Emission estimates for diffuse sources
Netherlands Emission Inventory

Sacrificial anodes on sluice valves

version dated June 2008

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

Sacrificial anodes on sluice valves

1 Description of emission source

These emissions are the emissions resulting from corrosion of zinc sacrificial anodes on sluice valves. Anodes are used to protect the portion of the valves below the water line from corrosion. In the past, zinc anodes were most commonly used; today, aluminium anodes are also very common. A newer method of preventing corrosion involves application of a rustproof aluminium coating on sluice valves, making zinc emissions a thing of the past.

This emission source is allocated to the governmental target sector "Transport" within the National Emission Inventory.

2 Explanation of calculation method

Emissions are simply calculated by multiplying an activity rate (AR), in this case the weight of zinc anodes on sluice valves in the Netherlands divided by the useful life, by an emission factor (EF) for zinc, expressed in emission per unit of AR. This method of calculation is explained in detail in the Guide to the Regional approach to diffuse sources [1].
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 load of the surface water.

3 Activity rates

The information on the number, the location and the weight of the anodes applied originates from a 1993 inventory by the Civil Engineering Division [2]. The table on page 3 gives a detailed overview of this information. For lack of up-to-date information, this data is assumed to be constant for the entire time frame from 1985 through 2006.

Table 1: Activity rate, zinc anodes

Year	Activity rate (weight of zinc anodes/useful life, in kg/year)	Reference
1985 through 2006	46,163	2

4 Emission factor

The assumption is that an average of 60% of the zinc anode dissolves before the anodes are replaced [3]. This means that an emission factor of 0.6 kg per AR unit can be used.

5 Effects of policy measures

Mars, Eleveld and De Graaf [4] show that emissions could be reduced in the future by replacing zinc anodes by aluminium anodes and improving the coating used on sluice valves. The "impressed current" system is an alternative to the use of anodes. Ros [6] claims that these alternatives are already in use to some degree, but in terms of hard data, few if any data is available.

Table 2: List of objects and locations of sluice vavlves using zinc and aluminium anodes [2]

Location	Object	Coordinates		Anodes			Zinc emissions (kg/year)		
		X	Y	weight (kg)	material	**close time (year)	total	50% fresh	50% salt
Bath	Sluice lock	74.80	378.85	858	zinc	8	64	32	32
Beerta	Nieuwe Statenzijl	276.60	584.30	1,335	zinc	8	100	50	50
Bergschediep	Bergschediepsluis	76.10	391.45	1,140	zinc	8	86	43	43
Bruinisse	Single lock	65.60	409.45	5,520	zinc	8	414	207	207
Den Helder	Koopvaardersschutsluis	114.60	551.55	6,558	zinc	8	492	246	246
Den Helder	Marine dock	113.70	552.80	3,432	zinc	8	257	129	129
Den Helder	Nieuwe Marinesluis	114.45	551.55	9,936	zinc	10	596	298	298
Hansweert	Central lock	59.25	386.00	8,744	zinc	10	525	262	262
Hansweert	Single lock 1 dock gate	59.30	386.00	535	zinc	10	32	16	16
Hansweert	Single lock 3 dock gate	59.25	386.10	535	zinc	8	40	20	20
Hansweert	Single lock	59.30	386.10	12,894	zinc	8	967	484	484
Haringvliet	Sluice lock	62.10	426.95	39,620	aluminium	25			
Haringvliet	Outlet lock	62.00	427.00	888	zinc	10	53	27	27
IJmuiden	Small Lock	100.90	497.65	4,464	zinc	8	335	167	167
IJmuiden	Southern lock	100.90	497.70	11,892	zinc	8	892	446	446
IJmuiden	Central lock	101.50	497.90	11,976	zinc	8	898	449	449
IJmuiden	Northern lock	102.30	498.00	108,584	zinc	8	8,144	4,072	4,072
IJmuiden	Northern lock rail construction	102.29	498.00	9,181	zinc	50	110	55	55
IJmuiden	Northern lock rail foundation	102.28	498.00	9,104	zinc	25	218	109	109
IJmuiden	Northern lock drainage gates	102.27	498.00	2,256	zinc	8	169	85	85
Kats	Zandkreekdam	49.40	396.10	9,200	zinc	10	552	276	276
Krammer	Duwvaartsluis	70.10	409.20	12,580	zinc	8	944	472	472
Krammer	Intake/outflow works	70.05	409.20	9,072	zinc	8	680	340	340
Krammer	Under-roll cars	70.10	408.90	2,496	zinc	8	187	94	94
Krammer	Embankment seal gates	70.10	408.80	39,609	zinc	10	2,377	1,188	1,188
Kreekrak	Intake/outlet works	74.60	385.00	11,139	zinc	10	668	334	334
Kreekrak	Embankment seal gates	74.60	385.05	1,280	zinc	15	51	26	26
Roompotsluis	Single lock roll gates	37.15	404.75	6,745	zinc	8	506	253	253
Roompotsluis	Single lock under-roll cars	37.10	404.75	1,864	zinc	8	140	70	70
Terneuzen	Central lock	45.60	372.80	7,402	aluminium	5			0
Terneuzen	Nieuwe Binnenvaartsluis	45.80	372.90	9,600	zinc	5	1,152	576	576
Terneuzen	Eastern lock	45.80	373.05	3,662	zinc	5	439	220	220
Terneuzen	Western lock	45.50	372.20	14,877	aluminium	5			
Terneuzen	Sea lock	45.50	372.30	16,636	aluminium	5			
Vlissingen	22m. Single lock Gate 1	30.50	385.30	1,236	zinc	8	93	46	46
Vlissingen	22m. Single lock Gate 2	30.50	385.29	1,236	zinc	8	93	46	46
Vlissingen	22m. Single lock Gate 3	30.50	385.28	275	aluminium	5			
Vlissingen	22m. Single lock Gate 4	30.50	385.27	780	zinc	8	59	29	29
Vlissingen	22m. Single lock Gate 5	30.40	385.30	1,129	zinc	8	85	42	42
Vlissingen	22m. Single lock Gate 6	30.40	385.29	1,129	zinc	8	85	42	42
Vlissingen	22m. Single lock Gate 7	30.40	385.28	275	zinc	8	21	10	10
Vlissingen	22m. Single lock Gate 8	30.40	385.27	275	zinc	8	21	10	10
Vlissingen	35m. Single lock Gate 1	30.50	385.15	910	zinc	10	55	27	27
Vlissingen	35m. Single lock Gate 4	30.45	385.15	910	zinc	10	55	27	27
Vlissingen	Inner safety lock Gate 1	30.45	385.30	913	zinc	10	55	27	27
Vlissingen	Inner safety lock Gate 2	30.50	385.30	913	zinc	10	55	27	27
Vlissingen	Inner safety lock Gate 3	30.45	385.35	817	zinc	8	61	31	31
Vlissingen	Inner safety lock Gate 4	30.50	385.35	817	zinc	8	61	31	31
Vlissingen	Outer safety lock Gate 3	30.50	385.25	1,200	zinc	8	90	45	45
Volkerak	Intake lock rails	87.00	412.00	5,120	zinc	10	307	154	154
Volkerak	Intake lock seal gates	87.00	412.00	30,110	zinc	10	1,807	903	903
Volkerak	Yacht lock	86.80	412.10	7,891	zinc	10	473	237	237
Volkerak	Lock 1	87.20	411.90	13,344	zinc	10	801	400	400
Volkerak	Lock 2	87.20	411.80	13,344	zinc	10	801	400	400
Volkerak	Lock 3	87.20	411.70	8,896	zinc	10	534	267	267
						total	**27,698**	**13,849**	**13,849**

It should be noted, however, that there is no reliable information available on the implementation and effects of these measures and developments in the past.

6 Time series of emission factors

Given that there is no known quantification of the effects of currently active measures, the emission factor remains constant in time. The emission factor in the table below is expressed in kg/year per AR.

Table 3: zinc emission factor from zinc anodes on sluice valves, from 1985-2006

Emission factor (in kg/year per weight of zinc anodes/useful life)	
year	**zinc**
1985 through 2006	0.6

7 Emissions calculated

The table below shows the emission, expressed in kg/year. The emission was calculated by multiplying the emission factor from section 6 by the activity rate shown in section 3. This puts the total emission of the zinc anodes on sluice valves at 27,698 kg/year. Given that the inventory of the Civil Engineering Division pertains to anodes on sluice valves in the coastal area, and accordingly, the emissions occur at the boundary between fresh and salt water, the assumption is that half of the emissions end up in the fresh surface water and half in the salt water. Because at this point, the National Emission Inventory has only reported on the impact on fresh surface water, a figure of 13,849 kg/year is maintained for this quantity. Emissions on salt waters will be included in the Emission Inventory as from 2006.

Table 4: Zinc emissions for the years 1985 through 2006

Emissions (in kg/year)	**Salt water**	**Fresh water**	**Total**
year	**zinc**	**zinc**	**zinc**
1985 through 2006	13,849	13,849	27,698

8 Release into environmental compartments

The full amount of emissions by zinc anodes on sluice valves go directly into the surface 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 [7] 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: summary of spatial allocation method

Element	**Locators**
Sluice valves	**Sluice location**

Sluice location

This locator is used for emissions by zinc anodes on sluice valves, and is based on historical emission data. Locations and emissions are taken from a RIZA study. The data are applicable for 1995.

10 Description of emission pathways to water

The emissions calculated here are direct emissions into water.

11 Comments and changes in regard to previous version

For lack of available and reliable current information, the estimates have remained constant for a number of years.

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 [5]. 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.

For the year for which the Civil Engineering Division took its inventory, the activity rate was very reliable, but thereafter this figure was not updated for more recent years. As a result, it is assigned the category C. The emission factor is a fairly roughly estimated average, and consequently classified in the category of D.
As far as the distribution of emissions among individual compartments and emission pathways is concerned, it is clear that all the emissions directly enter water, so category A applies here. The spatial allocation of the emissions is in principle fairly reliable, but developments after 1993 are not taken into account, and accordingly this is assigned a reliability class of C.

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

The main areas where improvements could be made are:

- Updating of applied weight of zinc anodes per sluice and application of alternatives, such as aluminium anodes. In the process, this also results in an updated spatial allocation.
- Improvement of the information on which the emission factor is based: the portion of the zinc anode dissolved on average.
- Review of whether the zinc anodes may contain relevant quantities of other heavy metals, such as cadmium, which may be released during corrosion.

13 Request for reactions

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14 References

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