Emission estimates for diffuse sources
Netherlands Emission Inventory

Shipyards

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NETHERLANDS NATIONAL WATER BOARD - WATER UNIT
in cooperation with DELTARES and TNO

Shipyards

1 Description of emission source

Emissions by shipyards are caused by ship repairs. The assumption is that emissions at new construction shipyards are negligible in comparison to emissions from repair shipyards. Emissions are released in various processes, particularly high-pressure cleaning, spray-cleaning of the dock after sandblasting and/or spray-painting, blowing of sand and paint, leaching of paint and sand residue on dock walls and leaching of ships docked at the shipyard.
The emissions are attributed to the governmental target sector “Other Industries”.

2 Explanation of calculation method

Emissions are calculated for each substance by multiplying an activity rate (AR), in this case the number of ships processed annually, by an emission factor (EF) expressed in kg of the specific substance per ship. This calculation assumes average ship size. This method of calculation is explained in the Guide to the Regional approach to diffuse sources [1] and is calculated according to the following equation:

Emission = AR x EF

Where:
AR = Number of ships
EF = Emission factor (kg/ship)

The formula above is used for the calculation of emissions by shipyards for seagoing vessels. Emissions by shipyards for inland waterway vessels are determined in reports [2], [3] and [4]. This is further elaborated in chapter 6.

3 Activity rates

The activity rate is the number of ships treated annually in shipyards for seagoing vessels. Table 1 shows how many ships are treated annually [6]. Due to lack of new information, the amount of ships treated is kept constant for the entire series.

Table 1: Number of vessels

	1985	1990	1995	2000	2005	2006
Ships at a floating dock	600	600	600	600	600	600
Ships at an excavated dock	200	200	200	200	200	200
Total ships treated	800	800	800	800	800	800

4 Emission factors

A number of emission factors are determined for the various processes that seagoing vessels undergo. The emission factors are shown in tables 2 and 3. For the determination of the emission factors, an average surface of 5000 m^2 per ship is assumed. Additionally, it is assumed that the ships are docked at the quayside for an average of three days after treatment [6].

Emission factors for copper are based on the CUWVO report on shipyards [5] and the copper basic document [7]. Because the data from these documents differ considerably in many cases, a decision was made to assume data based on measurement data. Where necessary, a further estimate based on expert judgment is made.

Emission factors from high pressure cleaning and spray-cleaning of the dock after sandblasting and spray-painting are based on the CUWVO document [5]. Blowing of sand and paint is based on the copper basic document [7] and differs between floating docks and excavated docks. Emissions from leaching of docks are estimated very differently by [5] and [7]. The assumption is that the leaching of docks is maximally equal to the leaching of ships. The leaching from ships is estimated at 7.5 kg/ship, based on [5]. Leaching from docks is set at the same figure.

Table 2: Emission factor for copper (kg Cu/ship)

	1985	1990	1995	2000	2005	2006
High-pressure cleaning	0.13	0.13	0.13	0.013	0.013	0.013
Spray-cleaning of dock after sandblasting	0.14	0.14	0.09	0.009	0.009	0.009
Spray-cleaning of dock after spray-painting	0.41	0.41	0	0	0	0
Blowing of sand and paint, floating dock	10	10	2	2	2	2
Blowing of sand and paint, excavated dock	5	5	1	1	1	1
Leaching of docks (excavated)	7.5	7.5	0.75	0.75	0.75	0.75
Leaching of ships at quayside	7.5	7.5	7.5	7.5	7.5	7.5

For organotin, the emission factors are expressed in kg Sn per ship. It is assumed that organotin consists of 38% tin.

Emission factors due to blowing are calculated based on the copper emission due to blowing and the average copper and organotin content in antifoulants [6]. For the leaching from docks, the assumption is (as with copper) that this is the same figure as the leaching from ships. The leaching of ships differs between conventional antifoulant and self-polishing antifoulant. It is assumed that 30% of ships use a conventional antifoulant, as reported in [5]. The emission factor for antifoulant is calculated by multiplying the leaching at anchor in port (with antifoulant applied far in the past) by 25. Values for leaching of copper show that the leaching after application of the antifoulant is 25 times higher than leaching of old antifoulant. With an average berth of three days at the shipyard, an emission factor of 3 kg Sn per ship for conventional antifoulant and an emission factor of 1.1 kg Sn per ship for self-polishing antifoulant is calculated [6].

Table 3: Emission factors for organotin (kg Sn/ship)

	1985	1990	1995	2000	2005	2006
High-pressure cleaning	0.0038	0.0038	0.0038	0.00038	0.00038	0.00038
Spray-cleaning of dock after sandblasting	0.0114	0.0114	0.0074	0.00074	0.00074	0.00074
Spray-cleaning of dock after spray-painting	0.0228	0.0228	0	0	0	0
Blowing of sand and paint, floating dock	0.9	0.9	0.18	0.18	0.18	0.18
Blowing of sand and paint, excavated dock	0.5	0.5	0.1	0.1	0.1	0.1
Leaching of docks (excavated)						
* conventional antifoulant	3	3	0.3	0.3	0.3	0.3
* self-polishing antifoulant	1.1	1.1	0.11	0.11	0.11	0.11
Leaching of ships at quayside						
* conventional antifoulant	3	3	3	3	3	3
* self-polishing antifoulant	1.1	1.1	1.1	1.1	1.1	1.1

The emission factors for copper and tin were first determined for the situation in 1985/1990. After that time, a variety of changes were implemented, which caused the emission factors to decrease:

- As of 1990, a measure was implemented in relation to the dock and slope floor discipline, with the object of limiting water pollution [6]. One of the components is that the sand must be carried away only after the painting. This reduces the emission factor for spray-cleaning the dock after painting to 0 kg/ship in 1995, and also means a reduction of 35% of emissions by spray-cleaning and sandblasting, and a reduction of 90% of leaching from the dock.
- Effective from 1995, all shipyards must have wind protection installed to prevent blowing. The assumption is that this reduces wind-blown emissions by 80% from 1995 on [6].
- As of 1995, supplemental treatment of waste water was introduced, reducing emissions from high pressure cleaning and spray-cleaning after sandblasting in 2000 by 90% (above and beyond the previous reduction at the dock and slanting floor discipline) [6].

5 Effects of policy measures

Measures that have had an effect on the emission factors of shipyards in sea travel are:
- As of 1990, a measure was implemented in relation to the dock and slope floor discipline, with the object of limiting water pollution [6]. One of the components is that the sand must be carried away only after the painting. This reduces the emission factor for spray-cleaning the dock after painting to 0 kg/ship in 1995, and also means a reduction of 35% of emissions by spray-cleaning and sandblasting, and a reduction of 90% of leaching from the dock.
- Effective from 1995, all shipyards must have wind protection installed to prevent blowing. The assumption is that this reduces wind-blown emissions by 80% from 1995 on [6].
- As of 1995, supplemental treatment of waste water was introduced, reducing emissions from high pressure cleaning and spray-cleaning after sandblasting in 2000 by 90% (above and beyond the previous reduction at the dock and slanting floor discipline) [6].

Measures that have had an effect on the emissions of PAH are:
- Treatment of waste water provides for a reduction of 90% as of 2000.
- The replacement of coal tar with a low-tar product also provides for a further reduction of 90% over the first measure.

6 Emissions calculated

The emissions for copper and tin are shown in tables 4 and 5.

Table 4: Emissions of copper by shipyards for seagoing shipping (kg Cu)

	1985	1990	1995	2000	2005	2006
High-pressure cleaning	104	104	104	10,4	10,4	10,4
Spray-cleaning of dock after sandblasting	112	112	72	7,2	7,2	7,2
Spray-cleaning of dock after spray-painting	328	328	0	0	0	0
Blowing of sand and paint, floating dock	6.000	6.000	1.200	1.200	1.200	1.200
Blowing of sand and paint, excavated dock	1.000	1.000	200	200	200	200
Leaching of docks (excavated)	1.500	1.500	150	150	150	150
Leaching of ships at quayside	6.000	6.000	6.000	6.000	6.000	6.000
Total	**15.000**	**15.000**	**7.683**	**7.523**	**7.523**	**7.523**

Table 5: Emissions of tin by shipyards for seagoing shipping (kg Cu)

	1985	1990	1995	2000	2005	2006
High-pressure cleaning	3,04	3,04	3,04	0,304	0,304	0,304
Spray-cleaning of dock after sandblasting	9,12	9,12	5,92	0,592	0,592	0,592
Spray-cleaning of dock after spray-painting	18,24	18,24	0	0	0	0
Blowing of sand and paint, floating dock	540	540	108	108	108	108
Blowing of sand and paint, excavated dock	100	100	20	20	20	20
Leaching of docks (excavated)						
* conventional antifoulant	180	180	18	18	18	18
* self-polishing antifoulant	154	154	15,4	15,4	15,4	15,4
Leaching of ships at quayside						
* conventional antifoulant	720	720	720	720	720	720
* self-polishing antifoulant	616	616	616	616	616	616
Total	**2.340**	**2.340**	**1.510**	**1.505**	**1.505**	**1.505**

The emissions from mineral oil are shown in table 6. These data originate from [6]. The background for these values, however, is unclear.

Table 6: Emissions of mineral oil (kg)

	1985	1990	1995	2000	2005	2006
Mineral oil	1.000	1.000	1.000	100	100	100

PAH emissions by shipyards for inland navigation are documented in report [5]. This results in emissions of 335 kg PAH. However, the progress reports for the Rhine and North Sea industrial discharge action plan [3] and [4] assume emissions of 200 kg PAH [6]. These are shown in table 6. The SPEED report PAH [2] determines the emissions of fluoranthene and benzo(a)pyrene. The emissions from the year 2000 are lower due to the treatment of waste water and the replacement of coal tar with a low-tar product. Each of these measures reduce emissions by 90%; together, they reduce this emission by 99% [6].

Table 7: Emissions of PAHs by shipyards for inland waterway shipping (kg)

	1985	1990	1995	2000	2005	2006
Total PAH 6	200	200	200	2	2	2
Of which:						
* Fluoranthene	30	30	30	0	0	0
* Benzo(a)pyrene	13	13	13	0	0	0

7 Release into environmental compartments

100% of shipyard emissions go directly into the surface water.

8 Description of emission pathways to water

The emissions calculated here are direct emissions into water.

9 Spatial allocation

The spatial allocation of emissions is assigned on the basis of a set of digital maps held by the Netherlands Environmental Assessment Agency (PBL) drawn up using emission records. These maps present the spatial distribution of all kinds of parameters throughout the Netherlands, such as population density, traffic intensity, area of agricultural crops, etc. For the purposes of emission registration these maps are used as 'locators' to determine the spatial distribution of emissions. The range of possible locators is limited (see [8] for a list of available locators), as not every conceivable parameter can be used as a locator. In practice the locator judged to be the best proxy of the activity rate of the emission in question is applied for the distribution of emissions.
It is assumed that the distribution of emissions throughout the country is proportional to the national distribution of the locator.

The table below shows the locator used for the spatial allocation of the various emission sources.

Table 8: Locators for spatial allocation

	Locators
Shipyards	Number of employees in NACE 35.1

The method used to determine the locators is described in [8]:

Number of employees
Non-individual commercial emissions (estimates) are divided by the number of people employed by each company. This data is taken from the Accommodation and Population Database created by BridGIS on behalf of RIVM.
This database itself is made up of data from the following three databases:

- The central geographical source, ACN (Address Coordinates in the Netherlands) which contains coordinates for all addresses (street name, house number, house number extension and postcode) in the Netherlands. This database is provided by the Land Registry.
- LISA (National Information System for Jobs and Registered Offices). This is the only nationwide database that contains the following information for each address: the number of people employed and the standard commercial classification code (NACE) as determined by Statistics Netherlands. This database is provided by the LISA foundation.

- Geo-Marktprofiel, a database containing the following information for each 6-position postcode (covering on average 16 dwellings): number of dwelling units, number of people, main type of dwelling unit and recorded main year of construction of the dwelling units. This database is provided by WegenerDM.

The most recent data is from 2005.

10 Comments and changes in regard to previous version

There have been no changes implemented as compared to previous version.

11 Accuracy and indicated subjects for improvement

The method used in the National Emission Inventory publications has been followed as far as possible in classifying the quality of information [10]. It is based on the CORINAIR (CORe emission INventories AIR) methodology. CORINAIR uses the following quality classifications:

A: a value based on a large number of measurements from representative sources;
B: a value based on a number of measurements from some of the sources that are representative of the sector;
C: a value based on a limited number of measurements, together with estimates based on technical knowledge of the process;
D: a value based on a small number of measurements, together with estimates based on assumptions;
E: a value based on a technical calculation on the basis of a number of assumptions.

The activity rate is the number of ships repaired in shipyards annually. There is no substantiation available for this figure, so it is classified as E.
The emission factors are based in part on measurements (mainly the emission factors in the years 1985-1995) and partly based on estimates and assumptions (particularly the decrease in emissions assumed for the years 2000 and later. Consequently, this is assigned a reliability of D.
The emissions go directly into the surface water, and so the distribution across compartments and the emission pathways to water are both classified as A.
Spatial allocation is based on the number of employees in shipyards, which is known fairly precisely.

Element of emission calculation	**Reliability class**
Activity rates	E
Emission factors	D
Distribution among compartments	A
Emission pathways to water	A
Spatial allocation	B

The most significant areas for improvement are:

- Updating the emission factors. The emission factors for the years 1985-1995 are based on actual measurements. For the years thereafter, assumptions on the effects of the measures were made. With new measurements, we can determine new emission factors for recent years. Additionally, other measures have been implemented relating to the types of permitted antifoulants; for example, tin may no longer be used. These measures also have an impact on the emission factors. These changes could be more consistent with the calculation of emissions from antifoulant.
- The activity rate is presently expressed in number of ships. However, the surface area of the ships is an important factor. The AR could be better expressed in the surface area of the ships treated.
- Emissions at new construction shipyards are not calculated, because these are supposedly negligible in comparison to repair shipyards. However, rusty new steel plates are also sandblasted at new construction shipyards. The possibility that these emissions are not actually negligible must be considered.
- TBT-based coatings were banned in 2003. This measure has yet to be accounted for in the emission factors.

12 Request for reactions

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