ACOUSTIC RECLAMATION PLANS FOR EXPOSED WORKERS, A LEGAL OBLIGATION, BUT ALSO AN OPPORTUNITY TO MITIGATE THE ENVIRONMENTAL ACOUSTIC IMPACT

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The exposure reduction plan (P.A.R.E.) is a document required by Italian law that integrates, in relation to noise risk, the Risk Assessment Document (DVR). In it the company indicates the prevention and protection measures to be carried out, and identifies the procedures for their implementation. But the P.A.R.E. can also be a valid opportunity to intervene effectively in order to reduce the environmental noise impact and the sound emissions to the receptors produced by the factory.

A case study is presented, where it was done, mediating on technical and organizational interventions, in order to obtain, at the same time, the reduction of the exposure of the employees and the re-entry within the legal limits of the emission of sound to the receivers.

Keywords: exposure, noise, reduction, impact, plan

1. Introduction

For 10 years it has been an obligation under the Consolidated Law on Work Safety: D.LGS 81/08, the drafting of company noise reduction plans, for companies with workers exposed to values above 85 dBA. But only from the publication of the UNI 11347 standard in 2015, companies are beginning to invest in corporate reduction plans. This also under the pressure of the awareness raising project to companies, also carried out by INAIL. INAIL Campania management, in fact, among the many projects, has realized the Co.SI. P.A.R.E - correct practices of company programs to reduce exposure of workers to noise. The present case study come to light from the work of Co.SI.P.A.R.E. Project. The opportunity to reduce noise pollution to the receptors by carrying out the obligatory work on the sources to reduce the exposure of the employees envisaged by the P.A.R.E., is particularly noticeable, outside the industrial shed.

This is the area of the store / service area for unloading / loading products, generally present in all types of medium / large sized companies and where forklift and warehouse workers are employed.
2. **Case study of the Plastic workshop in an industrial area**

The case study concerns the external loading area, of a multinational engineering company, which carries out the production activity of manufacturing planks and bumpers for cars, in a continuous cycle plastic workshop. The company shows two issues that are relevant from an acoustic point of view:

1. The undue exposure to noise produced by workers in the service area for unloading / loading products;
2. Exceeding the receptor sound emission limit nocturnal period.

3. **Receptors and Municipal Acoustic classification**

As receptors we mean the buildings, the spaces used by people or communities or habitats, presumably more exposed to the noise coming from the production plant. Considering the acoustic zones, the distance, the directionality and the height of the sources, the propagation of noise, the height of the windows of the exposed buildings, we identify two receptors R₁ and R₂ figure 1.

![Figure 1: Acoustic classification and receptors](image)

2.1 **Noise source**

In the external area of the plant two types of sound sources are insistent: fixed sources: such as plants and machinery, and mobile ones, such as trucks and vans for goods transport. The Fixed sources are to be mitigated by favoring technical interventions directly on the source or on the propagation path (example: covering, screen, acoustic absorbent treatment, etc.). The mobile sources are instead to be mitigated by giving preference to organizational interventions (example: change route, change timetables, etc.).

The sound investigations were, therefore, aimed at investigating these two types of sources, with two different approaches.

3. **Acoustic monitoring and reclamation**

The mobile sound sources are mainly internal shuttle trucks that transport goods, semi-finished goods and raw materials. These vehicles access the loading / unloading area of the plant, systematically passing the receiver R₁ along the road a few meters away. This receptor is the most exposed and get into class IV of the Municipal Acoustic Zoning (nightly limit: 55 dBA).

The plant and the R₂ receiver, on the other hand, get into the V zone (nightly limit: 60 dBA).
3.1 Moving sources noise monitoring

For mobile sources, a station with sound analyzer was used in two fixed positions, with a microphone on a pole at a height of 4 meters. The stations have been allocated: one near the exit of the shed (P₁) and one near the most exposed receptor (P₂) (figures 2 and 3), for a time of about 30 minutes each.

Figure 2: Time history of sound pressure level, 4 meters height at P₂ point (R₁ receptor)

Figure 3: Time history of sound pressure level, 4 meters height at P₁ point (exit plan).

3.1.1 Route change mitigation measures

According to the indications provided by the company, the following table shows the quantities of vehicles (trucks and vans) that access the factory, for the delivery and collection of goods / raw materials / semi-finished products.
It is evident that the internal service of shuttle transport planks and bumpers, organized between two production divisions of the company, is the prevailing transport service.

Table 1: Number of deliveries and pick up of goods / semi-finished goods / raw materials

<table>
<thead>
<tr>
<th>N. Truck</th>
<th>N. Trips (Shift)</th>
<th>N. Trips (Daily)</th>
<th>N. Trips (weekly)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>-</td>
<td>27</td>
<td>-</td>
<td>Shuttle - Dashboard</td>
</tr>
<tr>
<td>1</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>Extra - Dashboard</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>15</td>
<td>-</td>
<td>Shuttle - Bumper</td>
</tr>
<tr>
<td>1</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>Collettame</td>
</tr>
<tr>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>Spare part</td>
</tr>
<tr>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>Mexico</td>
</tr>
<tr>
<td>11</td>
<td>-</td>
<td>11</td>
<td>-</td>
<td>Forniture</td>
</tr>
</tbody>
</table>

From the study of the time history of sound pressure level in points P₁ and P₂, it is found, by masking the transits of transportation means, that their sound contribution can be quantified in about 5.7 dBA to the R₁. In light of this, it is assumed for the mobile sources an organizational action "change route" only for the internal shuttle service, with an increase of about 100 meters.

3.2 Unmoving sources noise monitoring

The fixed sound sources are identified in the systems and the machines located outside the shed. These are: air extractors, air conditioners, booster pumps, shredders and compressor units.

A portable sound level meter placed on a stand at a height of 1.5 meters, was used for spot sampling of noise from the systems. It has been placed at one meter from each source, for a time of acquisition of a few minutes, sufficient to adequately characterize each source.

In order to reduce the noise exposure of workers in loading/unloading area and the acoustic emission to the receptors, we want to intervene on the most relevant sources, such as: pumps booth and mill shredder air vent grid.

Figure 4: Current route (1.6 Km red) and alternative route (1.7 km dotted green).

Figure 5: Time history of sound pressure level, 1.5 meter height, at cabin pumps.
3.2.1 **Pumps cabin mitigation measures**

The necessary interventions on the cabin Pumps, consist in the sound-proof environmental treatment of the cab, and in the installation of a mobile acoustic screen.

The pump cabin dimensions are:

- base=2.13 x 5.00 m; h₁=2.3 m; h₂ = 2.6 m; support area =11 m²; machinery volume =26 m³

The installation of a mobile screen does not provide a high insulation capacity, but shows a low cost index, it must be placed close to the sources and with the internal sound-absorbing side directed towards the source.

**Screen size:**
- h₁:3 m, L: 3 m; Panel surface 9 sqm.
- Panel covered in 100 mm thick metal; with good resistance to impacts and atmospheric agents, REI certification.
- Internal (micro-perforated) and external (staved) sheet in Fe 250 prepainted steel, 6/10 mm thick
- Thickness: 50 mm
- Weight 13,80 Kg/mq
- Sound Transmission Class: STC=32 dB.

3.2.2 **Mill shredder mitigation measures**

It is necessary to install n.2 air vent grid used for industrial ventilation systems, with Sound-absorbing element (mineral wool protected by micro-stretched sheet) to reduce the sound emission in the local mill.
Grid size:
- $h_1=2500$ mm, $L=2500$ mm;
- Thickness: 200 mm;
- Weight 30 Kg;
- Zn Steel DN with elettro-solder net; bird stop, Zn Steel netting 10x10 mm;
- Air flow rate: 10.000 m$^3$/h.

![Figure 8: air vent grid silencer](image1)

Expected benefit from acceptance test plan: About 8 dBA reduction
Cost estimation: 2.000 € tax and assembly excluded - Time of implementation: 20 days delivery.

As an alternative to increase the reduction could be installed a rectangular silencer with sound-absorbing partitions

- 10 mineral wool sound absorbing partitions;
- Thickness: 1000 mm;
- Covered with micro-stretched sheet;
- Distance between partitions: 150 mm;
- Maximum crossing speed: 20 m / s.

![Figure 9: Rectangular silencer with sound-absorbing partitions](image2)

Expected benefit from acceptance test plan: About 12 dBA reduction
Cost estimation: 3.000 € tax and assembly excluded - Time of implementation: 20 days delivery

**Table 2: Summary of mitigation measures and related noise abatements**

<table>
<thead>
<tr>
<th>Rif.</th>
<th>Machinery</th>
<th>L$\text{aeq}$ dB</th>
<th>Priority</th>
<th>Action</th>
<th>Reduct. dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cabin pumps</td>
<td>86,2</td>
<td>Necessary</td>
<td>Mobile screen</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Proof environmental treatment of the cab</td>
<td>2/4</td>
</tr>
<tr>
<td>2</td>
<td>Mill shredder</td>
<td>88,3</td>
<td>Necessary</td>
<td>Air vent grid</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Necessary</td>
<td>Alternative to Grid</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alternative to Grid</td>
<td>Rectangular silencer with sound-absorbing partitions</td>
<td>12</td>
</tr>
</tbody>
</table>

**4. Acoustic modelling: Cadna A noise prediction software**

The basic equations used by the model are reported in paragraph 6 of ISO 9613-2.

The total value of the A-weighted equivalent sound level is obtained by summing the contributions of all the octave bands of all the sources present according to the following equation:
\[ Leq(dBA) = 10 \cdot \log \left( \sum_{i=1}^{n} \left( \sum_{j=1}^{8} 10^{0.1(Lp(j)+A(j))} \right) \right) \]

where:
- \( n \): number of sources;
- \( j \): indicates the eight standard octave band frequencies from 63 Hz to 8kHz;
- \( A(j) \): A weighted curve.

Starting from the measurements taken near the sources, the mathematical model "current scenario" has been constructed using the equations and propagation models of the Cadna A (Computer Aided Noise Abatement) prediction software.

Noise levels were calculated at predefined receiver points, on grids to produce noise maps and at building R1 facades. The model was constructed using the 3D mode representation of the shed, considering its precise dimensions. The specific reflection/absorption characteristics of all construction materials, were considered. The road noise calculation was based on traffic flow and percentage of heavy vehicles, considering the change of route. The noise sources were represent as source point, with the exception of the two air vent grid, that were represent as sources areas. For organizational interventions the attenuation to the R1 receptor from the alternative entry route of the shuttles was considered: -3 dBA. For technical interventions we have considered: the installation of air vent grid silencer to the local mill with noise reduction of -8 dBA; the installation of the screen barrier for the pump cabin (-8 dBA) and its environmental treatment (-2 dBA).

### 4.1 Result of noise prediction “scenario”

The noise prediction “scenario”, is represented by isophonic curves, the 4 dBA boxes shown, indicate the levels expected in the points of interest.

![Figure 10: Noise abatements prediction “scenario”](image-url)
The mathematical model has been elaborated, attributing, to the risky sound sources (>85 dBA), the values of sound emission, mitigated by the mentioned technical and organizational remediation interventions.

The value box 80.3, indicates the estimated sound level, after reclamation work, at two meters of height at a distance of 2 meters from the two noisiest sources: mill shredder and cabin pumps.

The value box 57.3 dBA indicates the level at the center of the office side of the shed, at the perimeter boundary, these are average integrated values. Therefore the contribution of measured compressor emissions is mediated. At receptor R₁, the marker shows an expected level in house façade of 53 dBA, so the intake levels are undoubtedly within 55 dBA night.

5. Conclusions

By means of appropriate acoustic modeling, of the data measured at the machines, and using the noise time history at points P₁ and P₂, a noise prediction scenario was produced to quantify the expected benefit following the reclamation of the sound sources.

Cadna A (Computer Aided Noise Abatement) prediction software was used with the following noise reduction interventions: air vent grid silencer (-8 dBA); mobile screen barrier (-10 dBA), environmental treatment of soundproof booth pumps cab (-2 dBA), change route (-3 dBA).

From the prediction scenario results:

• The values expected from the most exposed receptor (R₁), after mitigation measures, fall within the limits allowed by law regarding the maximum intake limit for the use class. The estimated value is lower than the limit of 55 dBA at night for class IV, and therefore, since the plants are continuous production cycle, the criterion of the differential noise level is not applicable;
• For forklift workers and personnel employed in the unloading/loading products service area, the daily exposure level (Lex,8h) are reduced of about 8 dBA. Therefore, the mitigation measures identified, would allow the undue exposure of the employees to be kept below the lower limit of 80 dBA!.

REFERENCES