Emission estimates for diffuse sources
Netherlands Emission Inventory

Railways, abrasion of pantographs and overhead wires

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

Railways, abrasion of pantographs and overhead wires

1 Description of emission source

A large proportion of trains, trams and underground trains are electrically powered. Electricity is supplied via copper overhead contact lines and is collected via pantographs installed on the locomotives. The part making contact with the overhead contact line (the pantograph slipper) is primarily made out of carbon with addition of copper and lead. When the vehicles are in operation, the overhead contact lines as well as the pantograph slippers are subject to wear. This wear leads to an emission of copper, lead and fine particulate. This emission source is allocated to the governmental target sector "Transport".

2 Explanation of calculation method

Emissions are calculated by multiplying an activity rate (AR), in this case the electricity consumption for electrically powered trams, underground and trains, by an emission factor (EF), expressed in grams of emission per unit of energy consumed. This method of calculation is explained in detail in the reference "Handreiking Regionale aanpak diffuse bronnen" [1].

Emission = AR x EF

Where:
AR = Electricity consumption (kWh)
EF = Emission factor per kWh (kg/kWh)

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

3 Activity rates

The activity rate is total yearly electricity consumption. This activity rate is to be considered as a proxy. In the original investigation [3] the amount of pantograph kilometres in which contact is made was used as the AR. However, data on these pantograph kilometres is not always available. The amount of kWh is therefore assumed as a proxy of the amount of pantograph kilometres . Electricity consumption for electrically powered trams, underground and trains is recorded by Statistics Netherlands (CBS), as shown in table 1 [2].

Table 1: Electricity consumption of electrically powered trains, trams and underground trains in the Netherlands (in millions of kWh)

	1990	1995	2000	2005	2006
Railway	1082	1278	1414	1360	1360
Tram/underground train/trolley bus	191	190	216	230	230

4 Emission factors

The emission factors for copper, lead and fine particulates are based on studies carried out by the Centrum voor Technisch Onderzoek (CTO) of the Dutch Railways (NS) [3,4] in 1992. These studies estimate the total copper emission in 1992, as shown in table 2. This estimate is based on observed wear of overhead contact lines and pantographs, assuming that overhead contact lines contain 100% copper and pantographs contain 25% copper and 10% lead.
The formation of fine particulates in the overall quantity of wear particles is estimated by TNO to be 20% of the total wear [5]. Emissions of fine particulates are calculated in different ways for overhead contact lines and pantographs:

- Overhead contact lines are made entirely out of copper, so the emission of fine particulates is 20% of the copper emission. In this respect, 20% of the emission of copper is also fine particulates (see table 2). There is therefore an overlap in the values set out in table 2. There is no double-counting in the emissions inventory database.
- The pantographs contain 25% copper. The total mass wear is four times the emission of copper; 20% of the overall mass worn away is released as fine particulate, so the fine particulate emission is 4/5^{ths} of the copper emission; 1/5th of the fine particulate emission comprises fine copper particles. Here too, 20% of the emission of copper and lead is also an emission of fine particulate. Apart from copper and lead, the fine particulates released when the pantographs wear down also comprises other substances. In this respect, there is no double-counting in the emissions inventory database.

The emission factors set out in table 2 are calculated on the basis of total electricity consumption in 1992 of $1200 \cdot 10^6$ kWh for trains and $186 \cdot 10^6$ kWh for trams and underground. NB: No emissions resulting from wear of pantographs are defined for trams and underground trains.

Table 2: Emission factors with electrically powered trains, trams and underground trains in the Netherlands

Substance	Emission in 1992 (kg)	Emission factor (mg/kWh)
Wear of overhead contact lines for trains		
Copper	20,700	17.3
Fine particulates (PM_{10})$^{1)}$	4100	3.4
Wear of pantographs for trains		
Copper	3000	2.5
Lead	1200	1.0
Fine particulates (PM_{10})$^{1)}$	2400	2.0
Wear of overhead contact lines for trams, underground trains		
Copper	2500	13.4
Fine particulates (PM_{10})$^{1)}$	500	2.7

$^{1)}$ 20% of the total emission comprises fine particulate. The emission of fine copper and lead particulates is counted twice in this table. For example, 2500 kg copper was released in 1992 from the wear of overhead contact lines. 500 kg of this comprises fine particulate. This 500 kg is recorded in the copper emission as well as in the emission of fine particulate.

Burkhardt et al (2008) [6] studied the emissions of heavy metals by train traffic in Switzerland with trains run by the SBB (Schweizerische Bundesbahnen) in 2003, with the support of a number of internal documents issued by the SBB. For copper, they establish an emission of 38 tonnes from overhead contact lines in 2003, which converts into an emission factor of 6.48 kg/km. According to the Swiss Federal Department of the Environment, Transport, Energy and Communications (UVEK) [7], electricity consumption in 2001, 2002 and 2003 was $2.3 * 10^9$ kWh – these values are in line with the electricity consumption figures reported by Brunner in 2001 [8] – so the emission factor per unit electric energy consumed can be calculated as 16.5 mg/kWh. This corresponds closely to the proxy emission factor of 17.3 mg/kWh recorded by the Dutch Railways (NS), so this value will be used in order to calculate the emissions.

5 Effects of policy measures

No effects of measures are known.

6 Emissions calculated

The results of calculations are set out in table 3.

Table 3: Emissions from overhead contact lines and pantographs (in kg/year)

	1990	1995	2000	2005	2006
Wear of overhead contact lines for trains					
Copper	18,680	22,064	24,407	23,480	23,480
Fine particulates (PM_{10})	3736	4413	4881	4696	4696
Wear of pantographs for trains					
Copper	2707	3198	3537	3403	3403
Lead	1083	1279	1415	1361	1361
Fine particulates (PM_{10})	2166	2558	2830	2722	2722
Wear of overhead contact lines for trams, underground					
Copper	2567	2554	2909	3094	3094
Fine particulates (PM_{10})	513	511	582	619	619

7 Release into environmental compartments

The distribution of emissions among the compartments is shown in table 3 [4]. 100% of emissions of fine particulates is released into the atmosphere. 20% of emissions of Cu and Pb is released as fine particulates and it is assumed that this 20% entails emission to the atmosphere (in other words 100% of the fine particulates involves emission to the atmosphere). The remaining share of emissions (coarse particulate) ends up in the soil or sewers or is left behind on the train, tram or underground train and is collected in the train washing systems.

Trams and underground trains primarily run within built-up areas. The share of emission to soil or sewers primarily goes into the sewers in such areas; trains primarily run outside built-up areas and, as a result, these emissions primarily end up in the soil.

Table 4: Distribution of emissions between compartments

	Substance	On train	Atmosphere	Soil	Surface water (direct)	Sewers (indirectly to water)
Train	Copper/lead	10%	20%	65.6%	4.4%	0%
	PM_{10}	0%	100%	0%	0%	0%
Tram, underground train	Copper	10%	20%	0%	0%	70%
	PM_{10}	0%	100%	0%	0%	0%

Table 5: Emissions to the atmosphere (in kg)

	1990	1995	2000	2005	2006
Copper	4792	5564	6172	5996	5996
Lead	217	256	283	272	272
PM_{10}	6415	7482	8293	8037	8037

Table 6: Emissions to the soil (in kg)

	1990	1995	2000	2005	2006
Copper	14,030	16,572	18,332	17,635	17,635
Lead	710	839	928	897	893

Table 7: Direct emissions to surface water (in kg)

	1990	1995	2000	2005	2006
Copper	941	1112	1230	1183	1183
Lead	48	56	62	60	60

Table 8: Emissions to the sewer system (in kg)

	1990	1995	2000	2005	2006
Copper	1797	1788	2036	2166	2166

8 Description of emission pathways to water

Emissions into water arise indirectly as a result of emissions from the sewer system, combined sewer overflows, and effluents from urban waste water treatment plants. The fact sheet "Effluents from waste water treatment plants and sewer systems " [12] describes this in further detail.

9 Spatial allocation

The spatial allocation of emissions is worked out on the basis of a set of digital maps held by the Netherlands Environmental Assessment Agency (PBL). 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. That is why the locator judged to be the best proxy of the activity rate of the emission in question is used.
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 9: Summary of spatial allocation method

Element	Locators
Railway	Traffic density on stretches of electrically powered railway
Tram/underground train/trolley bus	Traffic density of trams

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

Traffic density on stretches of electrically powered railway
Traffic density on stretches of electrically powered railway is calculated in the light of information contained in the map: ‘distribution over stretches of railway’. Data on the location of stretches of railway and corresponding traffic intensity is included from the Quality of the Local Environment (LOK) team at the Netherlands Environmental Assessment Agency (PBL), and also from the railway company ProRail. The data in question is taken from the ASWIN database (formerly the ‘Akoestisch Spoorboekje’). This information is collated each year, with the main aim of facilitating the calculation of noise levels. To this end, in addition to traffic density, data is also collated on noise intensity per pathway, speed and presence of noise protection barriers. In the distribution of traffic intensity, a distinction is made between electrified and non-electrified track. This data comes from a file produced by Statistics Netherlands in 2005.

10 Comments and changes in regard to previous version

There have been no changes in the calculation methodology compared to previous publications, such as [9].

11 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 [11]. 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 calculation of the emission factors is based on detailed research, and is classified under category C. The activity rate is monitored very exactly. However, the selected AR may not be the best proxy of the AR for wear, so is assigned to category C. The distribution of emissions among the various compartments is assigned to category C. The emission pathway to water is as a consequence quite clear, and is classed as C. Finally, the spatial allocation of emissions is given classification C.

Element of emission calculation	**Reliability classification**
Activity rates	C
Emission factors	C
Distribution among compartments	C
Emission pathways to water	C
Spatial allocation	C

12 Request for reactions

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13 References

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