Re-designing illumination level in printing working area

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Abstract. This research was conducted in four printing business in Medan city. The illumination level on the research object is very low around 30 Lux far below the required value of government regulation at 200 Lux. Poor lighting has an impact on the number of defective products that pass the inspection, so we need to improve the workspace lighting to improve the quality of work. The method of determining the measuring point follows SNI 16-7062-2004, and the measuring instrument used is 4 in 1 Environment Meter. The results show that almost all workspaces under study require improved lighting, because the light bulbs used are not able to meet the lighting needs. This research recommends improving the workspace lighting using LED (Light Emitting Diode) lights because it has high energy efficiency and relatively more lifetime compared to the existing lamp.

1. Introduction
The results of good working need a conducive environment conditions. Operators who work in bad environment, then the quality of their work can decrease. Research conducted previously shows that lighting, humidity, and temperature of the work environment affect the productivity of workers [1-6].

Lighting greatly affects the human ability to see objects clearly, quickly, and without error. The need for good lighting will be more necessary when humans do work that requires precision of vision. The lighting is too grim to cause the eyes of the workers get tired quickly because the eyes will accommodate maximum to be able to see clearly. Tired eyes can lead to mental fatigue, further the situation can cause damage to the eyes. The ability of the eyes to see objects is clearly determined by the size of the object, the degree of contrast between the object and its surroundings, the luminance, and the duration of view [5-11].

Measurements of illumination at several measuring points in the work area scattered throughout production floor of the printing business under study showed a number with a range of 22 lux - 34 lux, while the lighting level standards for rough and continuous work specified in Health Minister decree amounted to 200 lux [12]. Illumination that doesn't meet existing lighting level standards can be said to be bad lighting. Bad lighting will impair vision so as to decrease the concentration of workers and result in poor work results. Furthermore, the result of the disturbance has an impact on the finding of defective products that pass the inspection [13]. This is in line with the opinion of operators who complain about the disruption of vision when doing inspection of the product result.

Recommendation of the requirements and procedures for the implementation of industrial working environment health according to decision of Health Minister No.45 year 2002 for work with machines and rough assembly requires 200 lux illumination. CIE (Commission International de l'Eclairage) and
IES (Illuminating Engineers Society) set the general lighting for the work space is 200 lux, as well as the SNI 03-6197-2000 [10].

2. Method and equipment

Illumination is many light currents that come in a unit of field and have a unit of lux (lumen/m2) or in other words illumination is the coming of light to an object. Luminance is the intensity of light emitted, reflected, or transmitted by an illuminated field unit or luminance is the passage of light from an object. The IES Lighting Handbook states that each object reflects a portion of the light on it [10]. Depending on the geometric arrangement, the exact size can be either total light reflectance, regular light reflectance, diffuse light reflectance, light reflectance or luminance. The light reflectance scale is between 0 and 100% from black to white [14].

Illumination for the field of work is measured horizontally as far as 75 cm above the surface of the floor, while for a certain area the illumination is obtained by taking the average value from several points of measurement (SNI 03-6575-2001) [15].

The determination of the point of illumination measurement is regulated in SNI 16-7062-2004 concerning Measurement of Intensity of Information in the workplace. Determination of measurement point on the lighting is divided into 2 categories:

1. Local lighting: work objects, in the form of desks and equipment; measurements can be made on an existing table. Measurement of illuminance and luminance can be done using luxmeter or 4 in 1 environment meter. Illumination measurement steps are as follows:
   a. Turn on the calibrated luxmeter by opening the sensor cover.
   b. Bring tool to a predefined point of measurement, either measurement for the intensity of local or general illumination.
   c. Read the result of measurements on the monitor screen after waiting for a while to get a stable value.
   d. Record the measurement results on the recording sheet for the local lighting intensity.
   e. Turn off the luxmeter after completion of the measurement of the intensity of lighting.

2. General illumination: the point of horizontal line length and width of the room at any given distance of one meter from the floor. Certain distances are distinguished by the wide of room. There are 3 categories of determination of the measuring point based on the area of the room that is:
   a. The space is less than 10 square meters: horizontal cutting point length and width of the room is at a distance of every 1 (one) meter.
   b. The space between 10 square meters to 100 square meters: horizontal cutting point length and width of the room is at a distance of every 3 (three) meters.
   c. Room area of more than 100 square meters: horizontal cutting point length and width of the room is at a distance of 6 meters.

The luminance for the work plane is measured using a lux meter. Measurement of luminance is done by placing the light sensor facing the surface of the object to be measured luminance level at a distance of 2 to 4 inches until the reading rate on the screen table is stable. The position of the sensor should be arranged in such a way as to avoid falling shadow of the tool or operator on the area to be measured.

The reflectance measurement method is divided into two ways, namely the sample comparison method is known and the light-coming light-reflection method. The sample comparison method is known to use a reflectance measurement card and is used to measure reflectance on surfaces that reflect light diffusely (spread). The light-coming light-reflection method is used to determine the reflectance (in percent) on a reflective or non-glossy surface. This method consists of three steps, that is:

1. Measuring the intensity of light that falls to the surface of the object.
2. Measuring the intensity of reflected light from the surface of the object.
3. Measuring the reflectance of the object's surface by dividing the intensity number of reflected light with the received light intensity.

The calculation of illumination at a point is influenced by the total light current in the relevant plane and the wide area. In addition, it is also influenced by the light intensity distribution of the luminaire, efficiency, shape, size of space, surface reflections, and the height of the lamps of the field of work.

During lamp usage, the light intensity will be reduced by the dust heap and the lumen values will shrink. Therefore, we need to consider the value of Light Lost Factor (LLF).

The value of CU (Coefficient of Utilization) is highly dependent on the surface reflectance. The higher the reflected surface of the roof, space, and floor, the higher the CU value will be.

The formula for calculating the required illumination level, F (flux luminous) is as follows:

\[
F = \frac{(E) \times (A)}{(CU) \times LLF}
\]

Where:
- \(E\) = Recommended illumination level on surface (lux)
- \(F\) = Required flux luminous (illumination level) (lumen)
- \(CU\) = coefficient of utilization
- \(LLF\) = light loss factor
- \(A\) = Area surface (m²)

3. Results and Discussions

This research was conducted in four printing business in Medan City. Printing becomes the object of observation to produce printed products such as forms, letterhead, invitation cards, books, newspapers, banners, or garment products. Sample printing 1 has several work stations including cutting work stations, printing work stations, numbering stations, and binding stations. Research in each work station is done to illumination level, reflectance number, luminal count calculation and lamp type selection.

For the first area under study is the area of the cutting station. The cutting station has an area of 11.2 m², the number of lamps 1 piece. The operator's work area coverage is only 1 m, then the four-point retrieval is taken along 0.5 m from the right and left front and rear operator shoulders and a point directly in front of the operator's head. So that obtained five measurement points approaching cutting operators as in Figure 1.

![Figure 1. Cutting Station Measurement Point](image)

Illumination values at five points of measurement at cutting stations can be seen in Table 1.
Table 1. Illumination of Cutting Station

| No | A  | B  | C  | D  | E  | F  | G  | (Lux) |
|----|----|----|----|----|----|----|----|-------|
| 1  | 70.0 | 75.0 | 72.0 | 65.0 | 67.1 | 73.0 | 66.0 |
| 2  | 49.2 | 47.9 | 45.7 | 50.3 | 60.1 | 49.2 | 41.5 |
| 3  | 42.5 | 42.1 | 46.1 | 41.9 | 40.0 | 43.4 | 46.2 |
| 4  | 40.0 | 41.5 | 42.7 | 38.6 | 37.3 | 42.1 | 43.4 |
| 5  | 76.0 | 77.9 | 75.7 | 80.3 | 80.1 | 79.2 | 81.5 |

Note:
A = Time 09:00 – 10:00 WIB
B = Time 10:00 – 11:00 WIB
C = Time 11:00 – 12:00 WIB
D = Time 13:00 – 14:00 WIB
E = Time 14:00 – 15:00 WIB
F = Time 15:00 – 16:00 WIB
G = Time 16:00 – 17:00 WIB

The level of luminance and the level of illumination is also measured on the object material located at cutting stations. Appropriate data measurement procedures for each object material at cutting stations, numbering and binding.

The calculation of the total reflectance number of the cutting station walls is as follows:

$$\rho = \frac{\sum_{k=1}^{n} \rho_k \times L_k}{\sum_{k=1}^{n} L_k} \times 100\%$$

$$\rho = \frac{(50.5 \times 12.0) + (47.7 \times 12.0)}{12.0 + 12.0} \times 100\% = 49\%$$

The total reflectance number of cutting station can be seen in Table 2.

Table 2. The Total Reflectance Number Of Cutting Station

| Dept.          | Measurement Field | Total Reflection (ρ total) |
|----------------|-------------------|----------------------------|
| Cutting Station | Wall              | 0.49                       |
|                | Floor             | 0.39                       |
|                | Roof              | 0.5                        |

From the data collection of the characteristics of the room and the room layout then it can be determined the number of light bulbs to illuminate each room for lights can be bright in accordance with the standard of Kepmenkes No 1405/MENKES/SK/2002, using the formula:

$$F = \frac{(E \times (A)) \times (U)x (LLF)}{(200) \times (112) \times (0.72) \times (0.76)}$$

$$F = 4093.56$$

The type of lamp used earlier in the factory is Philips Essential lamp 23 W with nominal luminous flux = @1900 lumen. Then the number of light bulbs used should be

$$F = \frac{4093.56}{1900} = 2\text{ lamps}$$

The research was also conducted on the printing work stations, numbering, and binding so as to obtain the recapitulation for all four stations as in Table 3.
Table 3. Recapitulation Illumination Level for Each Work Station

| Time | K  | L     | M  | N  |
|------|----|-------|----|----|
| A    | 55.6 | 209.5 | 90 | 97 |
| B    | 56.9 | 218.5 | 90.4 | 98.4 |
| C    | 56.5 | 207.9 | 89 | 99.4 |
| D    | 55.3 | 215.2 | 85 | 98 |
| E    | 57  | 216.6 | 87.1 | 96.9 |
| F    | 57.4 | 221.1 | 87.3 | 95.7 |
| G    | 55.8 | 213.8 | 86 | 94.8 |
| **Average** | 56.4 | 214.7 | **87.9** | **97.2** |

Note:
- A = Time 09:00 – 10:00 WIB
- B = Time 10:00 – 11:00 WIB
- C = Time 11:00 – 12:00 WIB
- D = Time 13:00 – 14:00 WIB
- E = Time 14:00 – 15:00 WIB
- F = Time 15:00 – 16:00 WIB
- G = Time 16:00 – 17:00 WIB
- K = Cutting Station
- L = Printing Station
- M = Numbering Station
- N = Binding Station

The Illumination level graphs for each are shown in Figure 2. Based on the graph it is seen that only printing stations whose work stations meet the lighting standards set by Kepmenkes No.1405.

![Figure 2. Average Illumination Recapitulation (Lux)](image)

Therefore, design of work area lighting can be performed on cutting station, numbering, and binding.

In the same way as the calculations performed at the cutting station, then obtained the recapitulation of the number of lamp lumen and the number of bulbs for all samples reviewed is shown in Table 4.
### Table 4. Recapitulation of The Number of Lamp Lumen Requirements and Number of Lamp at The Four Sample Locations

| Sample | Station | Number of Lumen Needs | Number of Lamp (unit) | Number of Lamp Needs | Number of Lamp Actual |
|--------|---------|------------------------|-----------------------|-----------------------|-----------------------|
| 1      | K       | 4.093,56               | 2                     | 1                     |                       |
|        | M       | 11.685,90              | 6                     | 1                     |                       |
|        | N       | 23.106,54              | 6                     | 4                     |                       |
| 2      |         |                        |                       |                       | 48.309,17             | 19                    | 18                    |
| 3      |         |                        |                       |                       | 92.380,00             | 19                    | 15                    |
| 4      |         |                        |                       |                       | 40.436,45             | 16                    | 8                     |

Note:
K = Cutting Station  
M = Numbering Station  
N = Binding Station

Sample 1 has a separate work space between workstations, while at Sample 2 to 4 all workstations are in one work space.

Some possible causes of low levels of illumination on the floor of production, that is:
1. Lack of illumination level (E) towards the area of room (A), this is influenced by the number of luminaires and the number of initial lumen of the luminaire.
2. The low value of CU (Coefficient of Utilization), this is influenced by luminaire's height from the work field, the proportion of the room, and the reflection of material objects.
3. The low value of LLF (Lost Light Factor), this is influenced by nonrecoverable factor and recoverable factor.

### 4. Conclusions
The conclusions from this research is that almost all work areas are reviewed require improvement of lighting, because light bulbs used aren't able to meet the needs of lighting.

This research recommends improving the workspace lighting using LED (Light Emitting Diode) lights because it has high energy efficiency and relatively more lifetime compared to the existing lamp.

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