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# THE CONNECTION OF METALLURGY AND INDUSTRY IN THE CONTEXT OF ILLUMINATION MEASUREMENT IN THE PLANT FOR THE PRODUCTION OF BEE CANDY

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*SUMMARY: Light as a phenomenon has been researched for several thousands of years, and in relation to it, there are different theories about its expansion. A human observes light with a sense of sight and within a limited range of its noticeable wavelengths very tiny differences are recognized as colours. In a modern world, we are exposed to everyday light, both natural and artificial one. However, the biggest problem for our health is the exposure to artificial light, which imitates daily light. A person's one-day biological rhythm or a circadian rhythm determines basic physiological activities according to the change of day and night. It is responsible for the production of melatonin, an antioxidant that fights against the development of cancer cells. Artificial light used during the night, as well as night work, can disrupt production of melatonin and that way expose our organism to various diseases. Nowadays, there are documents making a legal framework in connection to lighting at workplace, which guarantee for its safe and quality use. This paper presents the results of illuminance measurement in the plant for the production of bee candy concerning the measurement points that include the plant, the warehouse and the mill. The purpose of these investigations is the review of compatibility of the existing arrangement of lighting units to valid regulations. Industrial processes, including the production of bee candy, often depend on the use of metal materials, technological solutions and appropriate equipment. The combination of appropriate metal materials, linking metallurgical achievements and optimal lighting contributes to a successful production process and achieving high standards in the bee candy production industry. The measurements showed that there is a need to review and improve the lighting fixtures and to harmonize the layout of the lighting fixtures with current regulations and the lighting of individual workplaces, which must be safe, functional and aesthetically pleasing.*

**Key words:** *light, light sources, lighting, illuminance measurement, metallurgical processes*

## INTRODUCTION

Light as a phenomenon since ancient times arouses the desire to discover all the secrets related to its origin, spread, composition and speed. Without light, the perception of reality and the

world around us would not be the same as with its presence. All information that a person receives and experiences around him is mostly received through visual stimuli. By this alone, it can be said that light directly affects a person's mood, so even today, by using different lighting systems, different effects can be created that contribute to the mood itself. What is important to say is that people, due to work and life obligations, have begun to spend more time inside buildings than outside. Given that people spend as much as 80% of their time inside a building, a good part of which is in the workspace, it is extremely important that the li-

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ghting of that space is as good as possible, so that the person is able to perform their work tasks with quality (*Workplace lighting*).

Good lighting is associated with certain physiological reactions in terms of better concentration, greater productivity, reduced fatigue, greater attention, and many other positive aspects of good and quality indoor lighting. On the other hand, poor indoor lighting can cause the opposite effect in terms of poor concentration, less productivity, greater fatigue, a greater chance of accidents, and even headaches (*Rihner et al., 1992*).

The quality of indoor lighting in workplaces must contribute to greater efficiency in performing work tasks and provide comfort without straining the senses of sight. Of course, different activities and jobs have different requirements for the quality of lighting (*Ordinance on occupational safety for workplaces, OG No. 105/2020*), so the level of lighting in an operating room will differ significantly from the level of lighting in a catering facility (*Mandić, 2017*).

Lighting of indoor workspaces is carried out in accordance with the Standard „Light and lighting - Lighting of workplaces - Part 1: Indoor workplaces“ (*HRN EN 12464-1:2021*), and with this in mind, requirements for lighting of people at workplaces in indoor spaces are determined (*Čabraja et al., 2016*.) In any case, interior lighting should be designed in a way that allows for minimal visual strain when performing various work tasks.

Bee candy production and the metallurgy industry are not related at first glance, however, there are several interesting factors that connect them through processes, technologies and similar working principles. This connection refers to the use of metal materials and equipment during bee candy production and the implementation of various quality control techniques in the work area, including illuminance measurement (*Ordinance on measuring and monitoring environmental illumination, OG No. 22/2023*).

Metal materials such as stainless steel, aluminum or copper alloys are essential for efficient and long-lasting bee candy production. Measuring illumination in a bee candy production facility can be linked to the metallurgical industry through se-

veral aspects including occupational safety, product quality, workplace lighting standards and the application of lighting measurement technology (*Barjoe and Gendler, 2024*).

Light plays an important role in ensuring quality during production in an industrial plant. With proper lighting, it is possible to adequately maintain industrial equipment, which is mostly made of metal materials. Light helps to identify cracks or corrosion on metal parts of the equipment, which allows for timely replacement or necessary repairs of the equipment. Optical methods are used to test the quality of metal plants, which are used to detect surface and internal defects, analyze the microstructure and evaluate material properties. These methods are important for quality assurance and extending the service life of tools and industrial components. The visual method is the most important method for noticing the first defects in the operation of an industrial plant. Adequate lighting allows a better assessment of the cleanliness of metal equipment and work surfaces. Proper lighting reduces the risk of accidents and makes it easier to handle sharp tools or metal parts of the equipment (*Lenk, 2011*.). In addition to adequate lighting in an industrial facility, devices that work on the principle of illumination can be used to analyze the surface and internal characteristics of metal materials, or materials that make up the structural parts of equipment in an industrial facility. Such devices that use a light source and optical principles are optical microscopes and scanning electron microscopes. Also, thermal cameras that work with the help of infrared light can detect temperature deviations on a metal surface. With the help of thermal cameras, an inspection of any internal cracks or inhomogeneities in the material can be carried out, and this method greatly contributes to improving the testing of large metal surfaces in real time (*Krstulović and Garma, 2024*).

Industrial processes, including the production of bee candy, often depend on the use of metal materials, technological solutions and appropriate equipment. The combination of appropriate metal materials, linking metallurgical achievements and optimal lighting contributes to a successful production process and achieving high standards in the bee candy production industry.

## EXPERIMENTAL PART

### Description of the facility

This paper presents the results of lighting measurements in the plant for the production of bee candy, a warehouse and rooms where sugar is ground to a given granulation. The production plant for bee food production and wax processing is part of a facility that consists of a sales area, a warehouse, a room for bee food production and wax processing, a changing room and a sanitary facility for employees, as can be seen in Figure 1. Lighting in all areas where workers perform work tasks is provided by a general lighting system using LED tubes, which have replaced the somewhat outdated classic fluorescent tubes and LED spotlights. Replacing classic fluorescent tubes with LED tubes proved to be a good decision by management, precisely from the point of view of reduced electricity consumption, durability, but also a greater amount of light using less energy (Stojkov et al., 2016).

LED tubes are made of metal materials for efficient heat dissipation, electrical conductivity and structural strength. Metals such as aluminum, copper and their alloys are important for their functionality and long life. Aluminum is a lightweight metal with high thermal conductivity, and ensures efficient heat dissipation generated by the LED chip (*Is Aluminum a Suitable Metal for an LED Heatsink?*). Copper ensures high conductivity of electricity. Steel is used for mounting components or connectors. LED chips are often mounted on metal bases that serve for stability during the actual construction of the general lighting system (Chenhui et al., 2022).

The aim of the work is to check the compliance of the existing arrangement of lighting fixtures with the applicable regulations and the lighting of individual workplaces.

### Creating a measurement network

The selected measurement locations and the area of illumination measurement can be seen on the floor plan of the bee candy production plant and warehouse, as can be seen in Figure 1. In the working rooms where the illumination was mea-

sured, there are artificial and natural light sources. Natural light sources are provided through windows located at a height of 5 m on the side walls of the rooms. Artificial lighting is provided by lighting fixtures with LED tubes and LED spotlights (Martinis and Mikuta-Martinis, 2008).

Given that the work in the plant is organized in two shifts, i.e. in the morning and afternoon shifts, the measurement of illumination at all workplaces, except in Mill 1 and Mill 2, was carried out in daylight and without the presence of daylight. Due to the fact that the working space in Mill 1 and Mill 2 does not have windows or skylights, i.e. daylight cannot affect the measurement results, it was not necessary to perform both daytime and nighttime measurements. The working spaces in which the illumination was measured are Plant 1, Plant 2, Warehouse 1, Warehouse 2, Mill 1 and Mill 2.

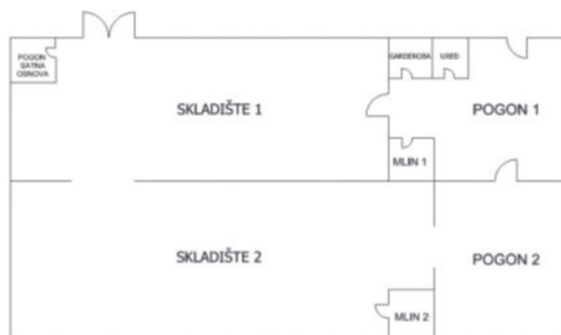


Figure 1. Floor plan of the bee candy production plant and warehouse

Slika 1. Tlocrtni prikaz pogona za proizvodnju pčelinjih pogača i skladišta

In the production of goods for beekeeping, the production and packaging of food for bees is carried out. As part of the facility, there is also a storage area for raw materials and raw materials that are used for the production of beekeeping candy and clock bases. Inside, there is a systematized workplace with special working conditions: operator of a machine for the production of fodder.

### Standard HRN EN 12464-1:2021, „Light and lighting - Lighting of workplaces - Part 1: Indoor workplaces“

The results of the illuminance measurements in work areas, obtained with the Testo 545 light me-

ter, were compared with the Standard „Light and lighting - Lighting of workplaces - Part 1: Indoor workplaces“ (HRN EN 12464-1:2021), which sets out the requirements for lighting for people at workplaces in enclosed spaces. In addition to the fact that the aforementioned standard clearly defines the requirements for most workplaces in terms of quality and quantity of lighting, it also provides recommendations in terms of good lighting practice. The main division of illuminance in workplaces can be expressed in 3 levels, as follows (Simetić, 2022):

- Corridors and rooms that are rarely used (20-200 lx)
- Workshops (general lighting, 200-2000 lx)
- Rooms and work areas where delicate work is performed (Operating rooms, 2000 – 20,000 lx).

Considering the type of activity and the type of space in which the illuminance measurement was performed, Table 1 shows the values for groups of activities in industry, production facilities and manufacturing, according to Standard „Light and lighting - Lighting of workplaces - Part 1: Indoor workplaces“ (HRN EN 12464-1:2021).

**Table 1. Illumination levels according to Standard „Light and lighting - Lighting of workplaces - Part 1: Indoor workplaces“, Industry, production facilities, manufacturing (HRN EN 12464-1:2021)**

**Tablica 1. Razine osvjetljenosti prema HRN EN 12464-1:2021, Industrija, proizvodni pogoni, manufaktura (HRN EN 12464-1:2021)**

Industry	Activity	$E_m$ (lx)	$UGR_L$	$R_a$
General spaces	Storerooms and warehouses	100	25	60
	Packing areas (pre-shipment)	300	25	60
Agriculture	Input and handling of goods, handling of equipment and machinery	200	25	80
	Animal buildings	50	/	40
	Food preparation, dairying, dishwashing	200	25	80
Bakeries	Preparation and baking	300	22	80
	Finishing, glazing, decorating	500	22	80
Cement, cement products, concrete, brick	Drying	50	28	20
	Material preparation, lime and mixer work	200	28	40
	Machine work - general	300	25	80
	Rough forms	300	25	80
Ceramics, terracotta, glass, glassware	Drying	50	28	20
	Preparation, general machine work	300	25	80
	Enameling, rolling, pressing, shaping of simple parts, glazing, glass blowing	300	25	80
	Grinding, engraving, polishing of glass, shaping of precision parts, production of glass instruments	750	19	80
	Grinding of optical glasses, grinding of crystals, hand grinding and engraving	750	16	80
	Precision work, e.g. decorative grinding, hand painting	1000	16	90
	Manufacture of synthetic gemstones	1500	16	90

Industry	Activity	$E_m$ (lx)	$UGR_l$	$R_a$
Chemical industry, rubber and plastic industry	Process installations with remote control	50	/	20
	Process installations with limited human interventions	150	28	40
	Work spaces with permanent presence of people in process installations	300	25	80
	Rooms for precise measurements, laboratories	500	19	80
	Production of pharmaceutical products	500	22	80
	Color control	1000	16	90
	Cutting, finishing, control	750	19	80
Electroindustry	Cable and wire production	300	25	80
	Galvanization	300	25	80
	Assembly, e.g. assembling switchboards, cabinets	500	22	80
	Precision measurement	1000	16	80
	Electronic workshops, testing, adjustment	1500	16	80
Food processing and delicatessen industry	Sorting and washing products, grinding	300	25	80
	Cutting and sorting fruits and vegetables	300	25	80
	Delicatessen food production, kitchen work	500	22	80
	Glass and bottle inspection, product control, sorting, finishing	500	22	80
	Color control	1000	16	90
Rotating mills, working with steel and iron	Manufacturing plant without manual labor	50	/	20
	Manufacturing plant with occasional manual labor	200	25	80
	Blast furnaces, industrial furnaces	200	25	20
	Mill train, winder, cutting line	300	25	40
	Control platforms, control panels	300	22	80

Legend:

$E_m$  (lx) – mean horizontal illuminance on the work surface (determined for the work area at working height  $H_r$ . Working height is  $H_r = 0.85$  m, unless otherwise defined).

$UGR_l$  – glare factor

$R_a$  – colour reflectance factor

Table 1 (HRN EN 12464-1:2021) clearly shows the jobs that, given the work tasks, may have more significant requirements for the illumination of the workspace and those with lower requirements for illumination. Jobs that require greater precision and more details, such as testing and adjustment tasks in the electrical industry, have higher requirements for illumination (Beštak, 2018). On the other hand, those jobs that require less precision and less details in their work tasks, such as a plant without manual labor, have lower criteria for the illumination of the workplace. Those workplaces that do not require the presence of workers or are fully automated have the lowest requirements for illumination. The bright spot of process automation is the fact that it creates significant energy savings on lighting fixtures (Očelić Bulatović, 2022).

In addition to data for minimum illuminance in various industries, Table 1 also shows the glare factor, or UGRL factor, as well as the color reflectance factor ( $R_a$ ), which for most processes should be above 80. For example, we can see that in bee candy production plants, the minimum illuminance value in accordance with the aforementioned Standard should be 300 lx, while, for example, in foundries and metal forming plants, the minimum values range from 200 to even 500 lx (Table 2).

**Table 2. Illumination level according to HRN EN 12464 in the foundry and during metal forming (HRN EN 12464-1:2021)**

**Tablica 2. Razina osvjetljenosti prema HRN EN 12464-1:2021 u ljevaonicama i tijekom oblikovanja metala (HRN EN 12464-1:2021)**

Interior type, task or activity	$E_{m}$ , lx	UGRL	$R_a$
Underfloor tunnels (human-sized), basements	50		20
Platforms	100	25	40
Sandblasting preparations	200	25	80
Clothes room	200	25	80
Workplaces at the dome and mixer	200	25	80
Forming area	200	25	80
Tamping area	200	25	80
Machine molding	200	25	80
Hand core molding	300	25	80
Pressure molding	300	25	80
Model making	500	25	80

## METHODS, TECHNIQUES AND MEASURING TEST EQUIPMENT

### Measuring test equipment

Illumination measurements at all workplaces and using all of the above methods were performed using a measuring device manufactured by the manufacturer Testo 545, Figure 2 (Testo 545), at a height of approximately 0.85 m from the floor.



*Figure 2. Light intensity measuring instrument, Testo 545 (Testo 545)*

*Slika 2. Instrument za mjerenje intenziteta svjetlosti, Testo 545 (Testo 545)*

The Testo 545 light meter is used to measure natural and artificial light using a light sensor. According to the instructions for use, the Testo

545 is used for selective and long-term light measurements. It can also record up to 3000 measurements using the built-in data logger and can be used to calculate selective and time-averaged measurements. The built-in software allows for the setting of up to 99 measuring points, which the device can subsequently display in the form of a curve. This feature can very clearly indicate the uniformity of the lighting in the room in which the measurement is being carried out (*Testo 545 Light Meter/Data logger*).

### **Illumination measurement methods and techniques**

In each of the aforementioned workrooms, three sets of measurements were performed, i.e. three different methods of measuring illumination were used.

#### **Measurement in parallel lines in space, slicing method**

The measurement of illuminance in parallel lines in space was done by the examiner moving around the space, first in one direction, recording the illuminance values, then in the opposite direction. With each new line, the examiner covered an increasing part of the space until he reached the end. The measured illuminance values were recorded during the measurement (*Instruction manual and Software Instructions*).

#### **Timer measurement**

In this measurement method, the device takes all the values while walking and calculates the average value. Since the device measures a certain value of illumination every second, a large number of measurement points are created, making the measurement more representative (*Instruction Manual and Software Instructions*).

#### **Measurement by positions or point measurement**

Point measurement, or position measurement, is used when there are work points in the workpla-

ce that pose an increased risk. Measurement positions refer to those places where workers work with machines and devices whose use may pose an increased risk to the safety and health of workers. From this point of view, position measurement represents a significant contribution to the detection and prevention of increased workplace hazards due to lighting (*Instruction Manual and Software Instructions*).

## **RESULTS AND DISCUSSION**

As previously stated, the results of the illuminance measurements were compared with the illuminance values prescribed by the Standard, which refer to the workspaces Plant 1, Plant 2, Warehouse 1, Warehouse 2, Mill 1 and Mill 2.

### **Plant 1**

Plant 1 produces bee cakes. Workers spend most of their working time directly next to the machine, packing the product into a box and placing it on a pallet. The rest of the time, workers supply the machine with raw materials necessary for its continuous operation.

The machine consists of two parts, a mixer in which the raw materials are mixed and converted into the final mixture, and a packaging unit that packs the final mixture into plastic bags. Such a product exits the machine and is transported by conveyor belts to a rotary table from which it is packed into packaging. The plant contains duplicators or large boilers in which the liquid phase for the production of bee candy is prepared. According to the Standard „Light and lighting - Lighting of workplaces - Part 1: Indoor working areas“ (*HRN EN 12464-1:2021*), the production plant has a requirement for an illumination level of 300 lx. As previously stated, the illuminance measurements were performed in daylight and in the absence of daylight. The results obtained from the measurements are presented in Table 3.

**Table 3. Day and night measurement results with respect to the measurement method for Plant 1****Tablica 3. Rezultati dnevnog i noćnog mjerenja s obzirom na metodu mjerenja za Pogon 1**

Illuminance value (lx)	PLANT 1					
	Daily measurement			Night measurement		
	Measurement in parallel lines	Measurement by positions	Timer measurement	Measurement in parallel lines	Measurement by positions	Timer measurement
Minimum value	178	143	/	100	121	/
Maximum value	554	497	/	520	532	/
Mean value	367	312	378	357	281	361
<b>SATISFACTORY</b>	YES	YES	YES	YES	NO	YES

Table 3 shows the values of the day and night illuminance measurements in Plant 1. According to the data from the table for the day measurement, three different methods of illuminance measurement were made, which are shown through the minimum, maximum and average values. With the method of measurement using parallel lines in space, so-called slicing, a large difference can be observed with respect to the minimum value of 178 lx and the maximum measurement value of 554 lx, which indicates uneven illumination by the lighting fixtures in Plant 1. With respect to the average illuminance value of 367 lx, it was established that the qualitative properties of the electric lighting meet the requirements of the standard (HRN EN 12464-1:2021). Measurement by positions, so-called point measurement, gives a display for the minimum value of 143 lx and the maximum value of 497 lx, which also indicates uneven illumination. The average value of 312 lx meets the requirements of the standard and is marked as satisfactory. The timer measurement method yielded a value of 378 lx, which is satisfactory according to the requirements of the standard.

According to the data from the night measurement table, slightly lower values were obtained, which clearly indicates a lack of daylight. The parallel line measurement method, so-called slicing, measured a minimum value of 100 lx, a maximum value of 520 lx, and a mean value of 357

lx, which is satisfactory according to the requirements of the standard. Positional measurement, so-called point measurement, gives a minimum value of 121 lx and a maximum value of 532 lx. The mean value of 281 lx does not meet the requirements of the standard and is marked as unsatisfactory. The timer measurement method yielded a value of 361 lx, which is satisfactory according to the requirements of the standard.

## Plant 2

In Plant 2, the same work tasks are performed as in Plant 1. Workers spend most of their working time directly next to the machine, packing the product into a box and placing it on a pallet. The rest of the time, workers supply the machine with raw materials necessary for its continuous operation. The machine also consists of two parts, a mixer in which the raw materials are mixed and converted into the final mixture, and a packaging unit that packages the final mixture into plastic bags. The machine capacity is twice that of Plant 1, so work in this plant is much more dynamic. Plant 2, according to the Standard „Light and lighting - Lighting of workplaces - Part 1: Indoor workplaces“ (HRN EN 12464-1:2021) has a requirement for an illumination level of 300 lx. Illumination measurements were performed in daylight and without the presence of daylight. The results obtained from the measurement are presented in Table 4.

**Table 4. Results of day and night measurements with respect to the measurement method for Plant 2****Tablica 4. Rezultati dnevnog i noćnog mjerenja s obzirom na metodu mjerenja za Pogon 2**

Illuminance value (lx)	PLANT 2					
	Daily measurement			Night measurement		
	Measurement in parallel lines	Measurement by positions	Timer measurement	Measurement in parallel lines	Measurement by positions	Timer measurement
Minimum value	168	99	/	143	144	/
Maximum value	356	298	/	304	282	/
Mean value	249	229	256	232	218	233
<b>SATISFACTORY</b>	NO	NO	NO	NO	NO	NO

Table 4 shows the values of daytime and nighttime illuminance measurements in Plant 2. Daytime illuminance measurements, using the parallel line measurement method, give values that are lower than the requirements set in the standard, which is the minimum illuminance level of 300 lx. The minimum value is 168 lx, while the maximum value is 356 lx. The mean value of 249 lx does not meet the requirements of the standard. Measurement by positions, so-called point measurement, gives a display for a minimum value of 99 lx and a maximum value of 298 lx. The mean value of 229 lx does not meet the requirements of the standard and is marked as unsatisfactory. The timer measurement method obtained a value of 256 lx, which is assessed as unsatisfactory according to the requirements of the standard.

According to the data from the table for nighttime measurements, the following values were obtained with respect to the measurement method. Using the parallel line measurement method, the minimum measured value is 143 lx, while the maximum measured value is 304 lx. The mean measured value of 232 lx does not meet the requirements of the standard and is marked as unsatisfactory. Using the position measurement method, the minimum measured value is 144 lx, while the maximum measured value is 282 lx. The mean

measured value is 218 lx, which does not meet the requirements of the standard. Using the timer measurement method, the value obtained is 233 lx, which is unsatisfactory according to the requirements of the standard.

### Warehouse 1

Bee candy produced in Plant 1 and Plant 2 are exported to Warehouse 1 with the help of a manual palletizer. Depending on the type of goods, the worker stores the products in the designated place in the warehouse. In the warehouse area of the facility, it is necessary to maintain inventory rotation in order to keep the amount of inventory with an expiration date as low as possible. Inside the warehouse, an electric forklift is used to transport and lift pallets of finished goods onto shelves. Given the above, quick and easy product identification is required, so the level of illumination is an important factor in this process. According to the Standard „Light and lighting - Lighting of workplaces - Part 1: Indoor workplaces“ (*HRN EN 12464-1:2021*) the warehouse area has a requirement for an illumination level of 100 lx. Illumination measurements were performed in daylight and in the absence of daylight. The results obtained from the measurements are presented in Table 5.

**Table 5. Day and night measurement results with respect to the measurement method for Warehouse 1****Tablica 5. Rezultati dnevnog i noćnog mjerenja s obzirom na metodu mjerenja za Skladište 1**

Illuminance value (lx)	WAREHOUSE 1					
	Daily measurement			Night measurement		
	Measurement in parallel lines	Measurement by positions	Timer measurement	Measurement in parallel lines	Measurement by positions	Timer measurement
Minimum value	32	15	/	22	17	/
Maximum value	145	151	/	145	131	/
Mean value	90,7	86	89	94,1	74,4	84
<b>SATISFACTORY</b>	NO	NO	NO	NO	NO	NO

Table 5 shows the values of the day and night illumination measurements in Warehouse 1. According to the data from the table for daily measurements, three different methods of illumination measurement were made, which are shown through the minimum, maximum and average values. Using the method of measurement with parallel lines in space, so-called slicing, it can be observed that the minimum illumination value is 32 lx, while the maximum measurement value is 145 lx, which indicates uneven illumination by the lighting fixtures in Warehouse 1. Given the average illumination value of 90.7 lx, it can be established that the qualitative properties of electric lighting do not meet the requirements of the standard. Measurement by positions, so-called point measurement, provides data for a minimum value of 15 lx and a maximum value of 151 lx, which indicates uneven illumination (*Light Pollution Law, OG No. 14/2019*). The average value of 86 lx does not meet the requirements of the standard and is marked as unsatisfactory. The timer measurement method yielded a value of 89 lx, which is also unsatisfactory according to the requirements of the standard.

As for the night measurement data, there is no major deviation from the daytime measurement, so the parallel line measurement method yielded a minimum measured value of 22 lx, while the maximum measured value was 145 lx. The mean measured value of 94.1 lx does not meet the requirements of the standard and is marked as unsatisfactory.

factory. The minimum measured value with the position measurement method was 17 lx, while the maximum measured value was 131 lx. The mean value was 74.4 lx, which does not meet the requirements of the standard. The timer measurement method yielded a value of 84 lx, which is assessed as unsatisfactory according to the requirements of the standard.

## Warehouse 2

Warehouse 2 is the area where raw materials for production and packaging are stored. All goods, including raw materials in solid or bulk form, packaging, i.e. boxes, foils, cardboard trays, etc., are imported by the warehouseman to Warehouse 2 and stored in the designated place. In accordance with the production process and production dynamics, workers go to Warehouse 2 and, as necessary, import raw materials and packaging into the production facilities. Given that Warehouse 2 is most often manipulated with an electric pallet truck and forklift, it is extremely important to take into account the precision of the manipulation itself, so as to avoid accidents when transferring cargo. For this reason, it is important that the lighting of the warehouse space meets the requirements of the standard (HRN EN 12464-1:2021) of at least 100 lx. Illumination measurements were performed in daylight and without the presence of daylight. The measurement results are shown in Table 6.

**Table 6. Day and night measurement results with respect to the measurement method for Warehouse 2****Tablica 6. Rezultati dnevnog i noćnog mjerenja s obzirom na metodu mjerenja za Skladište 2**

Illuminance value (lx)	WAREHOUSE 2					
	Daily measurement			Night measurement		
	Measurement in parallel lines	Measurement by positions	Timer measurement	Measurement in parallel lines	Measurement by positions	Timer measurement
Minimum value	16	10	/	8	6	/
Maximum value	35	29	/	26	27	/
Mean value	24	18,7	25	15,9	17	16
<b>SATISFACTORY</b>	NO	NO	NO	NO	NO	NO

Table 6 shows the values of the daytime and nighttime illuminance measurements in Warehouse 2. The results of the daily measurement, using the parallel line measurement method, showed a minimum illuminance value of 16 lx and a maximum value of 35 lx. The mean value of 24 lx does not meet the requirements of the standard. Measurement by positions, so-called point measurement, provides data for a minimum value of 10 lx and a maximum value of 29 lx. The mean value of 18.7 lx does not meet the requirements of the standard and is marked as unsatisfactory. The timer measurement method obtained a value of 25 lx, which is also unsatisfactory according to the requirements of the standard.

According to the data from the nighttime measurement table, the values obtained also indicate insufficient illuminance in Warehouse 2. Namely, given the lack of daylight during nighttime measurement, the measured values are very low and can certainly pose a problem for workers when identifying certain raw materials or packaging. Using the parallel line measurement method, the minimum measured value is 8 lx, while the maximum measured value is 26 lx. The mean measured value of 15.9 lx does not meet the

requirements of the standard and is marked as unsatisfactory. Using the position measurement method, the minimum measured value is 6 lx, while the maximum measured value is 27 lx. The mean measured value is 17 lx, which does not meet the requirements of the standard. Using the timer measurement method, the value obtained is 16 lx, which is unsatisfactory according to the requirements of the standard.

### Mill 1

Mill 1 is the area where sugar is mechanically ground to a given granulation. From Mill 1, sugar is transported mechanically, using screw conveyors or spirals, to the mixer. The presence of workers in the Mill 1 area is not necessary, and given this fact, Mill 1 is classified as a Process Installation with Remote Control, which according to the standard (*HRN EN 12464-1:2021*) has a requirement for an illumination level of 50 lx. Since the working area in Mill 1 has no windows or skylights, i.e. daylight cannot affect the measurement results, it was not necessary to perform both day and night measurements. The measurement results are shown in Table 7.

**Table 7. Measurement results with respect to the measurement method for Mill 1****Tablica 7. Rezultati mjerenja s obzirom na metodu mjerenja za Mlin 1**

Illuminance value (lx)	MILL 1		
	Measurement method		
	Measurement in parallel lines	Measurement by positions	Timer measurement
Minimum value	95	109	/
Maximum value	157	165	/
Mean value	129	140	137
<b>SATISFACTORY</b>	YES	YES	YES

Table 7 shows the values of the illuminance measurements in Mill 1 with respect to the measurement method. The results obtained using the parallel line measurement method showed a minimum illuminance level of 95 lx and a maximum illuminance level of 157 lx. The mean illuminance value obtained is 129 lx, which meets the standard requirements of a minimum of 50 lx. The measurement of illuminance by positions gives a minimum value of 109 lx and a maximum illuminance value of 165 lx. The mean illuminance value obtained is 140 lx and as such meets the standard requirements. The timer measurement method obtained a value of 137 lx, which is assessed as satisfactory according to the standard requirements.

## Mill 2

As already mentioned in the description of the technological process for Mill 1, in Mill 2, sugar is mechanically crushed to a given granulation using a sieve. The only difference between the mills is the number of augers or elevators that transport the sugar out of the mill into the mixer in the plant. Namely, in Plant 2, two mixers are used in the technological process, so Mill 2 is significantly more heavily loaded with work. The same lighting conditions apply to Mill 2 as for Mill 1, i.e. according to the standard (*HRN EN 12464-1:2021*), it has a requirement for a lighting level of 50 lx. Since the working space in Mill 2 has no windows or skylights, i.e. daylight cannot affect the measurement results, it was not necessary to

perform both daily and night measurements. The measurement results are shown in Table 8.

**Table 8. Measurement results with respect to the measurement method for Mill 2****Tablica 8. Rezultati mjerenja s obzirom na metodu mjerenja za Mlin 2**

Illuminance value (lx)	MILL 2		
	Measurement method		
	Measurement in parallel lines	Measurement by positions	Timer measurement
Minimum value	54	48	/
Maximum value	99	88	/
Mean value	71	70,1	73
<b>SATISFACTORY</b>	YES	YES	YES

Table 8 shows the values of the illuminance measurements in Mill 2 with respect to the measurement method. The minimum illuminance value, measured using the parallel in lines method, is 54 lx, while the maximum measured value is 99 lx. The mean illuminance value is 71 lx, which meets the standard requirements of a minimum of 50 lx. Measurement by positions, so-called point measurement, provides data for a minimum value of 48 lx and a maximum value of 88 lx. The mean value of 70.1 lx meets the standard requirements and is marked as satisfactory. The timer measurement method obtained a value of 73 lx, which is also satisfactory according to the standard requirements.

Based on the measurement results, it can be concluded that, given that the obtained illumination values in Plant 2, Warehouse 1 and Warehouse 2 are unsatisfactory, it is necessary to improve the lighting fixtures and harmonize their arrangement, in order to meet the values prescribed by the standard in the bee candy production plant and ensure that workers have illumination of their workplaces, which must be safe, functional and aesthetically pleasing.

Based on all of the above, it can be concluded that the results of measuring the level of illumination in the bee candy production plant and the warehouse at certain measuring points are not

in accordance with the prescribed standard (*HRN EN 12464-1:2021*). The measurements established that not only are there significant deviations from the minimum lighting values prescribed by the standard, but that these deviations can have significant consequences for the safety and productivity of workers, as well as for the quality of the final product. Insufficient lighting levels measured in the bee candy production plant and the warehouse, given the measurement method and measuring points, can lead to an impact on worker productivity. According to Animashaun et al. (*Animashaun et al., 2014*), insufficient lighting in the workplace affects not only vision but also the biological rhythm of the organism, the level of alertness and concentration of workers. The level of lighting directly affects work efficiency, reduces fatigue and improves employee well-being. Given this, workers in the bee candy production plant and warehouse may experience certain visual strain caused by insufficient lighting in the workplace, which can lead to faster fatigue, reduced concentration, and slower task performance. Also, according to Beštak (*Beštak, 2018*), long-term exposure to poor and insufficient lighting in the workplace can lead to headaches, eye irritation, and increased sensitivity to stress.

Insufficient lighting levels in Plant 1 and Plant 2 can also lead to an increased risk of accidents at work. According to Łakomy (2023), insufficient lighting levels in the workplace can significantly endanger worker safety. First of all, it reduces visibility, increases eye strain and leads to faster fatigue, which results in reduced concentration and a higher risk of accidents. Given this, workers in the bee candy production plant may be exposed to difficulties in recognizing hazards such as slippery floors, sharp tools and moving parts of the machines they handle at the workplace. There may also be an increased risk of hitting structures, machines or surface edges, as well as burns associated with the welder and heaters used in the technological process of packaging bee candy. As warehouse workers manipulate electric forklifts and hand pallet trucks to lift heavy loads, insufficient lighting levels can make it difficult to react in a timely manner when maneuvering, which can cause collisions and injuries.

It has been observed, particularly in Warehouse 1 and Warehouse 2, that workers have difficulty finding adequate packaging that needs to be distinguished by color and size, which is used to package the finished product, due to reduced lighting. In this case, this can lead to a slowdown in the production process, as workers spend more time adjusting to the lighting conditions, which can lead to more frequent work interruptions and reduced efficiency. Also, the level of lighting is of great importance when delivering the finished product from the Warehouse, as it is necessary to deliver a correctly labeled product. Insufficient lighting levels in Warehouse 1 and Warehouse 2 can make it difficult for workers to find a specific product by label and type, which can lead to product substitutions and reduced efficiency.

The criterion used in this paper, which concerns the assessment of satisfactory illumination, is the mean horizontal illuminance on the work surface -  $E_m$  (lx), which is defined with regard to the Standard HRN EN 12464-1:2021, Light and lighting - Lighting of workplaces - Part 1: Indoor working areas (*HRN EN 12464-1:2021*). Accordingly, the illuminance value for production facilities is 300 lx, 100 lx for storage and warehouses and 50 lx for remotely controlled process installations, i.e. for Mill 1 and Mill 2.

The specified illuminance levels are crucial for the smooth flow of work processes, worker safety and optimal productivity. If the illuminance values are lower than the minimum prescribed values with regard to the standard, visibility will be reduced, which can significantly slow down the work process. Workers may have difficulty recognizing hazards and performing tasks accurately, which consequently increases the risk of accidents. On the other hand, too high illuminance values can also have negative consequences. Increasing the light intensity beyond the recommended limits can cause glare, especially in areas with metal surfaces, machinery, or other reflective objects. These glares can reduce visual clarity, cause eye strain, and even cause headaches in workers.

## CONCLUSIONS

The level of illumination is an important factor in the working environment which, if not met, can affect the performance of work tasks and activities in terms of productivity and quality (*Occupational Safety Act, OG No. 71/2014*).

Unsatisfactory lighting values affect production processes and quality control. Namely, inadequate lighting in any part of an industrial plant can significantly hinder the visibility of irregularities in metal parts of machines, which increases the risk of malfunctions or product contamination. Poor lighting makes it difficult to maintain machines in a timely manner and replace worn metal parts, which can result in malfunctions and costly production downtime.

It can also affect the possibility of an accident if the level of illumination does not meet the minimum level according to applicable regulations. By measuring the illumination in a bee candy production plant, the results were reported as satisfactory and unsatisfactory in comparison with the Standard "Light and lighting - Lighting of workplaces - Part 1: Indoor workplaces" (*HRN EN 12464-1:2021*) for the individual workplace in which the measurement was performed, as follows:

- Plant 1 – The illuminance measurement in Plant 1 gave satisfactory results during the daytime illuminance measurement, compared to the standard that prescribes a minimum of 300 lx for production facilities, with respect to each of the measurement methods. The nighttime illuminance measurement yields slightly lower values, but still satisfactory, except for the illuminance measurement by positions where the mean value was assessed as unsatisfactory.
- Plant 2 – The illuminance measurement in Plant 2 did not give satisfactory results during the daytime and nighttime measurements, considering the standard that prescribes a minimum of 300 lx for production facilities.
- Warehouse 1 – The illuminance measurement in Warehouse 1 did not give satisfactory results during the daytime and nighttime measurements. The measured values

are below the minimum of 100 lx prescribed for storage areas. A large oscillation can be observed between the minimum and maximum values obtained, which indicates uneven illumination of the space.

- Warehouse 2 – The illumination measurement in Warehouse 2 did not give satisfactory results during the day and night measurements. The measured values are, with respect to the standard, below the minimum of 100 lx prescribed for storage spaces.
- Mill 1 and Mill 2 – The illumination measurement in Mill 1 and Mill 2 gave satisfactory results during the daytime illumination measurement, compared to the standard that prescribes a minimum of 50 lx for spaces with process installations with remote control, and with respect to each of the measurement methods.

The influence of daylight generally does not make a big difference in the obtained values, because the window panes are small and covered with roofing sheeting, so there is no direct sunlight entering the working area. The measurements carried out indicate the need to review and improve the lighting fixtures and to align the arrangement of lighting fixtures with applicable regulations and the illumination of individual workplaces, which must be safe, functional and aesthetically pleasing. In any case, it is necessary to consider the issue of proper lighting from the point of view of safety at work, as well as the prevention of injuries at work and the occurrence of occupational diseases.

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### **POVEZANOST METALURGIJE I INDUSTRIJE U KONTEKSTU MJERENJA RASVIJETLJENOSTI U POGONU ZA PROIZVODNJU PČELINJIH POGAČA**

*SAŽETAK: Svjetlost kao pojava proučava se već nekoliko tisuća godina, a uz nju se vežu i razne teorije u vezi s njezinim širenjem. Čovjek opaža svjetlost osjetilom vida te unutar ograničenog raspona njezinih valnih duljina koje može zamijetiti, raspoznaje vrlo sitne razlike koje vidi kao boje. U suvremenom svijetu čovjek je svakodnevno izložen svjetlosti, bilo onoj prirodnoj ili umjetnoj, no najveći problem za njegovo zdravlje predstavlja izloženost umjetnom svjetlu koje imitira dnevnu svjetlost. Čovjekov jednodnevni biološki ritam ili cirkadijani ritam određuje osnovne fiziološke aktivnosti prema izmjeni dana i noći. Isti je odgovoran za proizvodnju melatonina koji je antioksidans u borbi protiv nastanka stanica raka. Umjetno svjetlo u noćnim satima te noćni rad mogu poremetiti proizvodnju melatonina i na taj način izložiti organizam raznim bolestima. Danas postoje dokumenti koji čine zakonodavni okvir u vezi s osvjetljenjem na radnom mjestu, a koji daju garanciju za njegovu sigurnu i kvalitetnu primjenu. U ovom radu su prikazani rezultati mjerenja rasvijetljenosti u pogonu za proizvodnju pčelinjih pogača s obzirom na mjerna mjesta koja obuhvaćaju pogon, skladište i mlin. Cilj ovog istraživanja je provjera usklađenosti postojećeg rasporeda rasvjetnih tijela s važećim propisima. Industrijski procesi, uključujući proizvodnju pčelinjih pogača, često ovise o upotrebi metalnih materijala, tehnološkim rješenjima i odgovarajućoj opremi. Kombinacija odgovarajućih metalnih materijala, povezivanje metalurških dostignuća i optimalnog osvjetljenja pridonosi uspješnom procesu proizvodnje i postizanju visokih standarda u industriji proizvodnje pčelinjih pogača. Mjerenjima je ustanovljeno da je potrebno preispitivanje i poboljšanje rasvjetnih tijela te usklađivanje rasporeda rasvjetnih tijela s važećim propisima i rasvijetljenosti pojedinih radnih mjesta koja moraju biti sigurna, funkcionalna i estetski ugodna.*

**Ključne riječi:** svjetlost, izvori svjetlosti, rasvjeta, mjerenje rasvijetljenosti, metalurški procesi

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