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Procedia - Social and Behavioral Sciences 48 (2012) 868 – 879

Procedia
Social and Behavioral Sciences

Transport Research Arena– Europe 2012

Noise emitted from ships: impact inside and outside the vessels

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Abstract

The noise generated by ships affects a wide range of receivers: crew and passengers inside the vessel, inhabitants of the coastal areas and marine fauna outside it. The time elapsed since these types of impact have been considered and the state of the art of the noise control for each of these fields is very different.
The paper aims at analysing the regulatory frameworks in the various fields, underlining differences in the present level of development and suggesting possible improvements in the general approach. The paper refers to the first phase of the SILENV collaborative project (EU 7th Framework Programme).

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"Keywords: ship; impact; waterborne noise; airborne noise; room criteria; strategic mapping;"

1. Introduction

The subject of the environmental impact is nowadays a key issue. The impact of anthropogenic activities is to be assessed in respect to a human environment (workplace, living areas) as well as to a natural environment (flora, fauna, landscape), at a local as well as global level. This has brought to identify and evaluate types of impacts that earlier were not at all (or only in part) considered. Among

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doi:10.1016/j.sbspro.2012.06.1064

these impacts is noise pollution: for shipping, as for other activities in the industrial and transportation sector, this subject has recently gained an increased attention.

The noise generated by the ship has a direct impact on the quality of the workplace and of the living environment for crew and passengers on board, but affects also third parties when ships sail along coasts, bays and channels or are moored at quay.

Noise is radiated into water too, generating similar effects on the local environment; moreover, it has been pointed out that the diffused source of noise represented by shipping has implied an increase in the background noise of the oceans, with a global modification of the living ambient of the marine fauna, .

Due to the multi-shaped aspects of the impact of noise emissions from ships, the assessment and control of such emissions require, therefore, a much more holistic approach than applied in the first attempts to deal with this problem.

This is the approach followed in the SILENV collaborative project (Ships oriented Innovative soLutions to rEduce Noise & Vibrations), funded by the E.U. within the 7th Framework Programme. The present paper refers to the first phase (Workpackage 1) of the project, related to identification of the needs for noise control and how they can be quantified and justified.

In the following, the subject of the acoustic impact of ships will be addressed with reference to the different environments affected (emissions towards the internal part of the ship, radiation in air, radiation in water: see also Badino et al. 2011a).

2. Noise inside the ship

2.1. Aims for noise control on board

The aim for noise control on board is dual: the safeguard of the health of the crew, and the comfort of both the passengers and the crew. These problems, which play nowadays a significant role in the design of boats and ships, are addressed by a number of national and international regulations and standards briefly recalled hereafter.

2.2. Normative review

ISO 2923:1996 is the standard containing techniques and conditions for the measurement of noise on board vessels, both inland and seagoing. Measurements can be carried out to different aims: check the exposure of seafarers to noise, ensure speech intelligibility and audibility of acoustical signals in key areas on board and compare the performance of different vessels. This international standard is of general purpose and can be a very useful reference in analyzing on-board noise.

From a regulatory point of view, international organizations primarily involved in the control of noise inside the ships are two United Nations' agencies: the International Labour Organization (ILO) and the International Maritime Organization (IMO).

Further specific requirements about noise levels on board have been issued by most of the Classification Societies (CS) in terms of Comfort Classes (CC), voluntary class notations assessing the comfort on board different types of ships.

At national level, most of the existing regulations are developed by local Coast Guard Agencies, and are generally based on IMO's requirements.

2.2.1. ILO

The ILO is the international organization responsible for drawing up and overseeing international labor standards. It is a United Nations agency that brings together representatives of governments, employers and workers to jointly shape policies and programs promoting rights at work. Giving the broad mission of the agency, the aspect of noise and vibration for workers is handled in very general terms in documents covering also a large number of other issues.

The most representative ILO document covering noise effects on workers is the Code of practice "Ambient factors in the workplace" (ILO 2001) which discusses a wide range of potential hazards for workers in general. As regards noise, the Code gives suggestions on the prevention and control of emissions, health surveillance and training for workers: no limits for workers' exposure to noise and vibration (N&V) are actually given, but the Code makes reference to international ISO standards.

Specific documents about working conditions on board ships, which anyway follow a similar format of generic requirements (without quantitative expressions), are the Maritime Labour Convention (ILO 2006), the ILO Convention No.188 - Concerning Work in the Fishing Sector (ILO 2007a) and ILO Recommendation No.199 - Recommendation Concerning Work in the Fishing Sector (ILO 2007b).

2.2.2. IMO

The International Maritime Organization (IMO) is a specialized agency for shipping of the United Nations with 169 Member States and three Associate Members. Its primary purpose is to develop and maintain a comprehensive regulatory framework, regarding safety, legal matters, environmental concern and efficiency of shipping.

The most specific document that covers extensively and in details the issue of noise control on board commercial ships is the Resolution A.468(XII) (IMO 1981), henceforth indicated with the term 'Noise Code'). Other mentions of noise control requirements are contained in the SOLAS International Convention for the Safety of Life at Sea (IMO 1974), which in its later amendments refer to the Noise Code.

The Noise Code applies to all ships in service, (over 1600 tons of gross tonnage) and "as far as reasonable and practicable, to the satisfaction of the Administration" also to smaller new constructions. Exceptions are represented by specific categories "dynamically supported craft, fishing vessels, pipe-laying barges, crane barges, mobile offshore drilling units, pleasure yachts not engaged in trade, war ships and ships not propelled by mechanical means". It is not a mandatory requirement in itself, but most of the National Norms issued in the meanwhile refer to it, so it became in practice a compulsory standard.

The Noise Code is designed to prevent potentially hazardous noise levels on board ships and to provide for an acceptable working environment for seafarers. The focus is on the crew health: limits are enforced on the noise power flow and to the total daily acoustic energy absorbed. The performances of the noise transmission path through partitions of spaces are also regulated.

Three types of provisions are reported:

- A-weighted noise level limits for various spaces on board
- Noise exposure limits setting a limit of 80 dB(A) for the equivalent average noise level $L_{eq}(24)$.
- Minimum values for the airborne insulation index for bulkheads and decks.

$L_{eq}(24)$ is defined in Equation (1):

$$L_{eq}(24) = 10\log_{10}\frac{1}{24h}\int_{24h}\left(\frac{p_a(\tau)}{p_0}\right)^2 d\tau \tag{1}$$

where p_A=instantaneous A-weighted sound pressure; p_0= reference pressure.

The code is published together with the “Recommendation on methods of measuring noise levels at listening posts” (IMO 1972) in the booklet “Noise Levels On Board Ships” (IMO 1982).

Dynamically supported crafts (not covered by the IMO Code) are regulated by the Code of Safety for Dynamically Supported Craft (DSC Code: IMO 1977). The wider category of high speed crafts is covered in the International Code of Safety for High-Speed Craft (IMO 1994 and IMO 2000).

In these documents, mention is made of qualitative provisions for noise control aimed at enforcing safety through audibility of signals and of commands.

2.2.3. Classification Societies: Comfort Classes requirements

The Comfort Classes (CC) requirements issued (with different degrees of details) by the various Classification Societies members of the IACS (International Association of Classifications Societies) are focused on the evaluation of the passengers and crew comfort on board ships. Different limits are available, able to rank the acoustical performances of the ship from a minimum to a maximum ‘grade’.

Limits in dB(A) are fixed for each space typology on board while, as regards the acoustical performances of partitions on board, requirements are set on the sound insulation index of vertical subdivisions (bulkheads) and on the noise impact level of horizontal subdivisions (decks). In the former case an important aim is to enforce privacy between cabins (or other spaces), in the latter, the problem addressed is the noise that people moving on the deck (jogging, dancing or simply walking) can transmit to the spaces below.

Criteria used to set limits on the perceived sound power [dB(A)] in the various passenger spaces on board are:

- Type of use of the space (private: cabin or public). In private spaces a lower noise level is required.
- The expected noise level: the passengers expect to find different noise levels in the different spaces in function of the activity that are carried out: high levels (discotheque), medium (restaurant), low (libraries)
- The time spent by passengers in the space. If a passenger spends only a short time in a space a higher level can be accepted. [ex: long stay (cinema, theatre, cabin), medium stay (restaurant), short stay (shop), passage (corridor)]

As regards the limits in the crew spaces, they are based only on the type of use of the space and most of the CC make reference to IMO 1981 (for the lowest grade).

2.3. Summary of norms (comments, trends)

As it is apparent from the very short overview above reported from the various documents, the background of ILO documents is not very technical: the texts never go beyond general motivations and aims, in some cases indicating means to improve the conditions of workers, but never giving precise or quantitative information on how to check the acceptability of conditions on board.

At IMO level, the most comprehensive reference is the Noise Code, which dates back some thirty years. IMO started recently an updating process for the Code. A correspondence group has been established on this matter (IMO 2011) aiming at discussing the criterion of application of the Code, making it mandatory for new ships, upgrading the standards for measurements and updating the limit levels for the spaces on board. In general the updates under discussion move in the direction of more severe noise limits (levels lower by 5 dB(A) are proposed for most of the spaces on board) and a similar increase [+ 5 dB(A)] in the minimum insulation indexes. This is in line with the modern needs for increased comfort and better working conditions for workers and with the improved technologies available for noise control on board. Provisions are similar both in type and in values to those enforced in other industrial sectors (ILO 2001).

As regards the assessment of comfort, it is noted that the present formulation of CC does not differ much, from a typological viewpoint, from requirements for the workers' health. CC mostly refer to merely energetic indexes, such as the A-weighted sound level, with the same approach of the Noise Code (even though with more restrictive limits).

A proper evaluation of the acoustic comfort should include in addition more refined criteria, like spectral composition of noise or the repetition over time. Enhanced acoustic indicators like the ones usually used in the civil engineering context, (e.g. the Room Criteria Mark II) could be used to value the noise annoyance on board ships, too. Adopting such indexes in the maritime context would give much more information about the quality of the sound wellness (intended as the perception of people as to the adequacy of the noise environment in the space they occupy) and could convey more information able to help in identifying the interventions needed for improving the situation (Badino et al., 2011c).

3. Noise emissions in air

3.1. Statement of the problem source-transmission-receiver

Air noise pollution from ships affects people living near channels or coastal areas with intense traffic of ships passing by or near ports, where ship enter and stay at wharf for loading/unloading processes. The ship source, accordingly, has characteristics in common with typical mobile sources like the other transportation means: road vehicles, trains, airplanes and also with stationary sources like industrial plants. Unfortunately, at present, specific instruments to characterize, assess and control the ship source type are not available and in many cases indicators are taken without adaptation from other sources categories, where experience is more.

In both cases (ship as mobile or stationary source) the impact of the radiation depends on the characteristics of the surrounding area (orography, spatial distribution of buildings and of population, even meteorological conditions: wind, snow). In other terms, both transmission paths and receivers are external to the ship and their characteristics are independent from the ship. This makes the assessment of the impact and of the control of external noise different from the case of the noise internal to the ship and has a paramount influence on the normative framework on the subject. The current situation is briefly recalled in the following (see also Badino, Borelli et al. 2011b).

3.2. Existing norms

At present, International Standards cover to some extent the subject of reproducibility and comparability of measurements of the airborne sound emitted by vessels, whereas European and National Regulations focus on defining limit values to preserve the population exposed to different noise sources types, without any specific reference to the noise emitted from ships.

3.2.1. International Standards

Three ISO standards are focused on the assessment of the airborne sound emitted by vessel for acceptance and monitoring tests:

- ISO 2922:2000 for all vessel types with the exception of recreational crafts (ISO 2000);
- ISO 14509-1:2008 (ISO 2008) and ISO 14509-2:2006 for recreational crafts (ISO 2006).

In ISO 2922:2000 two classes of test conditions are considered: for the vessel under way and for the vessel alongside at wharf or at anchor. For moving vessels, the A-weighted sound exposure level, L_{AE}, and the maximum AS-weighted sound pressure level L_{pASmax}, are to be measured, whereas for stationary vessels the time-averaged A-weighted sound pressure level, L_{pAeq}, is surveyed.

Measurements can be carried out under specific environmental conditions, operating conditions and test side specifications, defined by this ISO standard. The method to assess the background level measurements is also reported in the same document.

For moving vessels at least two passages are required by the test procedure. The measurement period should cover the highest 10 dB of the sound from the vessel passage. For monitoring tests slight deviation from the test conditions specified before may be tolerated. For stationary vessels the measurement period is not less than 30 s.

In ISO 14509, devoted to recreational crafts, only the condition of moving vessel is considered. The Standard is divided in two parts. The first part specifies the procedure to be applied to powered recreational craft of up 24m length for measuring L'_{pASmax} (maximum AS-weighted sound pressure level during the passage) and the L_{pASmax} (L'_{pASmax} after applying background noise correction and distance correction). The evaluation of LAE is optional. Inboard engines, stern drives, personal watercraft and outboard motors are included.

The second part of the above mentioned ISO standard specifies a comparative procedure to assess the maximum sound emission of powered mono-hull recreational craft of up to 24m length using the concept of reference craft.

All these measurement standards are mainly aimed at carrying out acceptance and/or monitoring tests.

3.2.2. Noise control

In order to analyze and control the environmental noise pollution the European Commission introduced the Directive 2002/49/EC (EU 2002), known with the acronym END (Environmental Noise Directive). Members States have to transpose this Directive into a National Law.

The END has introduced a very useful tool of acoustic planning in order to analyze and to control the environmental noise pollution: the Noise Strategic Mapping (NSM). Day-Evening-Night Level (L_{den}) and Night Level (L_{night}) are the noise indicators recommended for the mapping. In Annex IV, the Directive underlines the importance to make NSMs for areas where the main noise sources are located (road, rail, or air-traffic noise, industrial noise, construction activities, etc.), including ports as well. The noise emitted by ships is one of the main categories of noise which must be taken into account during a port NSM (see: NoMEPorts 2008).

The END establishes that the noise limit levels have to be defined by State Members. Limit levels may vary for different types of noise sources or be the same for all sources. At present, no State Member has established yet noise limit values in accordance with the above mentioned Directive. Previous national regulations are currently in force, in which other types of sources are considered. In several States the noise limit values are commonly expressed in terms of equivalent sound pressure level weighted A, L_{Aeq}, and they are referred to time periods changing from country to country (for a review of policies in the field of noise control for ports, please see: Badino et al., 2010)

3.3. Gaps to be filled

As mentioned above, the international Technical Standards for the measurement of the ship noise, define procedures to carry out mainly acceptance and monitoring tests; they don’t have as a main aim a proper acoustic characterization of the ship. A proper modeling of the noise propagation calls for a proper acoustic characterization of the sources represented by the different ship categories. This is essential for the application of the NSM concept to ports, the ships noise map being one of the most relevant maps to be derived.

3.3.1. Characterisation of ship source

The ship source features very large dimensions, particularly if compared with the local geography of the sites to be evaluated. It also features a strong directivity. These characteristics make more difficult a complete acoustic characterisation which, however, is needed for a accurate prediction of the external sound propagation. The subject has been analysed in the SILENV Project and a set of complementary measurements, additional to those recommended by the International Standards have been identified. In setting guidelines for these measurements, it a flexible approach in the choice of the surveys parameters was followed, as the best choice to fit the wide variety of vessels and internal noise sources characteristics.

For moored vessels, in particular the additional measurements suggested in SILENV were:

- more than one row of measurement points at different distances from the ship hull, in such a way that the superimposition of local sources can be analyzed and solved;
- measurement points located at more than one height from the ground, with the aim of evaluating the sound generation from higher sources, e.g. ventilation systems, vents, funnels which are at a certain height in the side or above the deck and even at the top of superstructures;
- to set the time duration for measurements according to the time period of noise.

For vessels under way, the aim of the test is to define a significant sound level for a transient phenomenon, as it happens when the vessel passes by. In general, pass-by tests are commonly utilized for measuring the noise emitted by mobile sources in motion. Concerning pass-by tests for ships, ANSI/ASA S12.64-2009 defines pass-by underwater measurements for ships. Following the same approach, an example of possible microphone positioning for measurements of airborne sound propagation, is reported in Figure 1. There, dCPA is the distance at the Closest Point of Approach, while DWL is the Data Window Length

3.3.2. . Matching the source to the environment (NSM)

To assess and to manage the environmental noise in ports, NSM is considered now the most suitable instrument of acoustic planning. It allows to identify the critical zones and to establish the improvement actions. This is essential to allow the development of trading activities, without compromising the quality of life in port cities. As in the port there are various sorts of sources, a noise map for each source category must be drawn, in particular one will cover ship noise.

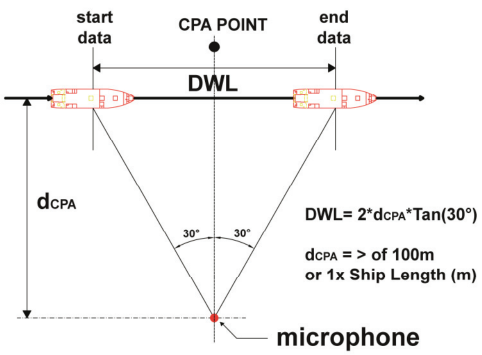

Fig. 1. Example of microphone position for pass-by measurements of one ship

A noise map is obtained in terms of L_{den} and L_{night} values by the superimposition of noise fields calculated for every ship-source. To make a ship noise map for a port a number of input data are required:

- the drawings of the port areas, including the places where each vessel typology is usually berthed and the transit lines along which the vessels are usually under way;
- the acoustic properties for each vessel typology (sound power levels on the basis of operating conditions, directivity of the source, etc) which all together characterize the ship emissions;
- the working hours of the specific sources: annual average value for each period of the day (day-evening-night);
- the vessels number for every typology: annual average value for each period of the day (day-evening-night);
- the number and time of transits for every ship typology: annual average value for each period of the day (day-evening-night)

The percentage of people exposed to high levels of L_{den} and L_{night} can be evaluated using noise maps. Furthermore, comparing limit values with L_{den} and L_{night} values, carried out by these noise maps, critical areas can be identified. Unfortunately limit values for ship noise are not defined yet. The situation is the same for other noise source categories.

It is worthwhile noting that the information can be used also ‘back-propagating’ the analysis to define the specifications in terms of radiation that ship should meet in order to access certain areas of the port without impacting too much the surrounding population.

4. Noise emissions in water

4.1. Statement of the problem: source-transmission-receiver

The problem of underwater noise emissions from commercial vessels has been addressed only very recently. The effect to be considered in this case is the impact on the marine fauna. Antropogenic noise, infact, can, by direct disturbance, cause marine animals to abandon their habitat and/or alter their behaviour or can interfere with their living activities masking acoustic communication signals over large areas (Hildebrand 2005). Higher sound levels could directly affect their hearing capabilities by producing either temporary or permanent hearing losses (Gordon et al. 2004), even though these cases are in general related to other kinds of anthropogenic noise than ship traffic, like sonars or underwater exsplosions.

The problem of the noise radiation in water from a ship is very complex and a good knowledge of all the elements involved (source, transmission path and receiver) is needed. As regards the source, ships characteristics are very different from each other but some common phenomena generating noise can be identified. In general underwater noise is mainly due to the following elements:

- propellers in cavitating and non-cavitating conditions
- main and auxiliary engines
- flow around the hull and in the propeller wake

Propellers, which are the main sources of underwater noise, are placed at the extreme aft end and this is shown in the directivity of the ships emissions. In fact the highest noise levels can be found behind the stern, where the direct noise from propeller and the noise reflected by the stern counter sum up.

The transmission of noise from the ship to potential receivers is influenced by many parameters: the celerity profile in the water column, the composition of the bottom and the relative position of source and receiver as well as the sea roughness. All these parameters, combined together, generate complicated transmission paths, different, moreover, for each frequency of the signal, further complicating the prediction of noise levels received by the animals.

4.2. State of the art

The problem of the impact of shipping noise on marine mammals has been addressed only very recently. On the other hand, for military aims, noise generation from ships has been studied since a longer time, but studies and results are often not available for security policies. In the following an overview of state-of-the-art for the characterization of source and receiver and a description of the available limits on underwater noise emission from ships are given.

4.2.1. Characterization of the ship source

Two main standards for the measurement of underwater noise emissions from commercial ships are up to now available (ANSI/ASA 2009 and DNV 2010). The first one offers three grades of measurement (A, B, C) which differ in terms of uncertainty, complexity and repeatability, while the latter one provides a unique procedure. In the ANSI/ASA standard the most complex configuration foresees three hydrophones deployed at three different depths [see Figure 2 (a)], with a total depth of sea greater of 75 m or 1x overall ship length for the lowest grade. On the other side in the DNV standard only one hydrophone is placed on an inclined sea bed [see Figure 2 (b)]. As regards the procedure for the measurements, in both cases, the vessel should pass at beam aspect at a fixed distance from the hydrophone both stern and port-side, but only in the DNV standard measurements during thruster maneuvers are contained.

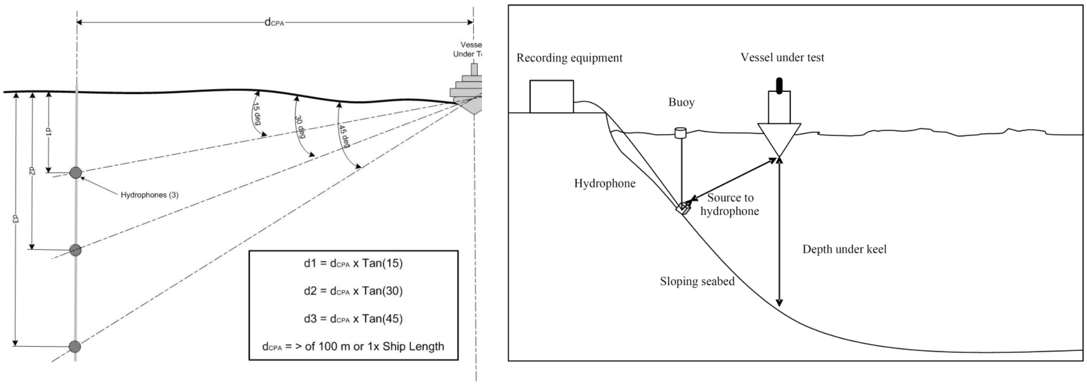

Fig. 2. Measurement layout: (a) as suggested by ANSI/ASA 2009; (b) as suggested by DNV 2010

To normalize the sound levels recorder to one meter from the source simplified laws are suggested and the results are presented in terms of 1/3 octave bands in both documents.

4.2.2. The receivers: marine mammals

An important set of receivers for the UWN radiated is represented by marine mammals. They are acoustic specialists and depend heavily on sound to communicate, to coordinate their movements, to navigate, to exploit and investigate the environment, to find food and mates and to avoid predators and other threats. These capabilities are the result of an evolution to adapt to the sea habitat, where vision is less developed and acoustic aspects are of a paramount importance. Marine mammals can be divided in two main categories: Mysticetes and Odontocetes. In the first group the largest mammals are included, such as the whales, while, f.i., dolphins are members of the second one.

Hearing sensitivities are available for the smaller marine mammals (dolphins), but no data are available for Mysticetes, due to their dimensions and the consequent difficulties in carrying out laboratory tests. Anyway, looking at Figure 3, some hypothesis can be done as regards the sensitivity of the larger mammals. In fact the audiograms of Odontocetes present a minimum (maximum of sensibility) in correspondence of their range of communication, as it happens for humans. For this reason it can be hypothesized that also the sensitivity of Mysticetes have a minimum in their range of communication, shifted in this case towards lower frequencies. As it can be noted from Figure 3, every species has a different audiogram, with sensibilities that can go from few Hertz to thousands of Hertz. Moreover, the communication range for the two groups (Mysticetes and Odontocetes) covers an extremely wide frequency range.

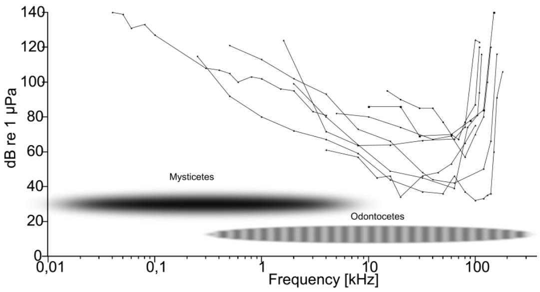

Fig. 3. Audiograms and communication ranges of Odontocetes and communication range of Mysticetes only

4.2.3. Limits on the underwater noise emissions

The International Council for the Exploration of the Sea (ICES) was the first institution that fixed limits for the underwater noise radiated from ships (Mitson 1995). Very recently the Det Norske Veritas classification society issued an additional class notation containing limits to the underwater noise from ships (DNV 2010). The approach followed by the two bodies as well as the aim of the limits is different. On one side ICES derived a limit curve starting from the cod's sensitivity to noise, while DNV limit curves are based on the state-of-the-art of the available technologies implemented in state-of-the-art vessels. The aim of ICES limit curve is to ensure that a vessel could approach fish stocks (in particular cods) at 20 m without scaring them. On the other hand DNV limits have the double aim "to ensure a low environmental impact and/or to ensure hydro-acoustic operational capability for vessels relying on hydro-acoustic equipment as an important part of their operation." Finally ICES provides a limit curve only for fishing research vessels while DNV provides limits for different ship categories, including fishing research vessels for which reference is made to the ICES limit.

4.3. Gaps to be filled

The available measurement standards use only simplified laws to normalize the noise levels recorder by the hydrophones to a distance of 1 m from the source. They do not take into account the large number of parameters that can influence noise propagation and reflections from the bottom and the free surface.

These effects are mitigated in the case of measurements carried out in deep water conditions, but for the major part of commercial ships, measurements of underwater noise emission have to be carried out during the sea trials; in this phase it is almost impossible to sail the ship to a very deep zone, f. i. for most of the shipyards situated in the Mediterranean Sea. To this aim the actual noise propagation should be studied especially for measurements carried out in shallow water. During measurements some important variables such as the celerity profile in the column water and the bottom composition should be monitored or estimated by existing data base and a propagation model, taking into account the different behavior of frequency components, should be used.

A possible improvement in setting limits to underwater noise emissions of ships is to focus on the receiver characteristics, i.e. on its sound perception. To do this, different strategies can be followed depending on if the target is to mitigate the behavioral effects or to reduce communication masking. In the first case a detailed knowledge of the sound perception of marine mammals is needed; in the latter case, in addition to mammals' audiograms, the characteristics of vocalizations and the ability to discriminate sounds is needed. The main limitation of such approach is represented by the lack of data regarding the bigger mammals, the Mysticetes, for which is very difficult to derive audiograms.

5. Discussion and conclusions

The three fields in which noise emissions from the ship have an impact show a very different situation as regards the degree of development of the studies on the phenomena involved, of the control means and of the normative framework. The development of control requirements depends on the time period in which the problem has been recognized and studied: the more than thirty years of development of norms for the preservation of the health of workers on board imply as a consequence that the framework of requirements is more coherent, structured and consolidated than what achieved in about a decade of development of external noise regulations and a few years of attention to underwater noise radiation (even though the experience from the military sector has been of great help in the recent developments)., Specific challenges are however still present in all the fields and can be foreseen as areas for future developments. Such areas can be identified for the control of noise on board, in a better definition of comfort, that takes into account more indicators than a mere quantification of the total perception of the noise power flow. For external noise in air, the evolution could be sought in the development of a more integrated set of requirements that can account on one hand for the specific characteristics of the noise radiation in air by ships (in comparison to other types of sources) and on the other hand for the number of players involved in the control process: IMO, shipbuilders, ship operators, port authorities, port state control, municipalities. As regards underwater radiated noise, the major challenge is represented by the characterisation of the perception of noise by the receivers (marine fauna), which should constitute the basis for a rational definitions of the targets of the noise control.

Acknowledgments

This work was developed in the frame of the collaborative project SILENV—Ships oriented Innovative soLutions to rEduce Noise & Vibrations, funded by the E.U. within the Call FP7-SST-2008-RTD-1 Grant Agreement SCP8-GA-2009-234182.

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