

Suggestive Methods to Improve Illumination of an Opencast Mine to Safeguard the Safety and Productivity of the Mine

[¹Aditya Prakash and ²Dr. Hrushikesh Naik]

Abstract—The main objective of this study was to assess the illuminance level in mines at different strategic locations as mentioned in statutory circulars by the Directorate General of Mines Safety (DGMS). This paper highlights the detailed field observations for assessment of the existing lighting condition of a mine and to quantify the effect of poor lighting on the safety and productivity of different Heavy Earth Moving Machineries. The second part of the work was to find out inherent problems in the illumination system of mines and design of most suitable illumination system for the haul roads by using DIALux software. The safety and health aspects were also included in this study. There were three mines namely Mine1, Mine2, and Mine3 chosen for field observation. The safety status of different locations inside the mines was examined by comparing illuminance levels at those locations with what was set by DGMS and by various typical issues faced by operators in those mines. The illuminance level was measured using a lux meter present in respective mines. Illumination survey was conducted at locations like haul roads, loading points, unloading points, operator's cabins, workshops, and electrical substations. Productivity analysis in Mine1 and Mine3 shows that the productivity of both dumpers and excavators was reduced in artificial illumination. Optimization of the existing haul road illumination system for Mine1 and Mine2 gives the horizontal illuminance on haul roads more than 10 lux. However, the wattage was increased from 240W to 275W in the case of Mine1 and pole spacing was reduced to 15m from 30m in the case of Mine2. It is found that glare on haul roads and high illuminance level at the intersection of haul roads was the two most serious health issues for the operators in the mines.

Keywords—dark zone, floodlight, glare, illuminance, lighting ergonomics, luminance, productivity, reflectance.

I. Introduction

Illumination in opencast mines plays an important role in ensuring the safety of employees and steady-state production. The movement of men and machinery at night-time is affected by the illuminance of the mine. Insufficient light causes a situation of non-visibility of objects in front of machine operators. This inability to clearly see the objects by these operators is the prime reason behind accidents at night-time.

Secondly, to avoid such accidents in mines, operators slow down their speed to avoid accidents due to collisions and crushing. The result is that this reduced speed increases the cycle time and thus productivity of different types of machinery. It is evident from above that sufficient light in mine is vital from both safeties as well as productivity point of view. Furthermore, the excess light in the mine can cause glare which makes operators momentarily blind, and they are not able to see any objects for a while. This situation is worst and can potentially cause disastrous accidents in mines. Thus, it is extremely important to properly assess the lighting condition in mines through periodic illumination surveys and to improve the illuminance wherever necessary, especially at strategic mining locations. Not only improvement in the existing lighting system is required but also to design of an optimum lighting system that should meet all statutory provisions and be competent enough from the cost point of view also.

Illuminance Measurements:

There are three recognized techniques that can be used based on the purpose of the survey. These are (Trotter, 1982) planar measurements, separate measurements of direct and diffuse lights, and maximum reading techniques. For this work, the planar measurement is used throughout the illuminance survey carried out in different mines. There are multiple factors on which the productivity of dumpers depends these are dumper operator efficiency, excavator operator efficiency, haul road condition, nature of loading and unloading points, and level of illumination in the mine.

Since the main aim is to quantify the illumination effect thus parameters that were kept constant are the same dumper operator, same lead means the same haul road to be traced in natural and artificial lighting, the same route between loading and unloading points, same excavator operator, no obstruction due to motor grader, water sprinkler, and dozer or simply no waiting by dumper due to these reasons, water sprinkling to be stopped for 1 hour to 2 hours.

By keeping the above parameters constant, the main parameter that changed is the time of taking the reading. However, other factors like operator's tiredness level, readiness to go home, dedication towards achieving productivity, incentives by the company, waiting time due to insufficient width, queuing at loading, and unloading points, etc. may affect productivity but efforts were made to replace all quantifiable factors such as waiting time due to insufficient width, waiting at loading points, etc. Factors like tiredness level, readiness to go home, and dedication towards achieving productivity cannot be quantified so easily that is why those

¹Aditya Prakash and ²Dr. Hrushikesh Naik
National Institute of Technology, Rourkela
India

factors were not taken into consideration for the calculation of cycle time and productivity of dumpers. However, the quantifiable factors were replaced from the total cycle time and only loading time, unloading time, loaded travel time, and unloaded travel time were summed up to get the total cycle time. All the waiting times were discarded from the actual total cycle time. In doing so, the effect of all quantifiable factors was made non-contributory in nature towards productivity.

II. Field Observations

The field observations were carried out to assess the existing lighting condition of the mine. For that multiple illuminance survey was conducted in three mines namely Mine1, Mine2, and Mine3. Cycle time was also noted in Mine1 and Mine3 for quantifying the effect of illumination on the productivity of dumpers and excavators. Illumination level was measured by lux meter available in respective mines. In all the mines the lux meter used was oval-shaped.

Illumination survey and field observations in Mine1:

Field conditions and manner of illuminance survey:

The reading was taken at 5m intervals along the length as shown in the illumination survey profile (Figure 1). The reading in line with a pole was taken at the end of the berm, which was on an average 2m from the poles. Readings were also taken on the middle of haul roads and along the opposite edges of haul roads near the raised ground.



Figure 1: Grid pattern illumination survey profile of haul road of quarry 2 & 6 in Mine1

Illumination survey inside dumper's cabin in Mine1:

The operator who operates the dumper must be able to clearly see the different arrangements to control the dumper. To maneuver the equipment without any glitches, there should be sufficient illuminance in the machine's cabin. Since horizontal illuminance allows the operator to clearly see the switches, gear, and speed meter, thus a measurement of horizontal illuminance is needed to improve the safety and visual health of the operators. The extent of seriousness to health and safety can be understood with the fact that wrongly pressing the switch can make the machine behave against the wish of the operator. This can potentially cause an accident in

mines. Thus, it is extremely important to assess the level of illuminance inside the cabin (Figure 2).



Figure 2: Illuminance level at frequently used features of dumper's cabin

Table 1: Illuminance level at the edge of the hopper

Points at edge of hopper	Horizontal Illuminance in Lux	Vertical Illuminance in Lux
A	15.47	12.3
B	18.1	14.1
C	14.29	11.8
A'	15.53	13.1
B'	18.32	13.9
C'	15.63	12.89

Table 2: Illuminance level at the last edge of the dump yard

Points at the edge of Dump yard of Mine1	Horizontal Illuminance (in Lux)	Vertical Illuminance (in Lux)
A	1.6	2.4
B	1.8	2.3
C	2.1	5.4
D	1.9	4.3
E	0.3	1.7
F	3.2	3.1

Observations after illuminance survey in Mine2:

Surface miner face: There was observable variation in horizontal and vertical illuminance levels. On one hand, the horizontal illuminance level was as high as 25.8 lux and as low as 10 lux, on the other hand, the vertical illuminance level varied from 6.7 lux to 25 lux.

Overburden face: The horizontal illuminance level was above 10 lux, but the vertical illuminance level varied from 9.6 lux to 29.2 lux. The reading was taken without machinery's own light.

Excavator operator's cabin: The horizontal illuminance level was 24 lux at the steering level.

Haul road junction: The horizontal illuminance level at the middle of the intersection of haul roads was 17 lux. There were two HPSV lamps mounted on an 8m high pole facing toward the intersection of the haul roads.

External overburden dump (topsoil): The horizontal illuminance level at the dump edge close to the HPSV pole was more than 20 lux but the level at the dump edge farthest from the pole was less than 6 lux. A similar level was observed in vertical illuminance also. There were four HPSV lamps mounted on an 8 m high pole.

Substation (33/6.6 KV): The horizontal and vertical illuminance reading was 93 lux and 132 lux respectively.

Control room: The horizontal illuminance level was 85 lux at the control panel level in the electric substation.

Excavation workshop: Only horizontal illuminance readings were taken, and the levels were more than 35 lux. The illuminance level was 35.6 inside the workshop where 250W LED light was fixed on the ceiling.

Illumination survey on haul roads:

The spacing between two poles of the height of 8m was 30m. LED type lamp of wattage 120W was in use to illuminate the haul roads. The width of the haul road was 15m. Illuminance level readings were taken at a distance of 10m due to a paucity of time and resources.

Illumination survey of different locations of Mine3:

Illuminance was measured at only those places where the operation of dumpers was involved because these places affect the productivity of dumpers (Table 3). Any lacking in lighting conditions affects the dumper's performance. The illuminance survey was carried out by an oval-shaped lux meter.

Table 3: Illuminance level at different strategic locations of Mine3

Average illumination at	Horizontal illuminance in lux	Vertical illuminance in lux
Loading Point	0.81	3.6
Unloading point	1.73	4.5
Bends on the haul road	3.71	5.6
The intersection of haul road	3.65	7.67
Normal haul road	12.37	13.07

Observations after illuminance survey in Mine3:

Loading point: The average horizontal illuminance was 0.81 lux in front of the shovel and vertical illuminance was 3.6 lux at the same place.

Unloading point: The average illuminance was 1.73 lux at the edge of the unloading point and vertical illuminance was 4.5 lux.

Bends on haul roads: The average illuminance level in the middle of bends on haul roads was 3.71 lux and 5.6 lux in the horizontal and vertical planes.

The intersection of haul roads: The average horizontal and vertical illuminance level at the mid-point on the intersection of haul roads was 3.65 lux and 7.67 lux respectively.

Normal haul road: The average illuminance level was 12.37 lux and 13.07 lux in the horizontal and vertical planes. However, this averaging makes overall illuminance higher than 10 lux but at some places, it was less than that value.

Cycle time and productivity study in Mine1:

The main objective of the cycle time study was to quantify the effects of poor lighting on the productivity of dumpers and

excavators. Cycle time was noted down in specific time only so that parameters can be made constant. Any change in cycle time between natural and artificial illumination is due to the lighting environment in the mine. In this way, the exposure of dumpers and excavators to poor illuminance levels is depicted using productivity and cycle time variation.

Cycle Time and Productivity Analysis of Dumper-36 and Dumper-37:

Specifications of Dumper-36 and 37:

- Make – TATA Hitachi EH 600
- Capacity – 35 Tonnes

The cycle time study was done on 04/10/2019, on that day artificial luminaires were switched on at 5: 45 PM. Readings of cycle time were taken both before 5: 45 PM and after 5: 45 PM. Cycle time noted before the time was in natural illumination whereas cycle time noted after the time was in artificial illumination. All other parameters were kept constant except the mode of illumination as mentioned in the methodology section.

Trip Wise Cycle Time and Productivity Analysis of Different Dumpers in Natural and Artificial Illumination:

The observations were carried out on 13/03/2020. In this study of cycle time, the readings were taken on different trips. Some of the cycle time for dumper-1 and dumper-2 was taken between 4 PM-6 PM in natural illumination on the other hand some of the cycle times were taken between 6:30 PM-8:30 PM. Readings were taken after seating in both the dumpers, and care was taken to exclude all waiting time because that time has nothing to do with the level of illumination. Cycle time was calculated by summing uploaded travel time, empty travel time, loading time, and unloading time. The total lead (distance between loading point and unloading point) of both dumpers was 1700 m. The percentage of lead in which no permanent lighting was present is 46% and in this lead length only some portable DG towers were commissioned. The effect of poor lighting across haul roads and at loading points on cycle time and productivity is summarized in Tables 4 & 5.

Table 4: Cycle Time of Dumper-1 and Dumper-2 in Natural Illumination

Different Trips	Cycle Time in Second	
	Dumper-1	Dumper-2
Trip 1	968	946
Trip 2	1087	905
Trip 3	920	1013

Table 5: Cycle Time of Dumper-1 and Dumper-2 in Artificial Illumination

Different Trips	Cycle Time in Second	
	Dumper-1	Dumper-2
Trip 1	1033	1014
Trip 2	944	1052
Trip 3	1049	1019

III. Illumination design for the haul roads in the mine using dialux software

Illumination models for Mine1 and Mine2 were developed using DIALux software based on their haul road lighting parameters like wattage of the luminaire, type of luminaire, mounting height, boom angle, etc. Throughout the illumination survey, it was detected that the prevailing system of lighting was found inadequate for the mine; hence an optimized system of illumination was developed which met the standard of lighting in opencast mines.

The planning consists of five basic steps (DIALux, 2019):

1. Selection of the standard and description of the road profile
2. Configuration of the lighting installation
3. Optimization of the lighting installation
4. Export all results as a *.csv file (optional)
5. Documentation of the plan

The following parameters in the lighting installation can be optimized: -

- a. Distance between the poles
- b. Mounting height
- c. The angle of the booms
- d. Light overhang

Optimization of Illumination System for Haul Road in Mine1 (Figures 3, 4, 5, & 6):

Input data for the haul road lighting: -

1. Spacing = 25 m
2. Width of Road = 12 m
3. Wattage = 240 W
4. Height of Pole = 9 m
5. Luminary Type = LED
6. Pole distance from Roadway = 1 m

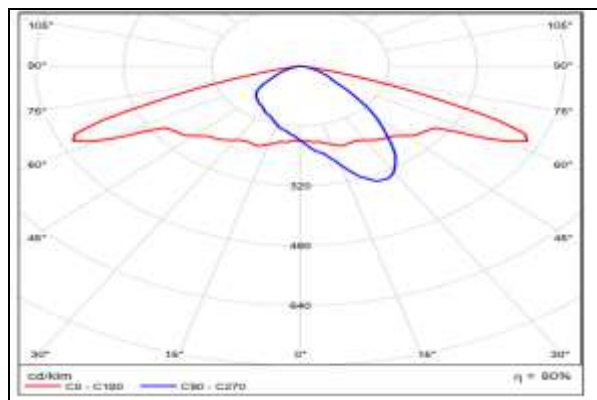


Figure 3: Luminous Emittance Projection of the Selected Luminaire of Mine1

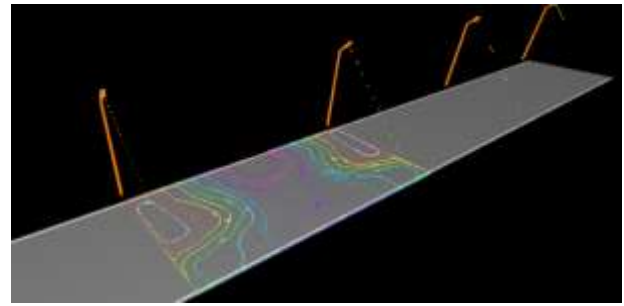


Figure 4: 3-D View of Haul Road with Luminary Parameter of Mine1

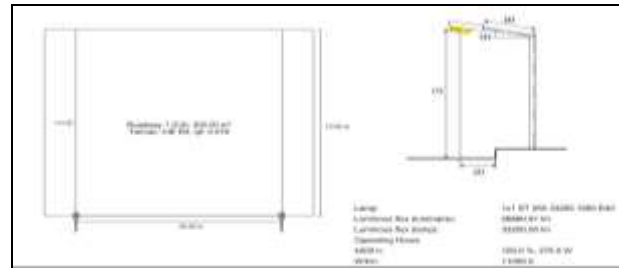


Figure 5: Luminaire Profile after Optimization in Mine1

Illumination output of selected Luminaire:

1. Light output ratio: 80.30%
2. Lamp luminous flux: 33200 lm
3. Luminaire luminous flux: 26661 lm
4. Power: 275.0 W
5. Luminous efficacy: 96.9 lm/W

The average illuminance level after optimization is 24.52 lux which is more than 10 lux values as set by the DGMS standard. The light loss factor was found to be 0.67 which is a significant portion of luminous emittance.

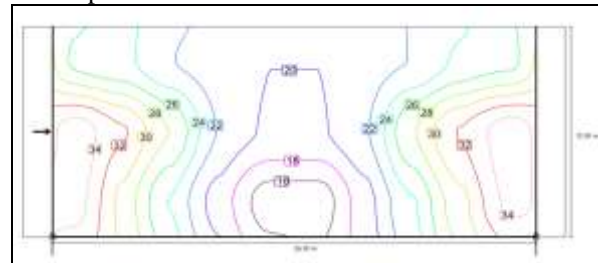


Figure 6: Isolux line showing horizontal illuminance in Mine1

Optimization of Illumination System for Haul Road in Mine2 (Figures 7, 8, 9, & 10):

Input data for the Haul Road Lighting: -

1. Pole distance = 30 m
2. Width of Road = 15 m
3. Wattage = 120 W
4. Light Centre Height = 8 m
5. Luminary Type = LED
6. Pole distance from Roadway = 1 m

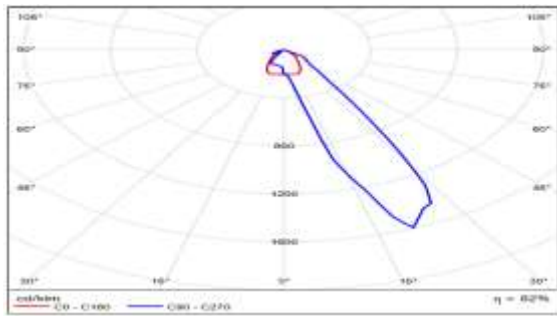


Figure 7: Luminous Emittance Projection of the Selected Luminaire of Mine2

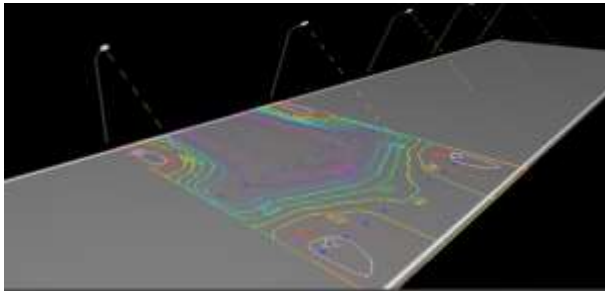


Figure 8: 3-D View of Haul Road with Luminary Parameter of Mine2



Figure 9: Luminaire profile after optimization in Mine2

Illumination output of selected Luminaire

1. Light output ratio: 82.06%
2. Lamp luminous flux: 15000 lm
3. Luminaire luminous flux: 12310 lm
4. Power: 165.0 W
5. Luminous efficacy: 74.6 lm/W

The average illuminance level after optimization was 12.56 lux which is more than 10 lux values as set by the DGMS standard. The light loss factor was found to be 0.67 which is a significant portion of luminous emittance.

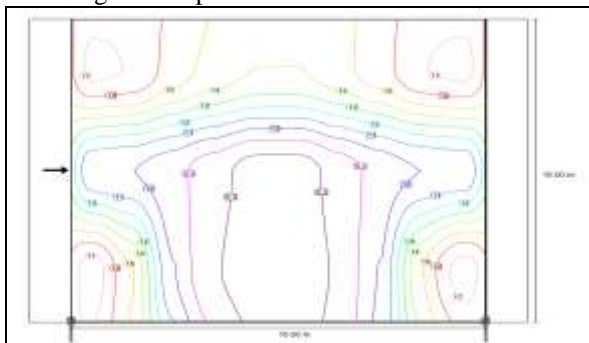


Figure 10: Isolux line showing horizontal illuminance in Mine2

IV. Results and Discussions

Discussion of Results Obtained after Illumination Survey in Mine1:

Illuminance Condition of Haul Roads:

The illuminance level was less than 10 lux in the central portion between the two poles. At the opposite edge of the haul road, the illuminance was more than 10 lux i.e., 11.2 lux horizontal and 27 lux vertical.

Illuminance Condition at Intersection of Haul Roads:

The vertical illuminance close to 5m from the portable DG tower was 140 lux which is very high illuminance and causes the excessive luminous flux to enter dumper operators as they approach the portable tower. So, we can say that this arrangement had not met the set standard of 10 lux beyond 15m from its base. The pertinent problems necessitate the requirement of permanent lighting in such strategic places.

Illuminance Condition Inside Operator's Cabin:

The horizontal illuminance at switches, gear lever, and speed meter was 13.8 lux, 13.8 lux, and 14.3 lux respectively. Horizontal illuminance at all the places inside the cabin should be more than 50 lux horizontal (DGMS_Metalliferous, 17). But nowhere inside the cabin, the value was more than 50 lux.

Illuminance Condition at Crusher Point:

Horizontal illuminance was very close to 15 lux as set by the standard of illumination in opencast mines (DGMS_Metalliferous, 17). But vertical illuminance at all points was less than 15 lux. It was as low as 11.8 lux and the maximum level was 14.1 lux.

Illuminance Condition at Last Edge of Dump Yard:

The lighting condition at the edge of the dump yard was very poor. The horizontal illuminance was 0.3 lux. When we compare this result of lighting with standards, we can easily say that the lighting arrangement in the dump yard was not adequate and improvement in lighting is inevitable.

Illuminance Condition at Loading Point:

Both horizontal and vertical illuminance level at all points was less than even 1 lux which are not in compliance with standards. The reason behind such a dismal level of illuminance was attributed to the unavailability of a portable high mast tower at the loading point in Quarry-2,6 of Mine1. The only illuminance source was the excavator's and dumper's own light. Secondly, the heavy water seepage at the working face made non-uniform lighting conditions and further aggravate the poor lighting at the loading point.

Status of Adequacy of Dumper's own Light without any External Luminaire:

It was observed that the vertical illuminance was more than 10 lux, but the horizontal illuminance remained below 10 lux even close to 2m from the dumper and it was only 1.48. Our interest is to ensure horizontal illuminance of at least 10 lux on haul road and when we solely rely on the dumper's own lighting arrangement then it is our mistake, which can culminate in accidents in mines.

Status of Adequacy of Dumper's own light with External Luminaire on Haul Roads:

The result of Horizontal illuminance in front of the dumper was quite satisfactory, at all the points the level was more than 10 lux which satisfies the standard of lighting on haul roads. The only lag in lighting level was observed at a point about 17m from the dumper's front face.

Analysis of Results Obtained from Reflectance Measurement:

After measurement of dry and wet reflectance at the intersection of haul roads, it was found that dry reflectance was 40.05% and wet reflectance was 12.96%. This huge variation in reflectance of surfaces in close vicinity made a non-uniform lighting environment at the location. This variation may cause adaptation of the operator's eye very frequently which is not good for the eye's health. Though the variation in dry and wet reflectance at the edge of the dump yard was not so as in the case of the intersection of haul roads this can also lead to a lesser uniformity ratio of the dump yard and can degrade the visual environment of dump yard.

Illuminance Condition in Mine2:

The only strategic area inside Mine2 was taken into consideration for the lighting survey. The horizontal illuminance level close to 250 W HPSV lamp was more than 15 lux but at the farthest point from the source, the horizontal illuminance value was 10 lux. Since surface miner comes under heavy machinery thus at least a 25-lux vertical illuminance level is required to cover the depth and height in which the machine operates as per mine lighting standards. To cope with the present lag in illumination at the working face of a surface miner, a portable high mast tower of matching mobility should be provided to maintain the adequacy of illumination at the surface miner's face.

The surface at the intersection of haul roads in Mine2 was wet because before taking of actual reading, the location was water sprinkled heavily to suppress dust on haul roads. There were two HPSV lamps mounted on an 8m high pole facing toward the intersection of the haul roads. The horizontal illuminance of 17 lux was found satisfactory after comparison with the standard illuminance level at haul roads as provided in illumination standards for opencast mines.

Result of Productivity Analysis in Mine1: Effect of Illumination on Productivity of Dumpers:

The productivity of Dumper-36 in natural light was 72 Tons per hour, which reduces to 61.6 Tons per hour in artificial light. This shows that the productivity of dumpers depends upon the level of illumination in the mine.

The productivity of Dumper-37 in natural light was 70Tonnes per hour, which reduces to 63.64 Tons per hour. The productivity of Dumber-37 does not vary as much compared to the Dumper-36, but the productivity got affected due to insufficient illumination.

When averaging the trip-wise productivity of Dumper 1, it was found that productivity in natural illumination was 182.39 TPH and reduces to 178.83 TPH. A significant reduction in productivity of Dumper-2 was observed wherein natural illumination; the productivity was 188.95 TPH, which reduces to 175.08 TPH.

Effect of Illumination on Productivity of Excavator:

The productivity of the excavator in natural light was 845 tons per hour, which reduces to 750 tons per hour in artificial light. This shows that the excavator's productivity is affected by the illuminance level.

Result of Productivity Analysis in Mine3:

It was found that the average productivity of RD-2K01 was 181.88 TPH in the natural mode of illumination and reduces to 161.57 TPH in the artificial mode of illumination.

v. Conclusions

Conclusions are drawn from Mine1:

The illuminance level on the haul road was not complying with established standards. It was found that the mine illumination is not only dependent on luminary wattage but also on operator preferences. A portable DG tower at the intersection of haul roads causes excessive lighting, which affects the operator's productivity and safety. The illuminance level in the operator's cabin was found inadequate as per the standard of illumination. At the crushing point, the illuminance level was insufficient as inferred from the illuminance survey and image analysis of the rear vision camera. The last edges of the dump yard were devoid of light and variable reflectance causes a variable visual environment. The maximum horizontal illuminance level in front of the dumper was 5.73 lux. Thus, the dumper's own light was found inadequate for the dumper to safely ply on the haul road. Horizontal illuminance achieved with the dumper's own light and two external luminaries was more than 10 lux. Both horizontal and vertical illuminance level at loading points was not as per mine lighting standard of 15H, 15V.

Conclusions Drawn from Mine2:

At surface miner face, no need to add additional lighting arrangement but the periodic installation of a new lamp was required. Horizontal illuminance was found adequate at the intersection of haul roads. Illuminance at the farthest edge of the dump yard from the light source was insufficient. Inadequate illuminance level inside the excavation workshop. The haul road lighting was found inadequate, especially in the

central portion between two luminaries. The Excavator operator's cabin was having less illuminance level as per standards of illumination. The horizontal level achieved after optimization was 12.56 lux. This was achieved by reducing pole spacing to 15m, luminary wattage to 165W, and including boom length of 1.263m.

The conclusions are drawn from Mine3:

Horizontal illuminance at bends of haul road was found to be inadequate. The average illuminance level at the loading and unloading point was insufficient. The productivity of RD-2K01 was reduced in the artificial illumination system.

References

- [1] Trotter, D. A. (1982). *The Lighting of Underground Mines*. Clausthal-Zellerfeld: Trans Tech Publications.
- [2] Parida, S. (2015). *Design of illumination system for an open cast manganese mine*, e-Thesis-NITRKL.
- [3] Tripathy, D.P. & Chowdhury, O. (2014). *Design of Haul Road Illumination System for an Opencast Coal Mining Project—A Case Study*, The Journal of the Illuminating Engineering Society of North America, 2014.
- [4] Lakshmi pathy, M., Murthy, Ch. S. N., and Aruna, M. (2014). *Problems Encountered in the Types of Lighting Systems Generally Used in Surface Mining Projects A Case Study*, The International Journal of Engineering and Science (IJES), Volume 3, PP. 61-72.
- [5] LYONS, S. (1980). *Exterior Lighting for Industry and Security*. England: Applied Science Publisher Limited.
- [6] NPTEL. (2009, 11 12). *TECHNICAL TERMS IN LIGHTING AND PHOTOMETRY*. Retrieved from NPTEL: http://content.inflibnet.ac.in/data-server/eacharya-documents/55d4535be413010824d8f93b_INFIEP_205/11/ET/205-11-ET-V1-S1_An_introduction_to_underground_mine_environment_and_ventilation:_lecture_11:_introduction_and_guidelines.pdf
- [7] CCOHS. (2019, October 4). *Lighting Ergonomics - Checklist*. Retrieved May 21, 2020, from What is an example of a lighting checklist?: https://www.ccohs.ca/oshanswers/ergonomics/lighting_checklist.html
- [8] CCOHS. (2019, October 4). *Lighting Ergonomics - Survey and Solutions*. Retrieved May 21, 2020, from How do you conduct a more detailed lighting survey?: https://www.ccohs.ca/oshanswers/ergonomics/lighting_survey.html
- [9] CHATTOMBA, A. (2010, 05 24). *EThesis @ NIT Rourkela*. Retrieved from ethesis.nitrkl.ac.in: <http://ethesis.nitrkl.ac.in/1966/1/10605039.pdf>
- [10] DGMS_Coal. (17, November 06). *Standards of Illumination in Opencast Coal Mines*. Retrieved from DGMS: http://www.dgms.gov.in/writereaddata/UploadFile/Cir_02_Legis_2017.pdf
- [11] DGMS_Metalliferous. (17, November 06). *Standards of Illumination in opencast metalliferous Mines*. Retrieved May 21, 2020, from DGMS: http://www.dgms.gov.in/writereaddata/UploadFile/Cir_03_Legis_2017.pdf
- [12] DIALux. (2019, 5 3). *DIALux*. Retrieved 5 21, 2020, from DIALux Evo manual: https://www.dial.de/fileadmin/documents/dialux/DIALux_downloads/DIALux%20evo%20manual.pdf

About the Author

Prof.
Hrushikesh
Naik, Ph.D.



The main objective of this study was to assess the illuminance level in mines. This paper highlights the detailed field observations for assessment of the existing lighting condition of a mine and to quantify the effect of poor lighting on safety and productivity.