Lighting Quality Affects Eyestrain of Operators at Sorting Station in Beverage Industry

Anizar* and Erwin

Department of Industrial Engineering, Faculty of Engineering, University of Sumatera Utara, Jl. Almamater Kampus USU Medan 20155

*anizar_usu@usu.ac.id

Abstract. This study observes sorters’ performance in two beverage industries whose job is to separate defect products found. Sorters observe bottles quality and beverage quality continuously, therefore requiring more focused eyes which makes eyes’ load heavier. Sorters’ eyestrain causes more defect products pass the selection. In this study, measurement is conducted toward illumination, operators’ time response, and defect products that pass the selection. Measurement is hold in 2 beverage industries for four days with four measurements per day, twice in the morning and twice in the afternoon. Illumination is measured with 4 in 1 environmental meter in grid 1m x 1m, while operators’ time response is measured with Flicker Fusion. Illuminance is generally higher in the morning than in the evening, but still under the standard of Indonesia. Overall, sorters’ time response is higher in the morning than in the afternoon. Higher time response shows that operators experiencing lower fatigue than lower time response. The sorting duration also affects operators’ time response and defect products which pass the selection.

1. Introduction

Beverage bottling industry in Indonesia has long been applying automated and efficient production process. Nevertheless, sorting for checking product qualities still largely depend on man power. Sorting at beverage industry is conducted visually within short distance for a long period of time. There are many defect products which pass inspection found during packaging stage, causing production target cannot be reached. Work with thorough vision requires high quality of illumination. Minimum standard of lighting in Industry is regulated by Government of Indonesia Health Ministerial Decree number 1405 year 2002 [1]. This study will show that many defect products which pass the selection are caused by operators’ tiredness.

Study regarding lighting can be found on some literatures. Eyes ability to look object with detailed is affected by visibility, illumination, and the speed of the object. Sharp vision will increase as illumination and contrast level increase [2]. Eyestrain happens on eyes which focus on an object for a long period of time, which may cause faulty work. Eyestrain is a very important factor that affects work performance, as eyes which are too tired may cause negative effects [3]. Illuminance in a work room is an important parameter in maintaining work result. In short term, lighting that does not meet the standard level will stimulate the eyes to be able to see, while in long term, this may affect eyes health [4]. Even though, lighting quality in a certain work environment affects performance greatly, physical characteristics also affects eyes ability [5]. Intensity, rather than illuminance, affects short vision the most, meanwhile colour has the biggest impact on long term individual work [6]. Lighting quality is
essential, since it can alleviate health problem among workers and has an impact on products quality and production performance [7]. Sensor placement to control illuminance in a work room can save energy if it is placed based on geographical season. Illuminance distribution measurement is needed in a room during summer and winter [8]. Measurement of illuminance in a study room is affected by tools and equipment inside the room. Dim light will affect one’s visibility [9]. Illuminance intensity and background colour has significant effects on reading performance. Reading performance is higher using white light, 500 luxs, and text or blue colour background [10]. Lighting selection used in a work room or building should consider using natural light from outside, therefore safer and less energy is used [11]. Lighting usage in the afternoon is an effective choice to cut energy consumption [12]. The problem of lighting in classroom is caused by dazzle, i.e when one part of vision is far brighter than vision field contrast level. Improvement can be done easily with cheap expense. This will affect the health of students and staffs, thereby improving efficiency [13]. The use of video projector in learning process shows that there is a significant correlation with eyestrains of the students [14]. The use of a very bright and dazzling lamp can cause health problem, such as dizzy, eyestrain, and even epilepsy. The lighting will affect visual performance, which makes vision less clear [15]. Colour filter usage can relieve eyestrains [16].

Some literatures show that many studies regarding illumination quality, both in industry environment, small merchant, post office, library, and even classroom have been conducted. Some modifications are made, such as illuminance, lamp colour, energy consumption calculation, lamp placement, etc. In spite of that, to the best of the authors’ knowledge, there is no study that discuss about the effect lighting quality in beverage sorting station toward operators’ eyestrain, which make many defect products pass the inspection. The result obtain is important for the world of beverage bottling industry to improve lighting quality to improve sorters’ performance.

2. Method
The study is hold at sorting station in 2 beverage industries in Medan city, Sumatera Utara. The study conducted is descriptive correlative which explains fact obtained from the object studied and to detect the relation between variable in the study based on correlation coefficient, i.e. the effect of illumination level on sorting station work result. The study is conducted in the sorting room to measure illumination level, luminance, reflectance of the room, sorters’ time response, and to identify defect products which pass the inspection.

Illuminance, luminance, and reflectance of the sorting rooms are measured using 4 in 1 environment meter for four days with four times of measurement per day. Measurement is hold on 09.00, 11.00, 13.00, and 15.00. Measurement point is decided using SNI 16-17062-2004, i.e. dividing rooms’ length and width by grid based on area of the room. Room area smaller than 10 m² uses 1m x 1m grid, room area of 10-100 m² uses 3m x 3m grid, and room area larger than 100 m² uses 6m x 6m grid [17]. Consequently, there are 4 point of measurement at every sorting station for both industries.

Operators’ eyestrain is measured using Flicker Fusion (FF) to obtain time response of operators looking at a flash stimulation measured in seconds. The measurement is hold 4 times per day, i.e. 2 times before work at 09.00 and 11.00 and 2 times after work at 13.00 and 15.00. Lower time response means eye is more tired than higher time response.

Several parameters and formulas are used to analise this study. Illuminance is calculated using,

\[ E = \frac{\varnothing \cdot \text{CU} \cdot \text{LLF}}{A} \]  

where E (lux) represents average illumination level, \( \varnothing \) (lumen) represents a total of light instensity on the corressponing area, CU represents coefficient of utilization, LLF represents light loss factor, A (m²) represents area.
Correlation test between illumination level with sorter’s eye strain use the formula of

\[
r = \frac{\sum_{i=1}^{n} X_i Y_i - (\sum_{i=1}^{n} X_i)(\sum_{i=1}^{n} Y_i)}{\sqrt{[\sum_{i=1}^{n} X_i^2 - (\sum_{i=1}^{n} X_i)^2][\sum_{i=1}^{n} Y_i^2 - (\sum_{i=1}^{n} Y_i)^2]}}
\]

The calculation of Analysis of Variance (ANOVA) for random model is used to see whether the input given has an impact on defect products that pass inspection. ANOVA calculation is used to understand the factor that give real impact on defect products number. The factor that has the impact are sorting process with rating factors sorting station and observation duration with rating factors observation time in the morning and in the afternoon.

3. Results and Discussions

Results that will be discussed include the average level of illumination, operators’ eyestrain, defect products that pass the inspection and analysis of variance calculation. The sorting process is done 2 times, sorting bottle quality and sorting beverage quality. Sorting is conducted on bottles coming out from dish washer, i.e. cracked bottles, dent bottles, and broken bottles. Beverage quality sorting, volume and water clarity, is done on bottle which already has water in it.

3.1. The average illuminance

The level of illumination at sorting station of beverage industry1 and beverage industry2 can be seen on Table 1.

| Tabel 1. The average illuminance in beverage industry |
|-----------------------------------------------|
| Time              | Point of measurement | Average |
|                  | 1       | 2       | 3       | 4       |          |
| Beverage         | morning | 28.26   | 44.36   | 26.12   | 44.14   | 35.72   |
| industry 1       | afternoon| 28.99  | 43.11   | 22.98   | 42.29   | 34.34   |
| Beverage         | morning | 140.82  | 117.75  | 129.89  | 125.18  | 128.41  |
| industry 2       | afternoon| 139.07 | 119.29  | 129.89  | 125.71  | 128.49  |

Table 1 shows the average illuminance at both industries in the morning and in the afternoon. Illuminance in the morning is generally higher than in the afternoon. Illuminance in beverage industry 2 is higher than beverage industry 1, but still below the standard set by Government of Indonesia Health Ministerial Decree. The average illuminance at floor production in beverage industry 1 is 36.11 luxs and 128.45 luxs in beverage industry 2.

Figure 1 shown according to the standard, for blue-collar type work and continuous work, the illuminance is 200 luxs, which means that beverage industry1 is far below the national standard, whereas beverage industry2 almost reach the standard. Low illuminance in beverage industry1 is caused by small number of lamp at sorting station and sheer number of stack of container bottles. Lamps are installed hanging from the roof which stand 7 meters from the floor and lamps are distributed across the 14.9m x 18m room. Illuminance at sorting room in the afternoon is lower, since less sunlight enters the room. In the morning, sunlight help lighting the room greatly.
3.2. Sorters’ eyestrain

Sorters in beverage industry 1 sort 23,000 bottles, while sorters sort 10,000 bottles in beverage industry 2. In beverage industry 1, bottle quality and beverage quality sorting are done by 4 operators, meanwhile only 2 operators do this work in beverage industry 2. Sorters’ separate defect products from good products for as long as 6 hours everyday continuously with 1 hour of lunch break. The activity requires high thoroughness which may cause eye strain. The measurement of operators’ time response is conducted to obtain the level of operators’ fatigue which is shown on Table 2.

| Time response (second) | Operator | Rata-Rata |
|------------------------|----------|-----------|
| Beverage               | Pagi     | 23.75     | 22.22     |
| industry 1             | Sore     | 17.55     | 18.50     |
| Beverage               | Pagi     | 43.13     | 47.31     |
| industry 2             | Sore     | 35.75     | 40.44     |

Figure 2 shows that operators’ time response is higher in the morning than in the evening. Operators’ time response in beverage industry 2 is higher than in beverage industry 1. In beverage industry 1, the average time response for sorting bottle quality is higher than beverage quality and an otherwise thing happened in beverage industry 2. Beverage industry 1 only has lamps hanging from the roof, which makes it hard to sort beverage quality, since the beverage all looks brown-black. Beverage industry 2 also has some 700-900 watt lamps placed in front of sorters. Beverage quality sorting is easier as the beverage shows a contrast red colour. In beverage industry 1, sorting process is done by 2 operators working alternately every 3 hours, while in beverage industry 2, only 1 operator do the sorting for 6 working hours. The sorting duration also has impact on sorters’ time response. Higher operators’ time response means that the operators experience more fatigue than the lower number.
3.3. **Defect products that pass the inspection**

Defect products that pass the inspection happens for both industries which is shown on table 3

| Time   | Illuminance (lux) | Time response (second) | Defect product which pass the inspection (%) |
|--------|-------------------|------------------------|---------------------------------------------|
|        |                   |                        | beverage industry 1                           |
| Morning| 36,57             | 22                     | 1.12                                         |
| Afternoon| 35,20            | 18                     | 1.44                                         |
|        |                   |                        | beverage industry 2                           |
| Morning| 128,41            | 47                     | 4.77                                         |
| Afternoon| 128,49           | 40                     | 5.72                                         |

In beverage industry 1, defect product which pass the inspection has lower percentage in the morning compared to the afternoon, i.e. 1.12 % and 1.44 % respectively. On the contrary, in beverage industry2, eventhough less defect products pass the inspection in the morning, the percentage is a little higher, 4.77% and 5.72% respectively, considering illuminance at beverage industry 2 almost reaches the standard of 200 lux set by Government of Indonesia Health Ministerial Decree.

Figure 3 shows the effect of illuminance on time response and defect products that pass the inspection in beverage industry 1 and beverage industry 2. Illuminance in beverage industry1 is far lower than in beverage industry 2, however time response of operators doesn’t show significant difference. Defect products that pass the inspection is even higher in beverage industry 2. This thing is caused by there are 2 sorters in beverage industry1 which work alternately each hour, whereas there is only one operators working consecutively for 6 working hours daily.
To understand the effect of illuminance at sorting station on work result, correlation level between illuminance and defect products that pass the inspection is calculated using moment pearson product method. Before correlaton test is conducted, normal test is hold first on both data. Normal distribution test used is kolmogorov-smirnov test. Based on data normality test calculation, Dmax value is 0.2734 and Dσ is 0.4090 for work station quality control, therefore: D ≤ Dσ, consequently Ho is accepted. It means, illuminance data and defect products that pass the inspection data is tested to be distributed normally. Pearson correlation test is used to test correlation between to variance which have normal distribution and have interval or ratio data taype and the value of r obtained is 0.5780.

3.4. Analysis of Variance (ANOVA)
The calculation using SPSS application with rating factors is time oberservation in the morning and in the afternoon, and sorting process. The result obtained shows that sorting process factor and observation time affect defect products that pass the inspection greatly. The value of F calculated can be seen on figure 4.

![Figure 3. Illuminance, time response, and defect products that pass the inspection](image)

**Figure 3.** Illuminance, time response, and defect products that pass the inspection

**Figure 4.** ANOVA analysis with SPSS in beverage industry
On figure 4, sig value is 0.044 ($\alpha$ 0.05) where 0.044<0.05, then Ho can not be accepted, therefore the factor of observation time in the morning and in the afternoon and sorting process affect the number of defect products that pass the inspection.

4. Conclusions

This article’s goal is to understand lightning quality effects on sorters’ eyestrain in 2 beverage industries. The main parameter is to know illumination level at sorting station, to obtain sorters’ time response, and defect products that pass inspection. The average level of illumination on industry floor at both industries is still below the standard of Government of Indonesia Health Ministerial Decree for blue-collar type work and continuous work which is 200 luxs. Sorter’s time response is higher in the morning than the afternoon. Higher time response means operators experience lower fatigue than higher time response. However, time response of sorters doesn’t depend solely on illuminance, working duration also has its own effect.

Acknowledgments

The authors gratefully acknowledge that the present research is supported by Ministry of Research and Technology and Higher Education Republic of Indonesia. The support is under the research grant BP-PTN USU of Year 2016 Contract Number 6049/UN5.1.R/PPM/2016.

References

[1] Government of Indonesia Health Ministerial Decree No 1405 Year 2002, 2002, Health Requirements of Work Environment at Office Complex and Industry.

[2] Lai Y K, Ko Y H, Shieh K K, Lee D S, Yeh Y Y and Yang T C 2012 Journal of Ergonomic Study 14(2) 119-126.

[3] Lin J T, Liang G F, Hwang S L and Wang E M Y 2010 Human Factors and Ergonomics in Manufacturing & Service Industries 461-469.

[4] Musa A R, Abdullah N A G, Che A A I, Tawil N M and Tahir M M 2012 Procedia – Social and Behavioral Science 60 318-324.

[5] Rekha V S and Chitra P 2016 IJSR International Journal of Scientific Research 5 126-129.

[6] Lin C C and Huang K C 2014 International Journal of Applied Science and Engineering 12(3) 193-202.

[7] Uttam D 2015 IJAREAS International Journal of Advanced Research in Engineering and Applied Sciences 4(2) 17-26.

[8] Park J I, Lee H and Kim Y 2015 International Journal of Smart Home 9(9) 185-194.

[9] Bellia L, Spada G, Pedace A and Fragliasso F 2015 Energy Procedia 78 3138-3143.

[10] Lin C C 2014 IJRDET International Journal of Recent Development in Engineering and Technology 3(2) 1-6.

[11] Herbert P, Peek G, Kang M and Frazier R S 2014 WIT Transcation on Ecology and The Environment 181 421-433.

[12] Navada S G, Adiga C and Kini SG 2016 International Journal of Applied Research 7 4711-4717.

[13] Winterbottom M and Wilkins A 2009 Journal of Environmental Psychology 29 63-75.

[14] Zamanian Z, Daneshmandi H, Mazidi F K, Nejad A D and Haghayegh A 2014 Jeniashapir J Health Res 5(1) 445-450.

[15] Evans B J W and Allen P M 2016 Journal of Optometry 9 205-218.

[16] Ticleanu C and Littlefair P 2015 International Journal of Sustainable Lighting 1 5-11.

[17] Indonesian National Standard, 2004, Lighting Intensity Measurement at Work Place.