Noise Exposure Among Machine Operators on Construction Sites in South Johor, Malaysia

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Abstract. Machine’s operators expose to excessive noise in the workplace that may lead to hearing damage. This study investigates construction machine operators’ noise exposure levels for eight hours or time weighting averages (TWAs), relationship TWA with machine noise emission level, the practices of using hearing protection devices (HPDs) and working in a closed machine cab. Heavy and non-heavy machine operators at five construction sites involved with excavation and piling activities were selected and measured by using dosimeters. 68% of operators were exposed to TWA of 85 dBA and 18% of the operators exceeded the permissible limit. 40% of operators work inside a closed machine cab, 18% wear earplugs and only 16% practiced both. Both operators of heavy machines (except excavators) and dump trucks are exposed to TWA > 90 dBA if they work in open machine cabs. The TWAs were found well correlated (r=0.41) with the machine noise emission, which ranged between 84 dBA to 125 dBA. Furthermore, this study proposes the type of HPD for the operators of typical machine to minimise the risk of hearing loss.

Introduction

Occupational exposure to excessive noise in the workplace leads to hearing damage. Of the construction workers around the world, 74% suffered hearing loss\(^1\) and it can be short term or long term. Short term is temporary loss lasting from a few seconds to several days while long term leads to serious hearing loss that causes the habit of shouting, and decisions making is affected\(^2\). Previous studies have shown that hearing loss leads to a high compensation cost paid annually by the government in Sweden and the US, approximately US$100 and US$200 million, respectively\(^3,4\).

The employment of many high noise emission machines, including heavy machinery, in many stages of construction\(^5,6\) lead to high noise exposure to workers. Some studies related high noise exposure levels among construction workers with high noise emissions of heavy machines\(^7-9\). Research stated that at the 85 dBA TWA limit the risk of developing hearing handicap is as much as 8% while at 90 dBA TWA it is as much as 18%. The margin of safety is 75 dBA TWA and the border limit that does not give any increased risk of hearing handicap is 80 dBA\(^10\). The use of quiet machines is the preferred way while wearing an HPD must be the last approach if all the other methods cannot be applied\(^11\).

Occupational Safety and Health Administration\(^12\) suggested that HPDs with sufficient noise reduction rating (NRR) should be worn either in the form of single or double protection; single protection with earplugs NRR20 to NRR33 and double protection with both earplugs and earmuffs. Besides sufficient NRR, only the regular use of HPDs can prevent the workers suffering from noise-induced hearing loss (NIHL)\(^13\). Working in a machine with an insulated cab further reduces the operator’s exposure to engine noise\(^14\).

This study investigates the construction machine operators’ noise exposure levels for eight hours or time weighting averages (TWAs) exceeding the permissible limit, relationship TWA with machine noise emission level, the practices of using hearing protection devices (HPDs) and working in a closed machine cab, and proposes the type of HPD for operators of typical machine in order to
minimise the risk of hearing loss. The type of machines are divided into two categories; heavy and non-heavy machines; while the operators were divided into two categories: operators working in equipment with a cab to shield them from engine noise and and in equipment without a cab.

Methodology

**Noise exposure levels.** Fifty-six machine operators in five construction sites around Johor Bahru in South Malaysia were selected (Table 1). Noise levels generated one metre from the machines at four points (left, right, front, and rear of the machine) were measured using a sound-level meter, and the average value of noise emission levels, $L_{eq}$ were calculated. The machine that exceeded 80 dBA at one metre was then chosen, and its operator underwent noise monitoring using a dosimeter. Data was then analysed using the Quest Suite Professional II software to obtain 8-hour time weighted average sound levels or TWA, $L_{peak}$ and $L_{max}$. In addition to the measurement, the use of hearing protection device and the practice of working in closed cabin were observed among operators.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Activity</th>
<th>Machines and number of machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Excavation</td>
<td>Bulldozer (1 no), Roller compactor (1 no.), Excavator (1 no), Dump truck (6 no), Excavator (4 no)</td>
</tr>
<tr>
<td>B</td>
<td>Pile driving</td>
<td>Backhoe loader (1 no.), Crawler crane (1 no.), Mobile crane (1 no.), Pile Driver (6 no), Excavator (2 no)</td>
</tr>
<tr>
<td>C</td>
<td>Excavation</td>
<td>Bulldozer , Dump truck (3 no), Excavator (2 no)</td>
</tr>
<tr>
<td>D</td>
<td>Excavation</td>
<td>Bulldozer (3 no), Dump truck (13 no), Excavator (3 no), Roller compactor (1 no)</td>
</tr>
<tr>
<td>E</td>
<td>Excavation</td>
<td>Excavator (2 no), Dump truck (2 no), Backpusher (1 no.), Roller compactor (1 no.)</td>
</tr>
</tbody>
</table>

The measured TWAs of all operators were compared with the exposure limit specified by Factory and Machinery Regulation (FMR) 1989 [15]. The regulation requires all workers exposed to noise levels exceeding 85 dBA for eight hours to be protected and no employee shall be exposed to noise levels exceeding the permissible limit of 90 dB (A), 115 dBA at any time ($L_{max}$), and the peak level of 140 dB.

**Propose the suitable HPD.** Suitable HPDs for operators exposed to 85 dBA are estimated by determining the protected TWA (PTWA) after engaging with HPDs with specific NRRs. The specific NRRs are obtained from Table 2 [11]. By selecting the suitable NRR, Eq.1 and 2 are used to obtain the PTWA to fall below 85 dBA. Fifty per cent is introduced to take into account the improper fitting of the earplugs or earmuffs and conflicts with other personal protective equipment. Except for NRR20, the value of NRR used in this study is the average value of the proposed NRR.

**Table 2: TWA and NRR recommended**

<table>
<thead>
<tr>
<th>TWA[dBA]</th>
<th>Proposed value[dBA]</th>
<th>NRR</th>
<th>NRR recommended in the study [dBA]</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 – &lt;90</td>
<td>20 or less</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>90 – &lt;95</td>
<td>20–30</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>95 – &lt;100</td>
<td>25–35</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>100 – 105</td>
<td>30 or more*</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

*Maximum in the market is NRR33.

Single protection with earplugs only:

$$PTWA(dBA) = TWA \text{ in } dB(A) – (NRR – 7)\times50\%$$

Double protection with both earplus and earmuffs:

$$PTWA \text{ (dBA)} = TWA \text{ in } dB(A) – \{(NRR – 7)\times50\%+5\}$$
Results and Discussion

Noise exposure level among operators. The range of TWA for 56 operators was between 73.1 dBA and 102.3 dBA with the average TWA at 88 ± 6.3 dBA. The lowest TWA was experienced by an excavator operator working inside a closed cab (73.1 dBA), while the highest noise was 102.3 dBA, experienced by bulldozer operators working without a cab. Sixty-eight per cent of operators have TWAs equal to or exceeding 85 dBA. Out of them, 32% suffer from noise exposure exceeding 85 to 89 dBA while 36% are exposed to noise levels above the government permissible level of 90 dBA (Fig. 1). 16% operators, including a pile driver operator, exceeded Malaysia’s permissible level of both noise exposure (90 dBA) and sound level (115 dBA, at any time). In this case, replacement with quieter machines will be more meaningful, while the use of earplugs and earmuffs is the last resort of management.

Relation between TWA and Noise emission. The machines noise emission levels are in the range of 84 dBA to 125 dBA, which is higher than the previous ranges during excavation studied by other research[6]. The TWAs were found to correlate well \((r = 0.41)\) with noise emission levels which confirm the previous research[7,8,9]. The trend curves that fitted the measurement with noise emission data are linear regression with \(R^2 = 0.229\), \(p < 0.005\).

Ear plugs wearing and the practice of using closed cab. Fig 2. shows the percentage of operators of each type of machines, and percentage of those worked in closed cab and with earplugs. 41% of operators work inside a closed cab, 18% wear earplugs, and only 16% employed both. Dump trucks were the most machines available in excavation work with non of them worn the earplugs and only 16\%(N=9) operators work in closed cab. Most of the pile driver operators employed earplugs as a result of awareness of the risk of noise to workers’ health. Bulldozer \((N=5)\), dump trucks \((N=15)\) and roller compactor \((N=3)\) operators that work without a closed cab exceeded 90 dBA which could have risk of developing hearing handicap as much as 18% (Fig. 3). While, pile drivers \((N=6)\) and the dump truck operators \((N=9)\) that worked in a closed cab had TWAs exceeding 85 dBA. On the other hand, excavator operators working in both closed and open cabs had average noise exposure of less than 85 dBA. Comparison among the sites showed that except Site E, operators on Sites A, B, C, and D had average TWAs exceeding 85 dBA.
Propose types of HPD. Figure 4 shows the type of HPD and NRR for operator of each machines’ type that were calculated based on the average TWA using Eq 1 and Eq 2. Only bulldozer’s operators should be protected using both earplugs and ear muffs while other machines’ operators including dump truck, pile driver’s operators only need single protection using earplugs. The use of cabs managed to decrease the NRR required by the operators. Thus, NRR20 earplugs worn by the pile driver operator work in closed cab are sufficient to reduce the risk of receiving TWAs exceeding 85 dBA.
Fig. 4: Operator’s working condition, TWA and recommended HPD for typical machine

**Conclusion**

In conclusion, 68% of construction machine operators are exposed to TWAs of 85 dBA (8% of developing hearing handicap) and 18% fall under the category of exceeding the permissible limit set by the Malaysian government (18% of developing hearing handicap). 41% of operators work inside a closed cab, 18% wear earplugs, and only 16% practised both. Those who wore earplugs were mainly operators from one site that involved with piling activities as a result of awareness of the risk of noise to workers’ health by the management team. Heavy machines operators (except excavators) and dump trucks operators are exposed to TWA > 90 dBA if they work within an open cab. The TWAs of the operators were found well correlated (r=0.41) with the noise emission levels of the machines, which ranged between 84 dBA to 125 dBA. Thus, besides piling operations, bulldozers and dump trucks that emitted high Lw, it’s operators should always wear HPD and work in a closed cab to avoid the engine noise. Furthermore, this study proposes the type of HPD for the operators of typical machines to minimise the risk of hearing loss.

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**References**