Industrial and communal sources
Netherlands Emission Inventory

Effluents from waste water treatment plants, monitored

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1 Description of emission source

This fact sheet describes the method used to determine effluents (residual discharge) from urban waste water treatment plants for substances to be considered as "monitored substances": total nitrogen, total phosphorous, the parameter chemical oxygen demand and the heavy metals copper, chromium, lead, zinc, cadmium, nickel, mercury and arsenic. The data is collected by Statistics Netherlands and reported in the context of the National Emission Inventory and environmental statistics.
In the National Emission Inventory the source 'UWWTP effluents (monitored)' is allocated to the governmental target sector "sewage and waste water treatment". The effluents are allocated exclusively to 'load of surface water' in the glossary of emissions and pollution. They do not count as part of 'emission' [1].

The effluent load of substances that are not monitored ('UWWTP effluents (calculated)') is determined by the Netherlands Centre for Water Management. Since the method used in that process is very different from the method used for measured substances, it is described in a separate fact sheet [2].

2 Explanation of calculation method

Statistics Netherlands takes an annual inventory of the influents and effluents of the substances listed in paragraph 1 for approximately 370 urban waste water treatment plants in the Netherlands. The data is collected via the Waste Water Treatment Survey. See [3] for descriptions of the methods and results.

a) Nitrogen and phosphorous.
Regarding nitrogen and phosphorous, the annual loads discharged via effluent are determined by the water management authorities on the basis of regular measurements of concentration and flow, as described in the Urban Waste Water Discharge Decree under the Surface Water Pollution Act [4]. Appendix 1 of that Decree specifies how samples are to be taken and analysed and how annual loads are to be calculated. The Water Management Authority calculates the discharged load on each day of measurement. The average of the daily loads is multiplied by 365 to work out the annual load of an urban waste water treatment plant.

The formula is:

$$Ve = \frac{1}{1000} \times \sum_{d=1}^{d=M} (c_d \times Q_d) \times \frac{365}{M}$$

V_e = the amount of a substance in the treated waste water in kg/year
d = the sampling date in question
M = the number of sampling days per calendar year
C_d = the concentration in the effluent at day d in g/m^3
Q_d = the quantity of discharged waste water at day d in m^3.

b) Heavy metals and arsenic
For metals, the calculation depends on the availability of sampling results from which a load can be calculated. The following method is used to calculate metal loads.

1. Metals in both influent and effluent are measured at a number of UWWTPs (approximately 100). This data is used by water management authorities to calculate influent and effluent loads using the same method as for nitrogen and phosphorous (see the formula under a)).

2. Metals in the effluent are also measured for around 100 UWWTPs. The annual load in the effluent is calculated in the same way as described under a). The influent load is estimated for these UWWTPs on the basis of the load in sewage sludge:

   Vi = Ve + Vs (see point 4 below on details how Vs is calculated).
3. The data produced by steps 1) and 2) is then used to derive an average removal efficiency R for all metals apart from cadmium, mercury and arsenic. This is done by executing a statistical analysis of the rates using SPSS. The 'weighted average according to Tukey' is used to estimate the average rate. This calculation method allows extreme values (outliers) to be given less weight when determining the average.

4. The average treatment rates calculated in step 3 are used to estimate effluents for UWWTPs in which the effluent heavy metal content is not measured. This is done on the basis of metal loads in the produced sewage sludge. The formula is:

$$L_e = L_s \; / \; R \times (100 - R)$$

L_e = load in the effluent in kg/year
L_s = load in the sewage sludge in kg/year;
R = Removal efficiency (%).

With:

$$Ls = \frac{1}{1000000} \times \sum_{d=1}^{d=M} (c_{s,d}) \; / \; M \times DM$$

$c_{s,d}$ = content in the sewage sludge, measured on day d, in mg/kg dry matter
M = number of measurements per year
DM = the amount of sewage sludge produced in kg dry matter per year.

For cadmium, mercury and arsenic fixed efficiencies, derived from [5], are used instead of the calculation described under point 3. This is because fewer measurements are available for these substances and because detection limits also often give cause to problems, which undermines the reliability of calculations of average efficiencies.
However, it is often possible to calculate effluents and influents on the basis of sludge load and a fixed assumed rate.

3 Effects of policy measures

Effluents from urban waste water treatment plants are affected by improvements in the treatment process and by effects of government directives towards the various sectors discharging into the sewer system.

a) Improvements in the treatment process
Most treatment plants now remove phosphate and most of the nitrogen from the wastewater in order to comply with the requirements of the Urban Waste Water Directive. The national target is a removal efficiency of 75% for both N and P. This target was met in 2006. Reference [6] contains an elaborate description of phosphate and nitrogen removal in urban waste water treatment plants.
Chemical phosphate removal led to an increase in efficiencies for a number of metals especially in the period from 1990 to 1995. Another important development is that many UWWTPs have been modernised and increased in size, as a result of the Urban Waste Water Directive and the target for nutrient removal. The proportion of ultra-low loaded active sludge plants has increased significantly as a result [6].
Longer retention times and the associated reduction in the level of sludge loading rates have led to an improvement in the uptake of most heavy metals in sewage sludge. This has improved removal efficiencies especially in the past five years. The recent opening of two new large, modern

UWWTPs has had a positive impact on national rates. More efficient removal of suspended matter (less sludge wash-out) has also improved metal removal.

b) Effects of policies in relation to the various emission sources.
The nutrients and heavy metals that end up in UWWTPs via the sewers come from a large number of diffuse and point sources. These include dwellings, industry, traffic and transport, corrosion processes and atmospheric deposition. It is impossible to list all the known effects of policy measures that influence trends in discharge into the sewer system. However, a brief outline of the main sources is given below.

In the case of point sources (industry), most emissions underwent a thorough clean-up process between 1990 and 2000, resulting in much lower industrial emissions to the sewage system. Discharges from dental practices are also much cleaner than they used to be.
There has been a decline in levels of cadmium, nickel, zinc, lead, copper and total N reaching the sewers through atmospheric runoff resulting from lower emissions into the atmosphere in the Netherlands and abroad. However, lead emission due to corrosion of lead sheets in residential and non-residential buildings has increased slightly as a result of increased volumes. Zinc emissions caused by corrosion of sheet zinc (gutters) have decreased because of lower SO_2 levels in rainwater (effect). There has been a fall in zinc emissions caused by corrosion of galvanised steel in objects such as street furniture and structural skeletons because of the use of coatings (directive).
In the case of copper, there has been no marked decline in emissions into the sewers except for the reduction in industrial discharge and atmospheric deposition. Emissions from the biggest source, namely dwellings (including copper water pipes), are continuing to rise because of the increase in volume. Considerable quantities of copper also end up in the sewers in runoff from asphalt as a result of tire-works and brake-wear which contain copper.

4 Emissions calculated

The information contained in the tables below is displayed as follows: table 1 contains the influent data). Table 2 reports emissions (effluents). Table 3 shows the nationwide removal efficiencies calculated on the basis of the nationwide influents and effluents. Finally, table 4 shows the trend over time of the average efficiencies used to estimate metal contents in effluent of UWWTPs for which no effluent data is known (see step 4 of the description above).

Table 1: Influents N, P (tonnes/year) and heavy metals (kg/year)

Substance name	1990	1995	2000	2005	2006
	1000 kg/year				
Phosphorous compounds as P	14357	13756	13300	14425	14341
Nitrogen compounds as N	81273	83978	84726	84825	85842
	kg/year				
Arsenic	4943	5673	5801	5891	6134
Cadmium	2049	1605	1030	1317	913
Chromium	38733	37098	22707	17128	17289
Copper	177145	183429	156891	159754	149586
Mercury	1049	710	511	419	376
Lead	96356	76552	59425	43817	42237
Nickel	32675	30951	25394	21507	20627
Zinc	497455	450635	438782	469266	435888

Table 2: Effluents N, P (tonnes/year) and heavy metals (kg/year)

Substance name	1990	1995	2000	2005	2006
	1000 kg/year				
Phosphorous compounds as P	6239	3529	2845	2651	2596
Nitrogen compounds as N	39292	36248	28952	21742	19057
	kg/year				
Arsenic	2471	2618	2787	2736	2645
Cadmium	820	380	471	252	251
Chromium	13130	5934	5035	3474	2993
Copper	36492	22640	17846	12235	9576
Mercury	315	172	143	97	102
Lead	25149	10293	8555	6249	5359
Nickel	19474	13447	12037	9660	9036
Zinc	140282	119868	100897	85047	75637

Table 3: National averaged removal efficienciess for N, P and heavy metals (%)

Substance name	1990	1995	2000	2005	2006
Phosphorous compounds as P	57	74	79	82	82
Nitrogen compounds as N	52	57	66	74	78
Arsenic	50	54	52	54	57
Cadmium	60	76	54	81	72
Chromium	66	84	78	80	83
Copper	79	88	89	92	94
Mercury	70	76	72	77	73
Lead	74	87	86	86	87
Nickel	40	57	53	55	56
Zinc	72	73	77	82	83

Table 4: Average removal efficiencies (%) applied for estimates of heavy metals in effluents.

Metal	1990	1995	2000	2005	2006
Arsenic	50	50	50	50	50
Cadmium	60	60	60	60	60
Chromium	66	81	79	78	83
Copper	79	90	92	94	95
Mercury	70	70	70	70	70
Lead	74	88	89	87	90
Nickel	40	50	55	56	58
Zinc	72	76	79	85	86

5 Release into environmental compartments

All effluents are attributed to the compartment “Load to surface water”. Emissions to the atmosphere also take place during the treatment process, and are related to the conversion of nitrogen and COD (in the sludge line and the water line). See the Greenhouse gases protocol for further details [7].

6 Description of emission pathways to water

This source covers 100% direct discharge into surface water.

7 Spatial allocation

The final destination of the effluent discharge from each UWWTP is linked to a catchment area via the surface water into which the discharge takes place.

8 Comments and changes in regard to previous version

No specific comments or changes

9 Accuracy and indicated subjects for improvement

In classifying the quality of information the method used in the Emission Inventory publications has been followed as far as possible [8]. 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.

Effluents of total N and total P are frequently determined by water management companies at all UWWTPs by means of measurements, so this element can be classified as A.
Effluents of copper, chromium, lead, zinc and nickel are classified as B because effluents are determined directly by measurement at more than half of all UWWTPs (accounting for two-thirds of design capacity), while in the case of the other UWWPTs these loads are estimated on the basis of sludge load measurements and average rates.
Some of the effluent measurements for cadmium, mercury and arsenic are not usable because of detection limit problems. In addition, it is difficult to derive yearly reliable removal efficiencies from the available data. That is why loads are determined for most UWWTPs on the basis of sludge load measurements and a fixed rate based on literature research. This element is therefore classed as C.
Compartment division and the emission pathway into water is 100% certain: class A.
The location, discharge point and surface water into which discharge takes place is recorded for all UWWTPs, and therefore spatial allocation is also classification A.

Element of emission calculation	**Reliability classification**
Effluents N and P	A
Effluents Cu, Cr, Zn, Pb, Ni	B
Effluents Hg, Cd, As	C
Distribution among compartments	A
Emission pathways to water	A
Spatial allocation	A

Areas for improvement:

- When determining heavy metal effluents, it is important that they are measured at as many UWWTPs as possible. Statistics Netherlands has emphasised this point several times in communications to water management authorities. But there are still some water management authorities that only measure heavy metals in sewage sludge. It should be stressed in future that measurements in the water line of UWWTP are also needed. It would also benefit water management authorities to continue (or start) measuring these substances in view of the importance of effluents to regional water quality.

- The removal efficiency used to estimate effluents of mercury, cadmium and arsenic is based on outdated bibliographical data. We recommend reviewing more recent studies in a search for usable alternatives.

10 Request for reactions

Any questions or comments on this working document should be addressed to:
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