Presentation of a Model to Identify Dominant Noise Source in Agricultural Sector of Sugarcane Industry

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ABSTRACT

In agriculture, people are exposed to numerous risks including exposure to various chemicals and physical agents like noise in this section. In this paper a model is proposed to identify the dominant noise source in the agricultural sector of sugarcane industry. We desired to recommend an index that can help us identify the sources deserving attention for sound control measures in the agricultural sector of sugarcane industry in southern Iran. For this purpose, the parameters considered to be the most important on the potential damage of noise were sound level, duration of exposure and the number of people exposed to noise. For measuring the sound pressure level in the ear area of operators, first a list of all machinery used in farming operations of the sugar cane industry was obtained from the relevant management. Then they were categorized into different groups based on the model and, the year made. A properly functioning machine was selected in each group.ISO5131:1996 was used to measure the operator exposure for this group of equipment. They were placed in the fixed state before measuring. There was not any obstacle and reflective vertical surfaces within 20 meters around them, and they were placed on a flat surface (ISO, 1996).When measuring noise, the cabin door and windows of machines that have a cab were closed completely and if there was a ventilation system, it was operated with maximum power and motor rotation. Using the basic acoustic knowledge, a formula has been proposed as an index of dominant noise source in the model. DSI is single-number quantity, higher the index indicates higher occupational noise risk. Index values for harvester (caseIH7000), tractor(Ferguson8160),tractor (Ferguson399), bulldozer(Caterpillar D8N), tractor (Ferguson285), grader (CaterpillarG14), scraper (V300PH), loader (Caterpillar90L) was 132.7, 122.7, 126, 105.6, 129.8, 129.8, 101.7, 101.7, 99.1 and 118.4 respectively. Results show that harvester is the major noise source within various types of farm machinery in agriculture part of sugar cane industry in Khuzestan. Using this model is easy and fast. It is applicable on similar parts of agriculture industry and also offers valuable information for prioritizing noise control measures. For preparing the model, we tried to identify and select the important factors of main sound risk correctly. The Index presents the practical, scientific, simple and fast solution for occupational hygienists and other relevant specialists. The results will be unreliable if not all of the important influential factors involved in selecting the main source are considered.

Key words: Dominant Noise Source; Agriculture machinery; Sugarcane industry;

Introduction

Emergence of technology in the workplace has brought along various hazardous agents, such as physical and chemical agents. Noise is one of the most common physical hazardous agents in occupational health. Noise exposure has been reported to induce tinnitus, hypertension, interference with oral communication, fatigue, performance reduction, temporary and permanent hearing loss, vasoconstriction and other cardiovascular impacts [2,5]. Farm workers experience one of the highest rates of hearing loss among all occupations [7]. This is caused in part to the many potential sources of loud noise on the farm: tractors, combines, grinders, choppers, shotguns, conveyors, grain dryers, chain saws, etc [7]. In recent years, the characteristics of
agricultural equipment noise have been the subject of various studies [3]. The studies of NIOSH show that the amount of sound produced by types of tractor and combine ranged respectively between 73-120 and 80-102 dBA [6]. This study was conducted to assess the noise danger of farm machines. We desired to recommend an index that can help us identify the sources deserving attention for sound control measures in the agricultural sector of sugarcane industry in southern Iran. For this purpose, the parameters considered to be the most important on the potential damage of noise were sound level, duration of exposure and the number of people exposed to noise. But despite the simplicity involved in its calculation, the proposed index can be a useful guide for prioritizing and selecting the dominant noise source in an industry like agriculture. Furthermore, doing this survey may be necessary because 84,000 hectares of Khuzestan land are under sugarcane cultivation with hundreds of pieces of agricultural machinery, and hundreds of people are exposed to high level noise at work that may be a risk to their health. The aim of the study is to approach a model to quickly identify the dominant noise source in this sector. For this intended purpose, an index was presented as dominant sound source index (DSI).

Materials and Method

Four factors were selected as the most effective elements on occupational noise risk, including the number of exposed people, the number of noise sources, the availability of driver’s cabin and the annual personal exposure for each group of agricultural machinery. Using basic noise theories and the above effective elements, the following equation was developed by the authors:

\[
DSI = 10 \log \left( P_n \times S_n \right) + \left( L_{EP, \text{year}} + NR_{\text{cabin}} \right) \tag{1}
\]

DSI: Dominant Source Index (dBA),

\(P_n\) is the number of operators exposed to each machine noise, \(S_n\) is the number of machines at each group, \(L_{EP, \text{year}}\) is the annual time weighted average noise exposure (dBA) and \(NR_{\text{cabin}}\) is the cab protection factor (the minimum noise reduction by the cab) (dBA). The \(NR_{\text{cabin}}\) with no cabin is zero and with a cab is 5 dBA.

The number of noise sources and exposed operators are converted into logarithms (with their reference number assumed to be unity) to make it possible to add the second and third terms of the equations that characterize the noise level and duration of the exposure. To support the idea the following equation, which is typically used for the total sound pressure level, is presented.

\[
LP_T = LP + 10 \log( N ) \tag{2}
\]

Where \(N\) is the number of noise source with sound pressure level of \(LP\) [1].

The daily amount of noise exposure was calculated from Equation 3 (i.e. the cumulative amount of noise exposure per day).

\[
L_{EP, d} = 10 \log \left( \frac{1}{8} \sum_{i=1}^{n} t_i \times 10^{LP_i/10} \right) \tag{3}
\]

This equation applies to data in which the \(t_i\) is in units of hours and the sum of \(t_i\) is 12 hours. \(LP_i\) is sound pressure level for the \(i\)th source.

The annual individual cumulative amount of noise exposure is as follows;

\[
L_{EP, \text{year}} = 10 \log \left( \frac{1}{2080} \sum_{i=1}^{n} t_i \times 10^{LP_i/10} \right) \tag{4}
\]

Where 2080 is the total exposure hours in a year. As before \(t_i\) in Eqn. 4 is in units of hours and the sum of \(t_i\) is 12 hours. Equation 4 adjusts the annual noise exposure of individuals in a given group (such as the sugarcane industry) to the annual exposure time of workers in epidemiologic studies upon which the 85 dBA limit is based.

In the above equation, variable (\(LP\)) is the sound pressure level (dBA) in the worker’s ear area for his work time (\(t_i\)). The background noise (dBA) at the times in which operators did other activities (except for their main job) in a year is also included in the calculation. All operators of the different machinery groups have worked the 12-hour daily shift during the year. Each operator is expected to have 20 working days during a month. Their method of shift work rotation was work 12 hours and rest 24 hours.

For each operator, the 12 hours daily work was divided into an eight hours work engagement and 4 hours preparation duties. This pattern means during each shift 8 hours noise source exposure and 4 hours background noise exposure exists. In this paper the duration of exposure to machine noise is identified by \(t_1\) and the duration of exposure to background noise is shown by \(t_2\). The average number of working days during a month were 20 in every case.

According to measurements, operators are usually exposed to background noise of 60 dBA. The number of months during the year that the machinery is used depends on the type of machinery (Table 1). According to Table 1, the duration each machine’s work and rest can be calculated during the year. Some other specifications of the tested agricultural machines are also prepared for comparison (Table 2). The cabin protection factor or the minimum noise reduction by the cab (\(NR_{\text{cabin}}\)) was assumed to be 5dBA, something that has been shown in other studies to vary [7]. Using this factor, the cabin effect is removed and all machines are treated likewise.

One of the quantities that must be determined for calculating the Dominant Source Index is cumulative
exposure of individuals to noise per year ($L_{EP, \text{year}}$, Equation 4). For measuring the sound pressure level in the ear area of operators, first a list of all machinery used in farming operations of the sugar cane industry was obtained from the relevant management. Then they were categorized into different groups based on the model and, the year made. A properly functioning machine was selected in each group. ISO5131:1996 was used to measure the operator exposure for this group of equipment. They were placed in the fixed state before measuring. There wasn’t any obstacle and reflective vertical surfaces within 20 meters around them, and they were placed on a flat surface [4]. When measuring noise, the cabin door and windows of machines that have a cab were closed completely and if there was a ventilation system, it was operated with maximum power and motor rotation. The sound pressure level of environment was be at least 10 dBA lower than the sound pressure level of the machine in accordance with the standard and wind speed was less than 5 m/s when measuring noise.

A Cell-440 Sound Level Meter and CEL-285 Calibrator were selected according to the above standard and the requirements of IEC 651 and IEC942. The microphone was positioned on the two sides of the operator’s seat at a distance 25 cm of the operator’s ears. All the measurements were done on the A scale and SLOW speed [4]. Three readings were performed at each of the two positions of the microphone. It is noticeable that the difference between readings were less than 3dBA, then the average reading was calculated and considered as representative of the Lpi.

An example of the calculated Dominant Source Index for the Case 7000 harvester using the information gathered in Table 1 and 2 is shown below using Equation 1:

$$D S I = 10 \log \left( \frac{P_n \times S_n}{L_{EP, \text{year}}} \right) + \left( L_{EP, \text{year}} - \frac{NR_{\text{cabin}}}{100} \right)$$

(Eqn.1)

According to Table 1, the number of noise sources from this model in the tested field is 26 and the number of operators for this particular machine is 94 according to Table 2. Since the machine has a driver’s cabin the $NR_{\text{cabin}}$ is set to be 50 dBA in the equation. The amount of individual cumulative annual noise exposure is also calculated using Equations 3 and 4. The driver's machine noise exposure was 98 dBA while the driver's background noise exposure was 60 dBA, therefore we have:

$$L_{EP, \text{year}} = 10 \log \left( \frac{1}{200} \sum_{i=1}^{26} 5 \times 20 \times 5 \times 10^7 \times (5 \times 20 \times 4) \times 10^7 \right) = 93.85 \text{ dBA}$$

Therefore:

$$D S I = 10 \log(94 \times 26) + 93.85 + 5 = 132.7$$

Results:

Some of the variables required to calculate the Dominant Source Index are presented in Table. Sound pressure level was measured at the two sides of the operator’s seat who worked on machines with sound pressure levels were above 85 dB A. The noise levels can be changed in proportion to the motor power and the presence and absence of the cab. The correlation in sound pressure levels with motor power is particularly noticeable within the three tractors. Bulldozer created the highest exposure level due to their high power and lack of a cabin; while the loader showed the lowest sound pressure level mean owing to having cab and its engine type.

The total work hours of the operators in a day were estimated to be 12 hours of which eight hours were on average exposed to the machine noise and the rest; they were exposed to background noise while doing some other activities. Their method of shift work rotation was work 12 hours and rest 24 hours. The number of month of usage for machinery depends on the type of its application. For example, the Harvester was used five months in a year in the harvest time. Bulldozers and scrapers are machines that got used only in the planting season, while all types of tractors, graders and loaders are operated at any time of the year. After calculating $t_1$ and $t_2$, it can be seen that machines like tractors, graders and loaders that are used during the whole year have more exposure time than harvester, scraper and bulldozer. $L_{EP, \text{year}}$ for operator of tractor 8160 is higher than the others due to the lack of a cab, more power 200HP and the operator’s exposure for the entire year. The $L_{EP, \text{year}}$ results indicate that $NR_{\text{cabin}}$ has the significant impact on the exposure amount. Tractors 8160 and 399 had less power than the harvester, but the noise levels ($LP_1$) for harvester, tractor 399 and tractor 8160 were measured 98 dBA, 98 dBA and 103 dBA respectively.

The results of DSI will be more realistic than the traditional combined noise exposure level. For example, the number of machines and the annual exposure to tractor 8160 noise was higher than the harvester, but the harvester was considered to be the most dangerous noise source due to the greater number of operators and of course the relatively high noise emission. The higher the Dominant Source Index the higher occupational noise danger.

Table 2 has the valuable information was listed by increasing values of $LP_1$, then you can find the effect of exposure times by the $L_{EP, \text{year}}$ values; and also the effect of $P_n$ and $S_n$ for prioritizing the control of noise sources.

If just $P_n$ or $S_n$ is used to calculate DSI, the results will vary. Considering $S_n$ when calculating DSI cause Tractor 8160 has the highest score. But by using $P_n$, Harvester 7000 will also have the highest DSI.
Table 1: Hours, days and months that the machinery operators are exposed to the background and machine noise

<table>
<thead>
<tr>
<th>Machine's Name</th>
<th>Model</th>
<th>Number of machines presents in the tested field</th>
<th>Job titles that drive the machine</th>
<th>Working hours during a day (12 hours)</th>
<th>Number of months that the machine is used in a year (number of months that workers are exposed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Season (5 months)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Permanent (12 months)</td>
</tr>
<tr>
<td>Harvester</td>
<td>CASE 7000</td>
<td>26</td>
<td>Harvester mechanic operator</td>
<td>8</td>
<td>4 ×</td>
</tr>
<tr>
<td>Tractor285</td>
<td>Ferguson MF</td>
<td>39</td>
<td>Agriculture machinery driver</td>
<td>8</td>
<td>4 ×</td>
</tr>
<tr>
<td>Tractor399</td>
<td>Ferguson MF</td>
<td>29</td>
<td>Road construction machinery driver</td>
<td>8</td>
<td>4 ×</td>
</tr>
<tr>
<td>Tractor8160</td>
<td>Ferguson MF</td>
<td>23</td>
<td>Road construction machinery driver</td>
<td>8</td>
<td>4 ×</td>
</tr>
<tr>
<td>Loader</td>
<td>Caterpillar 90L</td>
<td>3</td>
<td>Road construction machinery driver</td>
<td>8</td>
<td>4 ×</td>
</tr>
<tr>
<td>Bulldozer</td>
<td>Caterpillar D8N</td>
<td>4</td>
<td>Road construction machinery driver</td>
<td>8</td>
<td>4 ×</td>
</tr>
<tr>
<td>Grader</td>
<td>Caterpillar G14</td>
<td>3</td>
<td>Road construction machinery driver</td>
<td>8</td>
<td>4 ×</td>
</tr>
<tr>
<td>Scraper</td>
<td>V 300 ph</td>
<td>7</td>
<td>Road construction machinery driver</td>
<td>12</td>
<td>×</td>
</tr>
</tbody>
</table>

Table 2: Variables measured to determine the Dominant Source Index in agricultural machinery

<table>
<thead>
<tr>
<th>Machine's Name</th>
<th>Sound Pressure Level (dBA)</th>
<th>Exposure time to machine noise (t1-hour/year)</th>
<th>Exposure time to background noise (t2-hour/year)</th>
<th>Annual Equivalent level (LEP, year- dBA)</th>
<th>Number of operators exposed (Pn)</th>
<th>Number of machines at each group (Sn)</th>
<th>Noise reduction by cab (NRcab, dBA)</th>
<th>Dominant Source Index (DSI- dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulldozer D8N (320HP)</td>
<td>104</td>
<td>60</td>
<td>1920</td>
<td>960</td>
<td>99.8</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Tractor 8160 Ferguson MF(200HP)</td>
<td>103</td>
<td>60</td>
<td>800</td>
<td>400</td>
<td>102.6</td>
<td>5</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>Harvester CASE 7000 (300HP)</td>
<td>98</td>
<td>60</td>
<td>800</td>
<td>400</td>
<td>93.85</td>
<td>94</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>Tractor 399 Ferguson MF(110HP)</td>
<td>98</td>
<td>60</td>
<td>1920</td>
<td>960</td>
<td>97.6</td>
<td>25</td>
<td>29</td>
<td>0</td>
</tr>
<tr>
<td>Grader Caterpillar G14(230HP)</td>
<td>89</td>
<td>60</td>
<td>800</td>
<td>400</td>
<td>88.6</td>
<td>7</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>
Discussion:

To prioritize the control measures for reducing employee’s noise exposure, the accurate identification of the main sound source is very important. No study has been published to provide a comprehensive model to identify the dominant source of noise in the agricultural machinery. Studies in this area have been limited to just the noise measurement.

Noise measurement is made with two approaches (source based and environmental). For implementing noise abatement measures, the results of overall measurement and analysis of noise have been usually considered.

In addition to the above issues, DSI considerers the most important factors affecting on occupational noise danger and there is no similar method for this purpose.

For preparing the model, we tried to identify and select the important factors of main sound danger correctly. The integrity of the study and validity of the results were obtained by using the same methods for the noise measurement in all machine groups, and the other influential factors, including the number of operators, number of machines, presence or absence of cabins and the annual cumulative exposure. The Index presents the practical, scientific, simple and fast solution for occupational hygienists and other relevant specialists. The results will be unreliable if not all of the important influential factors involved in selecting the main source are considered.

Noise can have many adverse health effects like hearing loss, so noise abatement procedures are required to protect the workers. For reducing exposure, it is not first necessary to control all noise sources and it is logical that consideration is given first to certain operations which reducing them is more important than ever. This article proposes the Index in which four criteria to identify the dominant noise source are considered. DSI goes beyond the parameters of noise that affect its damage potential such as noise level and exposure duration. These factors alone will cause the damages, but in DSI they are all integrated. It can be debatable index and every one can look at it from a different perspective. Nevertheless DSI is a new step and experience in this area and its elements can change depending upon the industry and the different conditions. For example, to engineer out noise, there has to be some spectral analysis of the noise and determine which frequency needs to be lowered through engineering controls. But our goal was not to cover this issue.

By using the Dominant Source Index, in the agricultural sector of sugarcane industry in Khuzestan the case IH7000 harvester was shown to be the dominant sound source in comparison to tractor Ferguson 8160, 399, 285, bulldozer D8N, scraper V300PH, Grader Caterpillar G14, loader L90. It showed that the higher danger levels the higher in necessity of the program development plan in order to reduce operator exposure in this industry.

Acknowledgments

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References