ENVIRONMENTAL IMPACT OF NOISE SOURCES IN PORT AREAS: A CASE STUDY

Salvatore Curcuruto, Giuseppe Marsico, Delio Atzori, Enrico Mazzocchi and Rinaldo Betti

ISPRA – Italian National Institute for Environmental Protection and Research, via Vitaliano Branca 48, 00144 Rome, Italy
e-mail: giuseppe.marsico@isprambiente.it

Tina Fabozzi, Valerio Briotti and Gianmario Bignardi

Regional Environmental Protection Agency of Lazio, via Boncompagni 101, 00187 Rome, Italy

Franco Guglielmetti and Fabio Bisegna

Sapienza University of Rome, Department of Astronautics, Electrical and Energetic Engineering, via Eudossiana 18, 00184 Rome, Italy

This study shows a survey carried out to characterize the noise due to moored ships in the Civitavecchia port area. A new methodology has been tested by means of short-term measurements on two different kinds of vessel – Ro-Ro ferry and cruise ship – whose results have allowed to characterize their acoustical emissions. The measured sound levels have been analyzed in terms of both frequency spectrum and overall noise levels, also taking into account the effect of sources aboard the ships. The suitability of the chosen methodology as well as its practical implementation to the specific noise source have been discussed.

1. Introduction

Port infrastructures raise relevant issues in assessing the environmental noise impact, as this kind of studies cannot be carried out basing on technically reliable criteria. Actually, the main problems consist in defying suitable methods of measurement for noise emission, related to various sources, and indentifying both the applicable limit values and the real effectiveness of noise abatement measures. Furthermore, in Italy there are additional problems arisen from an incomplete national regulatory legislation, even not harmonized with the EU provisions[1].

Port areas are characterized by a variety of noise sources, some of which already subject to specific rules: road and rail infrastructures, commercial and industrial activities and other anthropogenic sources. To the sound emission generated by these kind of sources, that due to different typologies of vessel are added, whose acoustical emission varies on the operating conditions: approaching and departing, docking and mooring. Furthermore, ground operations – e.g. loading and unloading, cargo handling, auxiliary plants etc. – contribute to the overall sound levels. Concerning
the time trend, noise sources in port areas are characterized by acoustical emissions depending on a weekly basis as well as a seasonal trend.

Numerical simulation provides the same issues, as noise emission modelling from a vessel in various operating conditions is hard to be carried out using the currently available prediction models.

This study shows the results of short-term noise measurements carried out in May-June 2014 in the Civitavecchia port. This activity is part of a survey which aims to develop a methodology to assess the noise of port areas. The measurements have been carried out to characterize the sound emission produced by two moored ships and to test an innovative method of measurement.

2. Regulatory Framework

The Italian legislation on environmental noise has been implemented over the years issuing the regulations required by the Framework Law n. 447/1995. In particular, transport infrastructures – roads, railways and airports – was given a special interest by several regulations providing procedures for the assessment and abatement of environmental noise. Such regulations defines the methods of measurement and monitoring, including a set of acoustical indicators. Furthermore, the national legislation established specific limit values within “buffers zones” from the infrastructures, notwithstanding the acoustical territorial zoning.

Though specifically provided by the Framework Law, ports have not been given yet any provisions on noise pollution. This legislative void does not allow to assess the environmental noise due to the sound sources of port infrastructures nor to implement any mitigation measures for the receivers laying within the affected areas. Nevertheless, the national legislation requires companies and managing bodies of public transport services to implement noise abatement plans and, lacking any specific rules, this duty is currently hard to be fulfilled.

Further issues arise from the Directive on Environmental Noise 2002/49/EC that requires to draw up noise mapping of urban areas, including ports too[2]. In such context, noise levels calculated by means of the EU indicators $L_{den}$ and $L_{night}$ should be harmonized with those expressed by the noise indicators provided by the national legislation, currently unavailable for ports. The Directive considers also a further development of action plans[3], which shall be based on the mitigation of noise levels below the limit values expressed by the EU indicators[4].

Furthermore, the current regulations regarding protection of workers – based on the Directive 2003/10/EC, transposed in Italy by means of the Legislative Decree n. 81/2008 and the following revisions – state a set of minimum disposals with the aim at mitigating the risks caused or that may be caused by the noise exposure. Transport infrastructures – e.g. airports[5] – was provided with methodologies for accomplishing such disposals, whilst it is still an issue for ports.

Regarding to the technical standards issued at international level, the noise generated by ships can be measured and calculated applying the following Standards:

- ISO 2922:2000, concerning the methods of measurement for all types of ship except for recreational crafts;

Both ISO 2922:2000 and ISO 14509-1:2008 state that measured sound levels should be used to characterize the emission of sources, not to verify the compliance with any limits values at receivers. ISO 2922:2000 sets out a method for moored ships, whose emission can be considered as a steady state noise. The acoustical indicator addressed for this measurements is the time average A-weighted sound pressure level, $L_{Aeq}$. Regarding to microphone locations, it is requested to be positioned at 3.5 m ± 0.5 m above the water surface and, if mounted on a solid surface, at least at 1.2 m above that surface. Concerning the distance from the ship, the microphone is stated to be placed 25 m ± 2 m from the side and at several points around the ship. For this kind of measurements, being in presence of steady state noise, the Standard provides a period a measurement of 30s at least.
3. Method of measurement for moored ships

With the aim to face the above mentioned issues, in the last years the EU Commission funded several research projects that define methodologies and guidelines for the assessment of port noise, also including numerical modelling.

One of the tasks of the FP7 SILENV project[6] was the characterization of airborne noise due to moored ships, testing different microphone set-ups along the side of the vessel. With regard to acoustical indicators, the provisions given by ISO 2922:2000 were considered, as well as for microphone locations. Actually, SILENV sets out a first method which provides a grid of points, laying on a parallelepiped measurement surface and oriented in directions parallel to the plane of symmetry of the ship and normal to it. In alternative, the project proposes also a simplified criterion: in this case, measurements can be carried out along an horizontal line of points, instead of a grid[7].

In this study, the latter method has been chosen, as the grid-surface has been considered quite hard to be implemented, mostly in complicated contexts like a port area[8]. Therefore, for the characterization measurements of moored ships, the microphone locations were placed at 25 m from the side of vessels, with a 10 m step and at 1.5 m above the ground. Fig. 1 shows the simplified method of measurement used with the indication of the distance considered for the microphone locations.

![Figure 1. Method of measurement used for the characterization of acoustic emissions of moored ships[7].](image)

All measurements had a duration of about 2 minutes: this period has been chosen to get a steady sound so that acoustical events others than that under investigation can be recognized in the data analysis. It is actually a challenging acoustical characterization, as ISO 2922:2000 provides to turn off the aboard sources – engines and ventilation fans[9,10,11] – for each point of the grid, in order to measure the background noise to be subtracted from the overall level. This operation is unlikely to be obtained in the normal operating conditions, and also for this reason this study wishes to assess the critical aspects of data resulting from the proposed method of measurement and how it properly can be applied.
4. Results of the measurements

4.1 Cruise ship

Usually, modern cruise ships are very silent while mooring, as a special attention is paid to soundproof the auxiliary engines, a request aimed at improving the comfort for passengers. For this reason, the measurements were carried out just a few minutes before the ship left the wharf, in order to better characterize the emission of the main engines of a cruise ship before leaving the port.

The source under investigation is a 800t DWT – Deadweight Tonnage – cruise ship, 133m length, whose funnel is placed at a 26m distance from stern. During the measurement time, just before leaving, four main diesel engines were turned on, instead of the auxiliary engines, providing an overall power of 9150kW.

The measurements have dealt with half of the ship’s length, as after the last one the vessel began to move. Nevertheless, the wharf was a very silent area so that no source other than main engines of the vessel affected the measurements and the measured sound levels can be considered as the emission of the source under investigation only.

Table 1 shows the measured values at 25m distance from the side of the vessel: frequency spectrum in $L_{eq}$ in octave bands and the overall $L_{Aeq}$, both expressed in dB; the measurement point n. 1 is in line with stern’s end.

**Table 1.** Moored cruise ship: measured values of frequency spectrum and overall noise levels.

<table>
<thead>
<tr>
<th>Measurement point</th>
<th>Frequency spectrum (Hz) - $L_{eq}$ (dB)</th>
<th>$L_{Aeq}$ dB(A)</th>
<th>Distance from stern (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>81.6 85.5 71.3 68.7 56.1 50.4 44.7 27.7 29.5</td>
<td>62.8</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>83.4 85.2 72.2 68.4 55.7 49.7 44.2 37.4 29.7</td>
<td>62.9</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>83.4 85.2 73.3 66.9 55.9 49.4 44.3 37.9 30.3</td>
<td>62.4</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>81.7 85.7 75.7 67.5 56.4 49.3 44.6 38.3 30.8</td>
<td>63.6</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>84.8 87.0 80.6 68.3 56.7 51.8 48.3 41.4 33.4</td>
<td>65.7</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>86.5 87.2 78.2 69.7 57.6 52.4 48.3 41.6 33.4</td>
<td>65.8</td>
<td>50</td>
</tr>
<tr>
<td>7</td>
<td>86.8 86.0 75.9 69.6 57.4 51.6 47.7 41.1 33.7</td>
<td>64.9</td>
<td>60</td>
</tr>
<tr>
<td>8</td>
<td>83.9 84.0 77.6 68.1 57.3 50.9 47.0 41.0 34.7</td>
<td>64.2</td>
<td>70</td>
</tr>
</tbody>
</table>

From the measured values, the frequency spectrum shows a prevalence of contributions in the bands 31.5Hz and 63Hz, though the A-weighting curve reduces them in the overall sound level.

Fig. 2 and Fig. 3 show such measured data as spatial trends respectively of single octave bands and overall A-weighted average level. Furthermore, it can be observed that the values of the overall noise varies in a range of about 3dB(A), from a minimum of 62.4dB(A) up to a maximum of 65.7dB(A); such almost constant noise over the measurement points can be noticed in the octave bands showed in Fig. 2.
4.2 Ro-Ro ferry

Unlike the above case, moored Ro-Ro ferries are characterized by noise from both auxiliary engines and ventilation fans, the latter usually located at bow.

The source under investigation is a 4700t DWT Ro-Ro ferry, 214m length, whose funnel is located at a distance of 87m from stern. During the measurement time, the auxiliary diesel engines were turned on, providing a total power of 1500kW; in addition to the engines, a ventilation fan at bow was turned on.

Table 2 shows the measured values at 25m distance from the side of the vessel: frequency spectrum in $L_{eq}$ in octave bands and the overall $L_{Aeq}$, both expressed in dB; as in the cruise ship, the measurement point n. 1 is in line with stern’s end.
they are reduced in clearly to the cruise ship, there is only was heard 120m increase getting closer to was a very silent area so that the measured sound levels motioning.

In the above set of measurements, the 60m distance has been missed, due to instrument malfun-
ing. As for the cruise ship, though measuring the background noise was impossible, the wharf was a very silent area so that the measured sound levels can be considered as the emission of the auxiliary engines and ventilation fan only.

Fig. 4 and Fig. 5 show such measured data as spatial trends respectively of single octave bands and overall A-weighted average level: in both figures it can be noticed how the acoustical levels increase getting closer to the ventilation fan. In particular, from the measurements points between 120m and 150m from stern both sources provide a relevant contribution, from 0m to 110m the funnel only was heard while in the two last points the fan was prevalent.

From stern up to 110m, sound levels are almost constant, varying over a short range of less than 3dB(A) in the overall levels from a minimum of 59.0dB(A) up to a maximum of 61.4dB(A). Similarly to the cruise ship, there is a prevalence of contributions in the bands 31.5Hz and 63Hz, though they are reduced in the overall sound level by the A-weighting curve.

<table>
<thead>
<tr>
<th>Measurement point</th>
<th>Frequency spectrum (Hz) - L_{eq} (dB)</th>
<th>L_{eq} dB(A)</th>
<th>Distance from stern (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>83.1 80.7 72.7 58.2 50.3 45.0 40.2 34.6 25.7</td>
<td>59.5</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>83.5 80.6 70.8 59.8 49.8 44.2 39.8 34.5 25.6</td>
<td>59.0</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>83.7 81.8 71.3 60.1 50.6 46.2 42.5 35.6 27.2</td>
<td>60.1</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>84.8 80.6 72.8 60.2 50.0 45.5 42.4 34.2 25.4</td>
<td>60.0</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>85.8 82.7 72.7 61.0 50.0 44.8 39.8 33.2 24.5</td>
<td>61.4</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>83.6 81.4 73.6 61.8 50.2 44.8 39.8 33.3 24.2</td>
<td>61.1</td>
<td>50</td>
</tr>
<tr>
<td>7</td>
<td>83.3 81.1 70.6 65.4 50.0 44.3 39.0 33.0 24.5</td>
<td>59.7</td>
<td>70</td>
</tr>
<tr>
<td>8</td>
<td>85.9 80.9 73.5 62.1 50.6 44.7 38.8 32.4 23.2</td>
<td>60.5</td>
<td>80</td>
</tr>
<tr>
<td>9</td>
<td>84.6 80.1 72.8 63.7 50.9 44.2 39.4 34.2 27.8</td>
<td>60.2</td>
<td>90</td>
</tr>
<tr>
<td>10</td>
<td>83.4 81.2 71.2 61.0 51.3 44.6 41.2 33.8 24.8</td>
<td>59.6</td>
<td>100</td>
</tr>
<tr>
<td>11</td>
<td>84.7 80.9 70.7 61.6 50.9 45.1 41.9 33.2 23.9</td>
<td>59.5</td>
<td>110</td>
</tr>
<tr>
<td>12</td>
<td>83.7 81.2 72.0 62.6 52.9 46.9 42.1 36.2 30.2</td>
<td>60.5</td>
<td>120</td>
</tr>
<tr>
<td>13</td>
<td>83.8 80.4 70.7 61.6 52.4 48.2 43.0 37.8 29.8</td>
<td>59.1</td>
<td>130</td>
</tr>
<tr>
<td>14</td>
<td>84.2 82.6 71.6 63.1 54.7 51.4 46.4 40.4 32.7</td>
<td>61.1</td>
<td>140</td>
</tr>
<tr>
<td>15</td>
<td>82.6 81.0 71.2 62.5 56.0 52.4 46.2 41.6 33.7</td>
<td>60.5</td>
<td>150</td>
</tr>
<tr>
<td>16</td>
<td>81.8 82.6 76.9 68.3 65.0 58.2 54.0 52.3 44.4</td>
<td>66.4</td>
<td>160</td>
</tr>
<tr>
<td>17</td>
<td>83.1 81.7 77.3 71.9 66.1 58.8 53.9 52.3 43.8</td>
<td>68.3</td>
<td>170</td>
</tr>
</tbody>
</table>

Table 2. Moored Ro-Ro ferry: measured values of frequency spectrum and overall noise levels.

In the above set of measurements, the 60m distance has been missed, due to instrument malfun-
ing. As for the cruise ship, though measuring the background noise was impossible, the wharf was a very silent area so that the measured sound levels can be considered as the emission of the auxiliary engines and ventilation fan only.

Fig. 4 and Fig. 5 show such measured data as spatial trends respectively of single octave bands and overall A-weighted average level: in both figures it can be noticed how the acoustical levels increase getting closer to the ventilation fan. In particular, from the measurements points between 120m and 150m from stern both sources provide a relevant contribution, from 0m to 110m the funnel only was heard while in the two last points the fan was prevalent.

From stern up to 110m, sound levels are almost constant, varying over a short range of less than 3dB(A) in the overall levels from a minimum of 59.0dB(A) up to a maximum of 61.4dB(A). Similarly to the cruise ship, there is a prevalence of contributions in the bands 31.5Hz and 63Hz, though they are reduced in the overall sound level by the A-weighting curve.
Figure 4. Moored Ro-Ro ferry: $L_{eq}$ in octave bands vs. measurement points.

Figure 5. Moored Ro-Ro ferry: overall $L_{Aeq}$ vs. measurement points.

5. Conclusion

Two short-term sets of measurements have been carried out, surveying a cruise ship and a Ro-Ro ferry. A new method proposed by the FP7 SILENV project has been tested, characterizing the noise emission of ships moored at wharf. A simplified version of the method, provided by the project itself, has been chosen as considered more suitable in complex areas like ports.

Such simplified method has been implemented in silent zones of the port, as it was impossible turning off the sources under investigation to measure the background noise. As an alternative, it may be useful carrying out a characterization of the affecting sources in order to make a numerical model of all the relevant sound sources.

All sound levels measured, lower than 70dB(A), vary on a range of about 3dB(A), while the Ro-Ro ferry is characterized by a relevant contribution due to a ventilation fan at bow.
6. Acknowledgements

The authors would like to thank everyone at the Port Authority of Civitavecchia for their kind and invaluable support, without which this work would not exist.

REFERENCES


