Overview of the Noise Measurements

Process in Recent Years

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Abstract

In the agro-forestry sector, every worker is exposed to risk for security and health; these risk are due to job location and to the using of tools and machinery that are necessary in the normal agricultural activity. Without protection and prevention actions, workers can be subject to accidents and dangerous illness. The observation of I.N.A.I.L. (Italian database) statistics about the workers accidents and illness, underlines the contrast trend. The accidents are fewer, while the professional illness have increased; this difference is due to the effects at prolonged exposition to dangerous agents, with a temporal gap of 20-30 years from the exposition start. The research is focalized to noise risk.

The hypoacusis is the professional illness generated from a long exposition to harmful sound event. The harmful effects of this pathology are known for time; the lawmaker tried already to limit this pathology in 1991 with Legislative Decree 227/91 (as transposition of 80/1107/CEE, 82/506/CEE, 83/605/CEE, 86/188/CEE). The hypoacusis caused by noise, is at the top of the professional illness classification from more than 20 years; nowadays these illness remains underestimate by workers, mainly because the symptoms aren't quantifiable in a short time. Laws and technical standards are available for workers. The lawmaker has determined timetables, measurement methodologies and has determined indications about the elimination, reduction, and the proper actualization of activities of prevention and protection.

There is a great request to substitute the measurements in loco with values contained in the noise database; therefore we have made a study about a comparison of many agro-forestry evaluation, from 1996 to 2012, with the aim of:
- studying the sound emission trend, which is due to the agricultural machinery wear during the years;
- establishing the risk zone common to the some type of machinery and operating machinery;
- searching for an eventual justification to use the table values overwritten.

Keywords: Noise, Overview, Tractors, Risks Class

1 Introduction

As a result of the increase of hypoacusis, the noise in workplace has already started to interest the lawmaker in Italy three years before the publication of the Legislative Decree n. 626/94. The Legislative Decree n. 277/91 (as transposition of 80/1107 / CEE, 82/605 / CEE, 83/605 / CEE, 86/188 / CEE) was about noise, but also about asbestos and lead.
In this Decree, principal obligations, duties, measurement mode sampling, exposure limits and prevention and protection measurements, were fixed. Subsequently, following the transposition of Directive 89/391/CEE, the decree has been incorporated by the Legislative Decree n. 626/94. In 2000 I.S.P.E.S.L. (Italian database) enacted the "Guidelines For Noise Risk Assessment in Workplace", as supporting measurements. These guidelines were updated in 2005, with a unique methodology for the execution of measurements. The Legislative Decree no. 195/06 (as transposition of Directive 2003/10/EC) integrated and modified the limit values of exposition, the action values and redefined the peak levels, that were contained in Legislative Decree no. 626/94. In 2008, at the same time with the exit of the Law about Security (Legislative Decree n. 81/08) that has incorporated the previous rules about health and safety at workplace, the technical standard ISO 9432: 2008 was updated. The UNI 9432: 2008 "Acoustics - Determination of personal exposition to noise in workplace" has acquired a considerable weight, redefining measurement methodologies and calculation of the noise risk in workplace. At international level the ISO 9612: 2011 "Acoustics - Determination of occupational noise exposure - Engineering method" redefines and unifies the measurement methods, calculation and noise risk assessment. The 550 measurements compared in this paper, derive from analyzes carried out in regions of central Italy and cover a time range from 1996 to 2012; clearly, the data analysis must take into account the different sampling methodologies and processing, whom these measurements have been developed with. The measurements from 1996 to 2008 were carried out following the indications of Legislative Decree 277/91, integrated with I.S.P.E.S.L. (Italian database) methodologies and guidelines and also with Legislative Decree n. 195/06. In April of 2008 with the publication of the Law about Security, the technical standard ISO 9432: 2008 before and the technical standard UNI EN ISO 9612: 2011 after, were followed.

1.2 Objectives

Lately, the associations ask to comply with legal obligations expected in the safety field at workplace, by means of evaluations that exclude the measurements. These because measurements sometimes are costly, as they require experienced staff on prevention and protection, that uses expensive instruments with special features. The replacement of the measurements carried out in loco in normal use conditions, with tabulated values of the noise database, has been proposed. The contents of the databases are a useful vehicle for users in the equipment selection during the purchase process or for the estimation of noise preventive emission; however, they don't take into account some variables (state of ground, state of shock absorbers, conduction velocity, etc.) that may change the results significantly. These databases don't consider the noise increases due to equipment
wear, in contrast to the field measurements that must be repeated at least every four years, according to law.

The purpose of this research is to compare:
1. the noise emission change caused by machines wear during the years, to observe if that ageing involves the insertion of these machines in a risk class;
2. to observe if we can identify and establish a risk band, that is common to the same type of machines and operating machinery according to their breakdown in belonging macro-groups;
3. to observe if the use of values that are in the noise database can be considered effective and efficient for any noise risk evaluations in the agricultural sector;
4. to observe if a particular type of machine, associated with a particular operator, falls under a certain risk class according to Art. 189 of Legislative Decree no. 81/08 (and integrations).

All this was possible thanks to the availability of a large database of evaluation assessments made in the agro-forestry from 1996 to 2002, in collaboration with the Servit HSE S.r.l.

2 Materials and methods

The research has been carried out at some farms in central Italy, in the period 1991-2012.

We carried out a study to obtain information about the noise performance of the machines over time, and to see if available database about noise in agriculture could be considered justifiable and usable. About 550 measures (period from 1991 to 2012) extracted from evaluations about noise in the farms workplace, have been taken into consideration.

The Italian legislation that has regulated in several years the argument was as follows:
- Law 626/94 as transposition of 89/391 / EEC;
- Law 195/06 as transposition of 2003/10 / EC, that integrated the Legislative Decree 626/94;
- Law 81/08, that replaced the previous decree and that is still enter in force.

The first phase of the work has concerned the selection of performed evaluations. Many older evaluations weren't available in electronic format so that we had to perform a search and selection in the paper database using the data; subsequently we have reinserted on digital database the extrapolated data.

Later on, a physical selection of evaluations present in digital format has been made by separating the evaluations carried out in the agricultural and forestry sectors from the other. In order to produce the objective and truthful results, we have verified:
1. the type of equipment used, composed by integrating class I photometers, equipped by regular calibration certificates;
2. the experience of the technicians who performed measurements over the years; all the technicians were regularly registered in Regional List of Competent Technicians in Acoustics;
3. Materials and methods of measurement and processing of measurements in different periods of different regulatory regime.
This last point has been difficult to do due to the succession of laws that have regulated the subject during the analyzed period. For this reason we had to compare the data obtained, according to the different regulations.
Since 1991, the legislature has required that in the reports, two aspects were had mainly to be evaluated:
1. The equivalent weighted sound level in curve A of noise exposure of workers during the eight working hours;
2. The peak level.

\[ L_{EP,d} = L_{Aeq,Te} + 10 \log \left( \frac{T_e}{T_0} \right) \] (dB(A))

(1)

where,

\[ L_{Aeq,Te} = 10 \log \left\{ \frac{1}{T_e} \int_0^{T_e} \left[ \frac{P_a(t)}{P_0} \right]^2 dt \right\} \]

(2)

Te represents the daily duration of worker exposition to noise;
T0 represents the duration of working turn of 8h;
P_a represents the acoustics instantaneous pressure weighted in curve A, expressed in [Pa];
P_0 represents the pressure of 20 μPa audibility threshold.

\[ L_{picco}(dB) = 10 \log \left( \frac{P_{peak}^2}{P_0^2} \right) \]

(3)

Where, P_{peak} defined come acoustic instantaneous pressure. This value had the purpose to quantify the characteristics of impulsive sound event because they represent an additional risk factor in the evaluation. The risk bands defined in the abrogated low were:
- \( L_{EP} > 90 \text{ dB(A)} \) o \( L_{picco} > 140 \text{ dB} \)
- \( L_{EP} > 85 \text{ dB(A)} \) e fino a 90 dB(A)
- \( L_{EP} > 80 \text{ dB(A)} \) e fino a 85 dB(A)
- fino a 80 dB(A) di \( L_{EP} \)
This bands procured rights, obligations and duties from the prevention figures, mentioned in the norm.

The equivalent measured levels (at least 3 measurements per station), were processed: the data series of equivalent collected levels, was represented through its arithmetic average, and the variability degree (data attitude to arrange around the average value) through the standard deviation:
\[
\sigma = \left[ \sum_{i=1}^{n} (LA_{eq,T} - LA_{eq,TM})^2 / n \right]^{1/2} \text{ [dB(A)] (4)}
\]

Where:
\(LA_{eq,TM}\) = level average equivalent value, calculated on \(n\) data.

With L. D. 626/94, evaluation methodologies didn’t change, compared to the previous legislation until the Legislative Decree 195/06, that integrated the Decree of 1994 with the Title V Bis. The Title V Bis, replaced by the daily noise exposure level (LEX, 8h): [dB (A) refers to 20 Pa]; defined by international standard ISO 1999: 1990, section 3.6. It was referring to all kind of noise at workplace, including impulsive noise;

\[
LEX, 8h = L_{Aeq,Te} + 10 \log \left( \frac{T_e}{T_0} \right) \text{ [dB(A)] (5)}
\]

From the point of view of calculation there was no difference between the LEP,d and the LEX, 8h; while a diversity observed with the peak level that wasn’t measured as \(L_{peak}\) in linear form but as a peak acoustic pressure (\(p_{peak}\)), that is the maximum value of the instantaneous acoustic pressure frequency weighted "C";

\[
L_{picco}(dB) = 10 \log \frac{p_{peak}^2}{p_0^2} \text{ [dB(C)] (6)}
\]

The introduction of Title V Bis went to change even the previous risk bands, imposing new exposition limits:

- LEX,8h = 87 dB(A) \(p_{peak} = 200\) Pa (140 dB(C) related to 20 \(\mu\)Pa).
- Higher action values:
  - LEX,8h = 85 dB(A) \(p_{peak} = 140\) Pa (137 dB(C) related to 20 \(\mu\)Pa).
- Lower action values:
  - LEX,8h = 80 dB(A) \(p_{peak} = 112\) Pa (135 dB(C) related to 20 \(\mu\)Pa).

The measurements to be carried out were at least three, where the average value was calculated, taking into account the standard deviation (4). With Law 81/08, the values to be measured and the calculations to be made remain unchanged; the reference to Article 181, encourages the evaluators to use the technical standard ISO 9432: 2008. Calculating method is established for the measurement approximation about:

- weighted equivalent continuous level A: \(u(LA_{eq,Tp})\); 
- daily exposure level (or weekly): \(u(LEX,8h)\); 
- peak sound level \(U(L_{picco,C})\).

A further change in the analysis methods and approximation calculation, happens in 2011 with the implementation of technical standard ISO 9612 "Acoustics -- Determination of occupational noise exposure - Engineering method". 

### Mathematical Notes

1. **Standard Deviation Formula**: The formula for standard deviation, \(\sigma\), is given by
   \[
   \sigma = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2}
   \]
   where \(x_i\) are the individual measurements, \(\bar{x}\) is the mean, and \(n\) is the number of measurements.

2. **Equivalent Level Calculation**: The equivalent level at time duration \(T_p\) is calculated as
   \[
   LA_{eq,Tp} = \frac{1}{T_p} \int_{0}^{T_p} LA(t) \, dt
   \]
   where \(LA(t)\) is the noise level at time \(t\).

3. **Daily Exposure Level Calculation**: The daily exposure level is calculated as
   \[
   L_{peak} = 10 \log \left( \frac{1}{8} \sum_{i=1}^{8} (L_i)^2 \right)
   \]
   where \(L_i\) is the noise level at time \(i\) of the day.

4. **Peak Sound Level Calculation**: The peak sound level is calculated as
   \[
   L_{picco} = 10 \log \left( \frac{p_{peak}^2}{p_0^2} \right)
   \]
   where \(p_{peak}\) is the maximum peak acoustic pressure, and \(p_0\) is the reference acoustic pressure.
3 Results

After the first control phase about the measurements veracity, we have entered the extrapolated data from the selected evaluations in a spreadsheet, organizing them so that they could be filtered on demand. In the columns we have included:
- Brand name, model and type of tractor;
- Operating machinery used on the tractor;
- Year of measurement (1991-2012);
- Equivalent level measured with the towed operating machinery and/or activated by that type of tractor;
- Matriculation year of the tractor.

We haven’t compared the peak levels because there was heterogeneity of data due to legislation change (Legislative Degree 195/06). Out below are illustrated the table and the histogram for each kind of tractor: the average value of the weighted equivalent levels in curve A (LeqA); the obtained standard deviation (4); the maximum value and the minimum value of LeqA, analyzed by type. On the right side of the tables we have given for each class of risk: the vehicles number that entered in a specific range.

<table>
<thead>
<tr>
<th>Tracked tractors</th>
<th>( L_{\text{eq} \text{A}} ) average (dBA)</th>
<th>RISK CLASS (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>94.8</td>
<td>&lt;80</td>
</tr>
<tr>
<td>Stand. Dev.</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>Max.</td>
<td>106.4</td>
<td>1</td>
</tr>
<tr>
<td>Min.</td>
<td>76.4</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: results of tracked tractors

Figure 1: histogram of tracked tractors
The analysis of the 123 tracked tractors, (Tab. 1) shows that the equivalent average level is 95 dB (A); this level exceeds the threshold limit value of 87 dB (A), for the 95% of cases. Few units (less than 1%) remain below 80 dB (A). The using maximum time to not exceed the daily threshold is about 75 minutes. The tracked tractors have the highest values of emissions due to technical characteristics and to the lack of the cabin. In this case, the employer has by law to: educate and inform his workers at particular risk; provide personal protective auditory equipment; process periodic medical examination of exposed workers; apply appropriate prevention and protection measurements to reduce the risk. The workers, in turn, have to: participate at formation and information courses; expos themselves to periodic medical examination; wear personal protective auditory equipment, delivered by the employer.

<table>
<thead>
<tr>
<th>Wheeled tractors</th>
<th>( L_{Aeq} ) average (dBA)</th>
<th>RISK CLASS (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>83.3</td>
<td>&lt;80 &lt;80; &lt;85 ≥85; ≤&lt;87 ≥87</td>
</tr>
<tr>
<td>Stand. Dev.</td>
<td>7.6</td>
<td>145 72 39 176</td>
</tr>
<tr>
<td>Max.</td>
<td>100.9</td>
<td></td>
</tr>
<tr>
<td>Min.</td>
<td>62.7</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: results of wheeled tractors

Figure 2: histogram of wheeled tractors

The 432 wheeled tractors (cabin cruisers and not), in table 2, shows that the average equivalent level exceeds the risk threshold, reaching to 83 dB (A). In this case the eight working hours are possible, followed the regulatory limits. The 34% of the evaluated cases is below the lower value of action 80 dB(A); in this case there aren’t special obligations from the employer and the workers. The
41% of the analyzed cases is greater than limit value and the 9% is between greater action values and limit values; in these two cases are valid the obligations indicated for tracked tractors in table 1. Although only in 2% of cases, worker that doesn’t wear the personal protective auditory equipment may be exposed to a moderate risk. In table 3 and table 4, the wheeled tractors are analyzed observing the cabin cruisers tractors separated from those without cabin cruisers.

<table>
<thead>
<tr>
<th>Wheeled tractors - with cabin cruisers</th>
<th>L_{Aeq} average (dBA)</th>
<th>RISK CLASS (dBA)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average</strong></td>
<td>80.8</td>
<td>&lt;80</td>
<td>&gt;80; &lt;85</td>
</tr>
<tr>
<td><strong>Stand. Dev.</strong></td>
<td>7.1</td>
<td>38</td>
<td>8</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>93.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Min.</strong></td>
<td>66.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: results of wheeled tractors with cabin cruisers

The cabin cruiser in the 77 tractors reduces the exposure level until the risk threshold. The average equivalent level remains below the upper action value of 85 dB(A), reaching around 80 dB(A). The using time is about 460 minutes to not exceed the risk threshold of 80 dB(A). The 50% of the cases is below the lower value of action. The 31% of tractors exceeds the daily limit threshold.
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Wheeled tractors - without cabin cruisers

<table>
<thead>
<tr>
<th>L&lt;sub&gt;eq&lt;/sub&gt; average (dBA)</th>
<th>RISK CLASS (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average</strong></td>
<td>83.8</td>
</tr>
<tr>
<td></td>
<td>&lt;80</td>
</tr>
<tr>
<td></td>
<td>≥ 80; &lt;85</td>
</tr>
<tr>
<td></td>
<td>≥ 85; &lt;87</td>
</tr>
<tr>
<td></td>
<td>≥87</td>
</tr>
<tr>
<td><strong>Stand. Dev.</strong></td>
<td>7.7</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>100.9</td>
</tr>
<tr>
<td></td>
<td>107</td>
</tr>
<tr>
<td></td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>152</td>
</tr>
<tr>
<td><strong>Min.</strong></td>
<td>62.7</td>
</tr>
</tbody>
</table>

Table 4: results of wheeled tractors without cabin cruisers

![Figure 4: histogram of wheeled tractors without cabin cruisers](image)

In the 57% of cases, the equivalent average level obtained from the analysis of the 355 wheeled tractors without cabin cruiser exceeds the risk threshold and stood below the upper action value of 85 dB(A). In 43% of cases this value rises above the limit value. The tractors without cabin cruiser can be used eight hours a day remaining below the legislative limit.

In table 5 a summary of what has been obtained is provided for the various kinds of tractors measured, indicating: the equivalent weighted average curve A (L<sub>eq</sub>A) obtained; the corresponding risk class (indicated in art. 189 of Law n. 81/08) and the maximum time of use of the tractor without using of auditory protection, in order to respect the legislative obligations.

<table>
<thead>
<tr>
<th></th>
<th>L&lt;sub&gt;ex&lt;/sub&gt; 8h (dBA)</th>
<th>RISK</th>
<th>RISK CLASS</th>
<th>Maximum time of using (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheeled tractors</td>
<td>83.3</td>
<td>Low</td>
<td>80 &lt; L&lt;sub&gt;ex&lt;/sub&gt; ≤ 85</td>
<td>480</td>
</tr>
<tr>
<td>Tracked tractors</td>
<td>94.8</td>
<td>Intolerable</td>
<td>L&lt;sub&gt;ex&lt;/sub&gt; ≥ 87</td>
<td>75</td>
</tr>
</tbody>
</table>
Table 5: summary of the various kinds of tractors measured

<table>
<thead>
<tr>
<th>Instrument</th>
<th>RISK</th>
<th>RISK CLASS</th>
<th>Maximum time of using (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plow</td>
<td>90</td>
<td>Intolerable</td>
<td>3</td>
</tr>
<tr>
<td>Plow with two plowshare</td>
<td>91</td>
<td>Intolerable</td>
<td>3</td>
</tr>
<tr>
<td>Spray nozzle and spraying machine</td>
<td>86</td>
<td>Average</td>
<td>2</td>
</tr>
<tr>
<td>Cutted plank</td>
<td>86</td>
<td>Average</td>
<td>2</td>
</tr>
<tr>
<td>Weeding barrel</td>
<td>86</td>
<td>Average</td>
<td>2</td>
</tr>
<tr>
<td>Blade, palette, attachment</td>
<td>81</td>
<td>Low</td>
<td>1</td>
</tr>
<tr>
<td>Hayfork, weight lifter</td>
<td>81</td>
<td>Low</td>
<td>1</td>
</tr>
<tr>
<td>Undercarriage</td>
<td>85</td>
<td>Average</td>
<td>2</td>
</tr>
<tr>
<td>Mixer car</td>
<td>85</td>
<td>Average</td>
<td>2</td>
</tr>
<tr>
<td>Trolleys</td>
<td>91</td>
<td>Intolerable</td>
<td>3</td>
</tr>
<tr>
<td>Fertilizer spreader</td>
<td>87</td>
<td>Intolerable</td>
<td>3</td>
</tr>
<tr>
<td>Harrows</td>
<td>89</td>
<td>Intolerable</td>
<td>3</td>
</tr>
<tr>
<td>Extirpator</td>
<td>85</td>
<td>Average</td>
<td>2</td>
</tr>
<tr>
<td>Mower</td>
<td>84</td>
<td>Low</td>
<td>1</td>
</tr>
<tr>
<td>Milling machine</td>
<td>90</td>
<td>Intolerable</td>
<td>3</td>
</tr>
<tr>
<td>Steamroller</td>
<td>84</td>
<td>Low</td>
<td>1</td>
</tr>
<tr>
<td>Baler</td>
<td>84</td>
<td>Low</td>
<td>1</td>
</tr>
<tr>
<td>Hay rake</td>
<td>83</td>
<td>Low</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 7: equivalent levels for the kind of operating machinery used

<table>
<thead>
<tr>
<th></th>
<th>Equivalent Level</th>
<th>Risk Level</th>
<th>Number</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trailer</td>
<td>82</td>
<td>Low</td>
<td>1</td>
<td>480</td>
</tr>
<tr>
<td>Ripper</td>
<td>86</td>
<td>Average</td>
<td>2</td>
<td>480</td>
</tr>
<tr>
<td>Seeder</td>
<td>89</td>
<td>Intolerable</td>
<td>3</td>
<td>300</td>
</tr>
<tr>
<td>Carrier</td>
<td>85</td>
<td>Average</td>
<td>2</td>
<td>480</td>
</tr>
<tr>
<td>Flail mower</td>
<td>88</td>
<td>Intolerable</td>
<td>3</td>
<td>360</td>
</tr>
<tr>
<td>Harvester</td>
<td>90</td>
<td>Intolerable</td>
<td>3</td>
<td>240</td>
</tr>
</tbody>
</table>

Figure 5: histogram with percentage in each risk class

4 Conclusions

These data have provided confirmation about the issue of hearing loss, resulting from the use of agricultural machinery. This phenomenon is still not completely marginalized, 615 cases in 2011 in the agricultural sector. Tractor drivers and contractors spend the whole day working on mechanical means, exposing themselves to the risks involved.

The results obtained show that the exposure to the physical noise is greater than the risk limit value of 80dB (A), reaching a low risk in wheeled tractors (about 82dB (A)) and to an high risk, intolerable, for tracked tractors (greater than 90dB (a)). The presence of the cabin cruisers in wheeled tractors induces the deduction of about 3 dB (A), while the risk level is above risk limit value of 80 dB (A). The class between the upper action value and the daily limit value is the fewer representative class (28%).

This is a particular data: assuming the use of tractors for eight hours, is not justified as it is stated in the Article 191 of the Legislative Decree 81/08: "Except the prohibition to the exposure limit values exceeded, for activities that involved high fluctuation of personal exposure levels of workers, the employer may allocate a noise exposure to these workers above the higher action values”, in fact, the band fewer represented.
About noise, the last generation cabins have discrete performance of reduction risk, bringing the risk level below threshold. Even in this case, proper maintenance of the cabin cruisers would affect to the efficiency of that cabin cruisers. The correlation analysis, even if they have failed, have provided guidelines to consider any future studies about that subject.

References


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