POSSIBLE SOLUTIONS FOR PORT NOISE MONITORING

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The subject of port noise is increasingly gaining attention due to the higher number of complaints from people living in the nearby urban areas. Moreover, unlike other kinds of transport noise, such as the one due to railways, airports or roads, the current normative framework in this sector is lacking a proper structure and is in general inadequate. Aim of this paper is to analyze the state of the art and, in particular, the available instrumentation and technologies that can be adopted in the field of harbor noise monitoring. In addition, the main norms and standards related to this topic will be summarized in order to establish which conditions are required for a proper evaluation of the port noise impact on the surrounding urban areas. New features of monitoring instruments and innovative measurement techniques that can successfully be applied to the port noise will be reviewed, in order to identify the best way to characterize the acoustic emissions of the various complex different sources typically present in harbors, and to achieve the goal of a proper and effective monitoring system that can be adopted to control noise in ports and its impact on the inhabitants living in its close proximity.

Keywords: port noise, monitoring, noise pollution, normative framework, Interreg maritime programme

1. Introduction

Port noise has long been overlooked, unlike other kind of noise coming from roads, railways or airports [1-3], as if the emissions generated were not relevant for the quality of life of the exposed population. Only recently the phenomenon has aroused greater interest, mainly because the reaction of the inhabitants of the port cities that no longer tolerate any annoyances and sleep disturbances coming from the ports.

The limited development of this topic, compared to the enormous amount of studies dedicated to other types of noise generated by transport infrastructures and/or industrial infrastructures, is well-documented, as well as the complexity of the subject. The acoustic impact of the ports is the result of an intricate overlap of noise generated by ships, cranes, loading and unloading of goods, embarkation and disembarkation of people, shipyards, trucks and trains, which affects the area both in daytime hours than nighttime hours.

Because of this complexity, several research projects have been carried out in order to define guidelines for analyzing and managing the port noise. In order to evaluate the acoustic impact, it was necessary to adopt various techniques based on instruments normally used in acoustic monitoring systems, for example, sound level meters, sound intensity probes, microphones grids, acoustic cameras, etc., the
choice of which depends on the type of source analyzed. Some of these measurement techniques do not seem entirely adequate for this complexity. If the characterization of mobile sources, such as vehicles, or of fixed sources, like many machines or industrial installations, has reached a high level of development and has been adequately standardized, for the ports the measurement campaigns do not have a well-established methodology. Furthermore, the very limited accessibility of harbour areas and the large size of the sources make monitoring operations more difficult.

2. Legislation and technical standard

The need for a specific law for the management of issues related to noise produced by harbour areas is urgent; however, even today, there is no regulatory act for the regulation of noise produced by port activities. Currently it is based on the Framework Law on Noise Pollution (Law 26 October 1995 No. 44) which is now almost entirely implemented through the issue of specific decrees for the regulation of noise generated by roads, railways, airports and industries. The specificity of port noise is often associated with Community legislation which defines the guidelines for the updated calculation methods for noise from industrial activity, aircraft, vehicular and railway traffic and the related noise data (Directive 2003/613 / EC), but this specificity is not treated exhaustively; this also happens in the legislation on the assessment and management of environmental noise (European Directive 2002/49 / EC) because, in the case of ports with a strong tourist and / or commercial component, it complicates the analysis excessively.


3. Instruments and techniques used for the monitoring of the port noise

To study port noise, which impacts on the surrounding environment and often on inhabited areas, various measurement tools and techniques have been developed. In the following an overview of the main studies available in literature is presented. Some of the studies were concentrated on single noise sources and mainly on ships which probably are the most peculiar sources inside the harbor. Some other studies faced the problem by trying to characterize the entire amount of noise generated by the harbor and transmitted to the surrounding areas.
3.1 Measurements with grids of microphones

The SILENV [4-6] project had among its objectives the identification and quantification of the airborne noise generated by the ship. To this aim, several measurement approaches have been adopted within the project.

Concerning moored ships, the first approach involved the placement of two grids of vertical microphones perpendicular to the symmetry plane of the ship and placed near the main sources (each with 9 points, positioned at 3 different heights and 3 different distances from the side); this solution had some issues, such as shadow zones in the two sections where the sound field is not regular, and a strong vertical directivity of the acoustic emissions [7]. This suggests that measurements carried out at quay at a small height above the ground, especially for larger ships, can fall into the shadow area generated by the hull and thus detect lower levels than those that can be radiated at greater heights from ship [8]. The second approach involved a parallelepiped measuring surface of microphone oriented in directions parallel to the plane of symmetry of the ship and normal to it. The chosen distance between the grid and the ship was 10 m as it was considered the most suitable to be free from obstacles in an industrial port [9]. An example of such a measurement configuration is reported in Figure 1.

![Figure 1: Example of measurement grid for ship airborne radiated noise](image-url)

From the data collected with this approach, the propagation in the measured sound field seemed to be dominated by near field effects and/or reflections (from the ground and other surfaces), making it difficult to identify simple procedures to identify acoustical losses. Therefore, this approach should be applied to a large number of cases in order to calibrate the limit value and support the actual feasibility of the procedure itself. Other measurements were performed with the same approach to verify the feasibility of this experimental procedure, considering 13 measurement positions distributed on the parallel-symmetrical plane to the ship at 3 different heights of 1.2 m, 17 m and 26.6 m. The results of the measurements confirmed that the sound pressure level increases as the height increases [10]. Furthermore, for this approach, procedures that take into account the already existing requirements [11-13] have been used to characterize the noise sources, their transmission paths and how these affect the various categories of receivers. A third approach suggested to place a grid of horizontal microphones, parallel to the plane of symmetry of the ship, aligned on three rows at different distances from the hull, at a constant height of 1.2 m. In this way the influence of the "shading" effect on the propagation of noise from a source placed at 1 m from the measurement position was highlighted; using this configuration, the sound pressure level measured in the first row (at 1 m from the hull) was lower than the one measured in the last row (at 19 m from the hull), and varies according to the microphone location [14]. Finally a further approach involved the placement of two grids of microphones oriented in directions parallel to the plane of symmetry of the ship, with measurement points aligned on two rows: a first row at a distance of 1 m from the hull of the ship and a second row at a distance of 25 m; for each one, various
heights are taken into consideration and the distance between one height to the other must be chosen according to the length of the ship and the distribution of the most significant noise sources. With the measurements of the first row it is possible to calculate the emitted sound power level of the ship, while the measurements of the second allow to validate the sound propagation model [15].

Regarding moving ships, if the environmental conditions do not allow the positioning of the microphone at a distance greater than or equal to 100 m, or at a distance equal to the length of the ship, it is possible to use a closer distance. If the sound sources on both sides are in the same positions, the measurements could be taken only on one side; otherwise, the measurements should be taken on both sides and at least two heights must be considered: one at 1.2 m above the quay level and one at the same height as the funnel. Additional heights can be added for larger ships or to improve accuracy.

### 3.2 Measurements with sound-level meters

During a campaign in the port of Naples, measurements were taken in various positions, at different distances and at different angles from the ship, in order to characterize the noise pollution coming from a moving ship, i.e. a ferry that entered the port and maneuvered in order to moor. The noise emissions fluctuated during the maneuver by more than 20 dB in the range 50-5000 Hz, reflecting the different conditions of the propulsion system and the different distance of the ship from the position of the receivers. The same ship was then monitored once it was moored at quay, and two operating conditions were detected there: the electric generators and the fans of the air conditioning system in operating and non-operating conditions. From the results emerged a quite different noise field. The fans of the conditioning system generate noise in the frequency range from 200 to 10000 Hz, while the propulsion system show stronger contributions in the frequency range up to 100 Hz. The ship in the quay generates otherwise higher emissions at higher frequencies, particularly in the range of 200-5000 Hz, where the emissions of generators and/or electric fans dominate. Considering ships in transit, the vessels differed a lot one to the other in terms of size, architecture, power and, consequently, radiation of noise. It is clear that even for these boats the fluctuations can be quite strong during the same maneuver. Furthermore, the differences between the noisiest and the quietest were up to 20 dB(A) [16].

Within the Eco.Port project, promoted by the Venice port authority, the values of the sound power level emitted by the different types of boats moored at the docks of the port were defined. These data were subsequently used within a calculation model in order to evaluate the effects induced in urban environments by the presence of different combinations of vessels. For ships in transit, a monitoring system was set up to record all the main acoustic parameters at one second intervals [17].

A notable case is that of the port of Lipari, which is affected by the noise emitted by the tanker ship that daily supplies water for the island during the night. The data acquired in two consecutive days, in the presence and absence of the ship, showed a generally constant and very variable noise, but on average higher in the presence of the ship, as expected [18].

In the port of Genoa, acoustic measurements were carried out in three different areas:

- zone A: industrial plant near a railway line;
- zone B: ships at berth in a port infrastructure adjacent to a residential area and crossed by the main urban road and from a railway line;
- zone C: an industrial plant immersed in a complex urban fabric and close to a motorway.

The results of the multi-day monitoring were the following: for case A, the various contributions (industrial activities and railway transits) have been highlighted and analyzed individually; for case B, the main effect of harbor emissions could be noticed with the alteration of the background noise (i.e. some frequency bands were statistically more significant than others), and finally for case C it was found that the observed noise behavior was the one characteristic of the situations dominated by traffic noise (in this case a motorway) [19].
The synthesis of the twenty-year experience of port of Genoa monitoring campaign shows that in the port areas the $L_{Aeq}$ does not exceed 80 dB(A), while near the port perimeter the noticeable noise is that due to the road infrastructure, that usually exceeds 70 dB(A). Finally, in the hill-districts at an average distance of 0.5 km from the port docks, the $L_{Aeq}$ is of the order of 50-55 dB(A), meaning that the sources of the port area are perceivable [20]. A similar methodology was adopted by the Port Authority of Guadeloupe to characterize the sound environments within the Grand Port project [21], making noise measurements in 10 different areas near the port.

In addition, measurements taken at Genoa’s Voltri Terminal Europa on moored ships showed that the actual noise caused by the generator was in the 100-250 Hz frequency range. With only one engine on, a level of 95 dB(A) was detected at the exit of the exhaust, reasonably due to the air displacement [22].

Regarding the port of Leghorn [23, 24], a simultaneous monitoring of noise and road traffic was made: it was observed that, in general, peaks of road traffic (both light and heavy) were associated with ferry arrivals in the port. This increase in vehicular traffic in almost all cases is associated with an increase in sound levels, usually around 7 in the morning and around 18-19 in the evening. Another measurement campaign dealt with the acoustical characterization of different small vessels at various speeds moving in Livorno’s canals, which branch off in a densely inhabited area; the analysis, made by means of short and long-term pass-by measurements, showed that “small motorboats, sailing boats, and rigid-hulled inflatable boats can be included in the same acoustical category, while small and medium sized fishing boats, fireboats, and public security boats are a different category” [24].

Another example comes from the city of Nice, which has a continuous and real-time noise monitoring system with 45 sound level meters. Among these, 7 are present around the port, 6 of class 2 and one of class 1, belonging to the Chamber of Commerce and Industry (CCI) and to the municipality of Nice.
Côte d'Azur (NCA). Depending on the holder of the data, these are available in different forms: while those acquired by NCA are available upon request, those for which CCI is responsible are distributed only to the Port of Nice.

### 3.3 Possible new techniques

The measurement approaches above described can be categorised as measurements taken in the proximity of a specific source (e.g. the ship), measurement taken at the boarder of the port area and measurements taken in remote position where the annoyed receiver can be found. In the first case difficulties are linked to the possibility of physically reaching and operating in the port areas during port activities that cannot be stopped or even slightly modified to carry out acoustic measurements for economic reasons. In the latter cases the main drawbacks are represented by the difficulty in clearly identifying the sources of annoyance. In order to partially overcome such problems, microphone arrays can be used either with acoustic cameras or with beamforming techniques. Acoustic cameras allow to visually identify the main contributors to noise, even in a specific frequency band, in a complex acoustic environment with multiple sources allowing to carry out measurements in remote positions. The main drawback is represented by the difficulty in obtaining a quantitative estimation of noise levels. Beam forming techniques, on the other hand, allow a spatial filtering of noise increasing the SNR (signal-to-noise ratio) for a given direction taking advantage of the array directivity. Such technique can be used for a quantitative estimation of noise, but the position of the noise source in respect to the receiver one must be precisely know in advance.

Both the above described techniques, with their pros and cons, deserves attention and within the EU-Interreg Italy-France Maritime program is foreseen to test them in a real port environment.

### 4. Conclusions

The problem of port noise monitoring has recently gained importance as a consequence of citizens’ complaints living in urban areas located close to harbours. The problem has been so far faced trying to adapt measurement procedures and instrumentation created for different aims. Presently no specific standards or requirements have been issued to specifically address port noise. This lack in regulations is mainly due to the number of entities and authorities involved and to the complexity of the harbour as a source of noise. As a matter of fact, a large harbour can be considered a small town with many different actives that can in their turn be considered complex noise sources. While most of the activities are already subject to noise limitation when located outside harbours, ships represent a completely new and understudied noise source. In response to complaints, many measurements campaigns have been carried out typically with classical phonometers either close to typical harbour noise sources such as ships or in the position where citizen reported disturbances or at the border between port areas and the surround city. When ports are located inside urban areas, which is the most common case in Europe and the only case regarding Mediterranean ports, measurements are always affected by the contribution of noise sources unrelated to harbour activities. In this scenario it is very difficult, if not impossible, to assess the exact contribution to the overall soundscape of the noise generated by harbour activities. The difficulties in precisely identifying the sources of noise makes also hard to take countermeasures that can be difficulty accepted by terminal operators if it has not been demonstrated that the noise emitted by their activities is responsible for citizens’ complaints. Current research in the framework of EU Interreg projects is trying to fill the gap regarding port noise by elaborating new measurements and monitoring technique aimed at characterizing the different sources of noise present in harbours.
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