	1	400*2	17.5	2.1	0.7	0.8	
22	73	22	11	1	400*2	25.2	6.95	2.6	1.6	Defective
23	79	33	11	-	-	0.2	0.3	0.3	0.7	No lights
24	62	33	11	1	400*2	13.4	3	0.5	0.8	Defective
25	68.40	10	11	1	400*2	24.2	9.8	6.8	3.8	
26	30.50	15	11	1	400	35.4	15.4	7.2	6	
27	61	20	11	1	400	14.7	7.6	3.7	1.6	
28	32	20	11	1	400	9.4	3.4	1.5	1.1	
29	48	20	11	1	400	18.1	8.6	4.4	3.3	
30	50	20	11	1	400	0.1	0.2	0.3	0.2	Defective
31	50	20	11	1	400	15.5	8	2.8	1.6	
32	38	20	11	1	400*2	28.3	12.3	7	2.5	
Lower Loop towards Coal face										

Table 5.2: Surface Miner Coal Face Illumination Survey Data in KOCP

Pole No.	Pole height (m)	Type of luminaire	No of lamps on pole	Consumption (watt)	Illuminance (lux)	
					Horizontal	Vertical
Upper Coal Face Area as on 14-06-13 @ 7:30 PM						
1	11	HPSV	2	1000*2	1.5	2.6
2	11	HPSV	2	1000*2	1.8	3.0
3	11	HPSV	2	1000*2	1.6	2.4
4	11	HPSV	2	1000*2	2.1	3.2
Upper Coal Face Area as on 21-09-13 @ 7:05 PM						
1	11	HPSV	2	1000*2	1.1	1.3
					0.9	1.2
					0.7	1.1
Coal Face Area: 160m * 80m						

Table 5.3: OB Face Illumination Survey Data in KOCP

Pole No.	Pole height (m)	No. of lamps on pole	Luminaire consumption (watt)	Horizontal Illuminance			
				Distance across the face (m)	Across the face (lux)	Distance along the face (m)	Along the Face (lux)
OB Face as on 10-06-13 @ 8:00 PM							
1	11	2	2*400	25	6.0	20	4.4
2	11	2	1000	30	4.6	30	3.2
3	11	1	1000	40	1.8	40	2.6
OB Face as on 28-01-14 @ 8:30 PM							
1	11	1	2*400	30	4.1	10	2.4
2	11	1	1* 1000	35	3.7	20	1.7

Table 5.4: Dumping Yard (Lower) Illumination Survey Data in KOCP

Pole No.	Pole height (m)	No. of lamps on pole	Luminaire consumption (watt)	Horizontal Illuminance			
				Distance across the face (m)	Across the face (lux)	Distance along the face (m)	Along the Face (lux)
Lower Dump Yard Area as on 27-01-14 @ 8:00 PM							
1	11	2	2*400	10	3.2	10	8.1
2	11	1	1000	30	2.8	20	5
3	11	1	1000	50	0.8	30	1.4
4	11	1	2*400	100	0.4	60	0.4
Lower Dump Yard Area: 160m * 100m							

Table 5.5: Dumping Yard (Upper) Illumination Survey Data in KOCP

Pole No.	Pole height (m)	No. of lamps on pole	Luminaire consumption (watt)	Horizontal Illuminance			
				Distance across the face (m)	Across the face (lux)	Distance along the face (m)	Along the face (lux)
Upper Dump Yard Area as on 28-01-14 @ 8:30 PM							
1	11	2	1000	20	3.6	30	3
2	11	1	1000	30	2.6	40	2.1
3	11	1	1000	60	1.2	50	1.8
4	11	1	1000	80	0.8	60	1.3
5	11	1	2*400	100	0.5	80	0.9
Upper Dump Yard Area: 120m * 80m							

Table 5.6: Dump Road (Lower) Illumination Survey Data in KOCP

Pole No.	Pole spacing (m)	Road width (m)	Pole height (m)	Type of luminaire	No of luminaires	Wattage (watt)	Illuminance (lux)		
							L1	L2	L3
1	50	40	11	HPSV	1	400	15.1	3.4	0.2
2	50	40	11	HPSV	1	400	14.4	2.9	0.4
3	50	40	11	HPSV	1	400	14.0	2.8	0.6
4	50	40	11	HPSV	-	-	15.2	3.6	0.3
5	50	40	11	HPSV	-	-	14.6	2.7	0.5
6	50	40	11	HPSV	1	400	15.3	3.1	0.7
7	50	40	11	HPSV	1	400	14.8	3.3	0.6
8	50	40	11	HPSV	1	400	14.3	2.9	0.8
9	50	40	11	HPSV	1	400	14.1	3.2	0.7

Table 5.7: Dump Road (Upper) Illumination Survey Data in KOCP

Pole No.	Pole spacing (m)	Road width (m)	Pole height (m)	Type of luminaire	No of luminaires	Wattage (watt)	Illuminance (Horizontal Lux)		
							L1	L2	L3
1	50	40	11	HPSV	1	400	18.4	4.3	1.9
2	50	40	11	HPSV	1	400	12.6	3.8	1.4
3	50	40	11	HPSV	1	400	12.2	4.1	0.6
4	50	40	11	HPSV	1	400	12.4	3.6	1.7
5	50	40	11	HPSV	1	400	16.2	3.8	1.2
6	50	40	11	HPSV	1	400	14.4	4.2	1.1
7	50	40	11	HPSV	1	400	13.4	4.3	0.9
8	50	40	11	HPSV	1	400	11.6	3.5	0.8
9	50	40	11	HPSV	1	400	10.2	3.4	0.7
10	50	40	11	HPSV	1	400	12.5	4.2	1.3
11	50	40	11	HPSV	1	400	11.8	4.0	1.2
12	50	40	11	HPSV	1	400	12.2	4.2	1.5
13	50	40	11	HPSV	1	400	13.4	3.8	1.1
14	50	40	11	HPSV	1	400	12.8	4.1	1.2
15	50	40	11	HPSV	1	400	12.6	4.3	1.3
16	50	40	11	HPSV	1	400	13.2	3.8	1.1
17	50	40	11	HPSV	1	400	12.8	4.2	1.2
18	50	40	11	HPSV	1	400	11.5	4.3	0.9
19	50	40	11	HPSV	1	400	12.6	3.9	1.0
20	50	40	11	HPSV	1	400	12.8	4.0	1.2

5.3. ILLUMINATION SURVEY OF HEAVY EARTH MOVING MACHINERY (HEMM)

Illumination studies were carried out at the Kusmunda Opencast Project to assess the lighting of various HEMMs at work. The HEMM illumination studies are listed in Tables 5.8 to Table 5.13.

Table 5.8 Illumination Study of Dozer Crawler

Make	Bharat Earth Movers Limited (BEML)			
Model	BS6D170-1			
Number of lights	Front-4, Back-3, Incandescent			
Illuminance level				
Horizontal		**Vertical**		
Distance	**Lux**	**Distance**	**Height**	**Lux**
10	5.2	10	2	20
Cabin Lighting	Open Cabin			

Table 5.9 Illumination Study of Pay Loader

Make	HINDUSTHAN			
Model	Wheel Loader 2021			
Number of lights	Front-4, Back-1, Incandescent			
Illuminance level				
Horizontal		**Vertical**		
Distance	**Lux**	**Distance**	**Height**	**Lux**
10	6.7	10	2	42
Cabin Lighting	34 lux			

Table 5.10 Illumination Study of Electric Drill

Make	REVATHI EQUIPMENTS	
Model	CP-750 E	
Number of lights	Front-2, Back-1, HPSV	
Vertical Illuminance level		
Distance	**Height**	**Lux**
4	2	30.6
Cabin Lighting	35.6 lux	

Table 5.11 Illumination Study of Shovel (P&H)

Make		P&H		
Model		1900 AL		
Number of lights		Front-6, Back-2, Metal Halide		
Illuminance level				
Horizontal		**Vertical**		
Distance	**Lux**	**Distance**	**Height**	**Lux**
6	92.8	6	2	220.6
Cabin Lighting		255 lux		

Table 5.12 Illumination Study of Shovel (BEML)

Make		BEML		
Model		182-M		
Number of lights		Front-3, Back-1, HPSV		
Illuminance level				
Horizontal		**Vertical**		
Distance	**Lux**	**Distance**	**Height**	**Lux**
8	19.3	8	2	29.2
Cabin Lighting		34 lux		

Table 5.13 Illumination Study of Surface Miner

Make		Wirtgen		
Model		2200 SM		
Number of lights		Front-2 Metal Halide, Back-2 HPSV		
Illuminance level				
Horizontal		**Vertical**		
Distance	**Lux**	**Distance**	**Height**	**Lux**
6	10.6	6	2	23.2
Cabin Lighting		30.5 lux		

5.4. SUMMARY OF SURVEY RESULTS AND DISCUSSIONS

This summary of the illumination survey results that were recorded during the illumination survey are presented in Table 5.14

Table 5.14: Summary of Survey Results of Various Working Places

Location	Minimum Illuminance Standards (DGMS) in Lux		Measured Illuminance (Average) in Lux		Remarks
	Horizontal	Vertical	Horizontal	Vertical	
Haul Road	0.5-3.0	-	4.65	-	Satisfactory
Coal Face	3	-	1.50	2.60	Not Satisfactory
Upper Dump yard	3 (Dump Edge)	-	0.9 (Dump Edge)	-	Not Satisfactory
Upper Dump Road	0.5-3.0	-	7.49	-	Satisfactory
Lower Dump Yard	3 (Dump Edge)	-	0.4 (Dump Edge)	-	Not Satisfactory
Lower Dump Road	0.5-3.0	-	7.46		Satisfactory
OB Face	3	-	4.4	-	Satisfactory

To design a suitable luminaire for the road lighting, prime concern is visibility issues because the surroundings are dark. The lumen output of the lamp should be enough so that the road surface has the required illuminance for visibility and even brightness. In general, high pressure sodium discharge lamps are preferred for the road lighting design because they have higher lumen outputs and efficiency compared to other lighting sources. HPSV lamps emit radiation with wavelengths that are less visible to insects and hence insects are not normally attracted to them **[28]**. Measurement of road illuminance was conducted by creating a virtual grid between two consecutive poles. The horizontal illuminance at each of the points was measured. The road was segregated into four sections along the width as L1, L2, L3, and L4 which represented points at distances of 10, 20, 30, and 40 m, respectively. The measurement was also taken between the midpoint of the two adjacent poles and the spread of light was observed. The illuminance measurement obtained during the survey for haul road and dump road satisfied the minimum DGMS lux levels but uniformity of lighting was absent which is a focus point for good road lighting as per the international standard **[29]**.

For the dump yard lux levels were checked at the edge of the yard. As, dump edges need to be seen clearly by the dumper operator hence it is essential to provide adequate illumination to avoid slide/fall accidents. Lighting arrangement can be provided for the area at a distance of 100m because of dumper workings and hence symmetrical lighting is used for the purpose. The installed luminaires on the mine dumping yard were unsymmetrical hence adequate lighting level was not obtained.

Overburden face lighting was satisfactory as per DGMS standards. The shovel mounted lights were enough to illuminate the area of 50m x 50m. Peripheral lighting was also provided. The problem with overburden face lighting occurs when blasting operation is performed, which totally damages the luminaries. So peripheral lighting cannot be permanent and hence mobile lighting system e.g. trolley mounted/truck mounted system is recommended.

Coal face in KOCP was operated by surface miner. It is difficult to provide lighting because the working face changes rapidly in both direction and depth. Therefore, mobile lighting arrangements are useful for the purpose, and if any setup may be installed it has to be repositioned after the face progresses. The current lighting system was provided from the top of the high-wall side face at a height of 50m, but adequate lighting level is not present because of the use of asymmetrical lights. Hence, proper changes/adjustments should be done to accommodate these needs which will improve the visibility conditions of the mine.

CHAPTER: 6

DESIGN OF MINE ILLUMNATION SYSTEMS

6.1. INTRODUCTION

Based on illumination requirement in various workplaces in the mine suitable illumination models were developed and presented in this segment. During the illumination survey, it was noticed that the existing system of lighting was found inadequate for the mine; hence a new system of illumination was developed and proposed at appropriate places where illumination levels were unsatisfactory. In this study, the design of lighting systems was performed using DIALux software. The illumination level calculations used for the designs were based on incorporating virtual Philips luminaires and corresponding lamp flux (lumen) and wattages are given in the design.

6.2. DESIGN OF ILLUMINATION SYSTEMS FOR HAUL ROAD & DUMP ROAD

The road lighting design utility in the software consists of a tool that is based on the CEN /TR 13201-1 technical report from the European committee for standardization, which helps the user to determine the ideal illumination conditions based on the user data input e.g. vehicle speed, difficulty of navigation, road traffic, dust conditions, dry/wet condition of the road surface, surface reflectance, surface coating, visibility conditions, etc. The illumination condition obtained for the mine under study was B1 and the illumination class was MEW5 **[30]**. The reflectance values used for the design were obtained using R3 and W3 tables, respectively, for the dry and wet conditions, which were integrated in the software. The simulation was performed by optimizing pole distance, height, inclination, and light overhang.

6.2.1. Design of Haul Road Illumination System

A model for haul road illumination system was simulated which resulted significant improvement in the uniformity ratio and also low wattage of lamp was used than the existing lighting. The optimized parameters for the lighting arrangement are given in the Table 6.1. The lighting arrangement for haul road is depicted in the Fig. 6.1.

Table 6.1: Details of Haul Road Lighting Arrangement Setup

Haul Road Specifications	
Road length	1.6 Km
Road Width	80m
Luminaire Specifications	
Lamp wattage	250Watt HPSV
Luminous flux (approx.)	28500 lumen
Lamp body	Die-Cast Aluminium Body
Reflector type	T-POT Reflector
Glass cover	Sealed, Toughened, Dust Proof (IP 66)
Light distribution	Asymmetrical
Luminaire Arrangement	
Pole arrangement	Dual row; Opposite with Median
Pole spacing	50m
Pole height	11m
Overhang	1.5m
Boom angle	15°
Boom length	1.5m

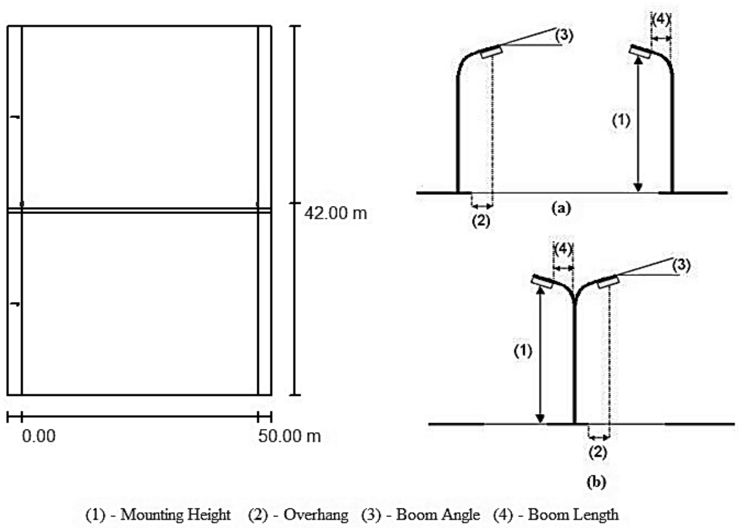

Figure 6.1 Plan View of Haul Road Lighting Arrangement for the Mine. (a) Lighting Arrangement Provided on Both Side of the Road Dual Row Opposite (b) Lighting Arrangement in the Median

6.2.2. Design of Dump Road Illumination Systems

The Dump road illumination system was facing the same problem as that of the haul road; it was found that the road side which has luminaires installed has much higher lux levels than the end point along the width of the road causing significantly less uniformity of light. A model for dump road illumination system was simulated which resulted in improvement of the uniformity ratio and also low wattage of lamp was used than the existing lighting. The optimized parameters for the lighting arrangement are given in the Table 6.2. The lighting arrangement for both dump roads is depicted in the Fig. 6.2.

Table 6.2: Details of Dump Road Lighting Arrangement Setup

Dump Road Specifications	
Upper Dump Road length	1Km
Lower Dump Road length	600 m
Road Width	40m
Luminaire Specifications	
Lamp wattage	250Watt HPSV
Luminous flux (approx.)	28000 lumen
Lamp body	Die-Cast Aluminium Body
Reflector type	T-POT Reflector
Glass cover	Sealed, Toughened, Dust Proof (IP 66)
Light distribution	Asymmetrical
Luminaire Arrangement	
Pole arrangement	Dual row; Offset
Pole spacing	50m
Pole height	11m
Overhang	1.5m
Boom angle	15°
Boom length	1.5m

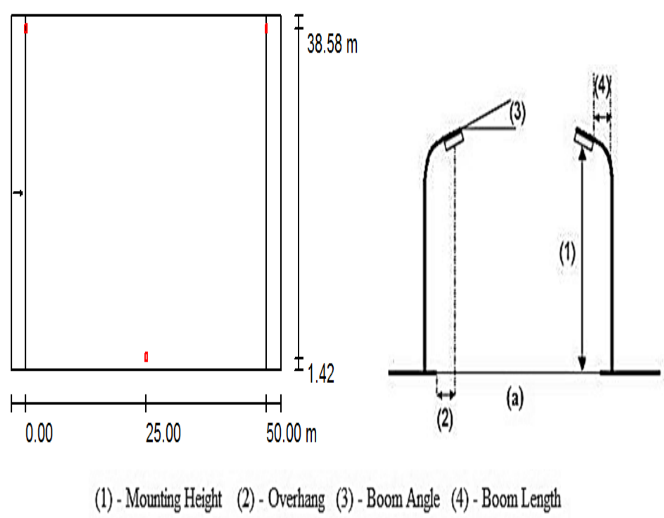

Figure 6.2 Plan View of Dump Road Lighting Arrangement for the Mine

6.3. Design of Dumping Yard Illumination Systems

The illumination design for dumping yards, as per the DGMS guidelines provides visibility of dump edges with a minimum horizontal illuminance level of 3 lux, to avoid slip/fall accidents. For designing point of view it is rather a challenging task to provide the suitable arrangement/positioning of the lighting setup because of the working of dozer crawlers and dumpers in the yard. Hence for arrangement of illumination setup in dumping yards symmetrical luminaires and HPSV luminaires are used for the purpose. The lighting arrangement for Upper dump yard and Lower dump yard is depicted in the Fig. 6.3 and Fig. 6.4. The luminaire arrangements for upper and lower dumping yards are given in Table 6.3 and Table 6.4 respectively.

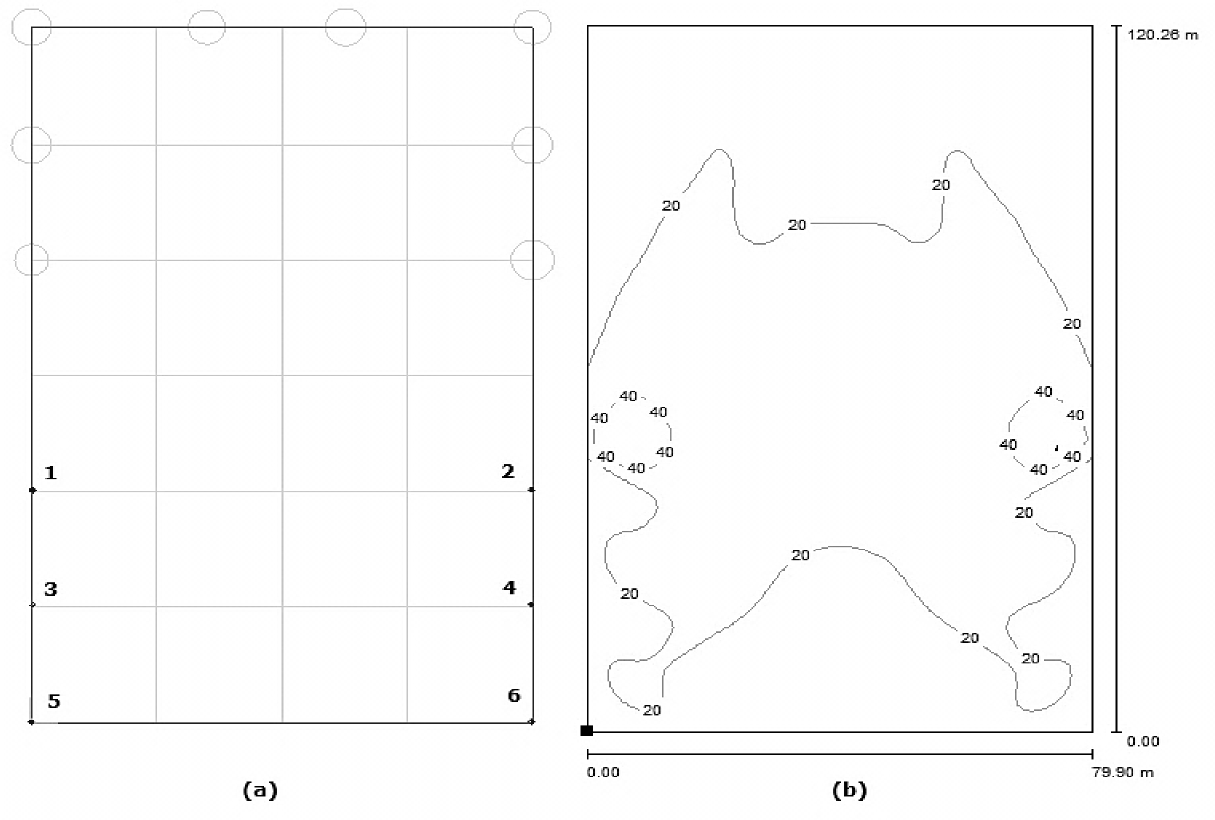

Figure 6.3 (a) Plan View of Upper Dump Yard Lighting Arrangement for the Mine (b) Isolux Diagram of the Lighting Design

Table 6.3: Details of Upper Dump Yard Lighting Arrangement Setup

Upper Dump Yard Specifications					
Upper Dump Yard Area				$120 \times 80\ m^2$	
Luminaire Specifications					
Lamp wattage				1000Watt HPSV	
Luminous flux (approx.)				130000 lumen	
Lamp body				Die-Cast Aluminium Body	
Reflector type				Conical Reflector	
Glass cover				Sealed, Toughened, Dust Proof (IP 66)	
Light distribution				Symmetrical	
Pole Arrangement for Upper Dump Yard					
Pole spacing				100m	
Pole height				11m	
Luminaire Arrangement for Upper Dump Yard					
Pole No.	Distance from Edge	No. of lamps	Positioning	Focus Angle	Focus Distance
1	80	2	L	6°	113.19 m
			R	7°	94.51 m
2	80	2	L	6°	113.19 m
			R	7°	94.51 m
3	100	1	-	6°	112.83 m
4	100	1	-	6°	112.83 m
5	120	1	-	6°	112.53 m
6	120	1	-	6°	112.53 m

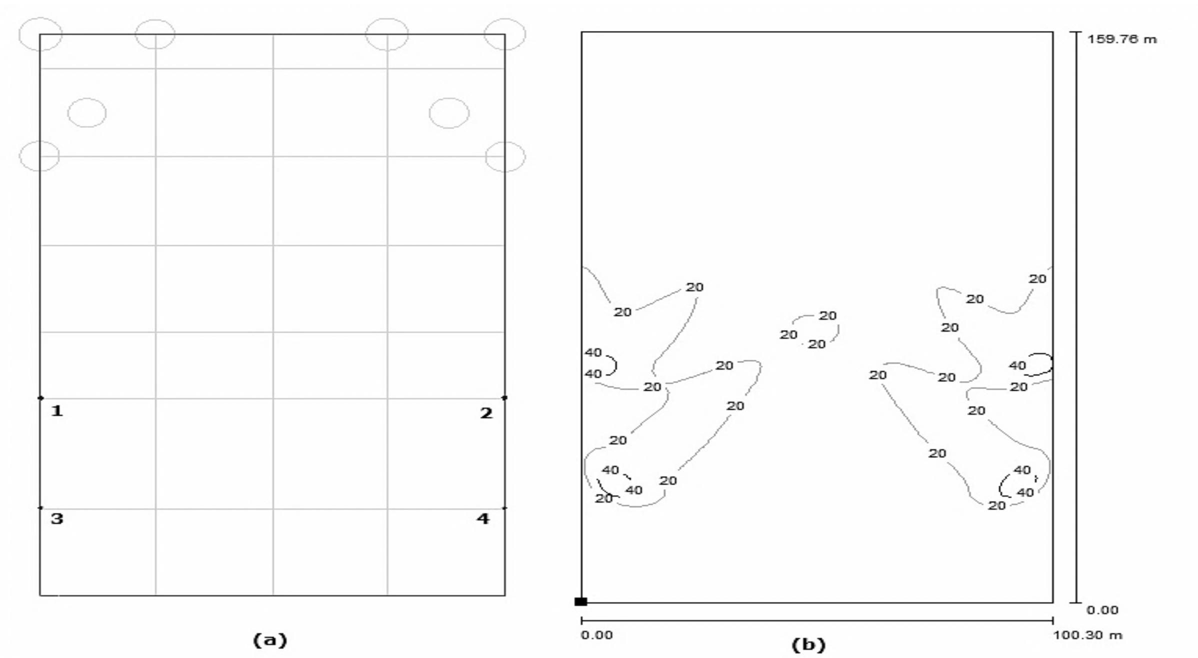

Figure 6.4 (a) Plan View of Lower Dump Yard Lighting Arrangement for the Mine (b) Isolux Diagram of the Lighting Design

Table 6.4: Details of Lower Dump Yard Lighting Arrangement Setup

<table>
<tr><th colspan="6">Lower Dump Yard Specifications</th></tr>
<tr><td colspan="4">Lower Dump Yard Area</td><td colspan="2">160 x 100 m^2</td></tr>
<tr><th colspan="6">Luminaire Specifications</th></tr>
<tr><td colspan="4">Lamp wattage</td><td colspan="2">1000 watt HPSV</td></tr>
<tr><td colspan="4">Luminous flux (approx.)</td><td colspan="2">130000 lumen</td></tr>
<tr><td colspan="4">Lamp body</td><td colspan="2">Die-Cast Aluminium Body</td></tr>
<tr><td colspan="4">Reflector type</td><td colspan="2">Conical Reflector</td></tr>
<tr><td colspan="4">Glass cover</td><td colspan="2">Sealed, Toughened, Dust Proof (IP 66)</td></tr>
<tr><td colspan="4">Light distribution</td><td colspan="2">Symmetrical</td></tr>
<tr><th colspan="6">Pole Arrangement for Lower Dump Yard</th></tr>
<tr><td colspan="4">Pole spacing</td><td colspan="2">100m</td></tr>
<tr><td colspan="4">Pole height</td><td colspan="2">11m</td></tr>
<tr><th colspan="6">Luminaire Arrangement for Lower Dump Yard</th></tr>
<tr><td>Pole No.</td><td>Distance from Edge</td><td>No. of lamps</td><td>Positioning</td><td>Focus Angle</td><td>Focus Distance</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">104m</td><td rowspan="2"></td><td>L</td><td>5°</td><td>144.36 m</td></tr>
<tr><td>R</td><td>5°</td><td>127.99 m</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">104m</td><td rowspan="2"></td><td>L</td><td>5°</td><td>144.36 m</td></tr>
<tr><td>R</td><td>5°</td><td>127.99 m</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">135m</td><td rowspan="2"></td><td>L</td><td>5°</td><td>140.44 m</td></tr>
<tr><td>R</td><td>5°</td><td>141.73 m</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">135m</td><td rowspan="2"></td><td>L</td><td>5°</td><td>140.44 m</td></tr>
<tr><td>R</td><td>5°</td><td>141.73 m</td></tr>
</table>

CHAPTER: 7

ILLUMINATION DESIGN FOR MOVING COAL & OVERBURDEN FACE

7.1. INTRODUCTION

Illumination in moving faces is a difficult task to perform because of the advancement of the working face and hence lighting setups are temporary and has to be change accordingly. Coal production in KOCP is achieved through surface miner in combination with pay loader. The approximate cutting depth per day by the surface miner is approximate 1m. Presently, the mine has two coal faces in which surface miners are operative. A mobile lighting arrangement or easy to install and maintain lighting arrangement was required for the lighting of the mine coal faces.

7.2 DESIGN OF MOBILE LIGHTING SYSTEM FOR COAL FACE

For Coal/OB face lighting the design should be mobile so that it can move as the face progresses. A design was made in the DIALux for the virtual coal face model of KOCP, using symmetrical metal halide luminaire fittings. The arrangements were tried in three positions left side corner (position 1), right side corner (position 2) and the center of the high wall side (position 3) of the surface miner face and the best result for the design is obtained with the design in position 3. The design consisting of eight symmetrical 1000 watt metal halide lamps positioned at the center of the face and focused as per the Fig. 7.1. The design model depicted in Fig. 7.1 and Fig. 7.2 for the above designs represents the plan view of the design model and the 3D CAD view of the model. The average illuminance obtained by the model was 9.87 lux and minimum illuminance level was 1.31 lux.

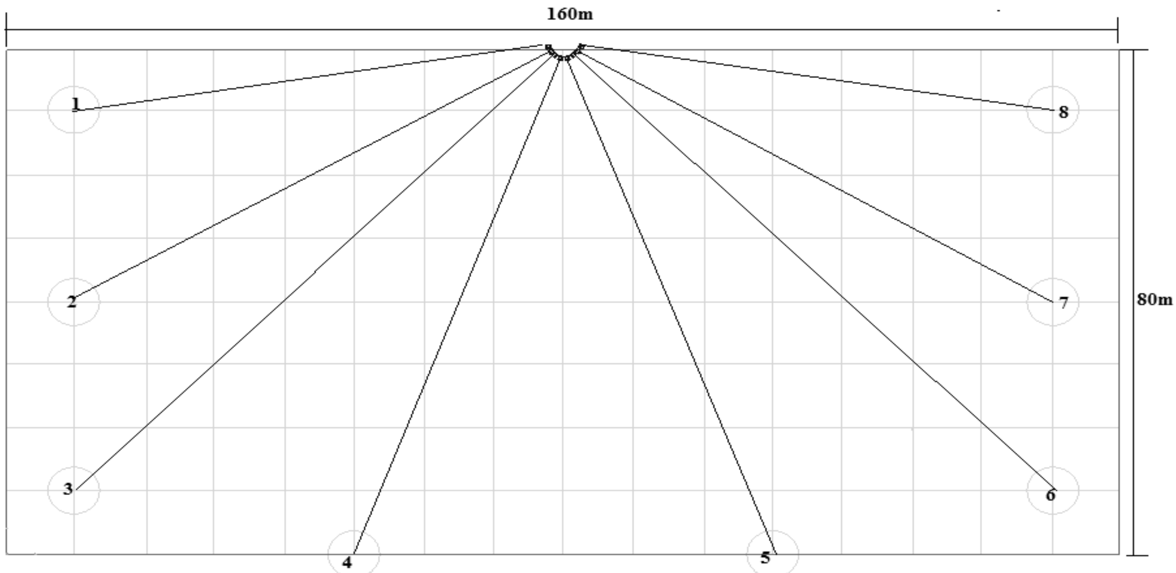

Figure 7.1 Plan View of Surface Miner Face Model with 8 x 1000 Watt Symmetrical Metal Halide Luminaire

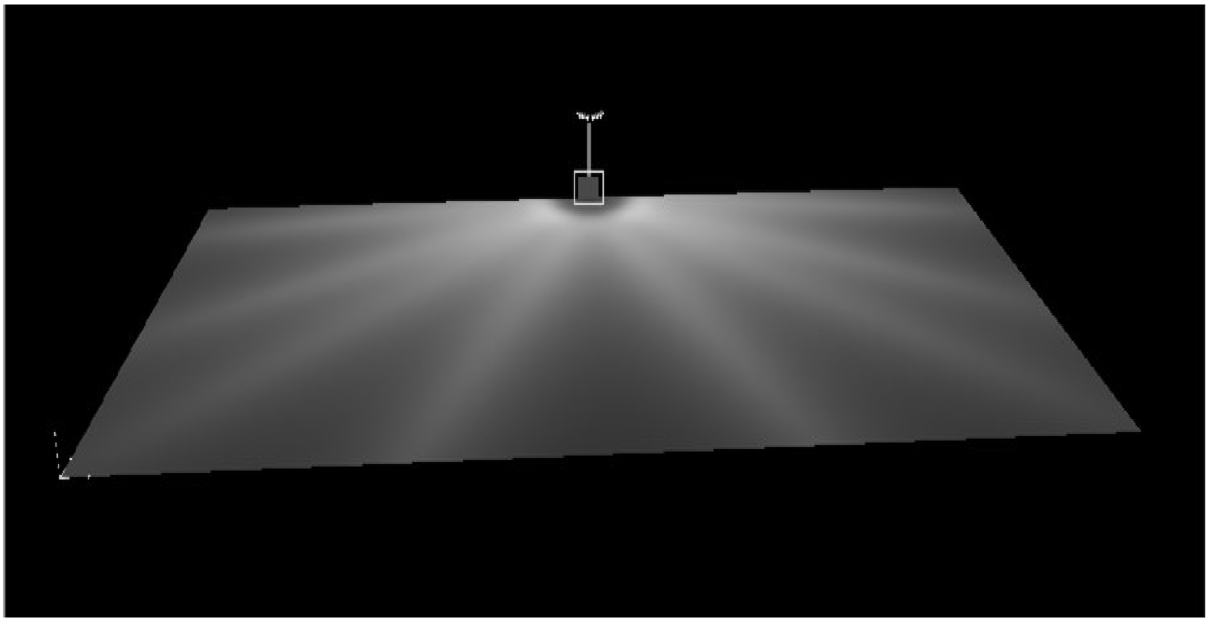

Figure 7.2 CAD View of Surface Miner Face Model

7.3. DESIGN OF MOBILE LIGHTING SYSTEMS FOR OB FACE

The approximate working area for the OB face in KOCP is 100m x 40m. The working bench height is 10m and bench width is 40m. The average and minimum illuminance obtained by the model was 16 lux and 4 lux respectively. The plan view of the luminaire setup for the design model is presented in Fig. 7.3.

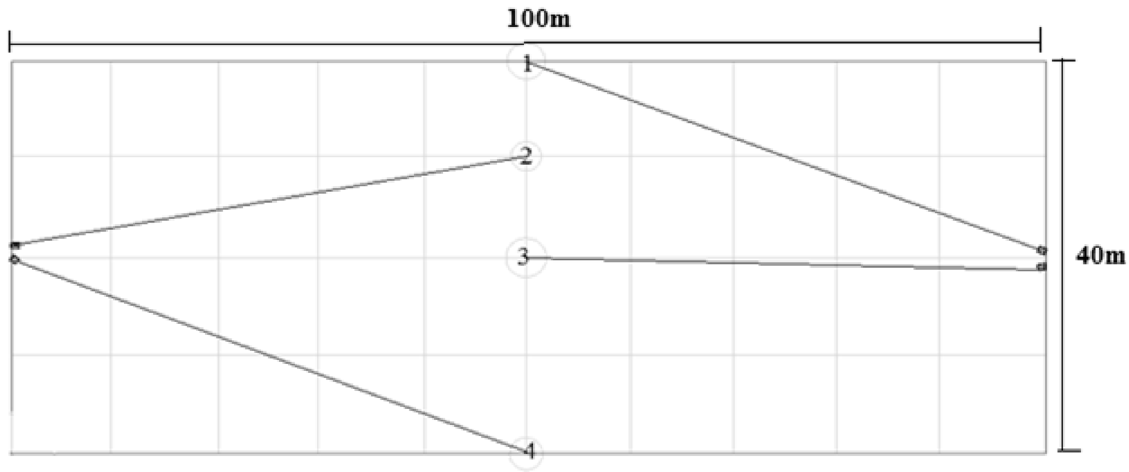

Figure 7.3 Plan View of OB Face Model with 4 x 1000 Watt Symmetrical Metal Halide Luminaire

CHAPTER: 8

CONCLUSIONS & RECOMMENDATIONS

8.1. CONCLUSION

The primary objectives of the project was to study illumination requirement of various workplaces at KOCP and to develop appropriate illumination designs for various places of work in the mine vis-à-vis DGMS standards. From the illumination survey, the following conclusions can be drawn:

- For haul road, it was found that although lux levels (4.65 lux) were satisfactory as per DGMS standards (0.5-3.0 lux) but non-uniform light distribution made it appear less illuminated than it should be.
- From dumping yards, it was found that proper illumination was not provided in the dump edges. The illuminance levels in the upper dumping yards (0.9 lux) and lower dumping yards (0.4 lux) were not satisfactory as per the recommended DGMS standards (3 lux).
- Although the illuminance levels of upper dump road (7.49 lux) and lower dump road (7.46 lux) were satisfactory but it was found that illumination levels were not uniform and was changing abruptly along the width of the road. This is because of single sided lighting arrangement of the luminaire arrangement.
- For the surface miner coal face, the illuminance levels were significantly low and only 2 luminaires were installed from the high-wall side face for the illumination of the face. The obtained reading for the illuminance was 1.5 lux while the recommended level of illuminance should be 3 lux.
- The illuminance levels found on the OB face (4.4 lux) were higher than the recommended levels (3 lux). It was found that the lighting provided by the shovel mounted lights contributed significantly on the lighting of the face. Also, peripheral lighting was provided for the illumination of the overburden face.

- Based on the shortcoming of the existing illumination levels at different place of work, effective and appropriate and modified illumination of lighting system was proposed using DIALux software which can enhance the working conditions in a much better way.

8.2. RECOMMENDATIONS

The following recommendations have been proposed to improve the visual level in the work places and are stated below:

- Installation of 150W HPSV luminaires for roads not exceeding length of 1 km and 250W HPSV luminaires for length exceeding 1 km and other installation details should follow the given design.
- Installation of Metal Halide luminaires for coal faces and HPSV for OB faces.
- Luminaires should be die cast aluminum built.
- Truck mounted illumination system can be used instead of fixed lighting system at coal face.

REFERENCES

1. Ganslandt, R., & Hofmann, H. Handbook of Lighting Design. New York (USA), Verlag Vieweg, 1992.
2. Hartman, H. L. SME Mining Engineering Handbook (2^{nd} Edition, Vol. 1). Colorado (USA), Society for Mining, Metallurgy, and Exploration, Inc., 1992.
3. Taylor, A. E. Illumination Fundamentals. New York (USA), Lighting Research Center, Rensselaer Polytechnic Institute, 2000.
4. Lighting Planning-Quantities, Units and Their Significance. Habo (Sweden), Fagerhult Group.
5. Halonen, L., Tetri, E., & Bhusal, P. Guidebook on Energy Efficient Electric Lighting for Buildings. Espoo (Finland), Lighting Unit, Department of Electronics, School Of Science and Technology, Aalto University, 2010.
6. Directorate General of Mines Safety. Legis. Circular No. 1. Dhanbad (India): DGMS (1976): pp. 385.
7. Rushworth, A. M., Talbot, C. F., Von Glehn, F. H., Lomas, R. M., & Franz, R. M. Role of Illumination in Reducing Risk to Health and Safety in South African Gold and Platinum Mines. Pretoria (South Africa), Safety in Mines Research Advisory Committee, 2001.
8. Van Graan, C.H., & Schutte, P.C. Underground Illumination and The Selection of Heavy Vehicle Drivers: De Beers Consolidated Mines. Johannesburg (South Africa), Chamber of Mines of South Africa. Research Organization Research Report No. 63/77, Project No. AX6H01C (1997), pp. 15.
9. Mishra, V.S., & Dixit, J.P. A New Psycho Engineering Strategy for Safety in Mines: Indian Mining and Engineering Journal (1978); pp. 7-12.
10. Trotter, D.A. The lighting of underground mines. Montreal (Canada): Trans Tech Publications.1982.
11. Franz, M., Ashworth, G., & Mthombeni, I.S. The Role of Environmental Factors in Mine Accidents. Pretoria (South Africa): Department of Minerals and Energy. SIMRAC Research Project GAP 203 (1995), pp. 1-182.

12. Mayton, A.G. Assessment and Determination of Illumination Needs for Operators of Mobile Surface Mining Equipment. Pittsburgh (USA): U.S. Department of the Interior, Bureau of Mines. Report No. IC 9153 (1987), pp. 37.
13. Odendaal, E.P.S. The Consequences of Poor Illumination on Underground Mine Workers and the Subsequent Effects on Productivity and Safety [Doctoral Thesis]. Johannesburg (South Africa): University of the Witwatersrand, 1996, pp. 220.
14. Sammarco, J.J., Reyes, M.A., Bartels, J., & Gallagher, S. Evaluation of Peripheral Visual Performance When Using Incandescent and LED Miner Cap Lamps. IEEE Industry Applications. 45(6) (2009): pp. 1923-1929.
15. Sammarco, J.J., & Yenchek, M.R. The Potential Impact of Light Emitting Diode Lighting on Reducing Mining Injuries during Operation and Maintenance of Lighting Systems. Elsevier Safety Science. 48(10) (2010): pp. 1380-1386.
16. Sammarco, J.J., & Lutz, T.J. Visual Performance for Incandescent and Solid-State Cap Lamps in an Underground Mining Environment. Proceedings of the IEEE Industry Applications Society 42nd Annual Meeting, New Orleans (USA) (2007): pp. 2090-2095.
17. Sammarco, J.J., Mayton, A., Lutz, T.J., & Gallagher, S. Evaluation of Glare for Incandescent and LED Miner Cap Lamps in Mesopic Conditions. CDC, Mining Engineering. 61(6) (2009): pp. 99-106.
18. Tyson, J. To See or Not to See: That is The Question! Designing To Maximize Operator Visibility in LHD Equipment. North Bay (Canada): Ontario Natural Resources Safety Association (1999).
19. Mayton, A.G. Investigation of Task Illumination for Surface Coal Mining Equipment Operators. Journal of Illuminating Engineering Society. 20(1) (1991): pp. 2-18.
20. Karmakar, N.C., Aruna, M., & Rao. Y.V. Development of Computer Models for Design and Economic Analysis of Lighting Systems in Surface Mines. 20th World Mining Congress on Mining and Sustainable Development, Tehran (Iran) (2005): pp. 541-543.
21. Aruna, M., & Jaralikar, S.M. Design of Lighting System for Surface Mine Projects. TELKOMNIKA. 10(2) (2012): pp. 235-244.
22. Das, R.C., & Roul, A. Illumination Design in A Highly Mechanized Opencast Bauxite Mine. Conference on Technological Advancements and Environmental Challenges in Mining and allied Industries in the 21st Century, NIT, Rourkela (India) (2005): pp. 369-380.

23. Pal, N., Krishna, V.S., Gupta, R.P., Kumar, A., & Prasad, U. Haul Roads Lighting System for Open Cast Mine Using Green Energy. Proceedings of the International Multi-Conference of Engineers and Computer Scientists, Hong Kong, 3 (2012): pp. 987-990.
24. Benya, J., & Schwartz, P. Advanced Lighting Guidelines. White Salmon (USA), New Buildings Institute, 2001.
25. Rea, M. S. The IESNA Lighting Handbook: Reference & Application. New York (USA), Illuminating Engineering Society of North America, 2000.
26. Land Restoration/Reclamation Monitoring of 50 Opencast Coal Mines of CIL producing more than 5 mcm (Coal+OB) based on Satellite Data for the Year 2012-13, Annual Report, CMPDI
27. Kusmunda Opencast Coal Mining Project. 2012. Annual Report, South Eastern Coalfields Limited. Chhattisgarh (India): KOCP
28. Barghini, A., & Medeiros, B.A.S. UV Radiation as an Attractor for Insects. LEUKOS. 9(1) (2012): pp. 47-56.
29. Comité Européen de Normalisation. CEN/TR 13201-1 Technical Report: Road lighting-Part 1: Selection of Lighting Classes, 2004.
30. Commission Internationale de l'Eclairage. Fundamentals of the Visual Task of Night Driving CIE 100-1992. Vienna (Austria), 1992.
31. <http://www.lynx-india.com/index.php?productID=18309> Accessed 2014 May 10.
32. < http://www.citelum.com.au/city-of-greater-shepparton> Accessed 2014 May 10.
33. <http://en.wikipedia.org/wiki/Korba_Coalfield> Accessed 2013 December 10.