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Noise from moored ships

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Abstract
In the slipstream to improve the air quality around ports, the noise from ships may change as well.
This paper presents the noise originating from moored ships, such as auxiliary engines, boilers and ventilation. A large number of different ships (container, tanker, bulk and RoRo-ships) has been measured. From these measures a trend line is derived for the sound power level as a function of the dead weight tonnage (DWT) or Lane Meters.
To improve the air quality, moored ships may run on shore power (AMP). For this situation an estimate is given for the remaining sound power level for each type of ship.

Keywords: ship, container, bulk, air quality, noise.

1 Introduction

The impact of ships on the air quality is substantial. For instance, in the Netherlands the influence is as shown in the figure below. To minimize these effects, several international measures are taken.

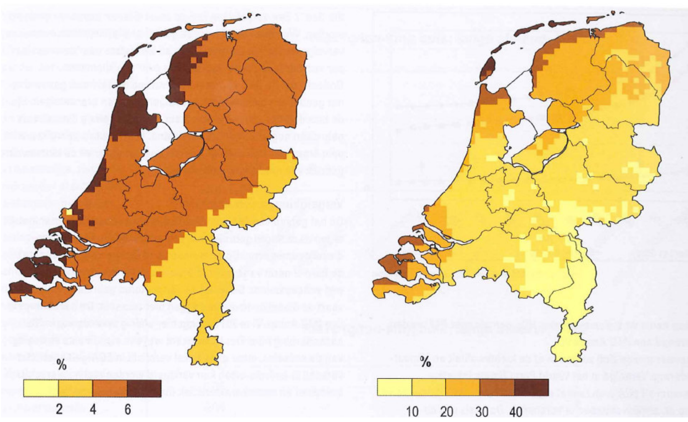

Figure 1 – Contribution of ships on PM_{10} (left hand side) and NOx (right hand side) in the year 2020 for the Netherlands without extra measures (Hamming et al 2007).

These measures include the use of low sulphur fuels for the coming years, see table 1. The Emission Control Area (ECA) is set by the International Maritime Organisation (IMO) and consists of the North and Baltic Sea, the English Channel, and parts of the north coast of America and Canada.

Table 1 – Percentage of sulphur in ship fuels.

<table>
<tr><th>year</th><th>ECA</th><th>world wide</th></tr>
<tr><td>2005</td><td>1,5%</td><td rowspan="2">4,5%</td></tr>
<tr><td>July 2010</td><td rowspan="2">1%</td></tr>
<tr><td>2012</td><td rowspan="2">3,5%</td></tr>
<tr><td>2015</td><td rowspan="2">0,1%</td></tr>
<tr><td>2020</td><td>0,5%</td></tr>
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The European Union (EU) prescribes a maximum sulphur percentage of moored ships of 0.1%.

However, many ports consider the possibility of further reducing the contribution of moored ships by putting the ships on shore power, like they do in California. However, because of the large power consumption of sea-going ships (4-14 MVA), the land based electrical power supply has to be changed dramatically at high costs.

2 Influence of moored ships

The noise coming from sea-going ships, sailing or moored, is not regulated. In the EU directive of equipment used outdoors, many sound power levels are maximized, but not from ships. In the Netherlands this is the same. Noise from rail, air and street traffic and industry are regulated but not the noise from sailing or moored ships. This is due to the lack of shipping jurisprudence for international ships visiting another country and also to the fact that, generally, sea-going ships do not cause many complaints. But this is not always the case:

- The container terminal in Amsterdam received many complaints due to moored ships at a distance of about 1 km.
- A RoRo-terminal in Rotterdam received many complaints due to a newly employed vessel (distance 200 m).
- One specific tanker was banned from delivering fuel in Vlissingen because of noise complaints (distance 2 km).
- Norway is investigating the noise from cruise ships because of complaints.
- Denmark is investigating the possibilities to oblige international vessels to comply with Danish legislation.
- In Copenhagen, Denmark, port authorities are looking for a different cruise terminal because of noise.
- In Oslo, Norway, research is undertaken into the use of shore power because of noise and air pollution.
- In Nice, France, complaints were made because of the noise generated by ships.

On many locations the influence of ships that are moored for over 24 hours, should seriously be taken into account.

3 Types of ships and regression lines

During our research in the ports of Rotterdam and Amsterdam we measured many sea-going ships. First in 1994 we discovered a relation between the so called Dead Weight Tonnage (DWT) and the sound power level of the ships up to a DWT of 30.000 tons [1]. But further growth of the DWT, especially for the container ships, made new investigations necessary [2].

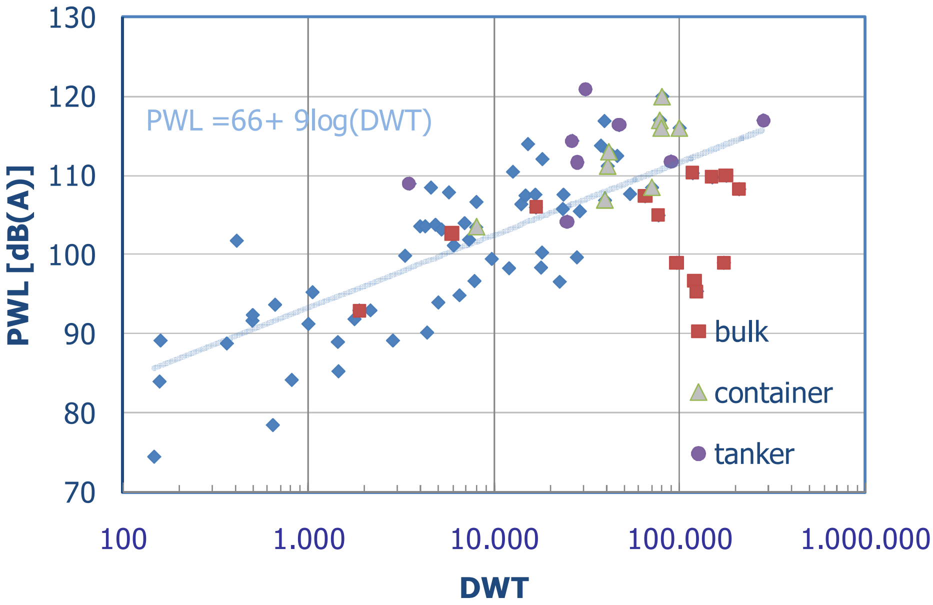

Figure 2 – The relation between sound power level and Dead Weight Tonnage (DWT) for all types of ships.

In figure 2 a clear distinction can be seen between the different types of ships. Where container and tanker ships can be found above the general regression line, the sound power levels of the bulk carriers are found below this line.

Table 2 – Overview of measured ships and the variety in DWT.

type of ship	number of ships measured	DWT (min-max)
bulk	17	2000 – 210.000
tanker	29	3.500 – 310.000
container	7	8.000 – 80.000
general cargo	44	150 – 45.000
total	**97**	**150 – 310.000**

The regression line that is sought after has the following form:

Sound Power Level = *A* + *B* log (*DWT*/DWTo) (1)

Where:
A: constant in dB(A)
B: directivity co-efficient in dB(A)
DWT: Dead Weight Tonnage in 1000 kg
DWTo: Reference DWT set to 1000 kg

3.1 Bulk ships

Bulk ships carry bulk products like grain, coal and ore all over the world. The main noise sources are:
- The exhaust from the auxiliary engines.
- The ventilation of the machine room.

Figure 3 – The inside of a bulk ship.

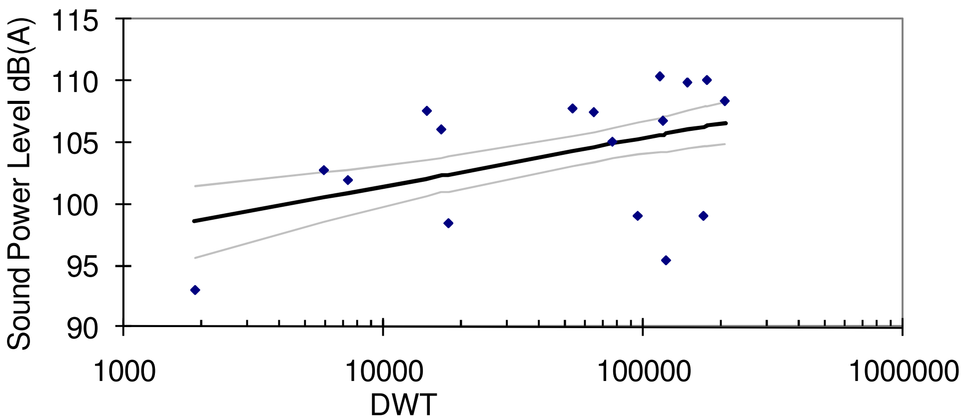

Figure 4 – Regression line between DWT and sound power level for bulk ships.

3.2 Tankers

Tanker ships transport mostly oil. The main noise sources when moored are:
- Pumps when pumping oil from ship to shore.
- Exhaust noise.
- Ventilation noise of machine housing.


Figure 5 – An example of an oil tanker.

The variety in sound power levels is large, mainly due to the large contribution of the pumps. The regression found has a low reliability, the regression line is almost a constant, see figure below.

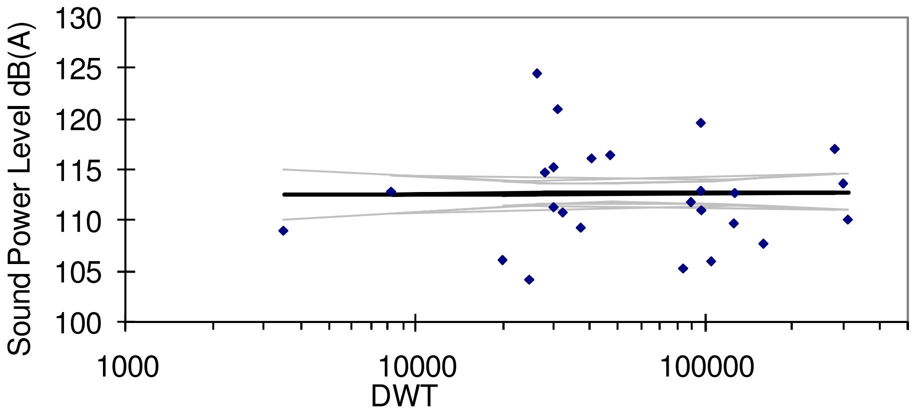

Figure 6 – Regression line between DWT and sound power level for tankers.

3.3 Container ships

Over the years, container ships are still growing in size. The largest vessel can now carry 15.000 TEU (number of 20 feet containers) but plans are made to construct a 22.000 TEU container carrier.
The main noise sources on a container ship are:
- The exhaust from the auxiliary engines.
- The ventilation of the machine room.
- The reefers (cooled containers).

Nowadays more containers are cooled because of the demand for conditioned transport.

Picture 7 – Moored container ship.

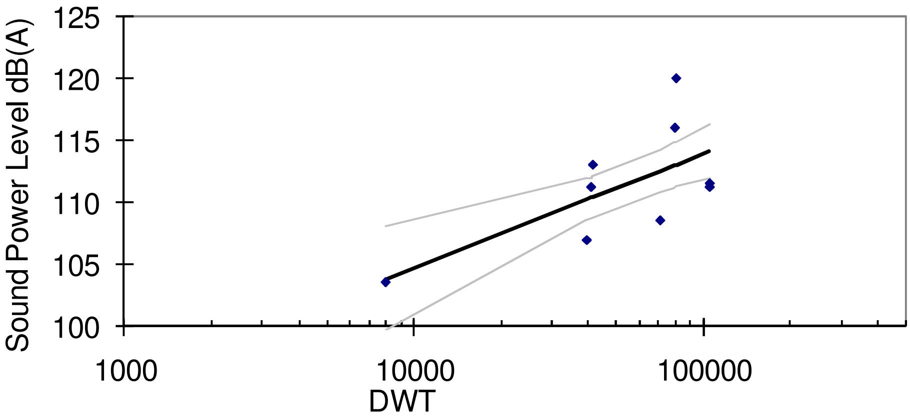

Figure 8 – Regression line between DWT and sound power level for container ships.

The peak levels while (un)loading a ship can also be a problem. This is often caused by placing the spreader on a container, removing hatch covers or “dropping” a container the last couple of centimetres.

3.4 General cargo ship

The other ships we investigated are grouped as general cargo ships. They may carry goods for instance in so called big bags or placed on pallets. The main noise sources are:

- The exhaust from the auxiliary engines.
- The ventilation of the machine room.

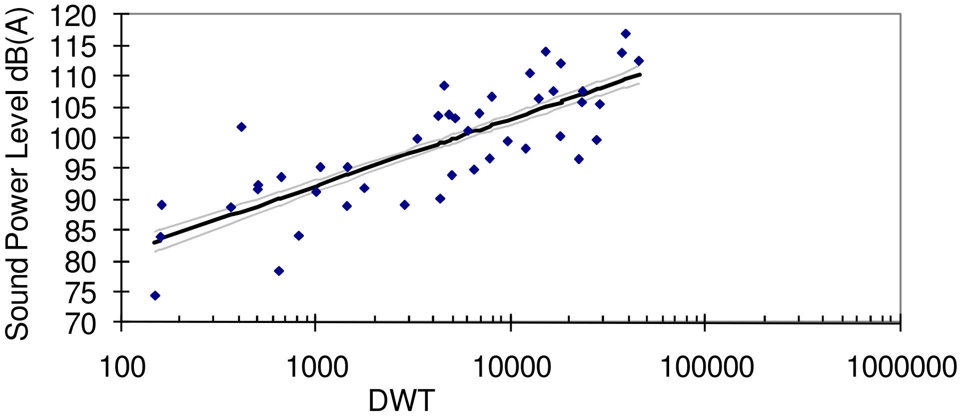

Figure 9 – Regression line between DWT and sound power level for general cargo ships.

3.5 RoRo-ships

RoRo (Roll on Roll off) ships are mainly used for relatively short trips that last just a few hours. The main noise sources on a RoRo ship are:

- The exhaust from the auxiliary engines.
- The ventilation of the machine room.
- The ventilation of the cargo decks.

The air change rate of the cargo decks when moored is about 35, so this can be considered an open area where no air quality measures have to be taken [3].
The peak levels while (un)loading the ship can be a problem here as well. This is often caused by trucks and trailers hitting the ramp.

Figure 10 – Unloading of a RoRo-ship.

The regression line of Lane Meters, describing the number of vehicles that can be stored on a ship, has more meaning than that of the DWT.

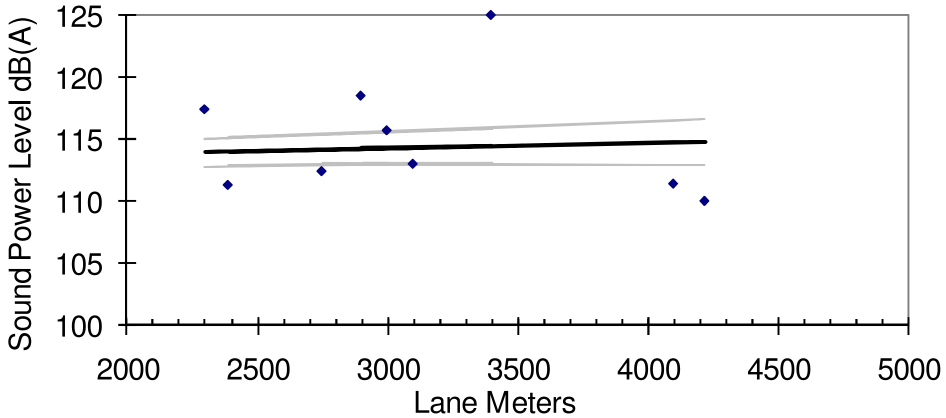

Figure 11 – Regression line between Lane Meters and sound power level for RoRo-ships.

This figure shows that there is hardly any relationship, just an average of about 114 dB(A).

3.6 Overview of regression lines

The regression lines found are given in the next table and presented in figure 12.

Table 3 – Overview of measured ships and the variety in DWT/Lane Meters (LM).

type of ship	regression formula between SPL and DWT or Lane Meters	correlation coefficient
bulk	85,8 + 3,9 log (DWT/DWTo)	45%
tanker	111,9 + 0,2 log (DWT/DWTo)	1%
container	68,1 + 9,2 log (DWT/DWTo)	66%
general cargo	59,5 + 10,9 log (DWT/DWTo)	80%
RoRo	103,1 + 3,2 log (LM/LMo) LMo = 1 m	13%

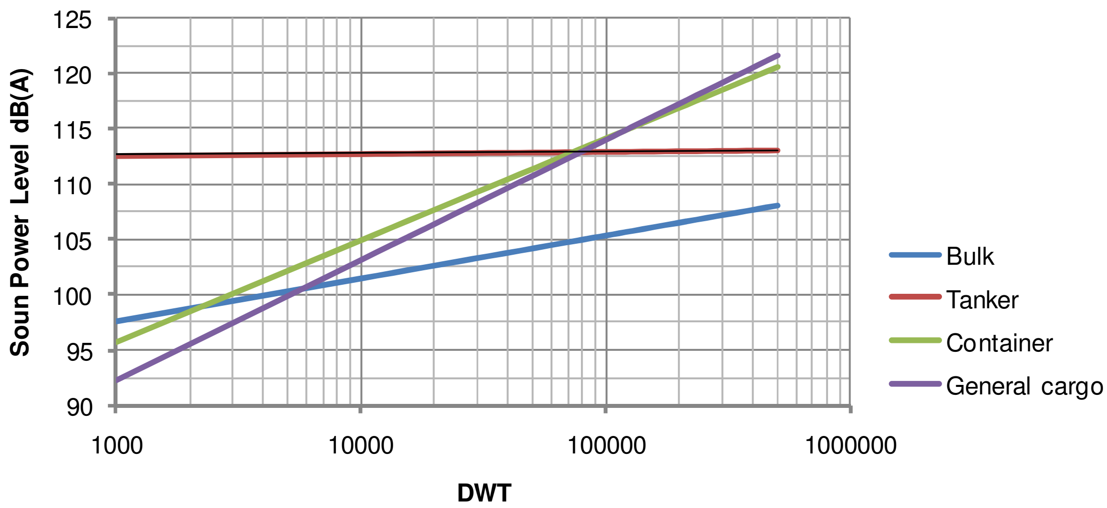

Figure 12: Regression line between DWT and sound power level for different type of ships.

The highest correlation between the different types of ships can be found for the General Cargo Ships. This also has the highest number of ships measured. Bulk and container ships show reasonable correlation. This can not be said for tankers and RoRo-ships. More and more precise measurements are needed, especially for the tankers.

4 Influence of shore power

When a moored ship is plugged in on shore power, not all noise sources are switched off. For all type of ships the auxiliary engine exhaust and auxiliary engine ventilation will have no relevant sound power level anymore. The noise of the machine room ventilation will be reduced by less in the engine room due to the fact that the auxiliary engine is shut down. Also the ventilation may be switched to a lower level. The ventilation and/or cooling for the bridge and living compartments will remain the same.

Table 4 – Difference in Sound Power Levels with shore power based on averaged DWT [4].

type vessel	noise sources	aux. engines		shore power		Δ	
		min	**max**	**min**	**max**	**min**	**max**
bulk	**total (calculated)**	90	109	85	93	5 -	16
DWT 75000	auxiliary engines - funnel	85	105	n/a	n/a		
	auxiliary engine - ventilation	85	105	n/a	n/a		
	main engine - ventilation	85	100	83	90		
	bridge/decks - ventilation	80	90	80	90		
tankers	**total (calculated)**	101	120	101	120	1 -	0
DWT 25000	auxiliary engines - funnel	85	105	n/a	n/a		
	auxiliary engine - ventilation	85	105	n/a	n/a		
	main engine - ventilation	93	107	91	97		
	bridge/decks - ventilation	80	90	80	90		
	pumps	100	120	100	120		
container	**total (calculated)**	107	119	105	111	2 -	8
DWT 35000	auxiliary engines - funnel	100	115	n/a	n/a		
	auxiliary engine - ventilation	100	115	n/a	n/a		
	main engine - ventilation	93	107	91	97		
	bridge/decks - ventilation	80	90	80	90		
	reefers	105	111	105	111		
RoRo	**total (calculated)**	110	119	110	118	0 -	1
DWT 19000	auxiliary engines - funnel	85	105	n/a	n/a		
	auxiliary engine - ventilation	85	105	n/a	n/a		
	main engine - ventilation	93	107	91	97		
	bridge/decks - ventilation	80	90	80	90		
	cargo hold ventilation	110	118	110	118		
gen. cargo	**total (calculated)**	88	103	83	91	5 -	12
DWT 5700	auxiliary engines - funnel	82	102	n/a	n/a		
	auxiliary engine - ventilation	82	92	n/a	n/a		
	main engine - ventilation	82	92	80	82		
	bridge/decks - ventilation	80	90	80	90		

5 Conclusions

In this paper the sound power level of different types of ships is given related to their DWT or Lane Meters. It has been shown that, when switched to shore power, the sound power levels will be significantly reduced for bulk and general cargo ships. Noise from container ships will only be modestly reduced because of the reefers on board. For tankers and RoRo-ships the reduction will be close to zero, because of the contribution of pumps and cargo deck ventilation.
Shore power may have great benefits for air quality for all type of ships, but the reduction of sound power levels strongly depends on the type of ship.

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