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**TNO-report**

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# Zinc load of surface waters in the Netherlands and the share of zinc metal products

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# 1. Introduction

In the last few years much energy was spent in the Netherlands on discussions between governmental organisations and representatives of the non-ferrous metals industry on the amount of zinc released by atmospheric corrosion from zinc and zinc coated building materials (shortly called "zinc products") into sewers and surface waters. The background of this discussion is that surface water quality in many cases does not meet environmental standards and target values as set by national governmental regulation. In 1999 a scientific study on this subject was carried out by TNO [1]. Parties from governmental and industrial organisations agreed on the results of this study, in which it was concluded that the load of zinc from atmospheric corrosion is about three to four times less than official figures indicated thus far. Official estimations about direct release of zinc products to surface waters in 2000 (base year 1995) were adjusted from 49 to 17 tonne zinc per year while official estimations about indirect release of zinc products to sewer systems were adjusted from 480 to 129 tonne zinc per year.
New discussions were raised when a report was published in 2000 [2] in which it was suggested that the share of zinc originating from building materials is very high (in the order of 30 to 50 percent) relative to load of surface waters from other sources. However in this publication it was not made clear that the percentages were based on the share of zinc from building materials in the emissions rather than the share in the actual load of surface waters. Aiming at the potential improvement of water quality only the share of sources in the actual load [1] of surface water is relevant [19].
In this report the actual share of zinc from building matearials in the load of surface waters in the Netherlands is discussed. Important sources of diffuse emissions of zinc that were omitted in the development of clean water policy towards zinc until now are also included.

1 In this report the load of surface waters ("Belasting oppervlaktewater") is defined according to the definition given in [4] page 51, figure 2.11

# 2. Load of zinc to surface waters

In this chapter the external man-made fluxes of zinc to surface waters on a national scale in the Netherlands are described. The share of run-off of zinc products in these loads is estimated. In the end the share of zinc metal products in the total man-made load to national surface waters is quantified.

## 2.1 Zinc discharges to surface water

Direct discharges of zinc, originating from all direct emissions sources, to surface waters were quantified at 135 tonnes [3], [4] in the 2000. However more recent direct emission figures of the year 1998 according to the official Emission registration amount to 157 tons. The latter figure is used in this report. These direct emissions are partly measured at individual companies and partly estimated with emission factors. Of these 157 tonnes, according to the national inventory, 17 tonnes are caused by corrosion of zinc metal building products.

Indirect discharges, i.e. total discharges of zinc that flow into the sewer systems, that are accounted for in the Dutch national emissions inventory [3], [4] amount to 333 tonnes. Of these 333 tonnes 123 tonnes reach the surface water by way of effluent discharges of sewage treatment plants (SWTP), assuming an average removal efficiency of 72.4 percent. The removal percentage is based on the mass balance of metals from SWTP's [5]which is relatively accurately assessed by the national statistical bureau (CBS). Applying the average removal percentage of SWTP to the estimated indirect discharges of zinc caused by corrosion of zinc products of 128.5 tonnes provides a contribution of 35 tonnes of zinc products to the discharges of SWTP effluents into surface waters.
The share of zinc products in emissions of combined sewer overflows and rainfall outlets are estimated assuming equal shares in total emission input in sewers and emission output of of combined sewer overflows and rainfall outlets .
It must be stated that the figures in the national emission registration of combined sewer overflows and rainfall outlets from separated sewer systems, are only rough estimates on this moment[1]. So, taken 128.5 tonnes (the share of zinc products) over 374 tonnes (the total calculated/accounted input of sewers systems including deposition) means that about 1/3 of the emissions of overflow discharges and rainfall

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[1] Note that the influx of SWTP in 1998 (which is rather well assessed by large numbers of measurements) was 445 tonnes in 1998 [5]. Also the effluents can be calculated by a sufficient amount of measurements. One of the factors for the difference between the assessed input of 333 tonnes and the actual input of 445 tonnes is that atmospheric deposition on build areas into sewer systems is not considered in the national emission registration. Using 130 g/hectare.year, a hard surface area of 0.42 million hectare (including traffic area) and a run-off coefficient of 70 % gives an extra amount of 38 tons of zinc in the sewer systems to be added to the official figure.

outlets are estimated to have an origin in zinc metal products. Based on 50 tons for combined sewer overflows and rainwater outlets given by the CCDM [4] this amount is about 17 tonnes for the year 1998. Since this figure of 50 tons given by the emission registration is quite uncertain, the figure of 17 tons for the contribution of zinc products is even more uncertain.

## 2.2 Deposition and leaching of agricultural soils

Two relatively important emission sources of zinc to surface waters, thus far are not (or not adequately) quantified in the official emission inventory. These sources are wet atmospheric deposition directly into surface waters and leaching of zinc from agricultural soils.

From several reports of the National Institute of Public Health and Environment about measurement programs of rainwater composition it can be derived that average content of zinc in rainwater is rather constant about 0.2 μmol/l [6], [7]. Under relative wet weather conditions in 1998 this results in about 200 $\mu mol/m^2$ or 130-gram zinc per hectare per year. For more average weather conditions 100-gram zinc per hectare per year is considered as a reasonable figure. With an area of surface waters in the Netherlands of 0.76 million hectares this accounts for 76 tonnes of zinc as a consequence of wet deposition only. The figure of 8 tonnes for deposition to surface water given by the national emission inventory is based on calculation with an air pollution dispersion and deposition model. A new investigation about atmospheric deposition to surface waters is currently underway and may produce new insight.

Leaching of agricultural soils is recognised as an important man-made source of emissions of zinc to surface waters already during several years [8], [9]. Nevertheless no official figure was produced up to this moment although a research program was started to estimate this emission load [10] more accurately.
Nevertheless several indicative figures about leaching of zinc form agricultural soils are available that give reason to accept that this process is one of the major influencing factors for the concentration of zinc in regional waters and underwater soil[1].
Groot [11] presented in 1993 indicative leaching figures between 332 (for extensively used pastures) and 384 (for intensively used pastures) grams zinc per hectare per year. The partitioning of the zinc flux between deep groundwater and surface water was not indicated.
In [12], a publication is cited [13] wherein leaching of zinc is measured by a lysimeter-experiment. For sandy soils a value of 200 g/ha.year was measured while for clay a value of 88 g/ha.year was assessed. These figures are not in contrast with a mean figure of 310 ton/year for agricultural soils which is estimated by van Til-

[1] This is one of the conclusions in the report of Kramer et al. [8] that are not taken into account up to today.

borg [14] and 267 ton/year given by Teunissen [2]. Using a total agricultural area of 2.3 million hectares in the Netherlands leaching in both studies is respectively estimated at 135 and 116 gram/ha.year. The above figures imply that for the Netherlands about 1/3 of the zinc flux resulting from leaching would be released into surface water. From other studies [18], it is known that between 10 and 50 percent of underground fluxes are reaching the surface water.
Following the indication in [2] the figure of 267 ton/year is taken as a provisional figure of the estimation of leaching from agricultural soils.

## 2.3 Influx through rivers

Water from the river Rine is led into the tertiary water system in the Netherlands to compensate for evaporation and infiltration losses. Depending on the location and the season the share of Rhinewater that is present in the tertiary water systems per region may vary from 10% to 90% [15]. From [17] in combination with [15] it can be derived that presence of 1% Rhinewater in a certain area demands addition of 70 $m^3$ Rhinewater per hectare. Based on maps in [15] an estimation was made from areas with a certain percentage of Rhinewater that is present on average. From this estimation of areas multiplied with an average presence of Rhinewater it was derived that on a national scale an influx in the tertiary system of about $1,75*10^9$ $m^3$ in a year with average rainfall is likely. So the average inlet of zinc through Rhinewater (20 μg Zn/l) is approximately 35 tonnes per year.
Another significant source is the influx of zinc to the IJsselmeer. Using the data from Middelkoop [16] we estimate an influx in the IJsselmeer of 300 ton Zn per year.

Although probably significant, the exact flux of zinc from the river Rhine to Dutch surface water is difficult to determine. Therefore, we will not include these figures in our zinc balance.

# 3. Zinc balance and conclusions

## 3.1 Zinc balance

Calculating the over-all share of emissions of zinc due to building materials, we estimate a total contribution of 70 tonnes per year to surface water on a total external input of 680 tonnes, resulting in a 10% share.

The fluxes of relevant zinc sources are given in figure 1.

**Zinc load of surface waters in the Netherlands 1998**

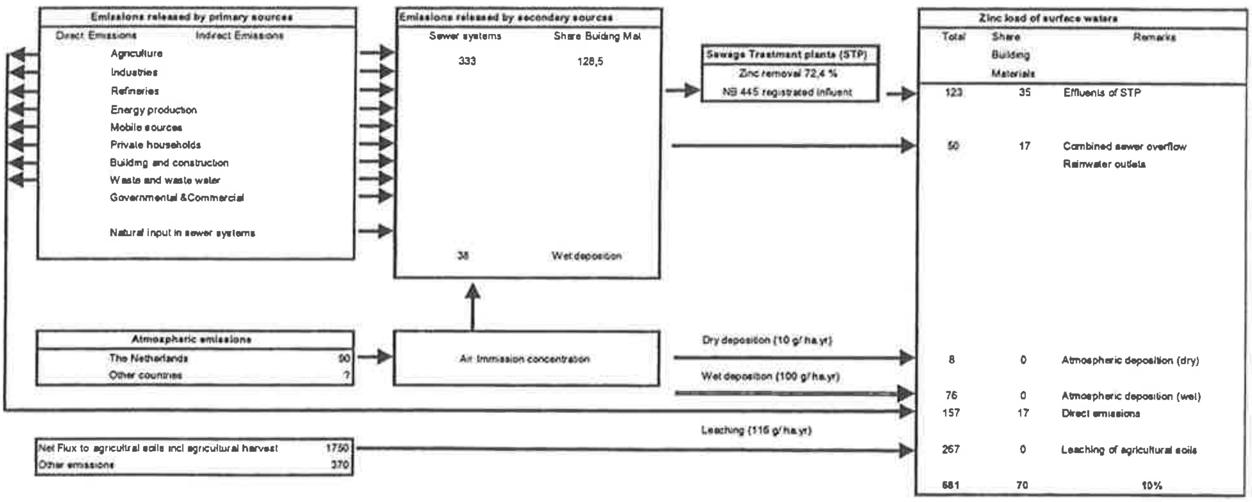


*Figure 1 Zinc load of surface waters the Netherlands (based on figures in this report)*[1]

*Uncertainty range*

Because there are so many uncertain figures and the SWTP input calculated does not comply with the assessed input, we have tried to provide some indication of the uncertainty margin in the conclusion.
In the table below, an expert judgement is given of the range of uncertainties in the figures presented.

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[1] All figures about fluxes in this figure (except two additional fluxes) are derived from the published results of the official Dutch national emission inventory and underlying data [3], [4].

*Table 1 Uncertainty range in the provided figures (expert judgement)*

| Source/Load | % Uncertainty<br>Total load | % Uncertainty<br>Share of zinc products |
|---|---|---|
| Effluent SWTP's | 10 | 25 |
| Mixed sewer Overflows+ sewers | 50 | 100 |
| Dry deposition | 100 | - |
| Wet deposition | 25 | - |
| Direct emissions | 25 | 25 |
| Leaching of agricultural soils | 25 | - |

Based on these uncertainty margins, one can conclude the total emissions to the surface water to be 700 ± 25% and the emissions from building materials 70 ± 40%, resulting in *a relative contribution of 3% - 17% (10% ± 7%).*

Although there are rather large uncertainties in some fluxes, the general picture of the relative importance of fluxes to surface water is rather robust. This means that conclusions drawn are valid.

## 3.2 Conclusions

Based on the calculations and estimations we reach the following final conclusions:

1. In the official Dutch emission inventory with respect to the emissions of zinc to surface waters some major sources are not taken into account up to now;
2. Leaching of agricultural soils is lacking while atmospheric deposition is not based on available good quality data about rain quality;
3. Although the share of zinc products in the zinc emissions to sewer systems is about 30 percent, the share of zinc building products in the load of surface waters is likely to be approximately 10 percent.
4. In this estimate, the intake from large rivers has not yet been taken into account, because this intake could not be defined with sufficient accuracy.

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# 5. Authentication

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