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Evaluation of Occupational Noise Exposure in a Plastic Manufacturing Industry: A Case Study

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ABSTRACT

Industrial workers need a safe working environment to ensure their wellbeing is protected while performing tasks. Occupational noise is one of the most prevalent problems in industries due to nature of the industry. Therefore, this paper aimed to evaluate the occupational noise exposure in one of the plastic factories in Klang Valley, Malaysia. Noise measurement has been done in all production lines, crushing department, packaging department and officers' area. The noise measurements were taken 1 to 3 metres from the source of noise at several points for each line and departments using sound level meter. Average noise level at all measurement location noted LAeq less than 80 dBA, except one point in line B and the crushing area. The packaging department recorded the lowest noise level, with LAeq 64.8 dBA and LAmax of 69.2 dBA. While, the crushing department is the noisiest area in the factory, with LAmax 105 dBA and LAeq 100.9 dBA. The average noise level at majority location in the factory is less than 80 dBA which means it is at a safe range. The workers do not need any personal hearing protection equipment during working, which was according to the Occupational Safety & Health (Noise Exposure) Regulations 2019 noise regulations in Malaysia, except the crushing area only. In conclusion, evaluation of noise exposure in each section can provide a good understanding of the occupational noise level experienced by different workers at different departments. It can help the management to strategize and plan the noise control approach, especially at the area that may have risk of hearing loss for their workers.

Keywords: Occupational noise; crushing task; plastic factory; sound level meter

INTRODUCTION

Noise is one of the problems that can be found in the work environment. The World Health Organization (WHO) estimates that approximately noise causes 15% of all occupational diseases, and 15% of the workers in developed countries are exposed to noise levels, which are harmful to hearing (Baskov, Ignatov & Isaeva 2018; Dias & Cordeiro 2008). Table 1 summarises the allowable daily noise exposure duration limit (*Industry Code of Practice (ICOP) for Management of Occupational Noise Exposure and Hearing Conservation 2019* 2019).

For more than 50 years, occupational health organizations started to set regulations for noise exposure. Occupational Safety and Health Administration (OSHA) regulations require that employer have to determine the noise limit time that employee is exposed to, with a maximum of eight hours with an average of 85 dBA (Hickman, Burson & Thompson 1979). Exposure to a continuous noise of 85-90 dBA could lead to progressive hearing loss and changes in the threshold sensitivities. These annoyance reactions are associated with the degree of magnitude, variety, and severity of daily activities. In 2003, the European Union defined a lower exposure action value of 80 dBA using a working time of eight hours, the upper exposure action 85 dBA, and exposure limit 87 dBA (Lombardo, Iannucci, Parvis, Corbellini & Grassini 2019).

Occupational noise is the amount of acoustic energy received by an employee's auditory system when they are working in the industry. A factory that produce plastic buttons in japan recorded noise level (LAeq) from 58 to 92 dBA. 30% of their measurement points showed noise level excess of 85 dBA. Furthermore, most of their workers exposed to the noise leveloft 69-76 dBA, while the second group who engaged in the production of plastic buttons was continuously exposed to the noise level of 82-86 dBA. However, their officers were exposed to noise level of 58-62 dBA (Morioka, Miyai, Yamamoto & MIYASHITA 2000).

There were many studies about noise exposure level in Malaysia in different areas such as at airports (Haliza et al. 2018), railway stations (Shahidan, Maarof, Hannan & Ali 2017), kindergarten buildings (Salleh, Kamaruzzaman, Riley, Zawawi & Sulaiman 2015), affordable housing area (Kamaruzzaman & Azmal 2019), public university (Haron et al. 2015), construction site (Nawi 2013), and other places (Saleha & Hassim 2006; Saw Bin, Richardson & Yeow 2010; Tahir, Aljunid, Hashim & Begum 2014).

Few more studies were done on industrial noise or occupational noise such as palm oil mill industry (Ruslan, Baba & Leman 2017), cutting tools manufacturing (Foo & Wong 2015), fire-fighters in an emergency (Abidin, Jusoh & Zakaria 2018), and rubber factories (Lim, Lee, Lee & Heng 2018; Mokhtar, Kamaruddin, Khan & Mallick 2007).

Eighteen grasscutters were monitored by Hanidza to determine noise exposure among grass cutters in Malaysia. The workers were exposed to noise level of 84.3-92.3 dBA, (mean 88.0 dBA). The LA_{max} value ranged from 100.4 dBA to 126.5 dBA (mean 109.5 dBA). 27.8% of workers exceeded the permissible level 90 dBA, and 83.3% exceeded the action level 85 dBA. (Hanidza, Jan, Abdullah & Ariff 2013)

TABLE 1. Allowable daily noise exposure duration limit by DOSH

Noise level dBA(A)	daily exposure duration limit	Noise level dBA	daily exposure duration limit
82	16 hours	92	1 hour 35 minutes
83	12 hours 42 minutes	93	1 hour 16 minutes
84	10 hours 5 minutes	94	1 hour
85	8 hours	95	48 minutes
86	6 hours 21 minutes	96	38 minutes
87	5 hours 2 minutes	97	30 minutes
88	4 hours	98	24 minutes
89	3 hours 10 minutes	99	19 minutes
90	2 hours 31 minutes	100	15 minutes
91	2 hours	101	12 minutes

Other studies in Malaysia, such as in the electronic industry (Chee & Rampal 2003), show that noise exposure (39.6%) was cited as the most confronting physical hazards and associated with the self-reported stress, irregular menstruation, and dysmenorrhea among the manufacturing workers. Besides, another study at petroleum refinery roller compacted concrete plant demonstrate that the LAeq noise levels varied between 45.2 dBA and 76.2 dBA during day time, and 42.8-56.0 dBA during night time (Ismail et al. 2008). Moreover, a study at a sewage treatment plant constituted the significant on-site risk, with the equivalent noise level LAeq of 94.2 dBA generated by the applications of pumps for wastewater flow, and blowers for air supply, (Malakahmad, Downe & Fadzil 2012).

Meanwhile, aggressive industrial noise can generally be generated from continuous machinery noise, flow-induced noise, high-speed repetitive actions and working tools associated with generators and electro-mechanical devices in the working area (Yuen 2014). Moreover, all of these noises are existing in the plastic factories; in addition, the occupational noise exposure was found in plastic factories due to the nature of interaction between plastic products and machines that were being used. Thus, it requires proper ans strategical noise management control at the manufacturing company. Therefore, this paper aimed to evaluate the occupational noise exposure in one of the plastic factories in Klang Valley, Malaysia and determine its risk on the potential of noise-induced hearing loss.

METHODOLOGY

STUDY FRAME

Plastic factories are spread worldwide in general and Malaysia in particular, as plastic manufacturing is one of the main contributions to Malaysia economy. Malaysian Plastics Manufacturers Association (MPMA) was contacted to obtain nominations for several factories which the study can be carried out, with later permission was granted to conduct a study from the management of one of the plastics factories at Klang Valley. The factory has six different production lines called (Line A, Line B, Line C, Line D, Line E, Line F), and few other departments such as crushing and packaging department. Each line has a different type of machines that emitted noise, different final products, and vary the number of workers.

OBSERVATION AND EVALUATION OF OCCUPATIONAL NOISE

The study focused on the production areas that were exposed to the daily noise, which covered all production lines, crushing department, packaging department, and the officers' area. The production lines have the largest number of workers and constitute the largest area of the factory area when combined with the crushing and packaging department.

In total, there were three shifts in the factory, the first shift from 08:00 AM until 4:00 PM, the second shift from 4:00 PM until 00:00 midnight, and the third shift from 00:00 midnight until 08:00 morning. The production department's total workers were 213 workers and distributed to three shifts (first shift has 154 workers, second shift has 48 workers, and third shift has 11 workers). The demographic data were randomly collected from 89 workers at the factory from the first shift since 89 number was the minimum number of workers required for the factory to be fully operated.

The noise measurements were measured at 20 points, including all six production lines, in addition to the crushing department, the packaging department, and the officers' area. The noise was measured using Sound Level Meter (SLM)

The measurement points were determined based on the division of each production line. Each line has three sets of machines or three sets of sub-production lines. The average distances between each set of location were 12 meters. Based on the DOSH Malaysia standard, the measurement was taken within one metre from the source using SLM (*Industry Code of Practice (ICOP) for Management of Occupational Noise Exposure and Hearing Conservation 2019,* 2019).

There were several packaging areas in the factory. However, only the primary packaging station was chosen to be measured because the remaining other packaging was closed most of the time and operate only at specified times. The SLM used was 01dBA (Solo Black Edition) model (GDBA-S DUO) class 1. Solo Black Edition is a versatile sound measuring instrument that can adapt to the user's needs. Its architecture can be used for applications ranging from the basic sound level meter to the real-time analyzer.

Total LAeq for the production lines calculated using the total LAeq formula for each line as defined in Equation (1), where Lp is the average Sound Pressure Level (LAeq), *N* = number of sample, L_j is the Sound level that was measured, and n is the number of points that measured at each line.

$$Lp = 10\,\mathrm{LOG}\frac{1}{N}\sum_{j=1}^{N} 10^{\frac{L_j}{10}} \qquad (1)$$

The SLM was calibrated by calibrator of GRAS type 42AB, IEC 60942 class 1. The calibration was performed before each measurement by setting a reference on 114 dB through the sound level meter, and the free field value was less than 0.1 dBA in each calibration. The measurement was conducted for 20 minutes at each point.

RESULTS AND DISCUSSION

89 workers were involved in this study. 11 workers (12.4%) at each production line and packaging department respectively, and six workers each (6.7%) at the crushing department and officers area as shown in Figure 1. Furthermore, the demography detail is shown in Table 2. From the demography result, no female workers work in the crushing department which has high-level noise, (81.8%) of workers in the packaging department are female workers, and (83.3%) of officers are female. Some studies stated that the effects of exposure to occupational noise on male workers are larger than females which is maybe due to male workers are usually working in specific work environments (Nelson, Nelson, Concha-Barrientos & Fingerhut 2005; Seidman & Standring 2010).

None of the workers who work in the crushing department holds a college degree. In contrast, all workers with a college degree are local workers. All workers in crushing department are a foreigner, while all officers are local workers. Moreover, workers mean age was 38.6 years with an age range of 19-65.

Table 3 shows all production lines have a total LAeq less than 80 dBA, with total LAeq 78.76 dBA for line A, 79.01 dBA for line B, 75.80 dBA for line C, 76.90 dBA for line D, 75.3 dBA for line E, and 77.20 dBA for line F. Furthermore, no LAeq more than 80 dBA in all points at all lines, except point 2 at line B with 80.90 dBA.

The packaging department noted the lowest noise level between all areas, with LAeq 64.8 dBA and a maximum value of 69.2 dBA. In contrast, the minimum value was

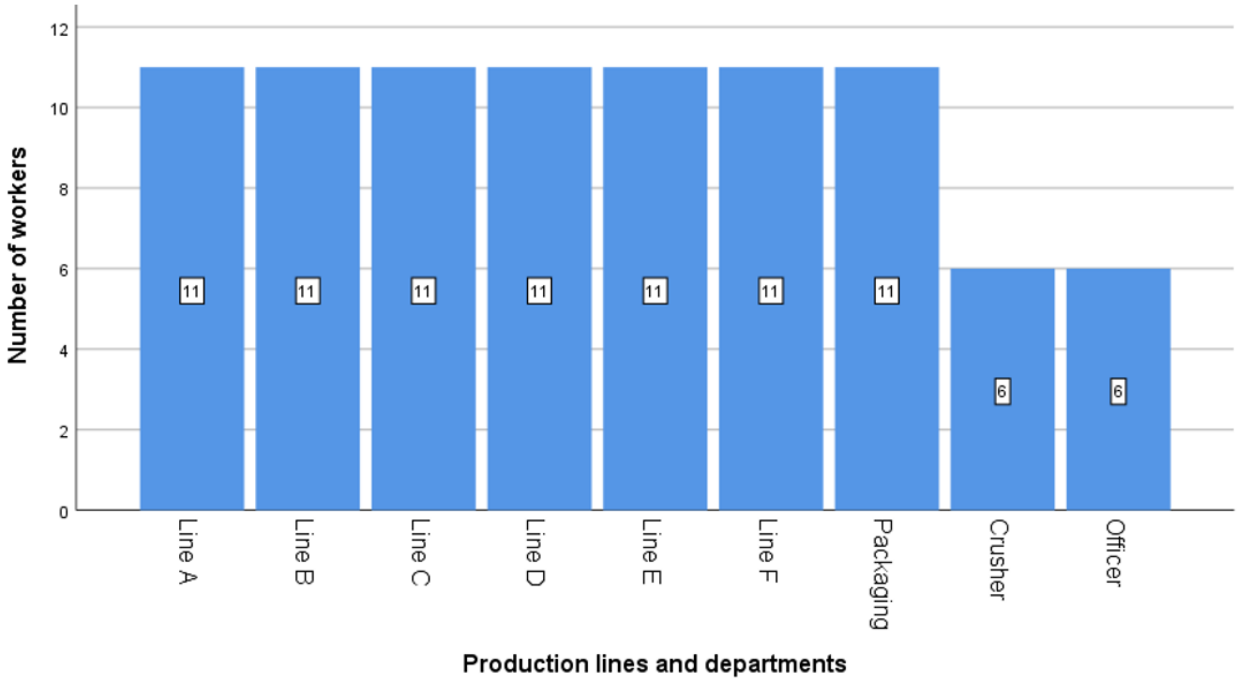

FIGURE 1. workers at production lines and departments

TABLE 2. Cohort characteristics based on the line and department

Location	Total number of workers	Gender		Nationality		Marital status		Education level		Duration of employment	
		Male	Female	Locals	Foreigners	Married	Non-married	Collage degree	Without collage	< 3 years	> 3 years
Line A	11	4	7	7	4	6	5	0	11	6	5
Line B	11	6	5	6	5	4	7	0	11	10	1
Line C	11	4	7	8	3	6	5	3	8	9	2
Line D	11	5	6	6	5	8	3	0	11	9	2
Line E	11	6	5	6	5	7	4	2	9	8	3
Line F	11	6	5	7	4	6	5	0	11	9	2
Packaging	11	2	9	10	1	6	5	0	11	8	3
Crusher	6	6	0	0	6	5	1	0	6	4	2
Officer office	6	1	5	6	0	6	0	6	0	5	1
Total	89	40	49	56	33	54	35	11	78	68	21

59.7 dBA, sometimes the gate between the area of production lines and packaging area are opened, which may explain the increasing level of noise to about 70 dBA.

Besides that, when looking at Table 2 and Table 3, the crushing section was run by male workers due to the nature of the task itself. Thus, male workers in crushing section are exposed with a higher risk of hearing loss. Additionally, all the workers in this department were foreigners which increases their risk of hearing loss if they were not taken care of their working welfare.

As shown in Table 4, there were different tasks at each line and department, and it was clear that crushing section was the noisiest department in the factory, with a maximum value of 105 dBA and LAeq 100.9 dBA. This section has a total of eight workers, six of them are permanent crushing workers, while two workers work as a crusher when needed. All crushing machines produced high level of noise, and this department located not far away from other production lines.

A study at a plastic factory recorded noise level for

TABLE 3. Noise level measurements at all points

Line	Point	LAeq (dBA)	LA_{max} (dBA)	LA_{min} (dBA)	During crushing work
Line A	A1	77.40	82.20	71.70	No
	A2	79.50	86.40	72.90	Yes
	A3	79.10	83.40	72.80	No
	Total LAeq	78.76	84.37	72.50	-
Line B	B1	78.70	90.20	71.80	No
	B2	80.90	92.60	72.20	Yes
	B3	76.20	87.40	71.80	Yes
	Total LAeq	79.01	90.56	71.94	-
Line C	C1	75.00	84.30	71.30	No
	C2	76.40	83.20	71.70	Yes
	C3	75.90	79.80	72.10	No
	Total LAeq	75.80	82.81	71.71	-
Line D	D1	77.00	87.50	71.70	Yes
	D2	77.00	86.90	72.90	No
	D3	76.70	91.70	73.20	No
	Total LAeq	76.90	89.26	72.65	-
Line E	E1	76.90	97.10	70.00	No
	E2	76.00	85.90	69.40	Yes
	E3	75.30	90.20	68.90	No
	Total LAeq	76.12	93.40	69.46	-
Line F	F1	75.20	85.90	71.30	Yes
	F2	77.20	83.50	71.50	Yes
	Total LAeq	76.31	84.86	71.40	-
Packaging	1	64.8	69.2	59.7	No
Crushing	1	100.90	105	93.40	Yes
Officers room	1	66.4	73.6	60.1	No

TABLE 4. Noise level based on tasks at each line and department

Line	Tasks	Noise level LAeq dBA
Line A	Plastic injection moulding	78.76
Line B	Produce the small plastic products (using as a special type of machines)	79.01
Line C	Produce small plastic products	78.60
Line D	Produce the medium plastic parts	75.00
Line E	Produce the medium plastic parts	76.40
Line F	Big machines for large products	75.90
Packaging	Collect the product and package it	64.80
Crusher	Crush some plastic parts to re-use the material again	100.90
Officer Office	Supervisor's room who manages the production lines and other departments and doing some offices works	66.40

two crushing machines and found the average noise level for each one is around 90 dBA (Ezzeddine 2015). Another study found the noise level within two meters from the crushing machine recorded 105 dBA (Shen, Qian & Yu 2016). The factory that was being studied in this paper has several machines in the crushing department that differ in their size and capacity. Nevertheless, on most days, the more massive machine is operated. The machine crushes and breaks old plastic parts to re-use them again in manufacturing. One worker directly feeds the machine with plastic parts within one meter from the machine while the other five workers bring and round the plastic parts to the main crusher. The crushing department has high-level noise due to the nature of the machine, and the workers work close to the noise source.

NOISE MAP AND MANAGEMENT STRATEGIZE

The noise map shows the location of the approximate points at which the noise measured using the SLM device. As shown in Appendix A, the production line A is not connected to the rest of other production lines, meaning that the noise produced in this line was independent noise from the rest of the factory, with LAeq 77.40 dBA, 79.50 dBA, 79.10 dBA according to the sequence of points A1, A2, and A3.

Meanwhile, production lines (B-E) fall into the same working area with different machines, tasks, and final products. As shown in the noise map, the noise level at production line B was 78.70 dBA, 80.90 dBA, and 76.20 dBA for each point with note that line B produces small plastic products (using a special type of machines). Production line C also produces small plastic products and has LAeq 75.00 dBA, 76.40 dBA, and 75.90 dBA for C1, C2, and C3, respectively. The medium plastic parts produced at line D, which has almost the same value for all points with 77.00 dBA, 77.00 dBA, and 76.70dBA for points D1, D2, and D3. Line E has a noise average similar to line D, and both produce medium plastic parts.

For line F, it was in the same area as lines (B-E) but had only two main areas for work. Although line F was the closest production line to the crushing machine area, the measurement shows no significant effect on the values compare to other production lines with the highest and lowest noise level at F1 point with 85.90 dBA and 71.30 dBA, respectively.

The measurements show that the crushing area noted a high noise exposure level, with a maximum value of 105 dA and L*Aeq* of 100.9 dBA. This level of exposure was notably high and hearing loss may occur for workers, especially if the workers do not wear any ear personal protection tools. The regulation of Department of Occupational Safety and Health Malaysia (*Industry Code of Practice (ICOP) for Management of Occupational Noise Exposure and Hearing Conservation 2019* 2019) set the limit time less than 15 minutes for 100 dBA of daily noise exposure.

Noise map and SLM measurements show that no L*Aeq* more than 82 dBA in all points at all lines, except 100.9 dBA at crushing department. In general, the noise level in the factory was within the accepted noise regulation level, which shows a good commitment and responsibility from the employer to produce a safe and satisfactory working environment. This level of noise will not cause hearing loss according to Morioke's study, which stated that noise level of 82–86 dBA did not affect the upper limit of hearing (Morioka et al. 2000).

However, due to the task behaviour, the crushing department was exposed to high noise exposure level of 100.9 dBA. Thus, hearing protection device (HPD) such as ear plug or earmuff with a good dB reduction is compulsory to be worn for a longer period of work. The HPD should have a noise reduction rate (NRR) at 45 dB. With that NRR, the estimated exposure would be almost 82 dBA (Malaysia 2019). Good quality of HPD and a correct way of wearing HPD can help to reduce the risk of the worker towards noise exposure. In Europe, around 20% of workers are exposed to noise during more than 50% of their time working. Furthermore, in the United States, about nine million workers are exposed to time-weighted average sound levels of ≥ 85 dBA. (Zhang et al. 2014). This prolonged noise exposure leads to disorders of the endocrine systems and the nervous, gastrointestinal tract, vascular tone, and impair functions of the vestibular system. Besides that, exposure to noise for a long time is a reason for cardiac and liver disorders. (Baskov et al. 2018)

The management of the factory is recommended to monitor the noise exposure from time to time in order to ensure the workers noise exposure are within the regulation. Furthermore, the management can strategize on crushing rotation schedule, the crusher cannot expose noise level up to 101 dBA for more than 12 minutes (*Industry Code of Practice (ICOP) for Management of Occupational Noise Exposure and Hearing Conservation 2019* 2019). Some workers from the crushing teams moved to continue working at the production lines after completing the crushing task while the crushing machine operated twice a day, with two hours per time, from seven until nine in the morning, and from five until seven in the evening.

Malaysian regulation stated that employer is responsible for the implementation of safe working environment such as noise control plan and program of action are developed, all levels of management and employees are aware of the control measures to reduce exposure to noise and a comprehensive personal hearing protection program. For that, the management also could strategize the implementation of safety regulation at the factory, including conducting random inspection on the compliance of their worker wearing HPD when required. Purchasing quieter machinery also can be a good strategy to minimize the risks from exposure of industrial occupational noise. It can minimize the cost and efforts needed to manage the high-level noise risk. Some countries have begun stating the specifications of the machines that must comply with noise regulations and started to order the manufacturers of the machines to reduce the noise level to the lowest level that can be achieved (Brereton & Patel 2016). Of note, an experimental study found that the noise level on plastic crushers decreases from 156 dB to 84 dB when using an optimized new blade structure. Sound insulation cotton is used to reduce the noise in trade caused by hitting between the crushing chamber and materials. Also, the noise level dropped from 105 dBA to 52 dBA (with cotton) for crushing noise within two meters (Shen et al. 2016).

The governments can encourage the factories to find quieter machinery to reduce occupational noise exposure on workers, besides, to provide comprehensive information on machinery noise levels, initiative for the company who are purchasing a quiet machine and also encourages machines manufacturers to design and optimize more quieter machinery.

CONCLUSION

The occupational noise level in all the factory areas noted with total LAeq less than 80 dBA except the crushing section. It indicated that the factory manages to provide a fair and safe working area, but still need to make some noise measurements using dosimeter to ensure that the factory implement the standard working period of eight hours without any time restriction. However, the crushing department that noted a high occupational noise level which can result to hearing loss problem to the workers if exposed for a longer period. The management of the factory is adviced to make regular audiometric tests for crushers to check their hearing, in addition to monitor the noise exposure at all production lines and departments from time to time to ensure that workers are working within allowable daily noise exposure duration limit following to the regulation. Worker rotation schedule and random check-up on the usage of HPD compliance among the required workers can minimize the risk of noise-induced hearing loss. Furthermore, the management is recommended to consider "Buy Quiet Noise Purchasing Policies" when purchasing their machinery to minimize the risks from occupational noise exposure due to the noisy machines. By having a smart and strategized approach in noise control management, the risk of occupational noise can be reduced, and a safer working environment can be created.

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DECLARATION OF COMPETING INTEREST

None

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Appendix A (NOISE MAP)