Emission estimates for diffuse sources
Netherlands Emission Inventory

Atmospheric corrosion of stainless steel in industries

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

Atmospheric corrosion of stainless steel in industries

1 Description of emission source

Emissions of nickel and chromium are released due to the atmospheric corrosion of stainless steel in industries. Stainless steel is present in buildings and in process plants. This emission source is attributed to the (governmental) target sector "Industry".

2 Explanation of calculation method

Emissions are calculated by multiplying an activity rate (AR), in this case the total exposed surface area of stainless steel (SS) in industrial plants in the Netherlands, by an emission factor (EF) per substance, expressed in emission per AR unit. This method of calculation is explained in detail in the Guide to the Regional approach to diffuse sources [1].

Emission = AR x EF

Where:
AR = exposed area of SS (km^2)
EF = Emission factor per substance per km^2 (kg/km^2)

The calculation method for emissions from this emission source is based on information from the water system survey of construction materials [2].

The emission calculated in this way is referred to as the total emission.

3 Activity rates

The study "WSV-studie Bouwmaterialen" [2] calculated the surface area of stainless steel in 1990 based on stainless steel consumption between 1982 and 1991, average steel thickness, and its density and life span. The result was 92 million m^2 in 1990. This figure was calculated by dividing the net consumption of SS in the Netherlands in 1990 (99,500 tonnes) by the density of SS (8.64 tonnes/m^3), dividing this figure by the thickness of SS sheets (0.005 m) and multiplying this figure by the average life span of 40 years.

Area = (tonnes/year)/(tonnes/m^3) x (1/thickness) x years of life span =
99,500/8.64 x (1/0.005) x 40 = 92 km^2.

Part of this area is exposed to atmospheric influences. Data about this atmospheric exposed part is not available, so the size of this area has to be estimated. Only stainless steel attached to the surface will be exposed to atmospheric influences. Assuming that commercial/industrial premises are square or rectangular in shape, it can be assumed that mainly the roof surface and one or two sides will be exposed to wind and rain. This amounts to more or less half of the available area, and therefore it was assumed that half of the area of stainless steel is exposed to atmospheric corrosion.

A time series has been derived by upscaling this figure on the basis of the total area of the industrial and port premises taken from data of Statistics Netherlands. The total area for 1989 [3, 4] was subsequently converted in the light of the increase in area used in the study "MV2" [5] delivering a figure of 5.03×10^8 m^2 for 1990. In the absence of any later data from Statistics Netherlands, figures for subsequent years are based on the growth trends in industrial premises areas shown in the European Renaissance scenario in the study "MV2", which pointed to growth of 1.2% a year between 1990 and 2000 [5].

Table 1: Activity rate time series (10^3 m^2)

Year	1985	1990	1995	2000	2005	2006
AR: total exposed area of SS	40,352	46,000	48,760	51,520	54,280	54,830

4 Emission factors

The emission factor was determined on the basis of a corrosion rate of 8 grams of steel per m^2 per year [6], equivalent to 1.44 grams of chromium and 0.64 grams of nickel per m^2 exposed Stainless Steel per year.

5 Effects of policy measures

No effects of measures are known.

6 Emissions calculated

Total emissions are shown in table 2.

Table 2: Nickel and chromium emissions (kg)

Year	1985	1990	1995	2000	2005	2006
Nickel	25,900	29,500	31,200	33,000	34,800	35,100
Chromium	58,100	66,300	70,200	74,200	78,200	79,000

7 Release into environmental compartments

The distribution of emissions between compartments is taken from the SPEED heavy metals report [6]: 80% of the emission ends up in the soil and 20% in sewer systems. The reason for this relatively high proportion of emissions ending up in the soil is that Stainless Steel is used mainly in industrial processing plants, the sub-soil of which is not connected to the sewer system. Tables 3 and 4 show emissions to the soil and to the sewer system.

Table 3: Emissions to the soil (kg)

Year	1985	1990	1995	2000	2005	2006
Nickel to soil	20,700	23,600	25,000	26,400	27,800	28,100
Chromium to soil	46,500	53,000	56,200	59,400	62,500	63,200

Table 4: Emissions to the sewer system (kg)

Year	1985	1990	1995	2000	2005	2006
Nickel to sewer system	5,200	5,900	6,200	6,600	7,000	7,030
Chromium to sewer system	11,600	13,300	14,000	14,800	15,600	15,800

8 Description of emission pathways to water

Emissions into water arise indirectly as a result of emissions from the sewer systems, combined sewer overflows, and effluents from urban waste water treatment plants. The fact sheet "Effluents from waste water treatment plants and sewer systems" [7] describes this in further detail.

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 5: Summary of spatial allocation method

Element	Locators
Stainless steel in industry	Number of inhabitants per grid cell measuring 500x500 metres

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

Number of inhabitants
The number of inhabitants per grid cell measuring 500x500 metres is derived from the PBL's map of grid cell distribution based on the number of inhabitants, residential dwelling units and inhabitants per sewage unit. This map is based on data produced by Statistics Netherlands (CBS) on numbers of inhabitants and numbers of residential dwelling units in each local authority (for 2005). The distribution of inhabitants among grid cells in a municipality was calculated using the comprehensive database of address coordinates in the Netherlands (which contains addresses and types of dwelling unit) and the 2003 sewage area database.

10 Comments and changes in regard to previous version

There have been no changes in the calculation methodology compared to previous publications, such as [1], [2] and [8].

11 Accuracy and indicated subjects for improvement

The method used in Emission Registration publications has been followed as far as possible in classifying the quality of information [9]. 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 emission factor calculation is subject to considerable uncertainty, and is classified as D.
The activity rate is also based on a very simple calculation, with a number of poorly-supported assumptions, and comes into category E. The distribution of emissions among compartments falls into class D. The emission pathway into water is as a consequence very clear, and is classed as B. Finally, the spatial allocation of emissions is given reliability classification C.

Element of emission calculation	Reliability classification
Activity Rates	E
Emission factors	D
Distribution among compartments	D
Emission pathways to water	C
Spatial allocation	C

The most significant areas for improvement are:

- Improving the activity rate. The method used to estimate this is very uncertain, and probably leads to a significant over-estimate as (a) it is assumed that all SS is used in construction, (b) there is no replacement, and (c) there is no cutting loss.
- The area of steel present is calculated by multiplying annual production in 1990 by a useful life of 40 years, which implicitly assumes that the production and use of SS in the period from 1950 to 1990 remained at a consistently high level. The assumption that use increased over time, and that therefore consumption in the past was much lower, should lead to a marked reduction in the AR.
- Improving the quality of the emission factor. According to source [6] very little information was available regarding emissions caused by corrosion under normal circumstances or wear.
- Spatial allocation of emissions could be made more accurate by allocating emissions to individual sewer systems.
- This would mean performing the spatial allocation of data on the basis of employees instead of inhabitants.

12 Request for reactions

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13 References

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