Emission estimates for diffuse sources
Netherlands Emission Inventory

Letting off fireworks

Version dated June 2008

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

Letting off fireworks

1 Description of emission source

Millions of kilograms of fireworks are let off each New Year. Coloured fireworks in particular contain certain amounts of heavy metals which give them their colour, but fireworks designed more for acoustic impact (detonation fireworks) also contributes to the emission of specific components. This factsheet describes how the letting off of fireworks contributes to emissions into air, soil and surface water. The method described is directed to fireworks used by private individuals. It does not deal with fireworks showed in commercial displays.
This emission source is allocated to the governmental target sector "consumers" within the national emission inventory.

2 Explanation of calculation method

Emissions for each substance are calculated by multiplying an activity rate (AR), in this case the amount of fireworks let off in the Netherlands in tonnes, by an emission factor (EF) expressed in g of the specific substance per kg of firework let off. A distinction can also be made between detonation fireworks and coloured fireworks. This method of calculation is explained in the Guide to the Regional approach to diffuse sources [1].

Emission = AR x EF

Where:
AR = amount of fireworks let off in the Netherlands (tonnes)
EF = emission factor per amount of fireworks let off (g/kg)

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

3 Activity Rates

The AR is the total amount of fireworks sold in the Netherlands, broken down into detonation fireworks and coloured fireworks. The amount of fireworks sold in the Netherlands was until 1996 registered by Statistics Netherlands as the difference between imports and exports. Imports and exports have not been tracked so closely since 1997, and a different method is now in use: sales data obtained from the market leading company (Schuurmans) is corrected for the estimated total market share. It is estimated that illegal imports of fireworks account for 31.6% of the quantity legally sold. Table 1 shows a time sequence for firework sales. The sales figure for 2006 probably is not identical to that for 2005, but it is estimated that it was about the same as the previous year.

Table 1: Amount of fireworks let off (millions of kg)

Year	1990	1995	2000	2005	2006
Fireworks	4.9	8.2	9.7	10.82	10.82

4 Emission factors

Emission factors for letting off detonation and coloured fireworks are listed in table 2. The final calculations were made using the emission factor for all fireworks (table 2, last column). It was assumed for the purposes of defining these emission factors that the total number of fireworks breaks down into 85% coloured fireworks and 15% detonation fireworks.

Table 2: Emission factors for the letting off of fireworks (g/kg fireworks)

Component	Detonation fireworks[1)]	Coloured fireworks[1)]	All fireworks
gaseous			
- carbon dioxide	22	47	43.25
- carbon monoxide	3.5	7.5	6.9
- methane	0.4	0.9	0.825
- hydrogen sulphide	0.6	1.3	1.195
- sulphur dioxide	1	2.1	1.935
- nitrous oxide	1	2.1	1.935
particulate			
- strontium		7.0	5.95
- barium		29	24.48
- copper		8.1	6.885
- antimony		1.1	0.935
- other particulate[2)]	52	113	104.19
fine particles (PM_{10})[3)]	5	15.7	14.244

1) These emission factors are derived from [2] and are based on data sheets with specifications for the pyrotechnic compounds used, supplied by the manufacturers. The proportion of the emission that enters the air in the form of fine particles is based on a comparison of immission measurements taken from the National Institute for Public Health and the Environment's national recording network [5] with the emission factors described below, and is estimated at 10% [2].
2) the other substances are mainly potassium carbonates, potassium sulphates and potassium sulphites in particulate form.
3) fine particles account for 10% of the total of the particulate Sr, Ba, Cu, Sb and other substances listed under footnote 2, that are not recorded separately. This means that fine particles appear twice in this table: 10% of the particulate take the form of fine particles, and this is listed under fine particles and for the component itself. There is no double-counting in the emissions inventory system itself.

5 Effects of policy measures

No effects of measures are known.

6 Emissions calculated

The table below shows the calculated total emissions.

Table 3: Calculated emissions from the letting off of fireworks (in kg)

Substance\Year	1990	1995	2000	2005	2006
methane	4,043	6,765	8,003	8,927	8,927
sulphur dioxide	9,482	15,867	18,770	20,937	20,937
hydrogen sulphide	5,856	9,799	11,592	12,930	12,930
nitrous oxide	9,482	15,867	18,770	20,937	20,937
carbon monoxide	33,810	56,580	66,930	74,658	74,658
carbon dioxide	211,925	354,650	419,525	467,965	467,965
antimony	4,582	7,667	9,070	10,117	10,117
barium	119,952	200,736	237,456	264,874	264,874
copper	33,737	56,457	66,785	74,496	74,496
strontium	29,155	48,790	57,715	64,379	64,379
total particulate	697,956	1,168,008	1,381,668	1,541,201	1,541,201
fine particles (PM_{10})[1)]	69,796	116,801	138,167	154,120	154,120

[1)] 10% of the particulate (Sb, Ba, Cu and Sr) consist of fine particles. Fine particles therefore appear twice in this table: this 10% of particulate emissions are counted under fine particles and under the component itself.

7 Release into environmental compartments

100% of the gaseous components are allocated to the compartment 'air'. 10% of the particulate is allocated to the compartment 'atmosphere'. Of the remainder, 40% is allocated to soil and 60% to the sewer system.

Table 4: Compartment breakdown

	Atmosphere	Directly - into surface water	Indirect – into sewer system	Soil
Gaseous substances	100%	0%	0%	0%
Total Particulates	10%	0%	54%	36%
Fine particulates (PM_{10})	100%	0%	0%	0%

The calculated emissions to the various environmental compartments are shown in tables 5 to 7. Fine Particulates comprises all particulates less than 10 micrometres in size, while total particulates includes all particles. There is double counting in both tables, as the emissions of particulate (Sb, Ba, Cu and Sr) are listed under fine particles/total particulate and under the specified metal component. There is no double-counting in the emissions inventory.

Table 5: Emissions to the atmosphere (in kg)

	1990	1995	2000	2005	2006
methane	4,043	6,765	8,003	8,927	8,927
sulphur dioxide	9,482	15,867	18,770	20,937	20,937
hydrogen sulphide	5,856	9,799	11,592	12,930	12,930
nitrous oxide	9,482	15,867	18,770	20,937	20,937
carbon monoxide	33,810	56,580	66,930	74,658	74,658
carbon dioxide	211,925	354,650	419,525	467,965	467,965
antimony	458	767	907	1,012	1,012
barium	11,995	20,074	23,746	26,487	26,487
copper	3,374	5,646	6,678	7,450	7,450
strontium	2,916	4,879	5,772	6,438	6,438
fine particles (PM_{10})	69,796	116,801	138,167	154,120	154,120

Table 6: Emissions to soils (in kg)

	1990	1995	2000	2005	2006
antimony	1,649	2,760	3,265	3,642	3,642
barium	43,183	72,265	85,484	95,354	95,354
copper	12,145	20,325	24,042	26,818	26,818
strontium	10,496	17,564	20,777	23,176	23,176
total particulates	251,264	420,483	497,400	554,832	554,832

Table 7: Emissions into sewer systems (in kg)

	1990	1995	2000	2005	2006
antimony	2,474	4,140	4,898	5,463	5,463
barium	64,774	108,397	128,226	143,032	143,032
copper	18,218	30,487	36,064	40,228	40,228
strontium	15,744	26,347	31,166	34,765	34,765
total particulates	376,896	630,724	746,101	832,248	832,248

8 Description of emission pathways to water

Emissions into water arise as a result of indirect 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" [3] describes this in further detail. Emissions to the sewer system take place via rainwater flow (rwf).

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 [5] 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 8: summary of spatial allocation method

Element	Locators
Fireworks	Number of inhabitants per grid cell measuring 500x500 metres

The method used to determine the locators is described in [5]:

Number of inhabitants
The number of inhabitants per grid cell measuring 500x500 metres is derived from the MNP'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 municipality (for 2005). The breakdown 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

The emission factors and the compartment breakdown were revised in 2008. In previous years emissions had been calculated using emission factors of unclear origin. The emission factors were readjusted in 2008 and based on [2]. The compartment breakdown was also changed from the approach used in previous years. It had previously been assumed that around 11 to 16% of particulate is released in the atmosphere (depending on the substance). Of the rest, 96% was transferred directly into the sewers, 3% upon the soil and 1% to surface water. It is now assumed that 10% of particulate emissions is released into the atmosphere, while the remaining 36% and 54% is transferred upon soil and into the sewer system.

11 Accuracy and indicated subjects for improvement

The method used in the National Emission Inventory publications has been followed as far as possible in classifying the quality of information [6]. 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 C.
The activity rate is also based on an unrepresentative sample and falls into class D. The emission breakdown among the various components has now been revised to make it the same as the breakdown of emissions caused by wear of the road surface within built-up areas. However, this is still an estimate and comes into reliability class D. Emission pathways into water pass through the sewer system and are therefore classified as C. The reliability classification for the spatial allocation of emissions is B.

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

The most significant areas for improvement are:

- The letting off of fireworks on special occasions (Queen's Day [a Dutch public holiday], etc.) is not taken into account in the AR. Adding the amount of fireworks let off on these occasions would therefore improve the AR.

12 Request for reactions

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13 References

[1] CIW/CUWVO werkgroep VI, februari 1997. Handreiking Regionale aanpak diffuse bronnen. Bijlage 1, par 2.2.

[2] Wesp, 1995: Werkgroep Emissies Servicebedrijven en Produktgebruik, Procesbeschrijvingen 1- consumenten, bouw, handel en dienstverlening, Hoofdstuk 3: vuurwerk. RIVM-rapportnummer 772414005.

[3] Netherlands National Waterboard, Water Unit, 2008. Effluents from waste water treatment plants and sewer systems. RWS-WD, Lelystad, juni 2008.

[4] Nijdam D.S., van Loon M.M.J., Brouwer J.G.H., Peek C.J., Emissies naar de lucht van consumenten en kleine bedrijven, methoden en verantwoording 1995, 1996, 1997 en 1998, publicatiereeks emissieregistratie, nr. 49, december 1999, Ministerie van VROM, den Haag.

[5] Molder, R. te, 2007. Notitie ruimtelijke verdeling binnen de emissieregistratie. Een overzicht.

[6] Most, P.F.J. van der, van Loon, M.M.J., Aulbers, J.A.W. en van Daelen, H.J.A.M., juli 1998. Methoden voor de bepaling van emissies naar lucht en water. Publicatiereeks Emissieregistratie, nr. 44.