Noise Levels in a petrochemical products transportation ship

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Abstract. *This paper presents the noise levels measured in the superstructure and engine room of an inland navigation ship that transports petrochemical products in the Lagoa dos Patos. Measured levels are compared with national standards for health (NR-15 and NHO-01) and comfort (NBR 10152) related with noise levels. Noise is a well known occupational health and safety issue in many work environments, and is an increasing concern in the naval industry. In a ship, the crew is subjected to the noise produced in the machinery room during most of the time onboard, including sleeping and resting time. Evaluation of noise levels in ships that performs this operation in this area have not been reported in scientific works. The results shows that the noise levels found in the various ambient where measurement were made are higher than the recommended by the NBR 10152 standard. Comparisons with NR-15 and NHO-01 also suggests that noise levels are too high in some locations of the ship, but, in this case, conclusions should be taken carefully, as these standards were designed for different working conditions.*

Keywords: *Noise, ships, petrochemical*

1. INTRODUCTION

The problems with occupational heath and comfort related with exposure to high noise levels in working environments are well known issues. According to Kovacs (1998), with the increasing concern of shipyards and shipowners on this subject, the international rules are becoming increasingly more restrictive with the limits imposed for noise levels on board boats.

The present work shows the results of noise measurements in the superstructure of an inland navigation ship, which transports petrochemical products in the Bacia do Sudeste, in the south of Brazil, linking Santa Clara terminal (Triunfo, RS) and Rio Grande port (Rio Grande, RS). Besides the results of these measurements, it is shown the comparison of the noise measured with Brazilian standards for noise exposure and comfort related with this subject. Measurements were made with the ship operating in normal conditions. The noise was measured in several locals in the superstructure, such as cabins, kitchen and mess hall. The noise was also measured in the engine room, which can be considered the main source of noise on board the ship.

Those measurements are a part of the development of a research project financed by FINEP (CTAQUA, project number 01.06.0813.00), which aims to find criteria to evaluate equivalent age for ships that are in operation in inland navigation in the Bacia do Sudeste for 20 years or more, and have been through major repairs or upgrades. This evaluation involves, amongst many other aspects, identifying the comfort levels and protection to the health of the crew offered by the ships, and it’s suitability to national and international applicable standards. Some general information about the ship use in the present work are shown in Table 1.

Table 1. General information from the ship on which measurements were made

Building year	1987
Nominal deadweight	3300 t
cargo DWT	2870 t
Carried products	Benzeno, Tolueno, Xileno, Etilbenzeno, MTBE e Metanol
Total length	91,50m
Project draft	3,30m
Maximum draft	3,47m
Light displacement	971 t
Loaded displacement	4131 t

The main source of noise in the studied ship is the engine room, which is underneath the superstructure, where all of the accommodations for the crew are located. The ship propulsion system is composed by three Scania diesel engines with nominal power of 552 CV at 1.800 RPM each, with a reduction gearbox with a 4.9:1 reduction rate. Each engine drives a four blade propeller with 1500 mm of diameter. The maximum speed of the ship at full load is from eight to nine knots. Besides the propulsion engines, there are five other diesel engine in the engine room. Two of them are for electric power generation, two are to drive the hydraulic pumps used in charge and discharge operation and one is for the fire fighting system.

2. The Noise Issue

Noise is a well known environment pollution agent, studied as a health problem in working environments and as a disturb factor to several activities. Two relevant examples of potentially negative influence of noise exposure are the interference with attention capability and the effects on sleeping quality. In Brazil, the NR-15 standard presents the reference values and basic procedures to evaluate the exposure of workers to noise in working environments. In the specific case o the working cycle found in ships, the application of this standard is limited, once it was designed to workdays up to eight hours long. In a ship, the crew is exposed to the noise on board during all the period the ship is in operation. In the case presented in this paper, a normal travel (one way only) has an approximate duration of 23 hours.

Another Brazilian standard that makes reference to occupational exposure to noise is the NHO 01, created by FUNDACENTRO. This standard was created based on criteria slightly different of those used in NR-15, and is also a little more extensive, presenting reference values of equivalent noise levels limits for daily exposures lasting um to 24 hours

Besides the standards related with occupational health, the NBR 10152:1987 presents two criteria to define ideal noise levels in locations dedicated to several applications. The standard allows evaluations based on equivalent sound levels measured in dB(A) or according to a value called NC, defined from a spectral analysis of octave band frequencies of the noise in the ambient. Some of the values defined in the standard, which can be applied for the locations in the ship, are presented in Table 2.

Table 2. Some reference values defined by NBR 10152

Locals	dB(A)	NC
Sleeping rooms	35 - 45	30 - 40
Living room	40 - 50	35 - 45
Management, project and administration rooms	35 - 45	30 - 40
Restaurants	40 - 50	35 - 45

The duration of a normal journey (23 h) makes imperative to the crew to sleep one night with the ship navigating in each journey. The average frequency of journeys is 14 in a month (seven in each way), so the crew needs to sleep 14 times each month during navigation. Tamura et al (1997) studied the effects on sleep produced by the noise produced by a ship with a sound level of 65 dB(A). The sound of a ship diesel engine was previously recorded and men were exposed to it in a sleep laboratory during a night of sleep. Several sleep quality parameters were measured. The results show adverse effects of the noise in night sleeping.

The noise issue in ships is also treated by Martins ET AL (2000), in a work where the noise in the tugboat Clarisse is analyzed. Measurements of the noise produced by a single source in the ship (a diesel engine used to electricity generation) are used to improve a model based on empirical formulae and numerical methods, designed to make acoustic predictions.

3. Measurements, Results and Noise evaluation

The noise measurements were made with the ship operating in normal conditions, transporting cargo from Terminal Santa Clara (in Polo Petroquímico de Triunfo) to the Rio Grande Port (see Figure 1), in the state of Rio Grande do Sul, Brazil. Most of this path is on the Lago dos Patos. In the specific moment of the measurements presented in this paper, the ship was loaded with approximately 3000 tons of products, distributed in a nearly homogeneous way through its 12 tanks.

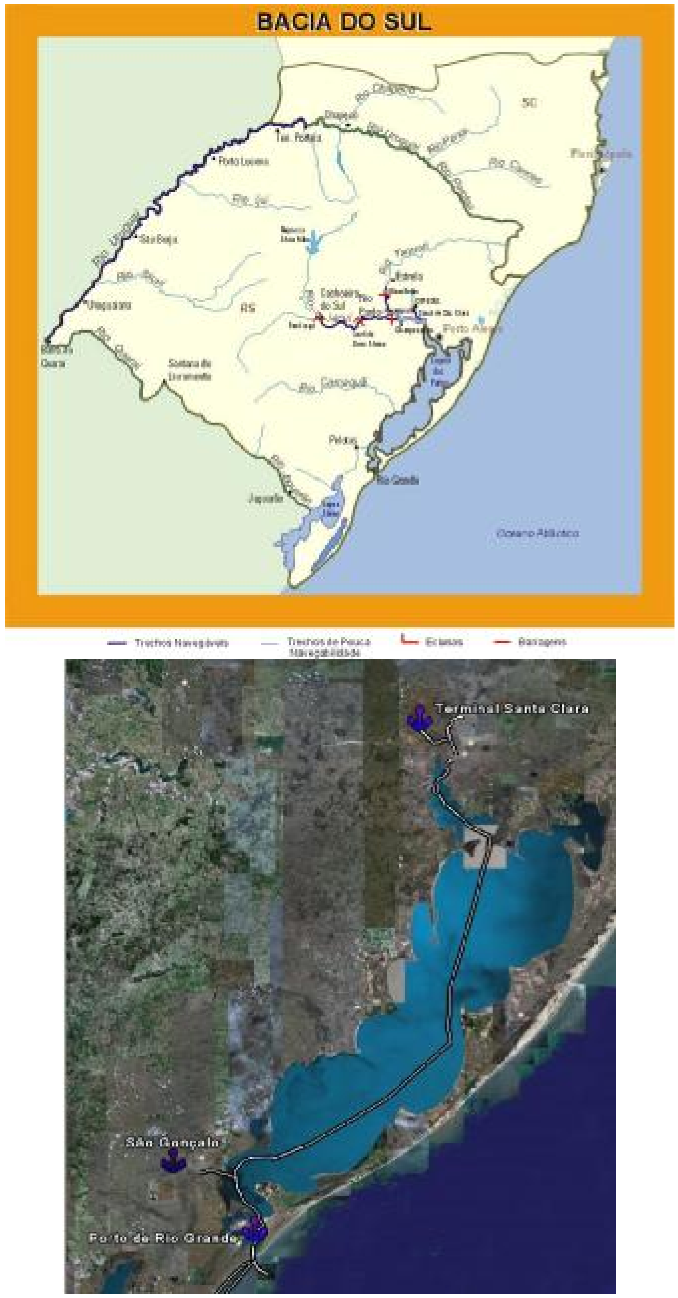

Figure 1. Location of the Lagoa dos Patos and the route made by the ship

The measurement locations were in the superstructure of the ship and in the engine room, which, in this case, is located immediately underneath from the superstructure. The locations are listed in Table 3. Measurements in all superstructure areas were made simultaneously with measurements in the engine room. In the engine room, measurements were taken near the main noise sources, as listed in the Table 3 and shown in Figure 2. The reason why the sound was measured in many points in the engine room, and simultaneously in the engine room and in the superstructure area, is to collect information for a future work, where an attempt will be made to correlate the sound measured in the superstructure with each of the possible sources in the engine room. In Figure 2, the locations of measurement in the superstructure and engine room of the ship can be identified.

Table 3. Measurement location

Deck	Name	Local
Main	Q2	Cook cabin
Main	R	Mess room
Main	C	Kitchen
Upper	Q1	Shipowner cabin
Engine room	MC	Central engine
Engine room	ME	Left engine
Engine room	MD	Right engine
Engine room	GE	Left generator
Engine room	GD	Right generator

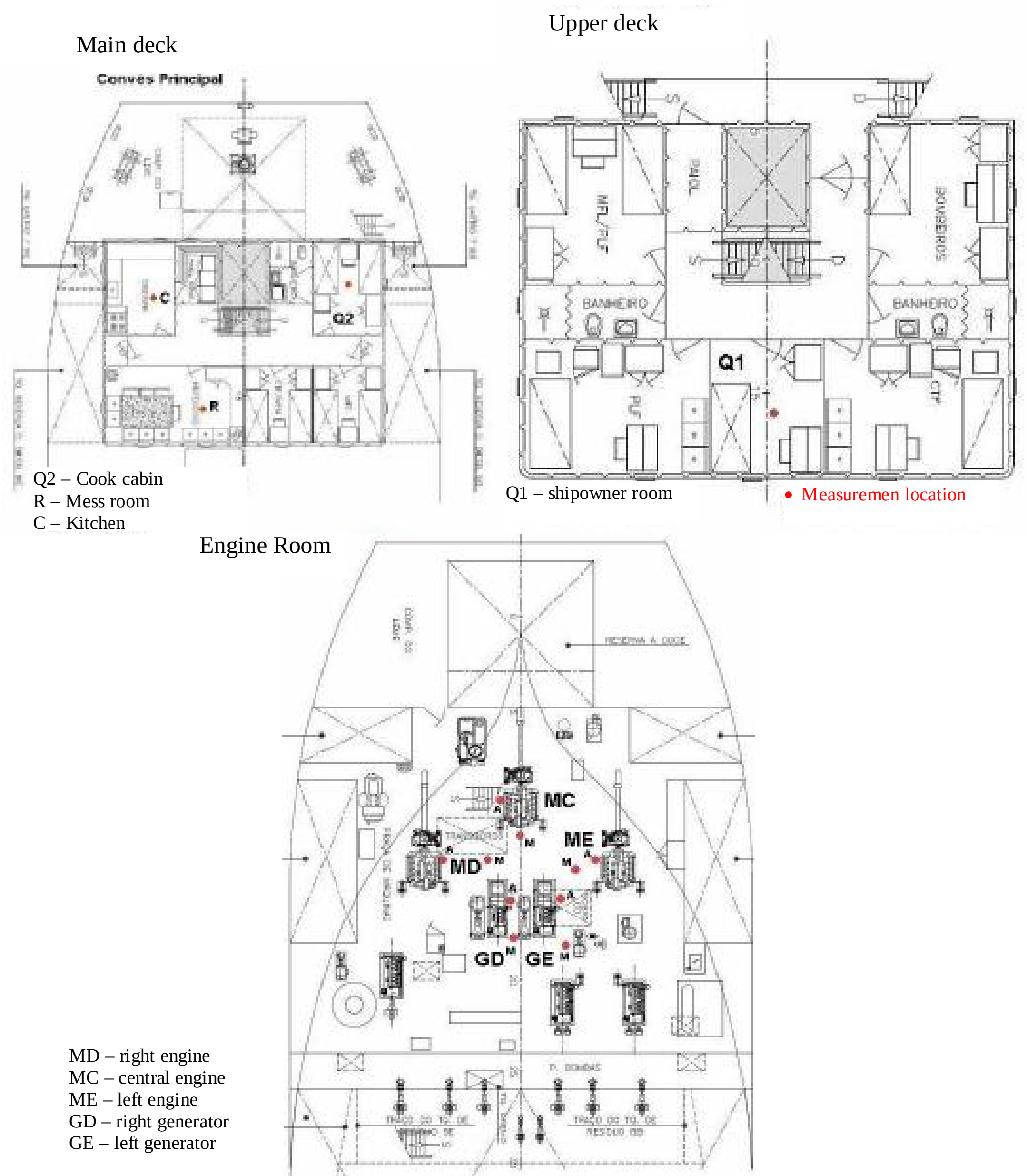

Figure 2. Measurement locations in the superstructure of the ship

Figure 3 shows images of some measurement spots. To evaluate the noise levels microphones were used to measure the sound pressure level in the environment. The equipment used in this measurements were two Type 4189-A-021 Brüel & Kjaer microphones, plugged to a PULSE Type 3560 acquisition system with 11 input channels and one output channel.

The microphone used in the rooms was fixed in a tripod. The microphone of the engine room was fixed in a pedestal, as it shows Figure 3. The height of the microphone was around 1,2 meters and both the tripod and the pedestal were placed as far as possible from any surface that could reflect the sound.

This Pulse system register the noise signal in a computer, so the signal can be post processed, allowing analysis such as spectrum (continuous or in frequency bands) and global levels identification (instantaneous and equivalent levels). Each measurement was made one minute long. As the noise produced in the engine room (main source of noise in the ship) is virtually continuous during navigation, this measurement time is long enough to characterize the noise. The measurement procedures are based on NBR 10151 standard recommendations.

Figure 3. Images from some of the measurement locations (mess room, kitchen, engine room)

In Table 4, it is shown the global sound levels measured in each measurement location, dB (no weighting) and in dB(A). The values are the equivalent sound levels for the one minute measurement interval. The values in dB(A) are used to evaluate each location according to NR15 and NHO-01 standards, from which is possible do estimate de maximum time a worker should stay at each place in a working day.

Table 4. Global values of sound levels in dB and dB(A) and comparison with NR-15 and NHO-01 limit exposure time

	Equivalent level		**Maximum time allowed in place**	
Local	**dB**	**dB(A)**	**NR-15**	**NHO-01**
Shipowner cabin	88,5	65,0	>24h	>24h
Cook cabin	86,5	73,9	>24h	>24h
Engine room	111,0	106,6	3,75 min.	25 min.
Kitchen	89,8	81,2	20h	>24h
Mess room	88,7	76,2	>24h	>24h

The NR-15 defines the highest equivalent noise level to which a worker can be exposed, without any protection, in a working day eight hours long, is 85 dB(A). To different exposure durations, the standard uses a criterion based in a doubling interval of 5 dB. This means that, with an increasing of 5 dB in the sound level, the highest exposure time is reduced to the half (for example, for an equivalent level of 90 dB(A), the maximum daily exposure time is 4 hours). Based on this criterion, the standard presents limit values of equivalent levels for exposure durations of eight hours or less. For exposure periods longer than this, the limit sound pressure levels can only be estimated, using the criterion previously exposed. From this, it can be estimated that a worker can be exposed to an 80 dB(A) level during 16 hours, and that to a 24 hours exposure duration, the maximum equivalent level should be approximately 77 dB(A).

The NHO-01 standard also establishes a 85 dB(A) limit for a eight hours daily exposure time, but for different exposure times, the criterion used in the standard is doubling interval of 3 dB (so, for a 88 dB(A) equivalent noise level, the maximum exposure time is 4 hours). Other difference is that, in the NHO-01, limit sound levels are defined for exposure times up to 24 hours. Using the criterion of this standard, a worker can be exposed to a 80 dB(A) equivalent noise level for approximately 24 hours. The limit time a worker can stay at each location measured on the ship are presented in Table 4 for both (NR-15 and NHO-01) standards.

Figures 4 to 5 presents the octave band spectrum of the noise levels (in dB) measured in each location in the ship, in the range from 63 Hz to 8000 Hz. These values are superposed to the noise criteria curves (NC) form NBR 10152. Based in this graphics, it is possible to identify the NC values to each measured location.

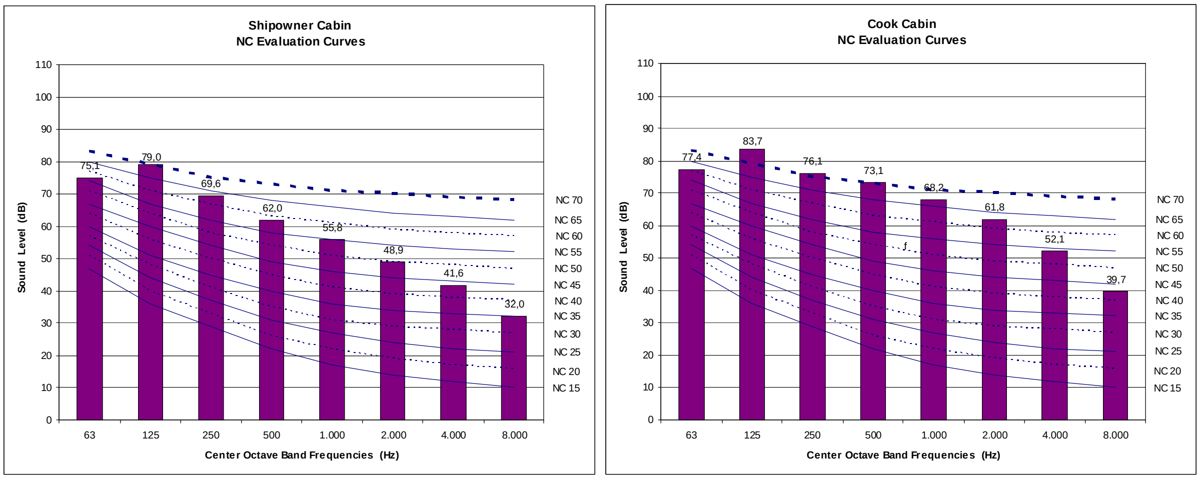

Figure 4. Octave band spectra of the sound level in the shipowner cabin and in the cook cabin, superposed to the NC curves from NBR 10152:1987.

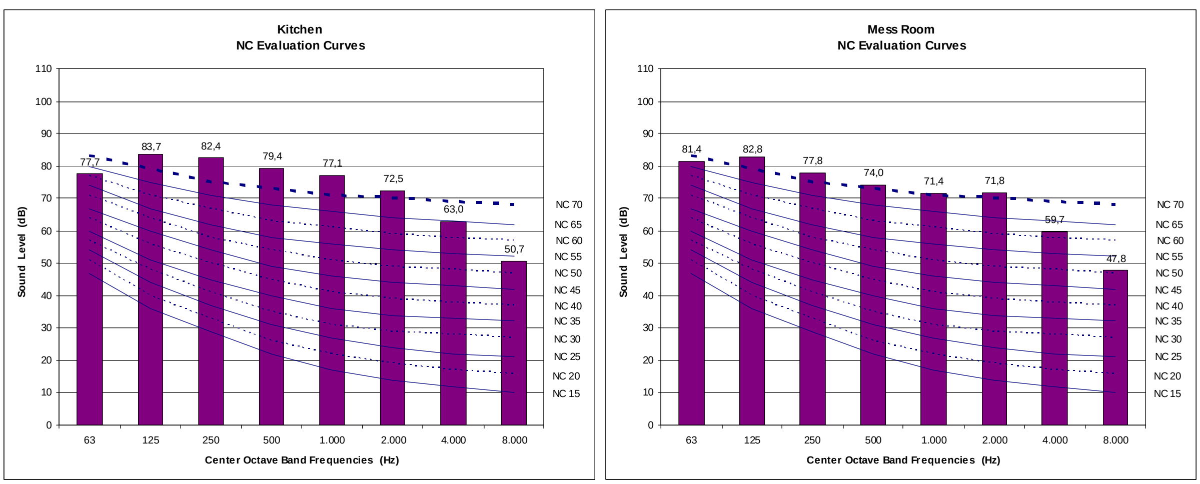

Figure 5. Octave band spectra of the sound level in the kitchen and in the mess room superposed to the NC curves from NBR 10152:1987.

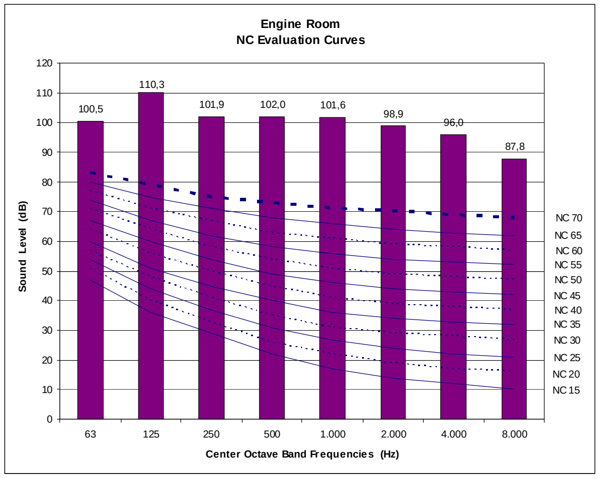

Figure 6. Octave band spectra of the sound level in the engine room superposed to the NC curves from NBR 10152:1987.

For comparison proposes, the cabins are considered sleeping rooms, and the kitchen and mess room are considered restaurants. The cabins can also be used as offices (the recommended NC values will be the same as used in the sleeping rooms) and the mess room is also used as living room (the recommended NC values will be the same as used in the restaurants). The engine room escapes from the target of the standard, so there are no adequate reference NC values to be used. Figure 6 is in this paper only to illustrate the spectral content of the noise generated in the engine room. For all other locations, Table 5 shows that the sound levels are always much higher than the recommended by the NBR 10152 standard.

Table 5. Comparison of measured sound levels and NC with the recommended by NBR 10152

	Valores encontrados		Valores recomendados	
Local	**NC**	**dB(A)**	**NC**	**dB(A)**
Shipowner cabin	70	65,0	30 - 40	35 - 45
Cook cabin	70	73,9	30 - 40	35 - 45
Engine room	>70	106,6	-	-
kitchen	70	81,2	35 – 45	35 – 45
Mess room	70	76,2	35 – 45	35 – 45

4. Conclusions

The noise levels measured in the ship used in this work indicate the necessity of improvements that decrease the noise levels in all of the locations were measurements were made. The highest sound levels, besides de engine room, were measured in the main deck level of the superstructure, which is immediately above the engine room (main sours of noise in the ship). Sound levels measured in the shipowner cabin, in the upper deck, were approximately 9 dB smaller than the levels found in the cook room, in the main deck. From the graphics in Figure 4, it can be seen that this difference is mainly due to the attenuation of the sound in the mid and high frequencies range.

So, any effective noise control modifications in the ship should be concern with low frequencies and with noise propagation through the structure. Future analysis should try to identify if the vibration generated by the engines is propagating through the structure and turning into noise in the superstructure of the ship. Such analysis can help to select the type of noise control modifications can best mitigate the noise problem in the ship.

5. ACKNOWLEDGEMENTS

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