The Effect of Illumination on Work Result in Sorting Department

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Abstract. In order to perform well and obtain a good result, working in a company requires conducive working conditions. Working conditions can be physical environment or a social organizational environment. The physical environment is including temperature, humidity, and illumination. The research was conducted in the sortation activity in the printing and plastic industries which were done separately. The workers in both industries have a task to separate defective products in the production. The lack of illumination conditions causes many defective products pass the inspection. This condition leads to complaints from customers because they receive the product that does not comply with the specification. This research was conducted through observation of the sortation activities, measurement of illumination level in the workspace, and identification the number of defective products which pass the inspection. Determination of the measurement points is done by dividing working areas by the grids based on room width and referring to SNI 16-7062-2004. Based on the observation results, Product Moment Pearson is used to seeing how much the influence of illumination levels to work result. This level of influence becomes the reference of the recommendations to improve working result in sorting department. It is recommended to increase the number of lumen lamps that use the existing lighting installation to meet the required level of illumination.

1. Introduction

In order to perform well, a working system requires good system components and interaction between components. Workers, working methods, working environment are part of the work system components that need to be organized well in order to work according to the expected specifications.

Working products which are delivered to consumers should fully meet the specifications that have been defined, but in some cases, consumers find defective products among the received products. The number of defective products will reduce the productivity of the company [1]. In this case, sorting activities of production play an important role in order to avoid this issue, in addition to the efforts to handle the defective products [2].

If the workers have performed their duties according to working methods, but the working condition is less conducive, it might not create an optimal work. The working environment can be the physical environment and the social organizational environment. Temperature, humidity, and illumination are some of the physical factors that affect the result of one’s work [3].

Illumination for workspaces can be derived from natural and artificial illumination. Artificial illumination is necessary because it can not fully depend on the availability of natural illumination [4].
Based on Grandjean, improperly designed lighting could give impact to fatigue in eye organ, mentally, headache, and damage of eyes. This fatigue will cause the reduction in working performance, efficiency, productivity, quality, and higher defective products and work accident.

This research was conducted in sorting activities in the printing industry and plastic industry, separately. Sorting workers in number printing activity in the printing industry are operating the machine, observing the printed numbers, and putting aside the products whose mold numbers are skewed, faded, or dirty. Sorting workers in the plastic industry are observing the sheet that has been cut and putting aside the product whose didn’t meet specification. The next operator has to collate the inspected sheet, re-inspect and put aside when the defective product found. Sorting workers in both industries have a task to separate defective products found in the production and identified visually.

The lack of illumination causes a lot of defective products pass the inspection. It leads to complaints from customers because they receive the product that does not comply with the specifications [5]. The illumination level is the amount of light which falls onto the surface of an object [6,7]. The luminance is measured by placing the sensor facing the surface of the object at a distance of 5 to 10 cm, until reading the lux meter which has been stable/unchanged. The luminance of an object’s surface can be measured using lux meter [8].

Based on government regulation about the health requirements of office and industrial work environment, and for the type of routine activities such as rough and continuous work, the minimum level of illumination is 200 lux [9]. The illumination conditions in the printing industry and plastic industry as the object of this study are still far from the standard which is specified above.

Printing activity which becomes the object of this study includes printing of documents, books, newspapers, garment products, and invitation cards. The plastic industry that was assessed produces 4 types of plastic packaging products, namely packaging of SW (Shrink Wrap), SIR (Standard Indonesian Rubber), Inter-layer, and packaging for a label. Dimensions for each plastics as follow: SIR has 97 cm x 64 cm x 0.35 cm; SW has 275 cm x 78 cm x 0.25 cm; Inter-layer has 105 cm x 105 cm x 0.1 cm; and packaging for label has 45 cm x 45 cm x 0.45 cm. The special research was conducted to assess the SIR type of plastic packaging.

2. Materials and Method
This research was conducted in some printing and plastic industries in Medan, North Sumatra. The research variables used such as space area, illumination, luminance, and defective product which passes inspection. The research instrument used was 4 in 1 environment meter. This research used observation of sorting activities and sorting room, measurement of the illumination level of sorting room and identification of defective products that passed the inspection.

Sorting activities studied in the printing industry are include to inspect the numbering machine product and put aside the defective products which were found. The defective product that passes the inspection was found by the re-inspected working result from the first operator. Sorting activities studied in the plastic industry are include to sort the plastic packaging products and fold the sheets of product sorting result before the product is packaged by the next operator. The defective product that passes inspection was found by the number of rejected products by the successor process.

Determining the measurement point was done with the guidance of SNI 16-7062-2004 (Indonesian National Standard about lighting in a workplace) which divides the length and width of the room on grids based on the room area as follow. [10]

| No | Room area                | Grid size |
|----|--------------------------|-----------|
| 1  | less than 10 m²          | 1 m x 1 m |
| 2  | between 10 m² - 100 m²   | 3 m x 3 m |
| 3  | more than 100 m²         | 6 m x 6 m |

Source: SNI 16-7062-2004
Workspace illumination was measured using 4 in 1 environment meter. In the printing industry, measurements were performed 4 times in each predetermined point. It was conducted during five days of observation. Luminance measurement was carried out on material objects in the workspace (walls, tables of materials, machines, ceilings, floors).

Illumination level in printing industry was measured in actual lighting condition. In plastic industry, the observation was done in sorting room and plastic packing. The illumination level in this research was set at 150 lux, 200 lux, 250 lux, and 300 lux, each in three times of replication.

On each day of observation, products which have passed the inspection were sorted, then defective products found were counted. The effect of illumination level to working result in sorting department can be calculated by Product Moment Pearson method [11].

During using a bulb, illumination level that will be reduced to a heap of dust and number of the lumen will shrink. Therefore, Light Lost Factor (LLF) need to be considered. The coefficient of Utilization (CU) value is highly dependent on reflectance value. The higher ceiling, wall, and floor reflectance, the higher CU value.

Lights lumen calculated using formula as follow:

$$E = \frac{F \times (CU) \times (LLF)}{A}$$  \hspace{1cm} (1)

$$F = \frac{E \times A}{(CU) \times (LLF)}$$  \hspace{1cm} (2)

Where:
F is the needed number of illumination (lumen)
E is recommended illumination level (lux)
A is working space (m²)
CU is coefficient of utilization
LLF is Light Lost Factor (%)

While to count the number of lights used, we might consider that the necessary light needed which was spread evenly throughout the room and had a fairly wide spread of light. The number of light bulb can be calculated using the formula:

$$N = \frac{F}{(FL)}$$  \hspace{1cm} (3)

where:
N is number of light bulbs
(FL) is a nominal luminous flux of light bulb (lumen)
1 lux = 1 lumen/m²

Choosing the right lamp depends on what is required of the lighting. [12] Lighting shares a large part in the global energy consumption, lighting consumption can be easily reduced with the use of efficient light sources [13,14]. Lighting technologies differ along multiple technical dimensions such as light output, color temperature, power usage, system weight, and functionality. An ideal lighting system for industrial applications have superior light output, lower power consumption, and increased usable lifetime. Lighting systems can also vary based on physical specifications such as weight, functionality, and ease of use; of course, ideal systems should be both light-weight and provide a high light output to cost ratio. Light emitting diode (LED) are becoming an increasingly common lighting option for industrial applications, offering superior power efficiency and longevity relative to conventional fluorescent technologies [15,16]. Based on Poret in Macorol, LED is digital light and the advantages versus conventional analog lighting are so huge and of major benefit to both users of this technology of digital light as well as to our planet. That’s why people believe to have plenty of good reasons for being passionate about LED Illumination [13].
3. Results and Discussions

3.1. Defective Products that Pass Inspection
Defective products found in sorting activities should be put aside so it would not be affiliated with the finished products and delivered to the consumer. Defective products collected by the criteria as shown in Table 2.

| No | Type of Defect       | Criteria                                                                 |
|----|----------------------|--------------------------------------------------------------------------|
| 1  | Faded number         | Printed number is unreadable, or hard to differ between 1 with 7 or 0 with 8 |
| 2  | Skewed printed number| Printed number is skewed                                                  |
| 3  | Dirty paper          | Printed paper is unclean because too high of tint intensity               |

However, based on the observation made in 10 batch printing for 5 days, the number and percentage of defective products which passed inspection were varied as shown in Table 3.

| No. Batch | Number (sheets) | Percentage (%) |
|-----------|-----------------|----------------|
| 1         | 568             | 11.36          |
| 2         | 489             | 9.78           |
| 3         | 315             | 6.30           |
| 4         | 375             | 7.50           |
| 5         | 294             | 5.88           |
| 6         | 462             | 9.24           |
| 7         | 392             | 7.84           |
| 8         | 349             | 6.98           |
| 9         | 245             | 4.90           |
| 10        | 311             | 6.22           |

A number of printed for each batch is 5000 sheets.

The amount of packaging that were not qualified and defect which passed from sorting activities in the plastic industry are shown in Table 4.
Table 4. The Number of Defective Packaging And Defective Packaging Which Passed Inspection in The Plastic Industry

| No | Number of Defective Packaging | Number of Defective Packaging Which Passed the Inspection |
|----|-------------------------------|---------------------------------------------------------------|
| 1  | 109                           | 43                                                                           |
| 2  | 120                           | 50                                                                           |
| 3  | 112                           | 44                                                                           |
| 4  | 58                            | 26                                                                           |
| 5  | 79                            | 28                                                                           |
| 6  | 60                            | 25                                                                           |
| 7  | 39                            | 6                                                                            |
| 8  | 49                            | 10                                                                           |
| 9  | 40                            | 6                                                                            |

Source: Observation Result

3.2. Illuminations Measurement

Illumination in the field of an operator in accordance with the government in health regulation number 1405 in the year of 2002 is a minimum of 200 lux; while according to CIE (Commission International de l'Eclairage) and IES (Illuminating Engineers Society) is 450 lux; and according to SNI 03-6197-2000 is in the range of 200-500 lux. The measurement result of illumination level in the area of numbering machine as per SNI 16-7062-2004 for several days is shown in Table 5.

Table 5. The Measurement Result of Illumination Level in The Working Area of The Numbering Machine Operator

| Days | Morning Observation Time | Afternoon Observation Time |
|------|--------------------------|----------------------------|
|      | 10:00 WIB | 12:00 WIB | Average | 14:00 WIB | 16:00 WIB | Average |
| I    | 25,03      | 27,58    | 26,31   | 29,04      | 27,27    | 28,16   |
| II   | 30,16      | 31,40    | 30,78   | 40,00      | 26,35    | 33,18   |
| III  | 27,77      | 27,90    | 27,84   | 27,71      | 24,84    | 26,28   |
| IV   | 30,60      | 31,39    | 31,00   | 30,37      | 27,73    | 29,05   |
| V    | 30,21      | 29,50    | 29,86   | 27,82      | 25,65    | 26,74   |

Source: Observation Result

Table 5 showed that lighting condition in the morning observation and afternoon observation differs less than 4 lux between them.

Illumination level in the printing industry and standard from the government as shown in Fig 1.
From the Fig. 1 show that the actual lighting condition is less compared to government lighting standard. Beside illumination measurement, luminance data for a number of objects found as shown in Table 6.

Table 6. The measurement result of luminance level of the numbering workstation

| No | Area   | Luminance Level | Remarks                                      |
|----|--------|-----------------|----------------------------------------------|
| 1  | Wall   | 16.80           | Painting is dull by ash                      |
| 2  | Floor  | 5.70            | Floor is covered by oil drops and hardened ink|
| 3  | Ceiling| 60.10           | A clean painting surface                     |
| 4  | Machine| 3.30            | Iron coating by the black paint              |
| 5  | Table  | 4.55            | Wood covered by a dull white paint           |

Total production of plastic packaging and the level of illumination for several days of observation as shown in Table 7.

Table 7. The Number of Production and Illumination Level

| No | Intensity (lux) | Number of Production |
|----|-----------------|----------------------|
| 1  | 150             | 1756                 |
| 2  | 150             | 1642                 |
| 3  | 150             | 1595                 |
| 4  | 200             | 1679                 |
| 5  | 200             | 1661                 |
| 6  | 200             | 1628                 |
| 7  | 250             | 1600                 |
| 8  | 250             | 1638                 |
| 9  | 250             | 1654                 |

Observations were also performed on illumination condition of 300 lux, but the operators complained because of over lighting intensity.

3.3. The Influence of Illumination in Sorting Department

To see how much the influence of illumination of working result in sorting department, therefore correlation level is calculated between illumination levels with the defective products that pass the
inspection by using Product Moment Pearson method. The data of illumination level in working area of the operator and defective products that passed the inspection in sorting activities in the printing industry as shown in Table 8 and Fig. 2. Illumination level was measured by the researcher on the inspected product.

Table 8. The Number of Defective Product and Illumination Level in Working Area of Operator

| No | Illumination Level | Defect Product that Pass Inspection (%) |
|----|--------------------|----------------------------------------|
| 1  | 22.00              | 11.36                                  |
| 2  | 22.00              | 9.78                                   |
| 3  | 32.00              | 6.30                                   |
| 4  | 32.00              | 7.50                                   |
| 5  | 30.00              | 5.88                                   |
| 6  | 30.00              | 9.24                                   |
| 7  | 31.00              | 7.84                                   |
| 8  | 31.00              | 6.98                                   |
| 9  | 32.00              | 4.90                                   |
| 10 | 32.00              | 6.22                                   |

Fig. 2. Illumination level and defective products which pass the inspection in printing industry

In Fig. 2, it can be seen that the level of illumination in printing activities varied between 22 to 32 lux and percentage of defective products which passed inspection decrease for a higher illumination level. The Data of illumination level and defective products that passed the inspection in sorting plastic packaging products as shown in Table 9 and Fig. 3. Fig. 3 shows the level of illumination on the plastic packaging products sorting activity which was 150-250 lux. while the number of defective products ranged from 6 up to 50 sheets of one batch inspection. The research was confined to 250 lux since a higher illumination level (300 lux) made operators complain about glaring.
Table 9. The Number of Defective Product and Illumination Level in Plastic Industry

| No | Illumination Level | Defect Product that Pass Inspection (Sheets) |
|----|-------------------|---------------------------------------------|
| 1  | 150               | 43                                          |
| 2  | 150               | 50                                          |
| 3  | 150               | 44                                          |
| 4  | 200               | 26                                          |
| 5  | 200               | 28                                          |
| 6  | 200               | 25                                          |
| 7  | 250               | 6                                           |
| 8  | 250               | 10                                          |
| 9  | 250               | 6                                           |

Fig. 3. Illumination level and defective products which passed inspection in plastic packaging products sortation

The results of calculations performed by the Pearson Product Moment Correlation. -0.82 was obtained for the correlation between the level of illumination and the percentage of defective products which passed inspection in printing; and -0.99 for the correlation between the level of illumination and the percentage of defective products which passed inspection in the sorting activity of plastic packaging. Both values show a strong, negative and significant relationship. that the higher the level of illumination, then the number of defective products that pass inspection decreases.

3.4. Discussion
If it is looked at the level of illumination in the printing activities, the value ranged between 22-32 lux; whereas the level of illumination in the plastic packaging activities was in the range of 150-250 lux. Both values of illumination level are much different but both give the same conclusion that the level of illumination affects the number of defective products which pass inspection.

The defective products that passed inspection were found mostly in the intensity of 150 lux because human eyes must accommodate in maximum number while working so that they can see the plastic packaging clearly. And defective products was found the least at the intensity of 250 lux since the eyes were used normally.

The luminance of some material objects at numbering station in printing activity is showed relatively low numbers. Machines, desks, floors, and walls had a luminance level ranging from 3.30 to 16.80 lux. Luminance level was low due to the paint on the walls that had been dull and machine coated with black paint. The only ceiling of the workspace had a relatively good luminance level which is equal to 60.10 lux. Low levels of luminance caused the room requires a better level of illumination so able to
see the defective products more clearly. To increase the luminance value of these materials, it might be done by repainting the room with a brighter color and cleaning the surface of the material.

In the sorting activity of plastic packaging products, the illumination level of 250 lux gave the smaller number of defective products which passed the inspection compared to the illumination level of 150 lux and 200 lux. Experiments which were conducted in the illumination level of 300 lux led to complaints from the operators. Therefore this research recommends the illumination level of 250 lux for the sorting activity of plastic packaging products.

In the printing activity, the illumination level of the printing area of the numbering machine had an average value of 30 lux, this value was significantly below the recommendations of The Decree of Ministry of Health and Indonesian National Standard (SNI) which was 200 lux [8, 9]. Therefore, the addition of illumination level is required.

The calculation results of required illumination in four printing area that were a subject of this study indicated that they need light bulbs more than the existing. In sample 1, light bulbs required at the numbering station are 6 bulbs respectively. On the other hand, the existing light bulbs are only 1 bulb.

In sample 2, the required bulbs are 19 units, while the existing bulbs amounted to 18 bulbs. The required bulbs in sample 3 are 19 light bulbs, but the existing bulbs are only 15 pieces. Sample 4 required an addition of as many as existing light bulbs (required bulbs are 16 but the existing bulbs are only 8 pieces). Illumination design improvement in sample 1 is shown in Fig 4.

From the figure 4, it shows the position of the measurement point and 6 bulbs that required from the calculation results. with each bulb has 1900 lumen. Illumination design improvement in sample 2 is shown in figure 5.

Fig 5 shows the position of the measurement point and bulbs in sample 2. Workstation area in sample 2 needs 19 bulbs with a number of lumens each bulb is 2500 lumen while actual condition number of the bulbs is 18. While in sample 4, the position of the measurement point and bulbs are shown in Fig 6. There is no figure for sample 3.
Figure 5. Design improvement of illumination level in sample 2

Figure 6. Design improvement of illumination level in sample 4
Workstation area in sample 4 needs 16 bulbs with a number of lumens each bulb is 2500 to be able to fill the illumination requirement. A number of lumen bulbs that used in calculation according to the lumen bulb in existing condition. Sample 1 to 4 is located in printing activities, while sample 5 is located in plastic industry. Actual condition and requirement for light bulbs for all samples as shown in Table 10.

Table 10. Requirement and Actual Condition of Light Bulbs in The Research

| Sample     | Num. of Required Lumen | Number of Light Bulb (unit) | Requirement | Actual |
|------------|-------------------------|-----------------------------|-------------|--------|
| Printing 1 | 11,685.90               | 6                           | 1           |        |
| Printing 2 | 48,309.17               | 19                          | 18          |        |
| Printing 3 | 92,380.00               | 19                          | 15          |        |
| Printing 4 | 40,436.45               | 16                          | 8           |        |
| Plastic Industry | 32,000.00 | 7                           | 2           |        |

The actual condition in sample 5 are used 2 bulbs that power each bulb has 36 watts. so it needs additional 5 bulbs more in order to 250 lux illumination requirement will be fulfilled. The addition of illumination level in the activities of printing and sorting of plastic packaging products can be done by increasing the number of light bulbs or adding lumen lamps. Increasing the number of light bulbs will require additional installation while increasing the number of lumen lamps can use existing lighting installations. In the case of sample 3, if it is replaced with a light bulb that has a lumen of 6000 lm/lamp, it would require 16 units of bulbs. Therefore, this research recommends the addition of lumen lamps to meet the required level of illumination.

4. Conclusions
This research can conclude that by optimal condition was found in 250 lux for sortation in plastic industry. All studied in printing industry showed that the number of illumination level is far below the required standard and recommended to change the bulbs with a higher lumen so that existing installation can be used.

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