Strategic Noise Mapping Prediction for a Rubber Manufacturing Factory in Malaysia

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Abstract. Rubber product manufacturing industry was found with severe occupational noise exposure problems due to improper noise management and lack of reliable noise information at the workplace. Strategic noise mapping provides important information in monitoring the occupational noise. Therefore, a case study was conducted to investigate the current noise exposure circumstances based on the information from the noise map and noise risk zones. The stochastic noise mapping simulation method was applied to predict these maps. Based on the results, most of the regions in the operation area were bounded with a noise contour level of 80 dBA and some small regions were exceeded the noise level of 100 dBA. More than 45 % of mapping area was categorised as extremely high risk and high risk zones. Workers are exposed to the high noise level in this workplace. The management should take immediate action for controlling noise and always supervise their workers in using the hearing protection equipment.

1 Introduction

Malaysia is a leading rubber producer and exporter in the world. According to natural rubber statistic, the total production and consumption of natural and synthetic rubbers were 26,702,000 tonnes and 26,779,000 tonnes worldwide in the year 2015 [1]. Sengupta [2] summarised seven general types of rubber product manufacturing processes, which are tyre manufacturing, tube manufacturing, moulded product manufacturing, extrude/calendared product manufacturing, fabricated product manufacturing, latex based products manufacturing and reclaimed rubber manufacturing processes. Industrial workers are exposed to high noise exposure level during the rubber product manufacturing process. Emadi [3] examined 240 workers from different departments in a rubber factory and found that 63 % had mild to severe hearing problems and 59 % still suffer from tinnitus symptom in this factory. Attarchi *et al.* [4] studied the effect of occupational noise exposure from a rubber factory on the workers' health. This report concluded that high noise exposure level and working shift are additional factors causing hypertension to industrial workers. Those who have hypertension may have the risk of having cardiovascular disease since hypertension is an important risk factor for this disease.

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The occupational noise exposure monitoring is crucial to be implemented in the noisy workplaces in order to minimise the noise exposure diseases. A strategic noise map is important in noise exposure monitoring to provide the information such as hazardous noise exposure area, the pattern of noise distribution and the location of noise source [5-7]. Based on this information, the management could decide the best solution to monitor and control the noise exposure level in their workplaces [8-11]. However, the current industrial noise mapping practice does not have a standardized method in plotting a noise map as reported by Lim [12]. It could affect the noise practitioners making a wrong decision on the noise exposure measurement and noise control strategies. Lim *et al*. [13] emphasized that the strategic noise mapping information should be plotted by considering several important factors, such as the random duty cycles and random movement of machinery, the complex interaction of noise level, and the combination of concurrent and non-concurrent activities. To cope with the current context, Lim [12] has established a stochastic noise mapping simulation method to predict a strategic noise map with the consideration of these important factors.

The rubber product manufacturing industry is important in supporting the economy of Malaysia. Previous studies had found many occupational noise exposure problems in this industry. Therefore, a case study was carried out to study the current noise exposure circumstances. This study adopted the latest noise mapping prediction method to predict strategic noise mapping and noise risk zones. The prediction results are used to conclude the current circumstances and propose appropriate strategies of noise control to minimise the noise exposure level in this workplace.

2   Stochastic noise mapping simulation method

The stochastic noise mapping simulation method was established to predict the spatial and temporal distribution of noise levels in a complex and dynamic working environment [12-13]. This method was developed by using the conceptual knowledge from the random walk and Monte Carlo approaches in the stochastic modelling. This method could simulate the noise level from the static and dynamic noise sources. The random walk approach was applied to simulate the random movement of the dynamic source in a bounded region. The Monte Carlo approach was used to predict the random noise emission level of the machinery based on the probabilities of duty cycles ('On', 'Idling', and 'Off' modes) during the operation period. This method considers the complex interaction of concurrent and non-concurrent activities during the simulation process.

Lim [12] programmed an application using the MATLAB programming software to facilitate this method. Some important inputs are required in this application before the simulation process, such as the information of mapping layout, background noise, the location of barrier and wall, and the machinery' properties. From the previous studies, Lim [12] had concluded that the simulation steps with 1,500 could achieve partially steady or steady value of absolute difference through the comparison of measurement and prediction results. In other words, the prediction results could attain the optimum prediction performance at the simulation 1,500 steps. The outputs from this application are strategic noise map, noise risk zones, standard deviation, probability density function, cumulative distribution function, noise indices and so forth. This method has high accuracy and high reliability in the prediction results. The accuracy of prediction results was less or equal to 3 dBA when comparing with the measurement results.

3   Methodology

Flowchart of this research methodology of this study is shown in Fig. 1. This study is of a noise measurement was carried out in a rubber production factory located at West Malaysia. Firstly, this study obtained information about the manufacturing process from the safety officer in this factory. This information was used to identify the noise hazardous area and the placement of machinery. The dimensions of site layout and the location of machinery were measured using the Distometer after identified the noise hazardous area.
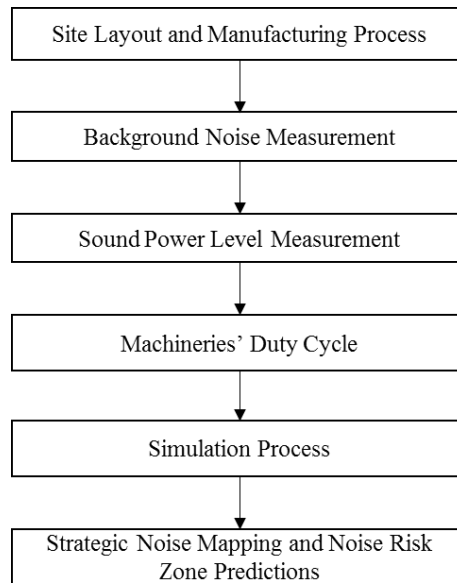
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┌─────────────────────────────────────────┐
│  Site Layout and Manufacturing Process   │
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│      Background Noise Measurement         │
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│      Sound Power Level Measurement        │
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│         Machineries' Duty Cycle           │
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│            Simulation Process             │
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│   Strategic Noise Mapping and Noise Risk  │
│            Zone Predictions               │
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Fig. 1. Flow Chart of Research Methodology

Next, the 3M SoundPro DL-2-1/3 Sound Level Meter (SLM) was used to measure the background noise level and the sound power level of machinery. The height of the measurement was 1.5 m as recommended by the Department of Environment (DOE) planning guidelines [14]. The background noise level was conducted in the early morning before the work starts and the measurement was recorded in 30 minutes. Then, the sound power level of each machine was measured after the work starts. The measurement method was referred to the British Standard BS EN ISO 3744:2010 [15]. The duty cycles of each machine, including the 'On', 'Off' and 'Idling' modes, were stated by the safety officer to reflect the working operation of machinery in this working area.

All these information from the measurement were used as the input for the noise simulation tool to predict the strategic noise mapping and noise risk zones. The simulation process was implemented 1,500 steps as the optimum step, which was recommended by Lim [12], to achieve high accuracy and high reliability of the prediction results. This simulation tool plotted the noise contour levels with the interval of 5 dBA and also estimated the percentages for different noise risk zones. Lastly, this study concluded the noise circumstances in this work and recommended further action to minimize the risk of occupational noise exposure.

4 Manufacturing process and noise mapping prediction results

4.1 Rubber product manufacturing process

A case study was carried out on a rubber manufacturing factory which specifically produced industrial rubber products, fabricated rubber products and miscellaneous rubber specialities. During the measurement, this factory was producing the conveyance rollers for office automation equipment, such as the photocopy machine. The moulded manufacturing process for the production of conveyance roller is illustrated in Fig. 2.
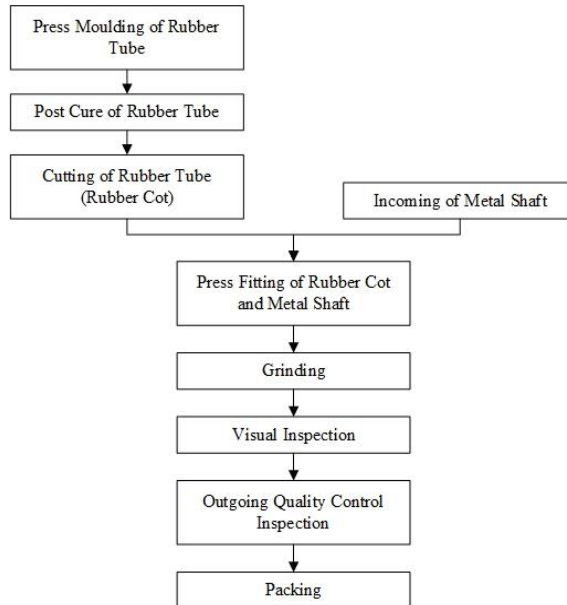
Fig. 2. Manufacturing Process of Conveyance Roller

This process originally refers to the selected factory. Firstly, the raw material was placed into the press moulding machine to force the rubber filling into the cavities and compressing it into a tube shape. In the post curing process, the rubber tube was put into a curing oven under high temperature. This process was purposely done to enhance the shaping and performance properties of mould rubber tube. After that, the rubber tube was removed from the curing oven and cooled down to room temperature. The rubber tube was cut into the required length and named as rubber cot. Then, the cot was pressed and fitted into the metal shaft. Grinding, visual inspection and outgoing quality control inspection play the role to ensure the conveyance rollers are under a good quality control without any product deficiency. High noise level was emitted during the moulding, curing and cutting process. In the last process, the rubber product was packed according to the quantity as requested by their clients and the product was delivered to their clients.

4.2 Workplace layout and sound power level

The measurement was conducted in a rubber production factory at the rubber moulding, curing and cutting area as shown in Fig. 3. The dimensions of the mapping area were 60 m x 36 m and the background noise was 53.9 dBA. It was the noisiest area because the workers used air guns to demould the rubber product from the mould and clear the dirt on

the rubber product. The sound power levels, machine dimensions and duty cycles were listed in table 1. A total of 18 air blow guns were used in the demoulding and clearing activities during the measurement period. The highest sound power level was obtained 115.2 dBA at the machines with the labels of S38 and S39. All these machines had released high noise levels by compressing and blowing air to the subject.
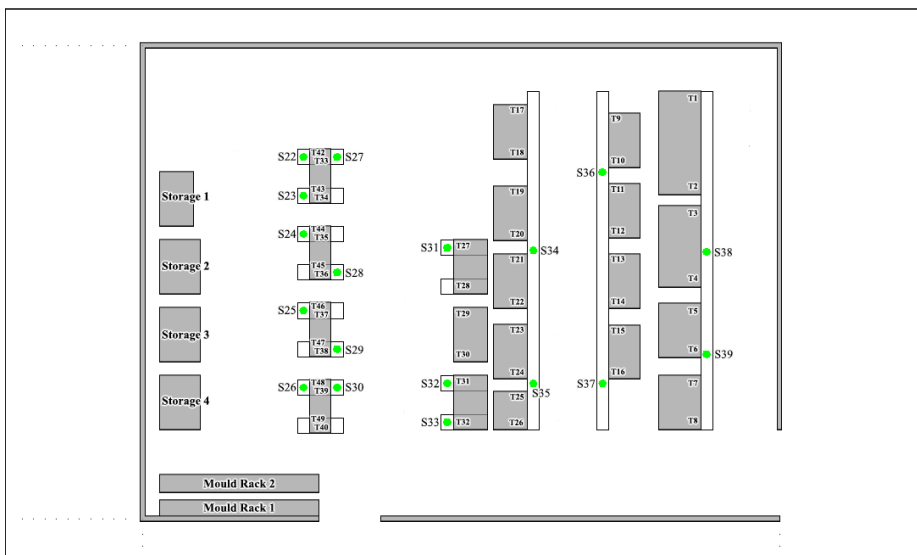

Fig. 3. The layout of Rubber Moulding, Curing and Cutting Area.

Table 1. Sound Power Levels.

Label	Machine	L_w, dBA	w, m	d, m	P_{on}	P_{off}	P_{iddle}
S22	Air Blow Gun	111.0	0.15	0.15	0.1	0.9	0.0
S23	Air Blow Gun	111.0	0.15	0.15	0.1	0.9	0.0
S24	Air Blow Gun	111.0	0.15	0.15	0.1	0.9	0.0
S25	Air Blow Gun	111.0	0.15	0.15	0.1	0.9	0.0
S26	Air Blow Gun	111.0	0.15	0.15	0.1	0.9	0.0
S27	Air Blow Gun	110.1	0.15	0.15	0.1	0.9	0.0
S28	Air Blow Gun	110.1	0.15	0.15	0.1	0.9	0.0
S29	Air Blow Gun	110.1	0.15	0.15	0.1	0.9	0.0
S30	Air Blow Gun	110.1	0.15	0.15	0.1	0.9	0.0
S31	Air Blow Gun	111.0	0.15	0.15	0.1	0.9	0.0
S32	Air Blow Gun	111.0	0.15	0.15	0.1	0.9	0.0
S33	Air Blow Gun	111.0	0.15	0.15	0.1	0.9	0.0
S34	Air Blow Gun	113.8	0.15	0.15	0.1	0.9	0.0
S35	Air Blow Gun	113.8	0.15	0.15	0.1	0.9	0.0
S36	Air Blow Gun	110.7	0.15	0.15	0.1	0.9	0.0
S37	Air Blow Gun	110.7	0.15	0.15	0.1	0.9	0.0
S38	Air Blow Gun	115.2	0.15	0.15	0.1	0.9	0.0
S39	Air Blow Gun	115.2	0.15	0.15	0.1	0.9	0.0

Note: L_w, sound power level; w, the width of the machine; d, depth of machine; P_{on}, the probability of on mode; P_{off}, the probability of off mode; P_{idle}, the probability of 'idling' mode;

4.3 Strategic noise mapping and noise risk zone results

The main activities have been discussed previously. The noise was produced when the workers used air guns to demould the rubber product from the press moulding machines, and to clear the dirt on the rubber product after the cutting process. The cutting process simply used knives as the tool to clear the irregular shape and cut the rubber product into the required length. A total of 72 workers were working in this area as shown in Fig. 3. Each worker was provided with an earplug by the management. In the observation, all workers were wearing earplug regularly because this workplace was too noisy and annoying during the working period. Eighteen air guns were used by the workers during the measurement. The air gun was operated only for a short moment. According to the information provided by the safety officer, the duty cycles of the air guns were 10 % on and 90 % off modes. This case study involved static noise sources, and the usage of each air gun was random and depended on the behaviour of workers.

In this case, the stochastic noise mapping simulation method applied the Monte Carlo approach to predict the noise mapping data. It is also implementing the stochastic noise mapping simulation process to simulate concurrent and non-concurrent activities in this area. The strategic noise map was predicted by considering concurrent and non-concurrent activities, as presented in Fig. 4. Apparently, the operation area was bounded with a noise contour level of 80 dBA. Also, the highest noise level contour was 100 dBA, which was obtained for ten small regions in the operation area. Neighbouring areas nearby the operation area were found to have approximately less than 75 dBA. The noise level was high in the operation area even though each machine was only operating at 10 % on mode. Notably, the noise polluted area can increase if the machines' on mode is increased or if more air guns are involved in this activity.

Stochastic noise mapping simulation method plotted the operation area to contain low risk, moderate risk, high risk and extremely high risk zones, as in Fig. 5. Extremely high risk and high risk zones were the major risk criteria in this area (see Table 2). Extremely high risk and high risk zones were covered 24.5 % and 21.1 % on this mapping area. Three risk zones, from tolerable risk to moderate risk, were also predicted in the adjacent areas beside the operation area. About 26 % of the mapping area was categorised as tolerable risk zone. Therefore, the hearing protection must be provided because of the existence of a potential risk to noise exposure in this operation area.

Table 2. Percentage of Noise Risk Zones.

S, %	TR, %	LR, %	MR, %	HR, %	EHR %
0.0	26.0	14.8	13.6	21.1	24.5

Note: *S*, safe; *TR*, tolerable risk zone; *LR*, low risk zone; *MR*, moderate risk zone; *HR*, high risk zone; *EHR*, extremely high risk zone;
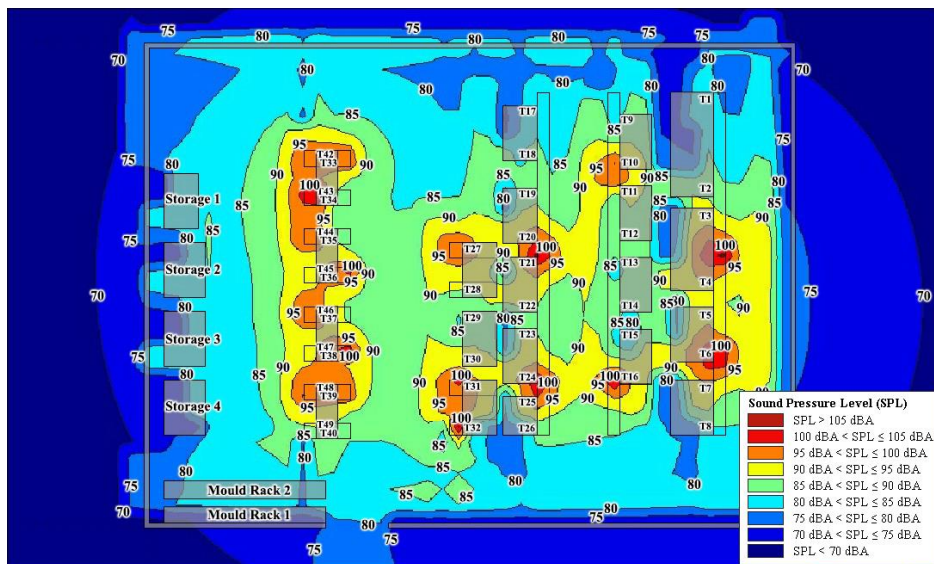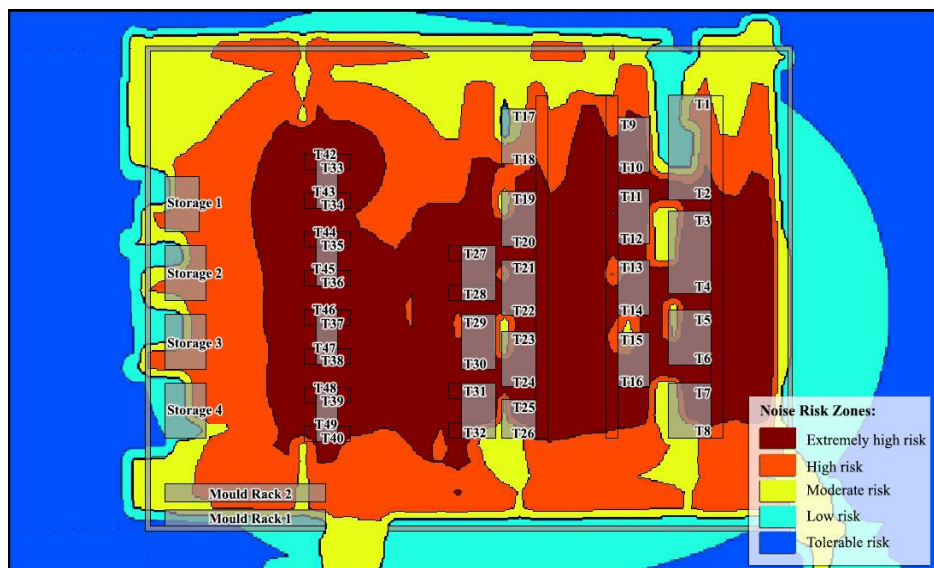
Fig. 4. Strategic Noise Map.

Fig. 5. Noise Risk Zones.

5 Discussion and conclusion

This case study has found with high noise exposure level at the selected workplace. This study supports the findings from previous studies [3-4], where workers have a high risk of hearing and health problems if excessive exposure to high noise level at the rubber product manufactory. Next, the noise mapping information from this study is important for the noise practitioners to refer and decide the strategy for implementing the personal noise exposure measurement. The predicted result shows high noise exposure level nearby the

machines in the operation area. They could select the operators from these regions to assess the daily noise exposure level.

The management had provided an earplug for each worker who works in this area. Although the workers were wearing the earplug during the operation period, the management must ensure that the noise reduction rating of earplug is sufficient to reduce the noise exposure level. This is due to some regions near to the machines are exceeded the permissible limit of 90 dBA, as mentioned in factories and machinery act 1989 [16]. The strategic noise map and noise risk zones from this study could be used as noise information and posted at the workplace. So, the workers could self-recognize the noise risk from this information, and always aware to take the preventive action, such as wearing the hearing protector regularly at their workplace. Besides, the management should decide an effective noise mitigation plan at this workplace. For example, they could design a noise barrier and erect it nearby the machines to reduce the noise exposure level and minimise the noise exposure problems.

In conclusion, the rubber product manufactory in this study is a noisy workplace and the management must take an immediate action to minimise the noise exposure risk and protect their workers from overexposing to the high noise level. It is recommended to conduct more studies in this industry in order to obtain more noise information under different operating processes and different noise exposure circumstances.

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