

**Emission estimates for diffuse sources
Netherlands Emission Inventory**

Sacrificial anodes, inland navigation

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

Sacrificial anodes, inland navigation

1 Description of emission source

These emissions are the emissions resulting from corrosion of zinc sacrificial anodes of ships in professional inland navigation. Anodes are mounted on the exterior wall of the ship's shell to serve as corrosion protection for the portion of the ship under the water line. Anodic protection is only required when two or more different metals under water are connected by an electric current, for example the steel of the hull and the brass ball plugs or the bronze of the propeller and the stainless steel of the propeller shaft. To prevent corrosion, "sacrificial" blocks (anodes) are used, which are made of a metal with a potential difference with the metal to be protected. The placement of the anode creates a potential difference by which the anode "sacrifices" itself, as it were, in favour of the metal to be protected, and gradually dissolves in the water. In inland navigation, the most commonly used "sacrificial" metals are zinc, aluminium and magnesium. This emission source is allocated to the governmental target sector "Transport" within the National Emission Inventory.

2 Explanation of calculation method

Emissions are calculated by a simple method which involves multiplying an activity rate (AR), in this case the number of active inland vessels in the Netherlands, by an emission factor (EF) for zinc, expressed in emission per unit of AR. This method of calculation is explained in detail in the reference "Handreiking Regionale aanpak diffuse bronnen" [5].

The emission calculated in this way is referred to as the total emission. As it relates to direct discharge into surface waters, the total emission is the same as the net pollution of the surface water.

3 Activity rates

Information on the number of active inland vessels in the Netherlands is taken from statistics produced by Statistics Netherlands (CBS) and the Transport & Public Works Inspectorate (IVW) [11]. These values were published by Statistics Netherlands annually up to 2002. After that, new data was only available from the IVW. Consequently, the amount of the AR originates from different sources.

Table 1: Activity rate, number of active inland vessels

Year	1985	1990	1995	2000	2005	2006
AR	6,371	6,282	5,494	4,410	4,382	4,580
Reference	[2, p.211]	CBS	IVW	IVW	IVW	IVW

4 Emission factor for 1985

The reference WSV *Doelgroepstudie en Beleidsanalyse Binnenvaart* [1] still assumes an emission factor of approximately 5 kg zinc per active inland vessel. This figure was based on the use of zinc anodes by 10% of the inland fleet and a consumption of 100 kg of zinc per vessel over two years.

An evaluation of this data by RIZA in 2007 among shipyards, experts and Regional Directorates of Public Works & Water Management showed that this estimate was too high, and led to a modification of the previous estimates (see section 11). The values shown below are based on a document concerning zinc anodes [9]. The new calculation assumes that 25% of the inland fleet uses zinc anodes, with another 50% using aluminium anodes and the last 25% using magnesium anodes. The latter two substances are not covered in this fact sheet. The high figure of 100 kg of zinc anodes per ship in two years being fully consumed seems to be primarily based on recommendations by manufacturers of zinc anodes. In practice, these values prove to be considerably lower: an assumption of 6 zinc anodes of approximately 3 kg each per ship being replaced in 3 years on average, appears to be more realistic. This gives an emission factor per ship of $(3 \times 6)/3 \times 25\% = 1.5$ kg of zinc per active inland vessel.

5 Effects of policy measures

The effectiveness of zinc anodes in fresh water is a matter of discussion. Recent insights have led to an increasing conception that zinc is less effective in fresh water than aluminium. There is an impression that the use of zinc anodes is declining, while use of aluminium anodes is rising. The "impressed current" (or IC) system is a potential alternative to the use of anodes, although technical and financial factors have so far prevented IC systems from being applied on a large scale in inland vessels.

However there is no reliable information available on the implementation and effects of these measures and developments.

6 Emission factor

Given that there are no known effects of currently active measures, the emission factor remains constant in time.

Table 2: Emission factor per active inland vessel in kg/year

Year	1985	1990	1995	2000	2005	2006
EF (kg/year)	1.5	1.5	1.5	1.5	1.5	1.5

7 Emissions calculated

The table below shows the emissions, expressed in kg/year. The emissions were calculated by multiplying the emission factor from section 6 by the activity rate shown in section 3.

Table 3: Zinc emission resulting from zinc anodes in inland shipping.

Year	1985	1990	1995	2000	2005	2006
Zinc emissions (kg/year)	9,957	9,423	8,241	6,615	6,753	6,870

8 Release into environmental compartments

All the emissions produced by corrosion of zinc anodes in inland navigation are directly released into the surface water.

9 Description of emission pathways to water

The emissions calculated here are direct emissions into water.

10 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 [10] 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 4: Summary of spatial allocation method

Element	Locators
Corrosion of zinc anodes	Professional inland navigation

The method used to determine the locators is described in [10]:

Professional inland navigation

The allocation is determined by multiplying the number of vessels per shipping lane segment by the length of that segment (in kilometres). A distinction is made between push-towing and other inland navigation.

The latter category is in turn subdivided into two classes based on cargo capacity.

Data on numbers of inland vessels originate from Statistics Netherlands; location and length of shipping lanes originate from the database "Nationaal Wegenbestand" (NWB).

11 Comments and changes in regard to previous version

Previous publications [1, 5, 6, 7] still assumed an emission factor of 4.78 kg zinc per active inland vessel (see section 4). The new estimate (February 2007) is lower by more than a factor of 3, which at the national level means a drop from approximately 21 tonnes of zinc to 7 tonnes in 2000.

The number of active inland vessels is no longer published by Statistics Netherlands. This data is now obtained via the IVW. Formerly, the IVW managed two files on inland navigation, the active inland fleet (Rhine Fleet) and the master list of the Netherlands inland fleet; these two databases were merged into one file, the "Rhine Fleet" [11], beginning in May 2005.

12 Accuracy and indicated subjects for improvement

The method used in Emission Inventory publications has been followed as far as possible in classifying the quality of information [8]. It is based on the CORINAIR (CORe emission INventories AIR) methodology, which applies 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 was updated by the CBS regularly, and is now updated by the IVW, and can be classified under category B. In general, we can conclude that the emission factor is based on a limited number of measurements of a number of years ago, which were recently compared against the actual situation. However, the effects of measures in progress were not taken into account. This means that we can classify the emission factor in category C.

As far as the distribution of emissions among individual compartments and emission pathways is concerned, it is clear that all the emissions directly enter the surface water, so category A applies here. The spatial allocation of emissions is fairly reliable, so the reliability classification is B.

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

The main areas where improvements could be made are:

- Improvement of the information on the effects of the measures specified in section 5 and developments through monitoring.
- Improvement of the information on which the emission factor is based, including the number of zinc anodes per vessel, the average weight per anode, the replacement period and the percentage of vessels that use zinc anodes.
- Improvement of the spatial allocation of emissions by taking differing corrosion rates in brackish and fresh surface water into account.
- Foreign ships sailing on Dutch waters are not taken into account, nor are the number of Dutch ships spending time in foreign waters. This could be taken as an improvement.

13 Request for reactions

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14 References

- [1] Waveren, R.H. en I. Zeegers, september 1997. Watersysteemverkenningen 1996. *Doelgroepstudie en Beleidsanalyse Binnenvaart*. RIZA rapport 97,063.
- [2] CBS. *Statistisch jaarboek 1996*. Voorburg/Heerlen.
- [3] CBS. *Statistisch jaarboek 1998*. Voorburg/Heerlen.
- [4] CBS. *Statistisch jaarboek 2001*. Voorburg/Heerlen.
- [5] CIW/CUWVO werkgroep VI, februari 1997. *Handreiking Regionale aanpak diffuse bronnen*. Bijlage 1.
- [6] Coenen, P.W.H.G. *et al*, mei 2001. Rapportagereeks Doelgroepmonitoring nr. 9. *Emissies in Nederland per regio, Jaarrapport 1998 en ramingen 1999*.
- [7] Harmelen, A.K. van *et al.*, november 2000. Rapportagereeks Doelgroepmonitoring nr. 6. *Emissies en afval in Nederland, Jaarrapport 1998 en ramingen 1999*.
- [8] Most, P.F.J. van der *et al.*, juli 1998. *Methoden voor de bepaling van emissies naar lucht en water*. Publicatiereeks Emissieregistratie, nr. 44.
- [9] Röling, I.S., 2002. *Zinkanodes binnenvaart*. RIZA werkdocument.
- [10] Molder, R. te, 2007. Notitie ruimtelijke verdeling binnen de emissieregistratie. Een overzicht.
- [11] Inspectie Verkeer en Waterstaat, toezicht beheereenheid, Den Haag. Databestanden Rijnvloot 1993-2005.