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Cadmium in the Netherlands - a special case?

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CADMIUM IN THE NETHERLANDS - A SPECIAL CASE?

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Cadmium in The Netherlands - a special case?

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1 Introduction

1.1 Goal and scope

Cadmium is a heavy metal causing environmental problems in many parts of the world. In various countries, environmental policies are directed at abatement of these problems. The Netherlands have their own cadmium policy laid down in a Cadmium Decree (Bulletin of Acts, Orders and Decrees of the Kingdom of the Netherlands 538, 1990). The European Union also has addressed the cadmium problems in a Directive (Directive 91/338/EEC).

The Cadmium Decree is formulated as a general ban mainly for products in which cadmium is used as a stabilizer, as pigment, for plating and products incorporating synthetic materials or paints with some exceptions (Annex 3 of the Decree). The threshold of the Cadmium Decree for products containing cadmium is **50 mg/kg (0,005%)**. The Directive lists only specific materials and products banned in the field of stabilizers, pigments and plating, permitting the use of cadmium in all other cases. Moreover, the limit to what falls under the definition of "cadmium containing" in the Directive is set at **100 mg/kg (0.01%)**. Especially for the low-concentration applications that both policies address, this would imply that more products would fall under the influence of the Dutch Decree than the EC Directive, and that the Decree is thus more restrictive than the Directive.

The EU and Dutch policies regarding cadmium contain more than the EC Cadmium Directive and the Dutch Cadmium Decree. There is additional policy on environmental quality, on fertilizers, on industrial emissions, on recycling and possibly still more. All these contribute to changes in cadmium flows and concurrent environmental problems. However, at this moment it is the Dutch Cadmium Decree that is under debate, in view of the EC Cadmium Directive. Therefore, we limit ourselves to these two documents.

The Commission engaged the private consulting agency Environmental Resource Management (ERM), London, to examine the scientific justification of the Cadmium Decree on grounds of environment and health protection (ERM, 1995). ERM compared the main environmental pathways in the Netherlands and six other Member States (the UK, Germany, Belgium, Denmark, France and Italy). It was concluded that no relevant indicator proved that there were special circumstances in the Netherlands to retain stricter measures when compared to other Member States.

The Netherlands have responded by quoting a report that states that the Dutch environmental situation regarding cadmium is indeed worse than the EU average (van der Voet, 1996, based on van Egmond, 1991), and have offered to come up with more evidence to support their request.

The first object of this study is to deliver materials for the comparison of the Dutch and the EU environmental situation regarding cadmium. A second topic of research is to look in more detail into the causes of the environmental problems, since the main controversy between EU and Dutch policy appears to be centered around a number of cadmium containing products.

The following three research questions are addressed in this report:

1. Are the environmental problems related to cadmium in The Netherlands worse than in the rest of the EU?
2. Is there/will there be transgression of environmental quality limits with respect to cadmium?
3. What is the contribution of the Cd applications as mentioned in the Annex of the Cadmium Directive to the environmental problems related to cadmium?

Ad 1. A comparison can be made of the Dutch situation and the EU average. In some cases, a more specific comparison with other EU countries is made. In this project, "the situation" can be related to environmental concentrations, but also to the cadmium flows causing these environmental stocks such as emissions into environmental compartments, atmospheric deposition on soils, leaching to groundwater etc. Other approaches, for example based on economic flows and stocks, are also possible. However, in this report we limit ourselves to the environmental flows and stocks and regard the economic flows only from their role as the causes of the environmental flows.

One can expect the environmental situation in the Netherlands to be worse than the EU average for a number of reasons:

- the large population density, with concurrent high density of use and disposal of waste;
- the delta situation of the Netherlands, causing pollution of upstream countries to accumulate in Dutch sediments;
- the presence of large industries connected with Cd: zinc and phosphate;
- the relatively high fertilizer use;
- the relatively large percentage of household waste being incinerated.

In the following, we investigate whether the data confirm these expectations.

Ad 2. Environmental quality standards mostly refer to concentrations in environmental media. Annema et al. (1990) show that currently several environmental quality limits are being transgressed in The Netherlands. Already existing policy - including the Cadmium Decree even when it was not yet valid - naturally influences the development of concentrations through time. In future, however, concentrations are expected to rise still further. Annema et al. show that even supposing a very strict environmental policy in all probability several of these problems will remain. In this report, we will address the question whether any EU environmental quality standards are being transgressed in the Netherlands, or will be transgressed as a result of the current cadmium management regime.

Ad 3. The request for confirmation under Art. 100a(4) concerns only the specific materials and products listed in the Annex to the Cadmium Directive. Therefore, a relevant question is to what extent the Cd-problems can be attributed to the Cd present in these materials, either intentional as a pigment, a stabilizer and for plating purposes, or non-intentional as a contaminant. The environmental impact of Cd in these applications may be expected to occur through waste treatment, especially by incineration which may cause cadmium emissions to the atmosphere and consequent deposition on soils.

1.2 Methods and materials

In view of the short duration of the project, we have made use of existing information only. Important sources are the already finished Substance Flow Analysis (SFA) studies for cadmium, because these make it possible to trace environmental problems to their origins and to view all emissions together in one perspective. For cadmium in the Netherlands, Annema et al. (1995) is the main data and modelling base, for cadmium in the EU that is the study by Van der Voet et al. (1996). Additional information is required with regard to other member-states. No SFA studies are available. In view of the available time, only easily accessible information has been used, such as production and trade statistics, agricultural statistics and already published emission inventories.

SFA studies do not provide information on current environmental concentrations. On this point, too, additional information is required. Many publications are available on this subject, among others the ERM study mentioned above (ERM, 1996). A selection has been made out of these, with attention for the reliability of the sources and the time period the data refer to.

When making a comparison between flows in the Netherlands and the EU, several angles can be taken. A first angle refers to the environmental stocks of cadmium: a comparison of the present Cd-concentrations in the various environmental media. A second angle is related to flows rather than stocks: a comparison of Dutch emissions and environmental flows with the EU ones. The environmental concentrations are the result of past practices, while today's flows determine the future concentrations. Just comparing flows does not provide sufficient information, therefore a further specification is required. We will make two of such specifications in order to be able to make a comparison:

- a translation into flows per capita
- a translation into flows per square kilometer.

The comparison per square kilometer seems to be the most relevant from the point of view of the environmental problems: the emissions per square kilometer decide the environmental dispersal and concentrations. The per capita comparison on the other hand is more relevant for the possibilities to combat emissions. Even with a low emission per capita, the emissions per square kilometer can be high, in case of a high population density. Both comparisons will be made, since both are relevant.

Research question 3, the contribution of specific cadmium applications to the environmental problems, is addressed by performing a computerized origins analysis for the several environmental problems related to cadmium, both for the EU and for the Netherlands. In this way, conclusions can be drawn regarding the relative importance of Cd product flows, but also it can be seen whether the contribution of these applications to the environmental problems in the Netherlands is different from that in the EU as an average. The SFA studies mentioned above are the basis for this origins analysis.

1.3 Contents of this report

In Chapter 2, the cadmium management regimes in the Netherlands and the European Union is sketched, based on the available SFA studies. Chapter 3 contains the main body of work: in this chapter, the comparison is made between the Netherlands and the EU average on the one hand, and other EU member states on the other hand. The areas are compared with respect to emissions, concentrations and environmental problem flows, and their economic origins. In Chapter 4, the specific cadmium applications for which the EC Cadmium Directive and the Dutch Cadmium Decree are at variance are singled out in more detail. In Chapter 5 finally, some conclusions are drawn regarding the three research questions stated above.

2 Cadmium flows in the Netherlands and the European Union

2.1 Main characteristics of cadmium management in the Netherlands and the European Union

Cadmium is a heavy metal causing environmental problems through its toxicity. Naturally, it occurs in the environment in very small quantities. By human activity, the availability has increased enormously. As an element, cadmium cannot be degraded; it therefore tends to accumulate in environmental sinks such as soils, sediments and landfill sites. It may pose a threat to human health through the food chain, due to accumulation in the agricultural cycle. It also may represent a risk for aquatic species as a result of accumulation in sediments. Risks from landfill sites may occur through dispersion from those sites.

Cadmium occurs naturally as a contaminant in ores, especially zinc ore, phosphate rock, iron ore and fossil fuels. Therefore, it also occurs as a contaminant in products derived from those ores. Cadmium in phosphate fertilizer, for example, is one of the major sources of accumulation in agricultural soils. There are no cadmium mines, but cadmium is intentionally extracted from zinc ore. On the one hand this extraction takes place because of regulation of the cadmium content of zinc products, but on the other hand because cadmium is a market product itself and is applied intentionally in a number of products. Most applications of cadmium are trace applications of cadmium compounds: for example, as a stabilizer in plastics or as a pigment in all sorts of materials. The largest application of cadmium as a metal is the application in nickel-cadmium batteries, a fairly recent but still growing application.

If we take a look at the flows of cadmium in the economic system of both the Netherlands and the EU, we see that the emissions from the economy into the environment are less than half the economic inflow with ores and raw materials. This means that a rapid and large process of stockbuilding in society is taking place. This societal stock, consisting of all kinds of cadmium applications, can be interpreted as a future risk, because one day these applications will enter the waste stage and will end up in the environment in one way or another. The size of this stockbuilding process is not only caused by growing applications, but also by the fact that the cadmium inflow (as a contaminant of other raw materials) is not determined by the demand for cadmium. Even with a decreasing demand, due to a decrease in applications and/or an increase in recycling, the inflow will remain at the same level. This characteristic shows more at the EU level than at the level of the Netherlands, since there is relatively less imports and exports with other areas.

2.2 Differences between the Dutch and the EU cadmium management

The Dutch and the European cadmium management show great similarities. There are also differences, which can be divided in differences of scale and differences of management.

Differences of scale show for example in the transboundary pollution through air and rivers. For the Netherlands, this flow is important and constitutes an important part of the environmental flows. For the European Union, this is of minor importance. Another difference of scale is the relative EU self sufficiency. Imports and exports of materials and products are relatively unimportant for the EU, while they are large for the Netherlands. The economic chains "from cradle to grave" are more complete for the EU, which means that waste and emissions can be traced to their origins in a better way. For the Netherlands, production and use are linked only to a minor extent: most of the

cadmium that is being produced is exported, while the main part of the cadmium applications is imported. Even from a policy point of view, this is important: the Netherlands can only influence what happens within their borders; imports and transboundary pollution are more or less a fact of life.

Differences of management are not very important, on the whole there are more similarities. Some differences can be recognized however, for example the Dutch sewage and waste treatment: a larger part of the households is connected to sewage treatment systems and a smaller part of household waste is landfilled in the Netherlands. Of dominant importance in the Netherlands are the zinc and phosphate refineries, these contribute significantly to the economic throughput and to landfill and surface water emissions. For the EU as a whole, these industries are important as well but less dominant. A number of industries, especially cadmium applying industries, are present in the EU and not in the Netherlands. Differences in recycling do not show in the basic year of the study which is 1990. For the Netherlands, recycling of cadmium containing batteries has increased significantly since 1990; for the EU as a whole this is unknown.

In the next chapters, the comparison between the Netherlands and the European Union is made in more detail. In Chapter 3, we focus on the environmental problem flows and emissions and their causes. In Chapter 4, we try to assess the contribution of specific cadmium applications to those problem flows.

3 Cadmium pollution in the Netherlands compared to the EU and other member states

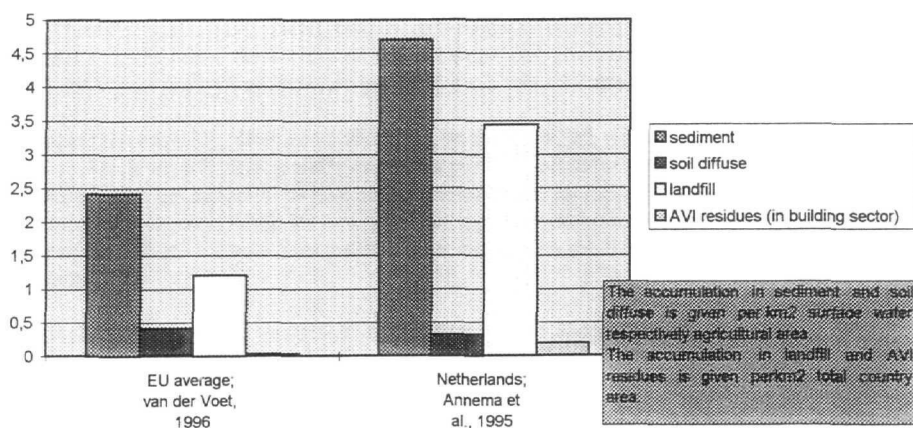
3.1 Environmental problem flows

As stated in Chapter 2, cadmium has a tendency to accumulate in soils and sediments. The environmental risks start from there: accumulation in soils may cause health hazard through food consumption, while accumulation in sediments causes ecotoxicological risks for the aquatic biota. Therefore, we have identified three environmental problem flows:

- accumulation in agricultural soils
- accumulation on landfill sites
- accumulation in sediments.

Data regarding these flows are from Annema et al. (1995) for the Netherlands, and an update of Van der Voet et al. (1994) for the European Union. Their magnitudes are compared in Figure 1 below on a per square kilometer basis.

Figure: Accumulation in compartments for the Netherlands and the EU
(kg/yr.km²)
(Annema et al., 1995 and van der Voet, 1996)



From Figure 1 it appears that the accumulation in sediments in the Netherlands is larger than the EU average. Also the accumulation on landfill sites and in AVI residues in the Netherlands is much larger than the EU average. This is not caused by a higher cadmium content of the waste or residues but is due to the higher waste production per km² and per capita in the Netherlands and the larger fraction of waste being incinerated (see appendix 4). The accumulation in agricultural soils is higher in the EU as an average. This used to be different, but the use of phosphate fertilizer in the Netherlands has decreased significantly over the last decade, while the EU average has not changed much. In Section 3.3, the origins of these problem flows are assessed. In Chapter 4, the contribution of the Cd applications under debate to these flows is specified.

Additional data on these environmental problem flows are not available. However, a large body of data is available for cadmium emissions in the EU member states. These emission data are treated in the next section, Section 3.2.

3.2 Emissions and loads

In Section 3.1, several environmental problem flows are distinguished. These flows are caused by emissions. Regarding emissions, the data availability is much better: the environmental problem flows really only can be analyzed by means of SFA. When we want to compare the situation in the Netherlands with other EU member states, we therefore must look at emissions.

In comparing the severeness of the cadmium problem in the Netherlands to the cadmium problem in other EU member states in terms of emissions to air, water and soil, various sources can be used. For cadmium these sources include Hutton (1982), Ross & Slooff (1988), van der Voet (1996), ERL (1990), OECD (1994), ESQUAD (1994), CBS (1994) and Annema *et al.* (1995).

ERM (1995) has written a report for the Commission of the European Communities (CEC) to enable the CEC to decide whether there is a case for the retention by the Netherlands of its own, more restrictive provisions, in place of the Council Directive 91/338/EEC on the control of the use of cadmium as a pigment, as a stabilizer and in plating. ERM performed a thorough analysis of Dutch emissions, concentrations and daily intakes compared to emissions, concentration and daily intakes in other EU member states. Important note made by ERM is that not many data on these issues are available, many are quite old, and analytical methods, sampling regimes, classifications of source and receptor categories and the reference year of sampling may all be different for the different member states, thus making country data mutually incomparable and uncertain. Nevertheless, ERM draws the conclusion that for emissions, concentrations and daily intake the Netherlands values are typical or rather low of those in other member states.

With respect to emissions, these conclusions can be argued which will be shown in the next two sections in which we will first quantify emissions per km² and subsequently per capita. The emissions per km² are supposed to give an impression of the cadmium burden to the national environment of a country, while the emissions per capita are supposed to give an indication of the (success of the) efforts a country makes to manage and reduce the environmental problems related to cadmium.

The basic data used for these quantifications are presented in appendix 1.

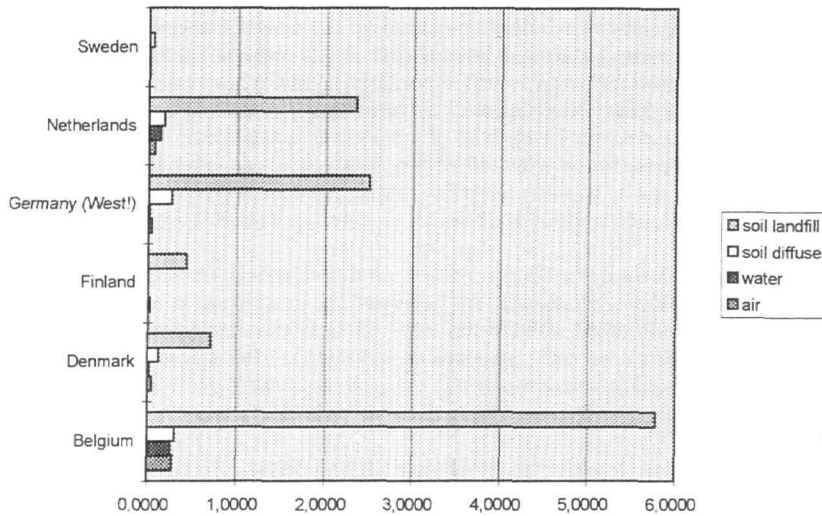
3.2.1 Emissions and loads per square kilometer

In this section, the emission data of the different sources mentioned before are related to country areas for the EU and for each EU member state considered. In this way emissions per km² are calculated per member state. Emissions per km² may, as stated before, give useful information on the cadmium burden to the national environment of a country. First, a comparison is made between the Netherlands and several other EU member states. After that, the Dutch emissions and loads are compared to the EU average.

The Netherlands and other EU member states

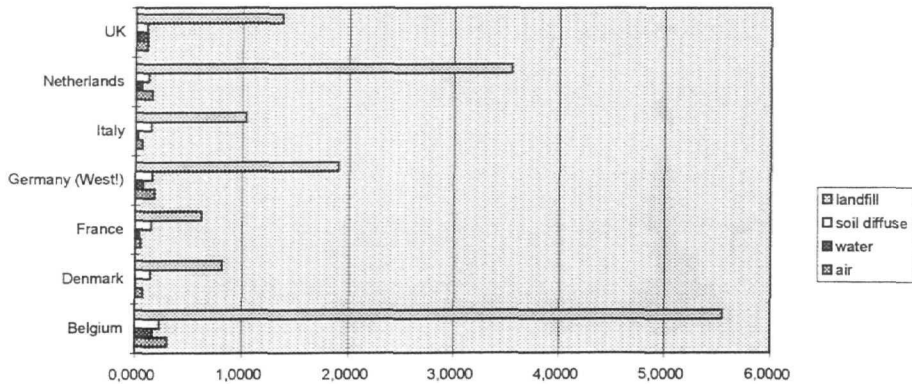
Based on the data of OECD (1994), one gets the following results:

Figure 2: Cadmium emissions per km² according to (OECD, 1994) for the Netherlands and some other EU member states (kg/yr.km²)



Based on the data of ERL (1990) (see ERM(1995)), one gets:

Figure 3: Cadmium emissions per km² according to (ERL, 1990) for the Netherlands and some other EU member states (kg/yr.km²)



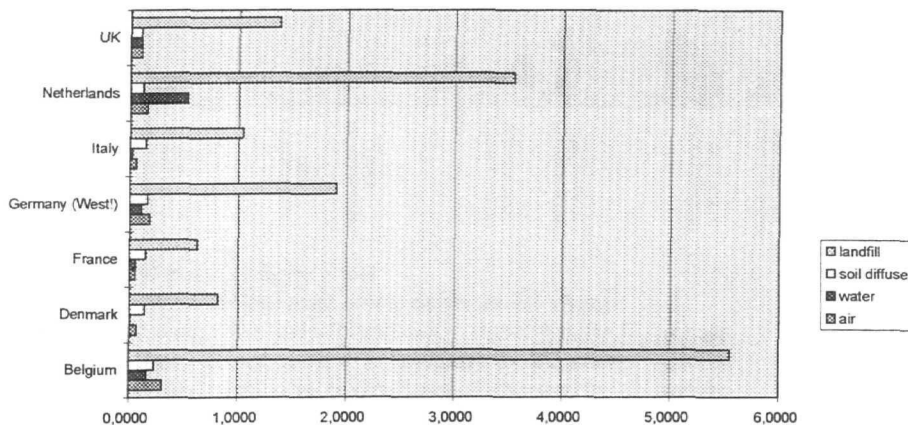
These pictures show that the largest part of cadmium is disposed through cadmium containing solid wastes, and that the Netherlands' value is rather high. In the ERM report solid wastes were not quantified per unit area of the countries; ERM only made unit area calculations for airborne and waterborne emissions, and concluded e.g. that the "inputs of cadmium to landfill are (absolutely) lower for the Netherlands [...] than for the other member states" (pp. 42). There is no apparent reason why diffuse emissions to soil and landfill wastes should not also be related to the total area of the countries.

The emission situation for the Netherlands gets even worse when some flaws in the ERL data for water emissions are corrected realizing that the *load* (or burden) of a national environment, i.e. the Dutch environment, is not only determined by the national emissions but also by transboundary inflow (and e.g. deposition). The flaws are:

1. In the ERM report it is argued that the waterborne emission of waste gypsum of phosphate fertilizers should not be taken into account because this waste gypsum is emitted to the sea and not to surface water, and it will be landfilled *in future*. However, waste gypsum is actually not (completely) landfilled but still partly emitted to surface water which is very near to the sea and polluting anyhow; the emission is estimated to be about 3,7 tonnes/year (Annema *et al.*, 1995). This emission to water should be added to the other water emissions of the Netherlands in figure 1. For reasons of completeness and comparability the emission of waste gypsum by the phosphate industry in France as mentioned in the ERL (1990) report, has also been added (10 tonnes/yr.).
2. In the ERM report the contribution from abroad is mentioned but not added to the water emission figures of the Netherlands. However, the Netherlands is a delta area which receives the results of foreign emissions through the water inflow of the Rhine, the Meuse and other smaller waters and serves as a sink for these foreign emissions. This burden should be added to the water emissions of the Netherlands in figure 1; it is currently estimated to be about 16 tonnes/year (Annema *et al.*, 1995).

After correction of the ERL (1990) data for these flaws, the cadmium emission situation compared to some other EU member states look as follows:

Figure 4: Cadmium loads per km² according to (ERL, 1990) after correction for the Netherlands and France, compared to some other EU member states (kg/yr.km²)



For other member states the contribution from abroad is not known, but is very likely to be much lower because of the specific geographical situation of the Netherlands.

Crux of this short exercition with numbers and values is that:

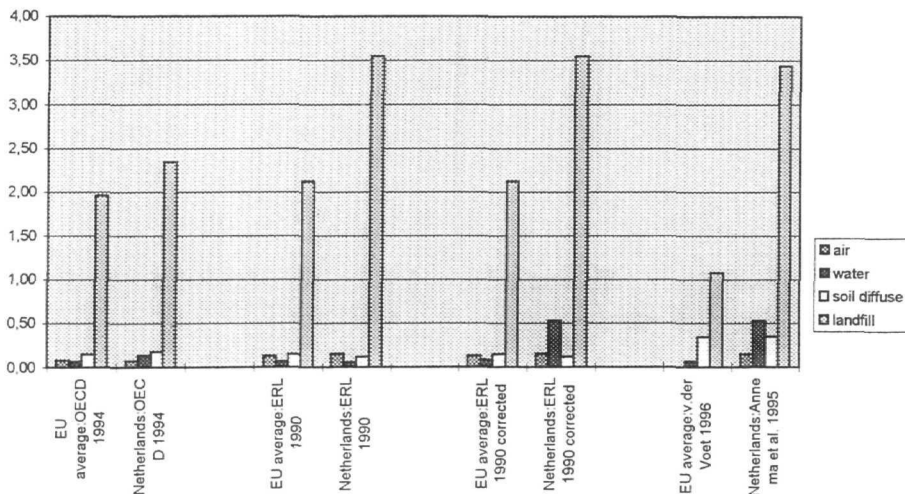
- one has to treat the data in an equal way: ERM did make unit area comparisons for airborne and waterborne emissions but not for soil emissions and wastes;
- in the Netherlands, and probably all over Europe, one has seen decreasing emissions to air and water of cadmium over the last decades while the inputs and use of cadmium have not really decreased but even increased. This implies that a shift of these emissions to for example the soil, which together with the aquatic soils are *the* sinks for metals, may well have taken place.

Therefore, the emissions and wastes to soil may be considered as the most important flow, and the Netherlands fares more badly in this respect (emissions per unit area) than most other EU member states.

The Netherlands and the EU average

The only source for EU-wide values is Van der Voet et al. (1994; in: Van der Voet, 1996). For the other sources, EU data can only be deducted. These average EU values can subsequently be compared to the emission data of The Netherlands. The most appropriate comparison seems to be these between data from the same sources, so EU average deducted from ERL (1990) and Dutch data as presented in ERL (1990). The data are given in the figure 5.

Figure 5: Four estimates of EU average cadmium loads per km² compared to four estimates of Dutch cadmium loads per km² (kg/yr.km²)



The general trend from this figure is that

- the Dutch cadmium air load more or less equals the EU average
- the Dutch cadmium water load is (significantly) higher than the EU average
- the Dutch diffuse soil load equals or is lower than the EU average¹
- the Dutch cadmium landfill load is significantly higher than the EU average.

However, it is not possible to draw firm conclusions from these data since figures given above are incomplete and the data sets are often incomparable between countries.² Because of these uncertainties and data lacks, the result of the figures should be taken as an indication of the general trend in available emission numbers and not as absolute values! Furthermore, it must be stressed again that for metals the soils and sediments are the main sinks. In this respect, the Netherlands

¹ The higher values for the cadmium diffuse load to soil of van der Voet (1996) and Annema *et al.* (1995) compared to the other sources are probably due to the fact that ERL only included cadmium load through phosphate fertilizers and OECD only included deposition and animal manure in some cases, while in the studies of van der Voet and Annema *et al.* these aspects were included in the data more systematically.

² The numbers one may find for cadmium loads are quite divergent in completeness and comparability. For example, in the OECD data deposition has only been included for Germany and Sweden and not for the other states. In the ERL data deposition has not been included in the unit area figures at all.

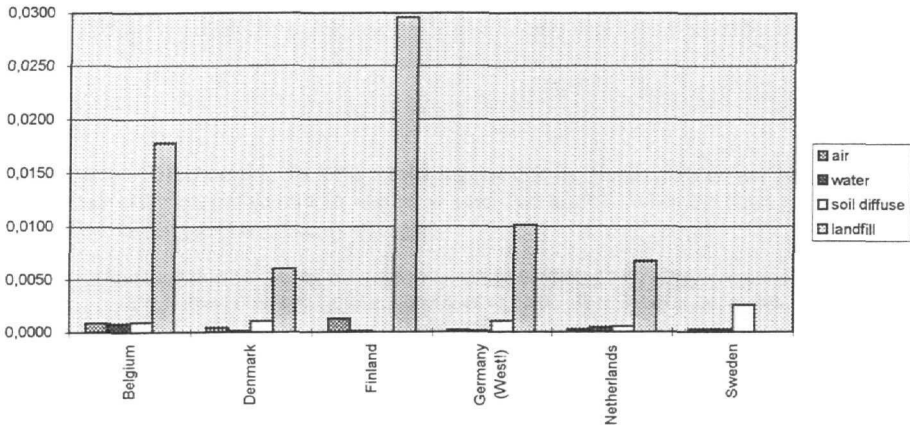
fares rather badly compared to other EU members states despite of the measures already taken. This is for a large part due to the geographical situation of the Netherlands, which as a delta area receives the results of waterborne emissions abroad.

3.2.2 Emissions and loads per capita

In this section the emission data of the different sources mentioned before are related to the number of inhabitants per country for each EU member state considered. In this way emissions per capita are calculated per member state considered. Emissions per capita may give useful information on (the success of the) efforts a country (already) makes to manage and reduce the cadmium problem.

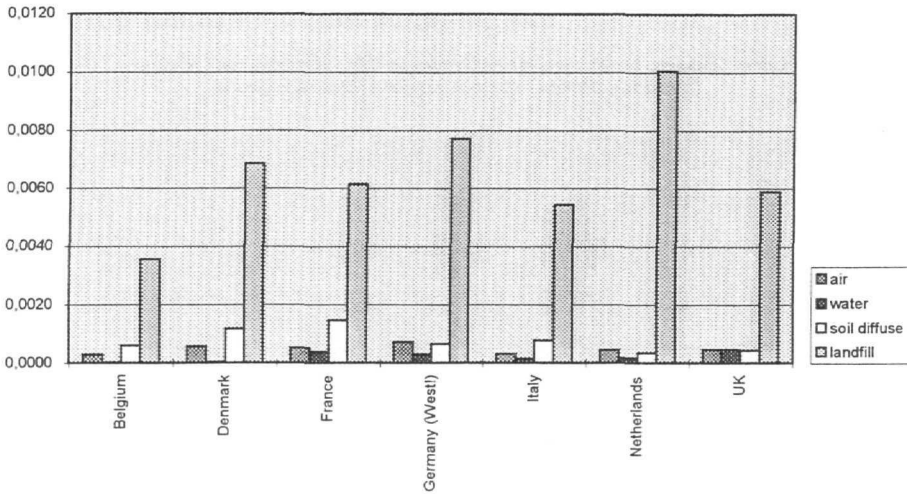
Based on the data of OECD (1994), one gets the following results:

Figure 6: Cadmium loads per capita according to (OECD, 1994) for the Netherlands compared to some other EU member states (kg/yr.capita)



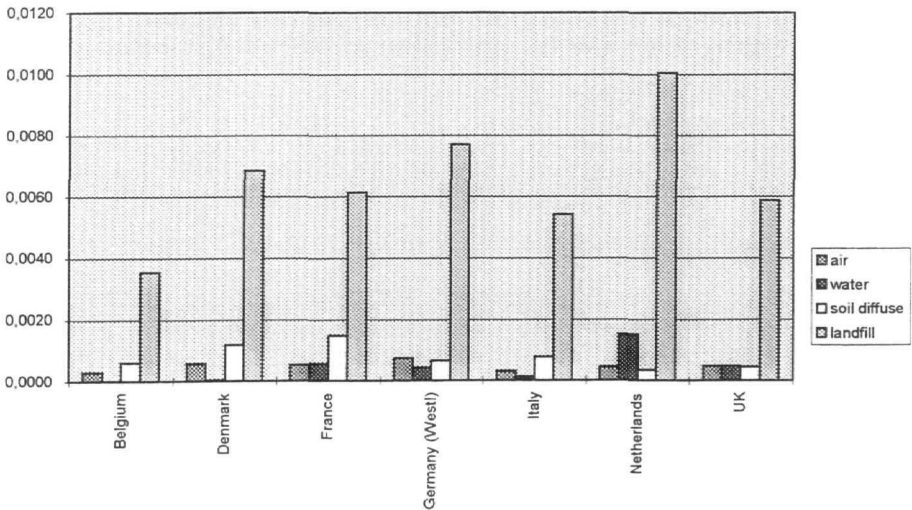
Based on the data of ERL (1990), one gets:

Figure 7: Cadmium loads per capita according to (ERL, 1990) for the Netherlands compared to some other EU member states (kg/yr.capita)



Contrary to the OECD results, the ERL results suggest that the Netherlands do not cope very well yet with their cadmium problems with respect to water and landfill. When the flaws in the ERL data are corrected this suggestion gets only stronger:

Figure 8: Cadmium loads per capita according to (ERL, 1990) after correction for the Netherlands and France, compared to some other EU member states (kg/yr.capita)

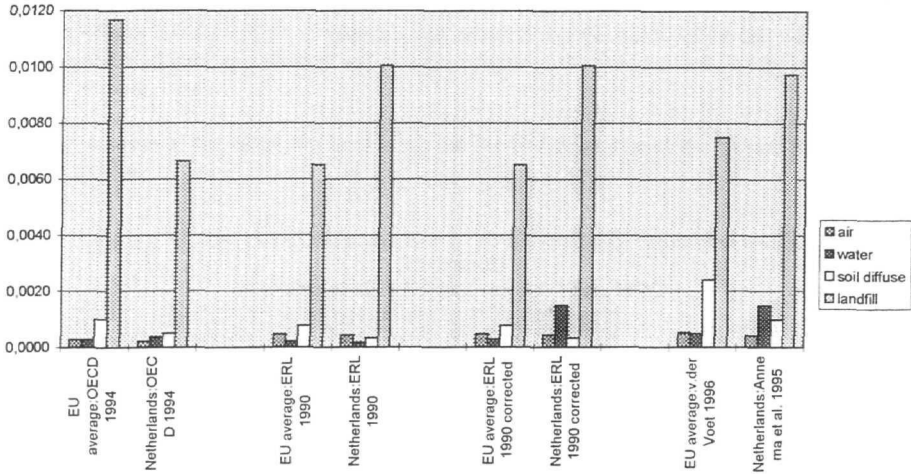


The differences between the results of the OECD and of ERL are probably largely due to the incomparability and incompleteness of both data sets (see before). This shows once more that it is

difficult to draw conclusions, or on the other hand that data can be found supporting any desired outcome.

Dutch cadmium emissions per capita compared to the average EU cadmium emissions per capita according to the different sources, gives the following result:

Figure 9: Four estimates of EU average cadmium loads capita compared to four averages of Dutch cadmium loads per capita (kg/yr.capita)



This comparison supports the conclusion that cadmium emissions per capita in the Netherlands are rather large with respect to surface water and landfill compared to the EU average. This picture is rather similar to Figure 5, the per square kilometer comparison. For surface water, this is explained by the fact that most of the water load comes from other countries and has nothing to do with Dutch policy. For landfill, the Netherlands' per capita value is high because of the presence of large industries.

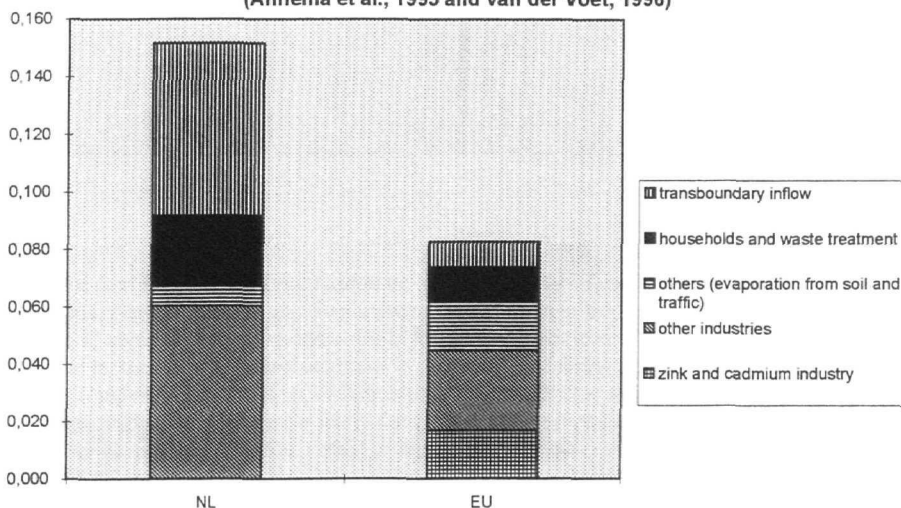
3.3 Sources of cadmium problem flows, emissions and loads

In this section we will focus on the sources behind the cadmium flows. For the Netherlands the data as reported by Annema *et al.* (1995) will be used, while for the EU slightly updated data as reported by van der Voet (1996) will be used. In appendix 2, sources behind the loads of the Netherlands compared to several other EU member states according to OECD (1994) and ERL (1990) are presented as background information.

The direct sources are also traced back to their ultimate origins. The ultimate origins are the extraction of ores and the import of materials and products and the inflow of air and water into the area. In appendix 3 the direct sources and ultimate origins of the cadmium load to the environment are given in more detail.

The direct sources of the cadmium load to air for the Netherlands and the EU are summarized in 10.

Figure 10: Sources of cadmium load to air for the Netherlands and the EU
(kg/yr.km²)
(Annema *et al.*, 1995 and van der Voet, 1996)



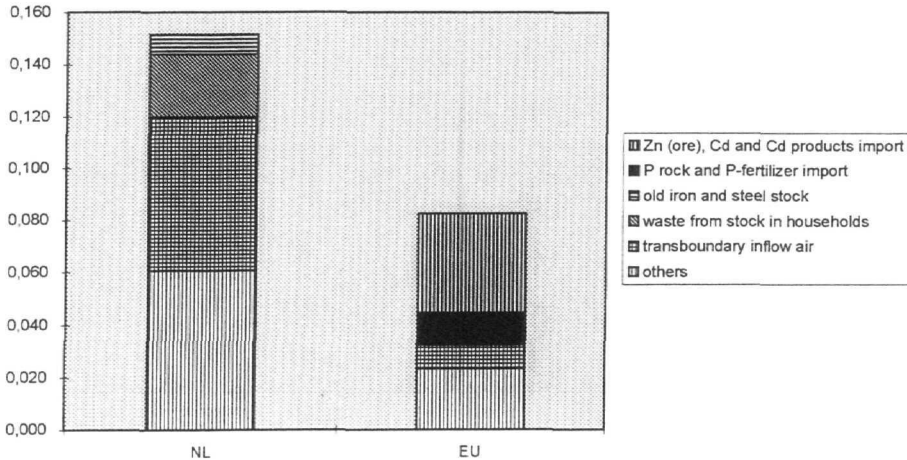
From Figure 10 it becomes clear that the Dutch cadmium load to air is significantly determined by transboundary inflow and furthermore by the production of iron and steel, waste incineration and the petrochemical industry. The remaining load is due to several kinds of combustion processes. The cadmium load in the EU is mainly determined by evaporation from agricultural soil, the combustion of coal and oil for the electricity production, the production of iron and steel, waste incineration and the production of zinc.

The main difference between the air load in the Netherlands and the EU is caused by the larger inflow of cadmium by transboundary inflow of air in the Netherlands. Furthermore the iron and steel industry in the Netherlands compared to the EU seems to be an important cause for the cadmium load to air in the Netherlands.

The ultimate origins of the cadmium load to air for the Netherlands and the EU are summarized in figure 11.

Figure 11: Ultimate origins of cadmium load to air for the Netherlands and the EU (kg/yr.km²)

(Annema et al., 1995 and van der Voet, 1996)

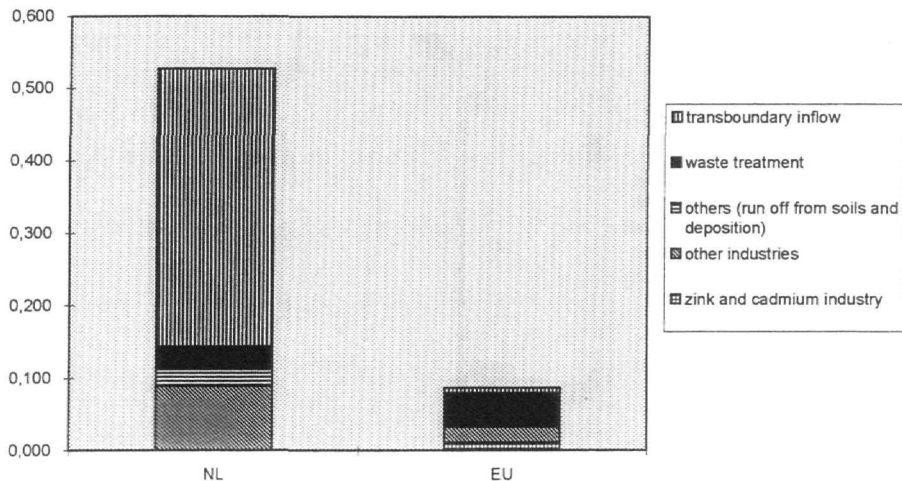


This figure confirms that the Dutch cadmium load to air is significantly determined by transboundary inflow through air. Furthermore the cadmium in iron ore, and in fossil fuels (like oil and coal) seems to be an important origin for the cadmium load to air in the Netherlands. Finally the incineration of household waste is an important source. Because there is no information about the composition of the stock of cadmium in households this source can not be traced back to its ultimate origins. However most likely the stock is build up of cadmium products and so the origins may be assumed to be the import of zinc ore from which cadmium is gained, cadmium and cadmium products.

For the EU the most important origins seem to be the cadmium in zinc ore and zinc, raw cadmium and cadmium products, fossil fuels (like oil and coal) and cadmium in P rock and P fertilizer.

The direct sources of the cadmium load to the surface water for the Netherlands and the EU is summarized in figure 12.

Figure 12: Sources of cadmium load to water for the Netherlands and the EU (kg/yr.km²)
(Annema et al., 1995 and vander Voet, 1996)



The main sources of Dutch cadmium load to water per unit area are the transboundary inflow, the production of phosphates and much smaller sources like the sewage treatment plant and the deposition from air.

The main sources of cadmium load in the EU are is the sewage treatment plant and the production of phosphates.

By far the most important difference between the cadmium load of water in the Netherlands and the EU is caused by the very large contribution of transboundary inflow through water in the Netherlands.

The ultimate origins of the cadmium load to surface water in the Netherlands and the EU are summarized in figure 13.

Figure 13: Ultimate origins of cadmium load to water for the Netherlands and the EU (kg/yr.km²)
(Annema et al., 1995 and van der Voet, 1996)

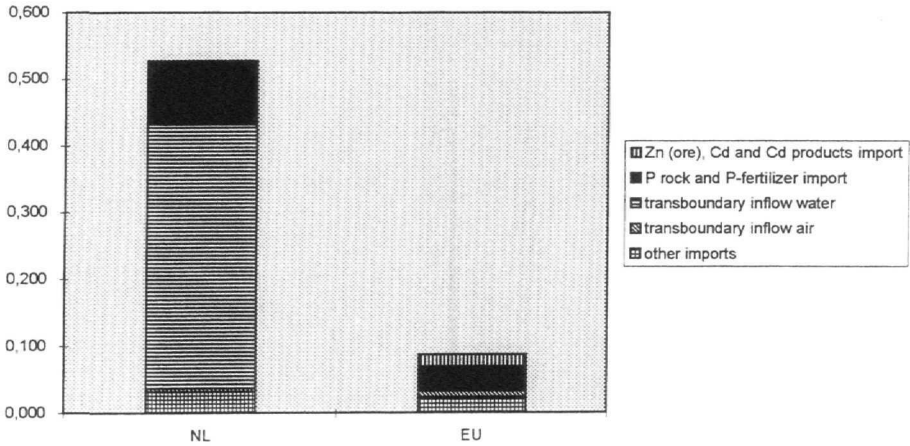
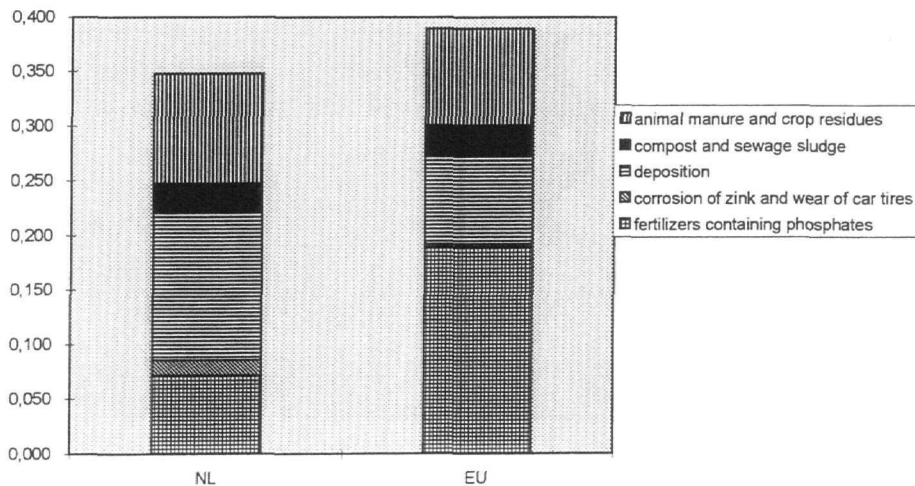


Figure 13 confirms the very large contribution of transboundary inflow to the cadmium load in the Netherlands. Another important origin of the cadmium load to water in the Netherlands seems to be the import of cadmium contaminated P rock and P fertilizer.

For the EU the most important origins can be traced back to the import of the cadmium contaminated P rock and P fertilizer and the import of raw cadmium and cadmium products.

The direct sources of diffuse cadmium load to soil for the Netherlands and the EU are summarized in figure 14.

Figure 14: Sources of diffuse cadmium loads to soil for the Netherlands and the EU (kg/yr.km²)
(Annema et al., 1995 and van der Voet, 1996)



The main sources of Dutch cadmium load to diffuse soil per unit area are deposition, animal manure and phosphate fertilizer.

The main sources of cadmium load in the EU are phosphate fertilizer, deposition and animal manure.

The load of cadmium to diffuse soil per unit area in the Netherlands and the EU is nearly the same. Also the main sources of cadmium to the diffuse soil are the same for the Netherlands and the EU.

The ultimate origins of the diffuse cadmium load to soil for the Netherlands and the EU are summarized in figure 15.

Figure 15: Ultimate origins of diffuse cadmium load to soil for the Netherlands and the EU (kg/yr.km²)
(Annema et al., 1995 and van der Voe, 1996)

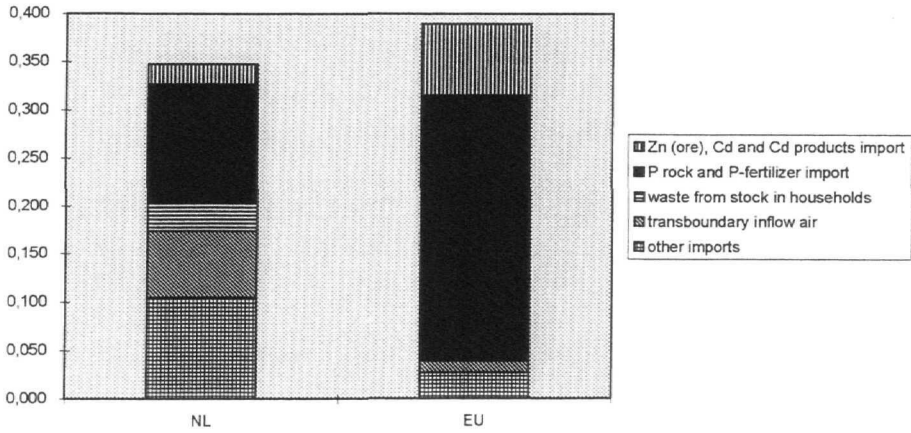
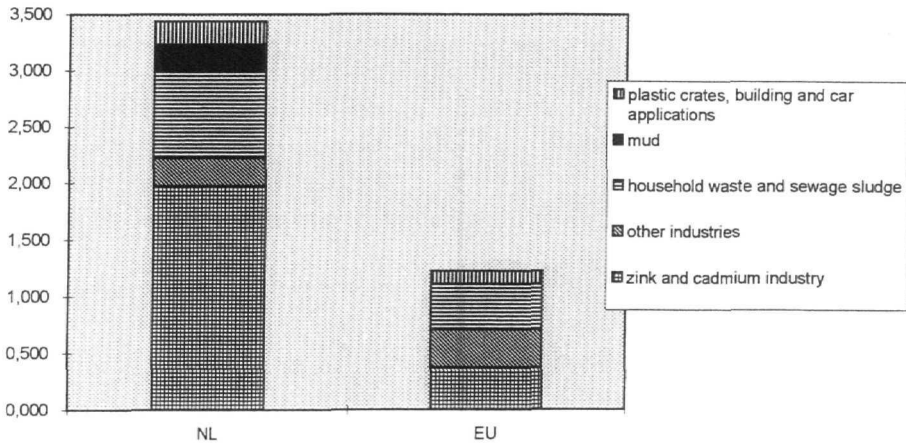


Figure 15 confirms the large contribution of the import of cadmium contaminated P rock and P fertilizer to the load to diffuse soil in both the Netherlands and the EU. For the EU by far the most important origin is the import of P rock and P fertilizer. Furthermore may be noticed the large contribution of transboundary inflow through air in the Netherlands compared to the EU.

The direct sources of the cadmium load to landfill for the Netherlands and the EU are summarized in figure 16.

Figure 16: Sources of cadmium landfill load for the Netherlands and the EU (kg/yr.km²)(Annema et al., 1995 and van der Voet, 1996)



The main sources of Dutch cadmium load to landfills per unit area are jarosite and household waste. Based on the available data, it is unfortunately not possible to trace the products in household waste which are mainly responsible for this cadmium flow.

Also for the EU the main sources of cadmium to landfills are jarosite from the zinc production and the dump of household waste.

The difference in load per unit area in the Netherlands compared to the load in the EU mainly is determined by the very large contribution of the zinc production in the Netherlands.

The ultimate origins of the cadmium load to landfill for the Netherlands and the EU are summarized in figure 17.

Figure 17: Ultimate origins of cadmium load to landfill for the Netherlands and the EU (kg/yr.km²)
(Annema et al., 1995 and van der Voet, 1996)

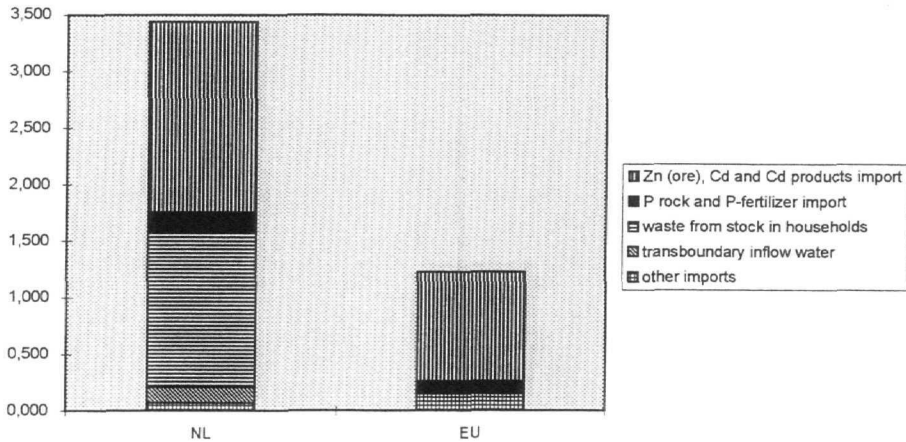


Figure 17 shows the two main contributors for the cadmium load to landfill in the Netherlands. The largest contributions are caused by the contaminated zinc ore and the dump of household waste in the Netherlands. Because there is no information about the composition of the stock of cadmium in households this source can not be traced back to its ultimate origins. However most likely the stock is build up of cadmium products and so the origins may be assumed to be the import of zinc ore from which cadmium is gained, cadmium and cadmium products.

Also for the landfill the origin of the load mainly can be traced back to the contaminated zinc ore and the import of cadmium and cadmium products (which after being used are dumped at landfill sites).

The direct sources of the cadmium load to waste incineration in the Netherlands and EU are summarized in figure 18.

Figure 18: Sources of cadmium to waste incineration for the Netherlands and the EU (kg/yr.km²)
(Annema et al., 1995 and van der Voet, 1996)

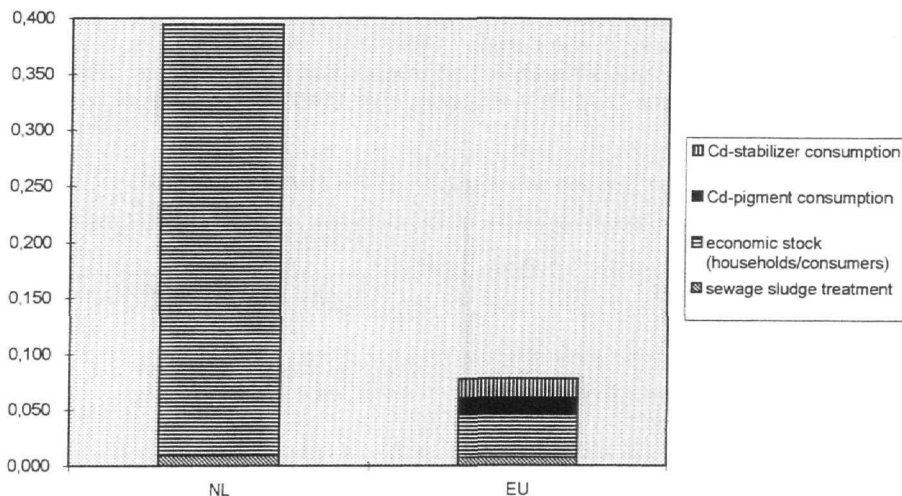


Figure 18 shows that the amount of cadmium waste being incinerated, per unit area, is much higher for the Netherlands than for the EU as an average. This is caused by the large fraction of waste which is incinerated in the Netherlands compared to other EU member states (appendix 4). In Annema et al. (1995) no information was available about the composition of the stock in households. Therefore it was not possible to trace the origins of the cadmium in the incinerated waste. However in a recent report concerning the input of waste in incinerators in the Netherlands it is concluded that 70% of the cadmium load to incinerators is caused by synthetics containing pigments and stabilizers. The remaining 30 % is mainly caused by batteries (Krajenbrink & Eggels, 1997).

3.4 Concentrations and standards

In the Netherlands an extensive set of standards have been adopted for cadmium concentrations in several compartments: fresh water, sediment, soil and groundwater. Moreover deposition standards have been adopted. At the EU level standards have only been adopted for two subjects: fresh surface water and for drinking water. In Annema *et al.* (1995) a comparison has been made of standards and observed field values. The standards used in Annema *et al.* (1995), however, differ from the standards as published in VROM (1991). Below, a table is presented comparing the VROM (1991) and EU standards with observed field values in the Netherlands. This table is thus largely based on Annema *et al.* (1995) with adaptations of the Dutch standards and the addition of EU standards.

Table 1: Comparison of Dutch and EU standards with observed field values in the Netherlands

subject	the Netherlands		EU		NL	
	standard	source	standard	source	observed values	source
air	MIC=0,05 $\mu\text{g}/\text{m}^3$				0,00034-0,00071 $\mu\text{g}/\text{m}^3$ (year average in '92); no exceeding	1
deposition	target value = 1.0 g/ha.yr guideline value = 1.0 g/ha.yr	10			target and guideline values are exceeded in parts of south Netherlands	8 (p.49)
fresh surface water	target value = 0,01 $\mu\text{g}/\text{l}$ limiting value = 0,06 $\mu\text{g}/\text{l}$	10	2,5 $\mu\text{g}/\text{l}$ (base quality in unfiltered sample)	6	37% of samples exceeds the (old limiting) value of 0,2 $\mu\text{g}/\text{l}$ in '91; 1% of samples exceeds EU 2,5 value	3 3 (p.82 table 2.2)
drinking water			5 $\mu\text{g}/\text{l}$	5	exceeding occurs in groundwater under forest soils; because of low concentrations systematic measurement have not been done since 1982	9 (p.60,97,102) 2
sediment (newly formed)	target value = 0,8 mg/kg dm ³ limiting value = 2 mg/kg dm ³	10			40-50% of samples exceeds limiting value of 2 mg/kg	3,8
soil	target value = 0,8 mg/kg dm ³	10			averagely 9,7% of samples exceeds target value in agricultural and natural soils (up to 85,7% in south of Netherlands)	4
groundwater	target value = 1,5 $\mu\text{g}/\text{l}$	10			about 10% of samples exceeded (old target) value of 0,4 $\mu\text{g}/\text{l}$ and 2,6% exceeded 2,5 $\mu\text{g}/\text{l}$ in '91; thus, about 3-10% of samples exceeded target value of 1,5 $\mu\text{g}/\text{l}$ in '91	8
leaching from	U1 value = 0,2 mg/kg dm	11			observed field values	7,12

MSW incinerator fly ash					between 0,01-260 mg/kg; U1 value averagely exceeded for more than a factor 100, which is for about 70% caused by plastics and 20% by NiCad batteries
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The value of 0,8 applies to a standard soil, the detailed target value is as follows: 0,4 + 0,007 (Fines content + 3 Organic Matter content) mg/kg dry matter.

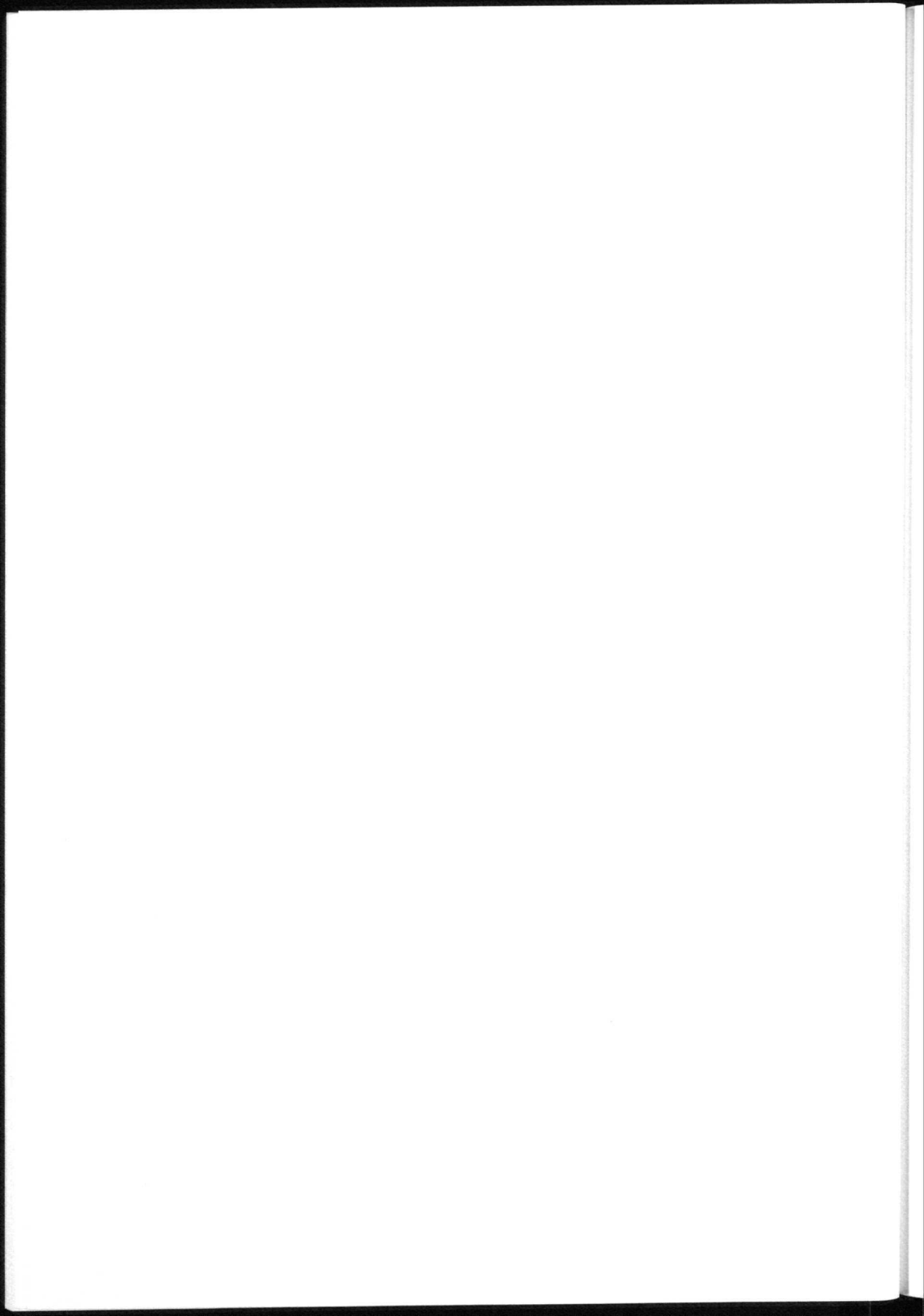
Sources:

1	Aben <i>et al.</i> , 1993	7	Krajenbrink en Eggels, 1997
2	CCRX, 1992	8	RIVM, 1992 (I)
3	Coppoolse <i>et al.</i> , 1993	9	RIVM, 1992 (III)
4	van Drecht <i>et al.</i> , 1996	10	VROM, 1991
5	EEG, 1980	11	VROM, 1996
6	83/513/EEG	12	VVAV, 1995

Within the short available time of this study it was not possible to gather more up to date field data (e.g. for 1995 instead of 1991) and data for other EU member states. However, from the results so far it can be concluded that

- for air no exceeding of any (Dutch) standards take place on a yearly average basis;
- for fresh surface water the Dutch standards are much more stringent than the EU values, and that the Dutch values were exceeded in 37% of the samples in '91, while the EU value was only exceeded by 1% of the samples;
- for drinking water and groundwater (assuming groundwater should be suitable for use as drinking water) Dutch and EU standards are quite different and that the more current Dutch standard of 1,5 µg/l was exceeded by 3-10% of the samples in '91, but the EU drinking water was exceeded only in some cases in forest groundwater;
- for sediment the Dutch limiting value was exceeded in 40-50% of the cases in '91;
- for soil the Dutch target value was exceeded in almost 10% of agricultural and natural soil in the Netherlands, with much higher values for the south of the country;
- and for leaching from MSW incinerator fly ash the Dutch U1 value is exceeded more than a factor 100 (VVAV, 1995), which is for about 70% caused by plastics and 20% by NiCad batteries (Krajenbrink en Eggels, 1997).

Overall conclusion is that for the eight subjects of table 1, Dutch standards are exceeded in many cases with respect to fresh surface water and sediment, in quite some cases for groundwater and agricultural and natural soils, and over a factor of 100 averagely for leaching from MSW incineration fly ash. Only for two subjects (fresh surface water and drinking water) there are also EU standards available; these are much less stringent than the Dutch ones and hardly ever exceeded in the Netherlands.



4 The contribution of specific applications to the cadmium related environmental problems

In this chapter the cadmium load to the different environmental compartments is allocated to the applications of cadmium. Cadmium may be intentionally applied in products, or may occur as a contamination in zinc, iron, phosphate and fossil fuels and the products derived from those materials. Intentional applications of cadmium are: pigments and stabilizers in synthetics, plating/surface coating, batteries and cadmium alloys. In this section the contribution of the above mentioned products to the various problem flows and emissions in the Netherlands and the EU will be compared. For the Netherlands the data as reported by Annema *et al.* (1995) will be used, while for the EU slightly updated data as reported by van der Voet (1996) will be used. In appendix 3 the contribution of the products to the environmental problems are given in more detail.

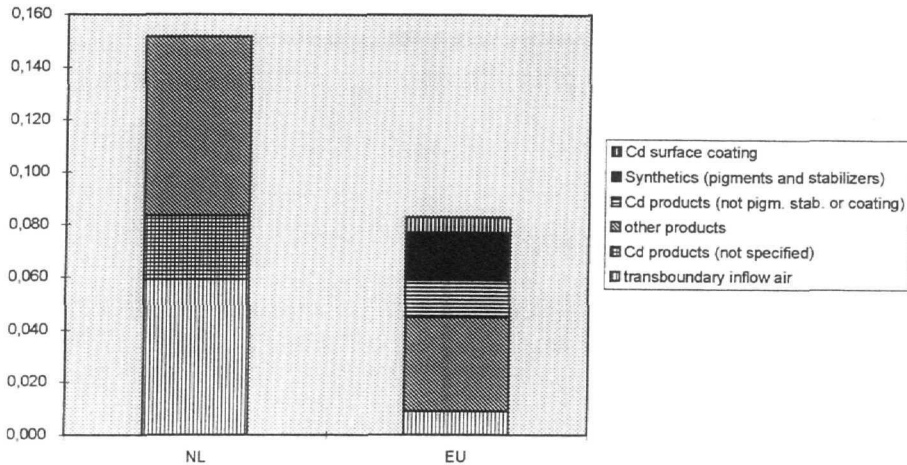
Data for the Netherlands and for the EU are not quite compatible for several reasons:

- the Dutch problem flows are for a significant part caused by transboundary pollution. This flow cannot be attributed to any specific products;
- not in all cases it is possible to attribute the Dutch emissions from industries to specific applications because the number of cadmium applying industries in the Netherlands is limited, when the raw material is exported we lose sight in what happens;
- the Dutch figure for "cadmium in household waste" cannot be directly linked to specific products.

The first two problems cannot be solved. The third can be eluded by defining a category "intentional cadmium applications" without specifying the exact application. In the figures in this section, these can be found as "cadmium products (unspecified)". The drawback of that is that the contribution of the applications under debate is not specified.

The absolute contributions of various products to the cadmium air load for the Netherlands and the EU are summarized in figure 22.

Figure 22: Contribution of products in cadmium load to air for the Netherlands and the EU (kg/yr.km²)
(Annema et al., 1995 and van der Voet, 1996)



The bars for the Netherlands and the EU differ enormously. We see the large contribution of the transboundary inflow for The Netherlands. Also the contribution from iron products appears to be very large for the Netherlands. Fossil fuels are important for the EU as well as for the Netherlands. The contribution of products (in case of the Netherlands: waste from household stock) appears to be much higher for the EU, relatively as well as absolutely: for the EU, it is roughly 50%, and only 15% for the Netherlands. However, as mentioned above, the “transboundary pollution” may also be caused partly by cadmium applications, although not used in the Netherlands.

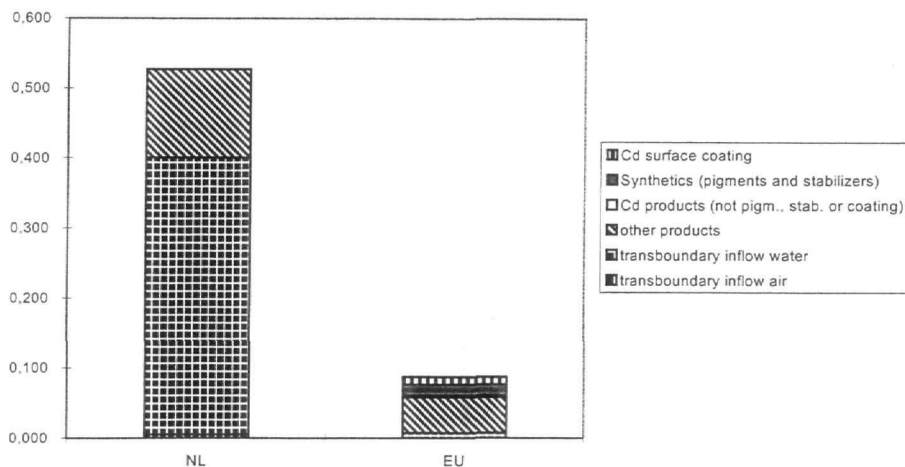
The relative contributions of the products to the cadmium air load in the Netherlands and the EU are summarized in table 2.

Table 2: Contribution of products (%) in cadmium load to air in the Netherlands and the EU.

	NL	EU
transboundary inflow air	39	11
iron products	29	1
fossil fuels	16	18
P-rock and P-fertilizer		15
others		8
waste related to Cd products	16	47
- synthetics (pigments)		10
- synthetics (stabilizers)		12
- Cd surface coating		7
- Cd batteries		16
- Cd alloys		1
- zinc products		1

The absolute contributions of various products to the cadmium load to surface water and the accumulation in sediment in the Netherlands and the EU are summarized in figure 23.

Figure 23: Contribution of products in cadmium load of water in the Netherlands and the EU (kg/yr.km²)
(Annema et al, 1995 and van der Voet, 1996)



Again, the importance of the transboundary inflow shows for the Netherlands. A recognizable item for both EU and Netherlands is the contribution of phosphate products. Intentional cadmium applications do not play a role in the Netherlands, and but a slight one in the EU, for the surface water and sediment related cadmium flows.

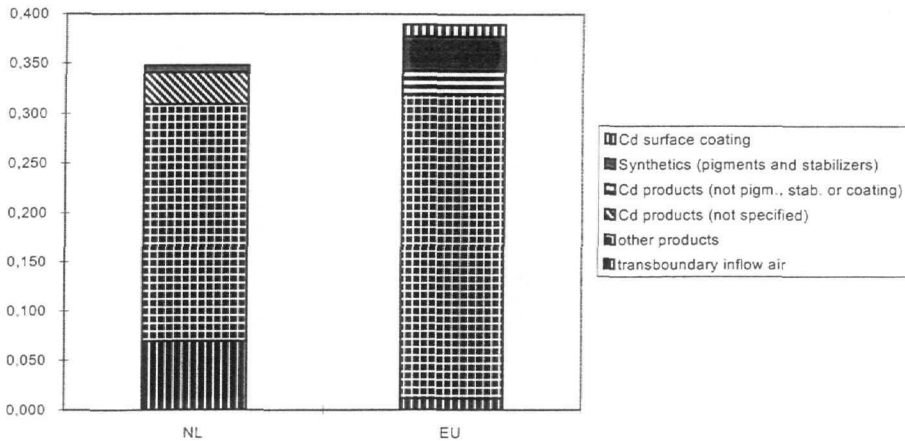
The relative contributions of various products to the cadmium surface water load and the accumulation in sediments for the Netherlands and the EU are summarized in table 3.

Table 3: Contribution of products (%) to the cadmium surface water load in the Netherlands and the EU.

	NL	EU
transboundary inflow water	75	9
P rock and P-fertilizer import	18	42
transboundary inflow air	1	
fossil fuels	1	
others	5	13
waste related to Cd products	-	33
- synthetics (pigments)		11
- synthetics (stabilizers)		7
- Cd surface coating		12
- Cd batteries		3
- Cd alloys		
- Cd various		
zinc products		1

The absolute contributions of various products to the diffusive cadmium soil load for the Netherlands and the EU are summarized in figure 24.

Figure 24: Contribution of products in diffuse cadmium load of soils for the Netherlands and the EU (kg/yr.km²)
(Annema et al., 1995 and van der Voet, 1996)



Phosphate fertilizer is dominant both in the Netherlands and the EU. The transboundary inflow shows again for the Dutch soils. Fossil fuels are a recognizable source for both areas. Intentional cadmium applications contribute roughly 20% for the EU, and 10% for the Netherlands.

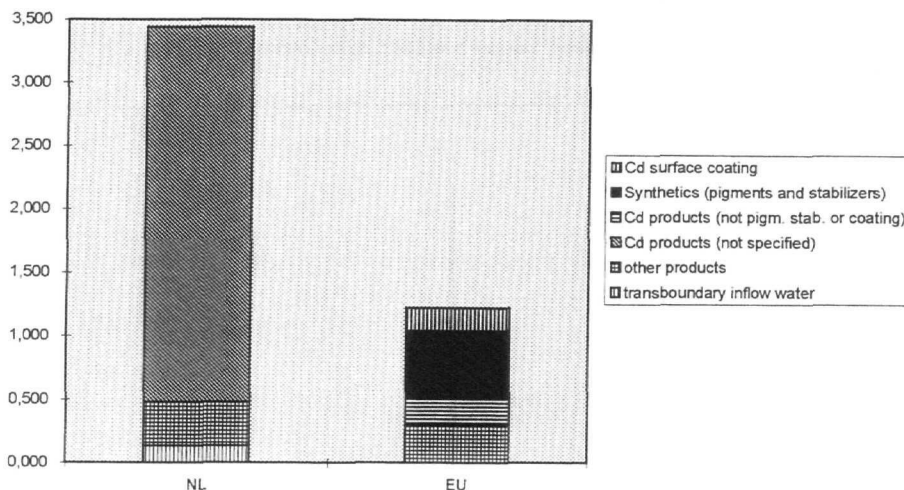
The relative contributions of the products to the diffusive cadmium soil load for the Netherlands and the EU are summarized in table 4.

Table 4: Contribution of products (%) to the diffusive cadmium soil load in the Netherlands and the EU.

	NL	EU
P-fertilizer	40	71
transboundary inflow air	20	3
iron products	12	
fossil fuels	8	5
others	5	2
waste related to Cd products	11	18
- synthetics (pigments)	2	5
- synthetics (stabilizers)		4
- Cd surface coating		3
- Cd batteries		6
zinc products	4	1

The absolute contributions of various products to the cadmium landfill for the Netherlands and the EU are summarized in figure 25.

Figure 25: Contribution of products in cadmium load to landfill for the Netherlands and the EU (kg/yr.km²)
(Annema et al., 1995 and van der Voet, 1996)



In the case of landfill, the intentional cadmium applications constitute the main part for both the Netherlands and the EU. The large contribution of "Cd raw material" for the Netherlands are the emissions of the zinc refinery and cannot be attributed to specific cadmium applications. It is even debatable whether these emissions should be allocated to cadmium applications at all, since this industry produces zinc as well as cadmium.

In absolute terms (kg/yr.km²), the contribution of intentional cadmium applications is larger in the Netherlands. In relative terms, it is in the EU, not counting the emissions from the zinc refinery in the Netherlands.

The relative contributions of the products to the landfilling of cadmium for the Netherlands and the EU are summarized in table 5.

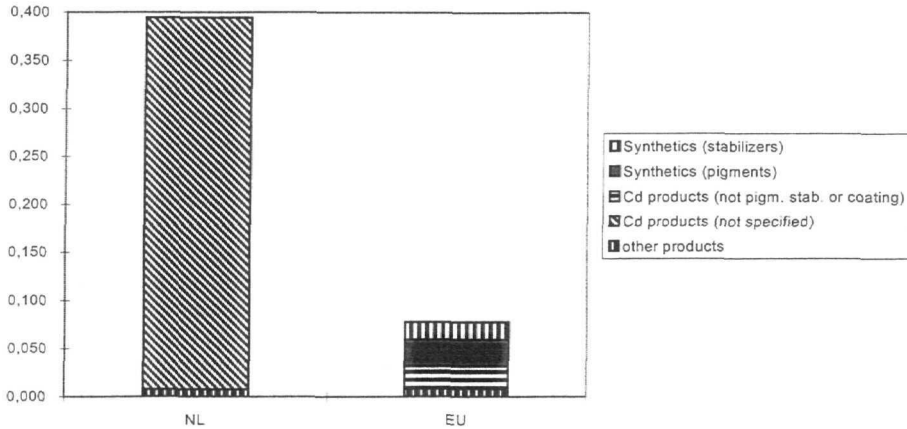
Table 5: Contribution of products (%) to Cd landfill in the Netherlands and the EU.

	NL	EU
P rock and P-fertilizer import	5	8
transboundary inflow water	4	
others	2	15
waste related to Cd products	45 (86)*	75
- synthetics (pigments)		21
- synthetics (stabilizers)		22
- Cd surface coating		15
- Cd batteries		17
zinc products	3	2

*41% is related to the production of Cd as a raw material which is exported and therefore is not directly related to the use of products in the Netherlands.

The absolute contributions of various products to the cadmium load to waste incineration for the Netherlands and the EU are summarized in figure 26.

Figure 26: Contribution of products in cadmium load to waste incineration for the Netherlands and the EU (kg/yr.km²)
(Annema et al., 1995 and van der Voet, 1996)



In Annema et al. (1995) no information was available about the composition of the stock in households. Therefore it was not possible to trace back the products and ultimate origins which are responsible for the cadmium load of the incinerated waste. However in a recent report concerning the input of waste in incinerators in the Netherlands it is concluded that 70% of the cadmium load to incinerators is caused by synthetics containing pigments and stabilizers. The remaining 30% is mainly caused by batteries (Krajenbrink & Eggels, 1997).

The relative contributions of various products to the cadmium inflow into the waste incinerators in the Netherlands and the EU are summarized in table 6.

Table 6: Contribution of products (%) to the cadmium flow to waste incineration for the Netherlands and the EU.

	NL	EU
detergents/soap		6
others	2	5
waste related to Cd products	98	89
- synthetics (pigments)	(70)*	36
- synthetics (stabilizers)		23
- Cd batteries	(30)*	28
- Cd alloys		2

* volgens Krajenbrink & Eggels, 1997

5 Summary, discussion and conclusions

The following three research questions have been addressed in this report:

1. Are the environmental problems related to cadmium in the Netherlands worse than in the rest of the EU?
2. Is there/will there be transgression of environmental quality limits with respect to cadmium?
3. What is the contribution of the Cd applications as mentioned in the Annex of the Cadmium Directive to the environmental problems related to cadmium?

With regard to the first research question, there is no easy answer. A number of literature sources is available with respect to cadmium emissions, but all provide different definitions to what constitutes those emissions. This means that not too much weight must be put to the absolute figures. Even with this in mind, however, it is possible to make some general remarks on the comparison of the Netherlands with the EU average and with several other EU member states. We have compared more or less comparable sources and have performed some corrections. As a general picture, the following emerges:

- Regarding the emissions and problem flows related to agricultural soils, the situation in the Netherlands and the EU do not show a great difference. In both cases, phosphate fertilizer is the most important source. The agricultural soils in the Netherlands appear to suffer more from other sources than the EU average.
- The atmospheric load in the Netherlands is somewhat higher than the EU average, but not compared to specific other EU member states. An important part of the Dutch load comes from sources outside the Netherlands.
- The emissions and problem flows related to surface water and sediments are much more serious in the Netherlands than in the EU as well as in other EU member states. The most important source for the Dutch situation is the transboundary pollution, something that cannot be influenced by Dutch policy but makes it imperative that Dutch additions to this problem be as low as possible. Phosphate applications are a large source both for the Netherlands and for the EU. Intentional cadmium applications contribute roughly 30%.
- The landfill of cadmium containing materials in the Netherlands is very high compared to the EU average and to specific EU member states. This landfill consist of household waste and jarosite from the Dutch zinc processing industries.
- The inflow of cadmium into waste incinerators in the Netherlands is also very high in the Netherlands compared to the EU average, due to the fact that a relatively large percentage of the Dutch household waste is being incinerated.

In all, we can conclude that the loading of the environment with cadmium in the Netherlands appears to be higher than the EU average for landfill and surface water/sediment. This also seems to be the case when compared to other EU member states, with the consistent exception of Belgium.

The second research question refers to environmental concentrations and the transgression of environmental standards. Overall conclusion is that Dutch standards are exceeded in many cases with respect to fresh surface water and sediment, in quite some cases for groundwater and agricultural and natural soils, and averagely over a factor of 100 for leaching from MSW incineration fly ash). Only for fresh surface water and drinking water there are also EU standards available; these are much less stringent than the Dutch ones and hardly ever exceeded in the Netherlands.

The third research question is related to the contribution of specific cadmium applications, especially the applications under debate: pigments, stabilizers and surface coating. For the EU, it has proven possible to attribute the environmental problems to those specific applications. For the Netherlands,

this is much more difficult since the cadmium from the zinc refinery cannot be followed through to specific applications. It is possible however to compare the contribution of intentional cadmium applications as a group to the different problem flows. This comprises not only Cd in stabilizers, pigments and surface coating but also in batteries and alloys. Then we can conclude that

- the contribution of those products to the accumulation in agricultural soil is minor, but somewhat higher in the EU than in the Netherlands;
- the contribution to the air load is roughly 50% in the EU (20% stabilizers, pigments and surface coating), and only 15% for the Netherlands. However, in the Netherlands the transboundary inflow is important which may for a part again be attributed to those products;
- the contribution to the surface water and sediment load is negligible for the Netherlands and is small but recognizable for the EU. Again, part of the large contribution of the Dutch transboundary inflow maybe attributed to those cadmium applications;
- the main part of the landfill can be attributed to those products, in the EU as well as in The Netherlands. In absolute terms, the landfill load due to intentional cadmium applications is higher in the Netherlands;
- the bulk of the amount of cadmium ending up in MSW incinerator wastes, i.e. 98%, is caused by Cd containing products. Plastics appear to contribute about 70% and NiCad batteries roughly 20%. For the EU this is contribution is 89%.

For the problems related to agricultural soil, air, and surface water, the specific cadmium applications do not appear to play a dominant role, neither in the Netherlands nor in the EU. Cadmium applications are a major cause for the flows related to landfill and waste incineration, both for the Netherlands and for the EU. Especially for waste incineration, the problems in the Netherlands can be attributed to cadmium applications as pigment, stabilizer or surface coating more than in the European Union as a whole.

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Appendix 1: Emission data for cadmium in EU member states

Emission data from (Hutton, 1982):

tonnes/yr	Belgium	Denmark	France	Germany (West!)	Italy	Netherlands	UK
air	2,55	4,3	19,63	30,26	14,83	3,65	16,19
combustion of coal and oil	0,3	0,1	0,9	1,6	0,2	0,1	2,4
zinc and cadmium production	0,05		5,03	8,84	3,03	0,03	2,7
production of iron and steel	1,4	0,5	6,3	10,7	7,7	0,9	5,9
waste incineration	0,8	3,7	7,4	8,1	3,9	2,6	4,8
sewage sludge incineration				1,02		0,02	0,39
not categorized, c.q. other							
water							
production of non ferrous metals							
production of iron and steel							
production of phosphates (gypsum)							
cadmium processing (e.g. plating)							
municipal sewage treatment plant							
paper and pulp industry							
not categorized, c.q. other							
soil diffuse	8	7	144	44	49	7	45
fertilizers containing phosphates	8	7	144	44	49	7	45
fertilizers without phosphates							
cattie feed containing phosphates							
deposition							
sewage sludge							
animal manure							
not categorized, c.q. other							
landfill	98,5	7,1	279,3	474,4	287,3	71,6	566,4
coal and oil combustion waste	16	5,5	43	80	12	5	118
jarosite from zinc/non-ferro production							
waste from production of iron and steel	28,5	1,6	67,7	100,4	73,3	11,3	56,4
waste from production of cement							
gypsum from production of phosphates	9	0	2,6	0	1	1,3	20
cadmium processing (e.g. plating) waste							
utilization of residues							
household waste	45	0	166	294	201	54	372
not categorized, c.q. other							

Emission data from (OECD, 1994):

tonnes/yr	Belgium	Denmark	Finland	Germany (West!)	Netherlands	Sweden
air	8,6	2	6,22	10,05	3,1	2
combustion of coal and oil	1,31		0,95	0,7		0,1
production of non ferrous metals	2,41		4,85	3	1	1,4
production of iron and steel	2,7		0,4	4,9	1,5	0,2
production of cement, glass and ceramics	0,48			0,95		
combustion of wood and peat						0,3
waste incineration	1,7		0,02	0,5	0,6	
not categorized, c.q. other		2				
water	7,818	0,7	0,45	4,5	5,7	2,1
production of non ferrous metals	2		0,12	4,5		0,1
production of iron and steel	3,5		0,01			1,1
production of phosphates	1,75		0,01		4	
cadmium processing (e.g. plating)	0,068		0,01			0,1
municipal sewage treatment plant	0,5				0,7	0,2
paper and pulp industry			0,3			0,6
not categorized, c.q. other		0,7			1	
soil diffuse	9,2	5,3	0	64,3	7,5	21,6
fertilizers containing phosphates	6,2	2,6		20,4	3	1,6
fertilizers without phosphates	1					
cattle feed containing phosphates	2					
deposition				41,5		20
sewage sludge				2,4		
animal manure					4,5	
not categorized, c.q. other		2,7				
landfill	176,19	30,6	146,41	619	98	0
coal and oil combustion waste	3,6		4,8			
jarosite from zinc/non-ferro production	87,99		135,5			
waste from production of iron and steel	25,4		3,5			
waste from production of cement	9,8					
gypsum from production of phosphates	9		0,2	226		
cadmium processing (e.g. plating) waste			0,01			
utilization of residues				158		
household waste	40,4		2,4	235		
not categorized, c.q. other		30,6			98	

Emission data from (ERL, 1990):

tonnes/yr	Belgium	Denmark	France	Germany (West!)	Italy	Netherlands	UK
air	9,3	2,9	29,1	44,9	17,9	6,5	26,4
combustion of coal and oil							
zinc and cadmium production							
production of iron and steel							
waste disposal							
sewage sludge disposal							
not categorized, c.q. other	9,3	2,9	29,1	44,9	17,9	6,5	26,4
water	5	0,2	20,6	18,6	7,9	2,4	26,4
production of non ferrous metals	2,5	0	5,2	7,6	3,4	1,4	4,5
production of iron and steel	2,4	0,1	3	6,3	3,6	0,9	3
production of phosphates (gypsum)							
cadmium processing (e.g. plating)	0,1	0,1	12,4	12,3	0,9	0,1	18,9
municipal sewage treatment plant							
paper and pulp industry							
not categorized, c.q. other							
soil diffuse	7	6	82	40	44	5	25
fertilizers containing phosphates	7	6	82	40	44	5	25
fertilizers without phosphates							
cattle feed containing phosphates							
deposition							
sewage sludge							
animal manure							
not categorized, c.q. other							
landfill	169,3	35,1	342,8	473,9	311,4	148,2	335,5
coal and oil combustion waste	9,4	5	18,7	59,6	11,2	5,3	25,7
jarosite from zinc/non-ferro production	71,2	0	41,1	64,8	44,1	48,3	6,2
waste from production of iron and steel	25,3	2,9	45,9	85	8,6	8,8	45,7
waste from production of cement	9,8	2,3	39	42,6	63,1	5,2	22
gypsum from production of phosphates	12	1	21	9	11	0	9
cadmium processing (e.g. plating) waste	1,2	0,4	32,5	30,1	3,6	0,4	33,2
utilization of residues							
household waste	40,4	23,5	144,6	182,8	169,8	80,2	193,7
not categorized, c.q. other							

()=corrections made by authors of this report

Emission data from (Ros & Slooff, 1990):

tonnes/yr	Belgium	Denmark	France	Germany (West!)	Italy	Netherlands	UK
air	22	5	29	33	26	4,12	14
combustion of coal and oil	3	1	8	9	5	0,72	2
zinc and cadmium production	18	1	12	14	11	0,78	6
production of iron and steel						0,55	
waste disposal	1	2	7	4	4	1,4	5
sewage sludge disposal						0,05	
not categorized, c.q. other	0	1	2	6	6	0,62	1
water	0	0	0	0	0	0	0
production of non ferrous metals							
production of iron and steel							
production of phosphates							
cadmium processing (e.g. plating)							
municipal sewage treatment plant							
paper and pulp industry							
not categorized, c.q. other							
soil diffuse	0	0	0	0	0	7	0
fertilizers containing phosphates						7	
fertilizers without phosphates							
cattle feed containing phosphates							
deposition							
sewage sludge							
animal manure							
not categorized, c.q. other							
landfill	0	0	0	0	0	81,5	0
coal and oil combustion waste						0,5	
jarosite from zinc/non-ferro production						25	
waste from production of iron and steel						2	
waste from production of cement							
gypsum from production of phosphates						0,5	
cadmium processing (e.g. plating) waste							
utilization of residues							
household waste						33	
not categorized, c.q. other						20,5	

Physical country data:

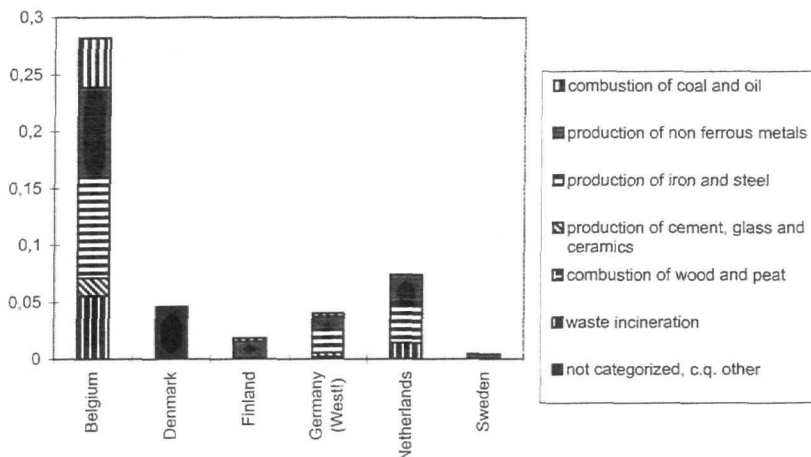
1988	km2	capita
Austria	83900	7,60E+06
Belgium	30500	9,90E+06
denmark	43100	5,13E+06
France	549100	5,59E+07
Finland	337000	4,95E+06
Germany (West!)	248700	6,15E+07
Greece	132000	1,00E+07
Ireland	70300	3,54E+06
Italy	301300	5,75E+07
Luxemburg	2600	3,75E+05
Netherlands	41785	1,48E+07
Portugal	92389	1,03E+07
Spain	504800	3,88E+07
Sweden	449964	8,44E+06
UK	244100	5,71E+07
EU	3131538	345594000

Source: EUROSTAT, 1990

Appendix 2: Sources of cadmium loads according to OECD (1994) and ERL (1990)

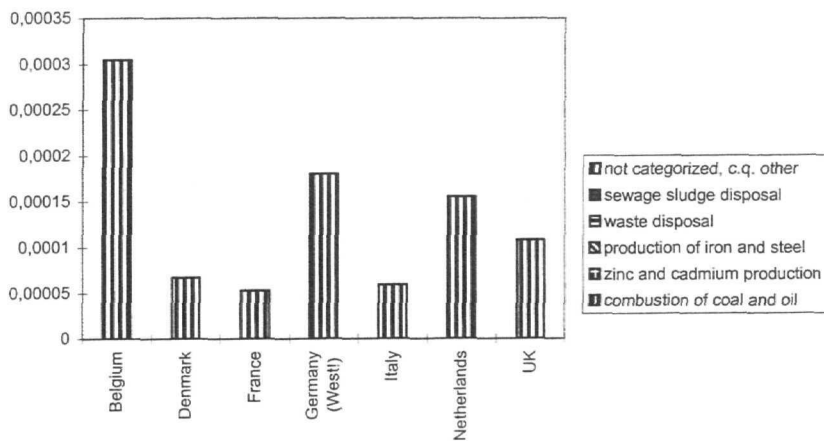
Air emissions according to OECD (1994) are built up as follows:

Figure 28: Sources of cadmium loads to air per km² according to (OECD, 1994) for the Netherlands compared to some other EU member states (kg/yr.km²)



Air emissions according to ERL (1990) are built up as follows:

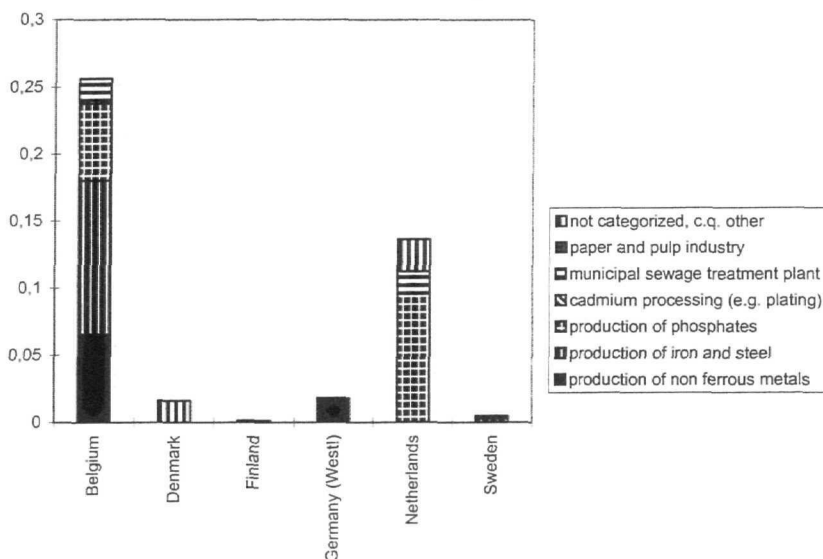
Figure 29: Sources of cadmium loads to air per km² according to (ERL, 1990) for the Netherlands compared to some other EU member states (kg/yr.km²)



From figure 28 and 29 it becomes clear that the Belgium cadmium load to air per unit area is the highest, and that the Netherlands is one of the subsequent major polluters per unit area. The Netherlands load is according to figure 28 (OECD, 1994) mainly due to refinery of zinc, production of iron and steel and incineration of household waste. From figure 10 (Annema *et al.*, 1995), it became clear that combustion processes also causes important emissions to air and that the Dutch cadmium load to air is furthermore significantly determined by transboundary inflow.

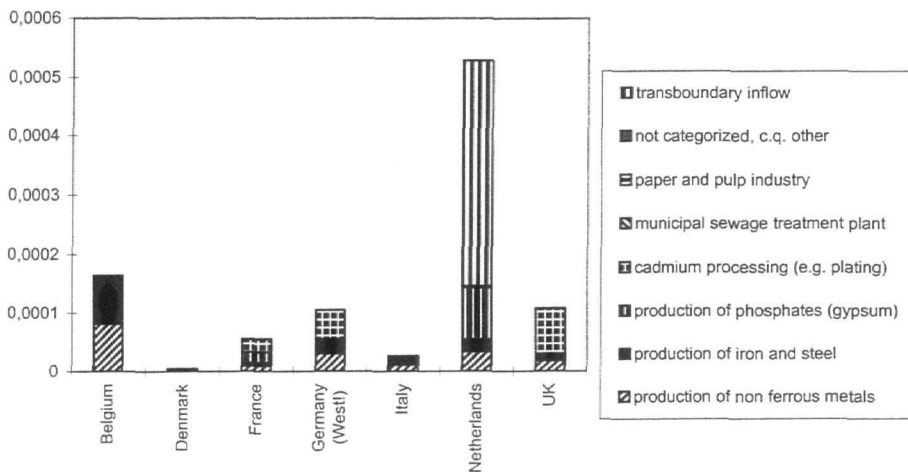
Water emissions according to OECD (1994) are built up as follows:

Figure 30: Sources of cadmium load to water per km² according to (OECD, 1994) for the Netherlands compared to some other EU member states (kg/yr.km²)



Water emissions according to ERL (1990) after correction are built up as follows:

Figure 31: Sources of cadmium load to water per km² according to (ERL, 1990) after correction, for the Netherlands compared to some other EU member states (kg/yr.km²)

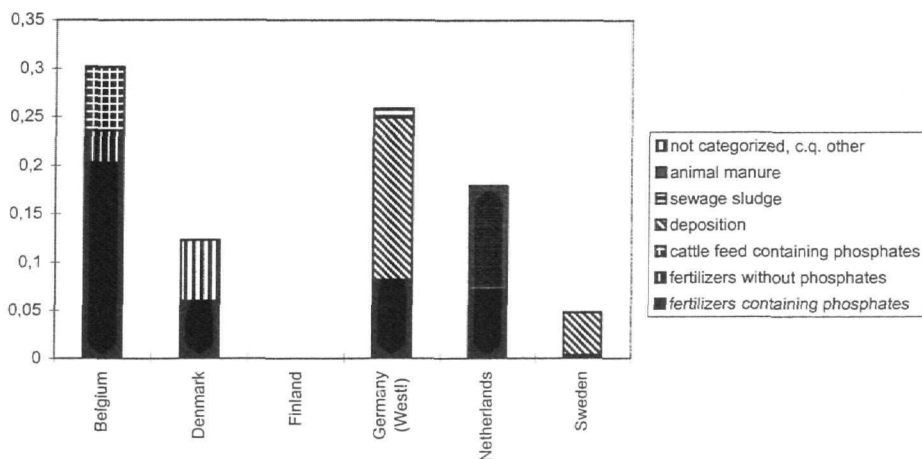


From figure 30 it appears that Belgium cadmium load to water per unit area is severest and that the Dutch situation is also relatively bad. From figure 31 it appears that the situation in the Netherlands per unit area is relatively worst if transboundary inflows of cadmium are taken into account; these inflows are not taken into account for other countries in figure 31, but, as argued before, it may be expected that transboundary inflows are relatively unimportant for these other countries.

In figure 30 the main sources of Dutch cadmium load to water per unit area are the production of phosphates, the production of zinc and the production of iron and steel; in figure 31 the main sources are the transboundary inflow, the production of phosphates, the production of zinc and the production of iron and steel. From figure 12 the main sources appeared to be transboundary inflow, production of phosphates, deposition, production of iron and steel and sewage treatment plants.

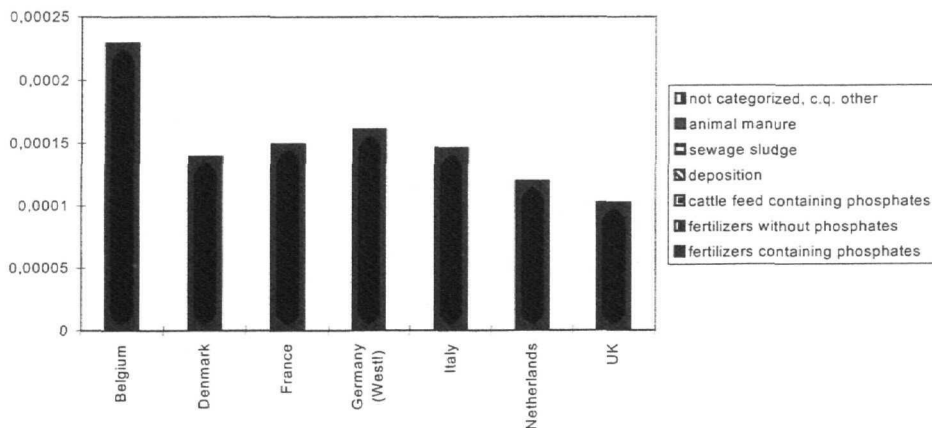
Diffuse soil loads according to OECD (1994) are built up as follows:

Figure 32: Sources of diffuse cadmium loads to soil per km² according to (OECD, 1994) for the Netherlands compared to some other EU member states (kg/yr.km²)



Diffuse soil loads according to ERL (1990) are built up as follows:

Figure 33: Sources of cadmium diffuse soil loads per km² according to (ERL, 1990) for the Netherlands compared to some other EU member states (kg/yr.km²)



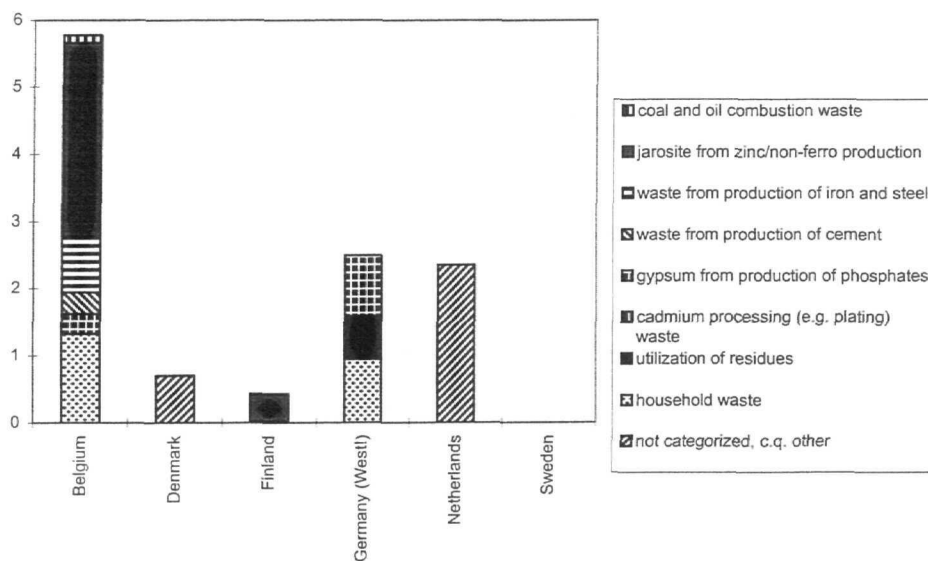
From figure 32 and 33 it appears that also in the case of diffuse soil Belgium has the highest load per unit area. The Dutch load is relatively low. In figure 32 the main sources of Dutch cadmium load to

diffuse soil per unit area are phosphate fertilizers and animal manure; in figure 33 the only source considered is phosphate fertilizer. From figure 14 the main sources appeared to be deposition, animal manure and phosphate fertilizer.

Note that from figure 32 it clearly appears that statistics differ per country defining emissions in a different way: for example, in the Belgium statistics cadmium in cattle fodder is considered to be an emission to soil, while in the Netherlands the animal manure is considered to be an emission to soil; furthermore deposition and non phosphate fertilizers (only in Belgium data) are only considered in some statistics. Whether this leads to double counting and uncomparable numbers is as yet unclear though very likely.

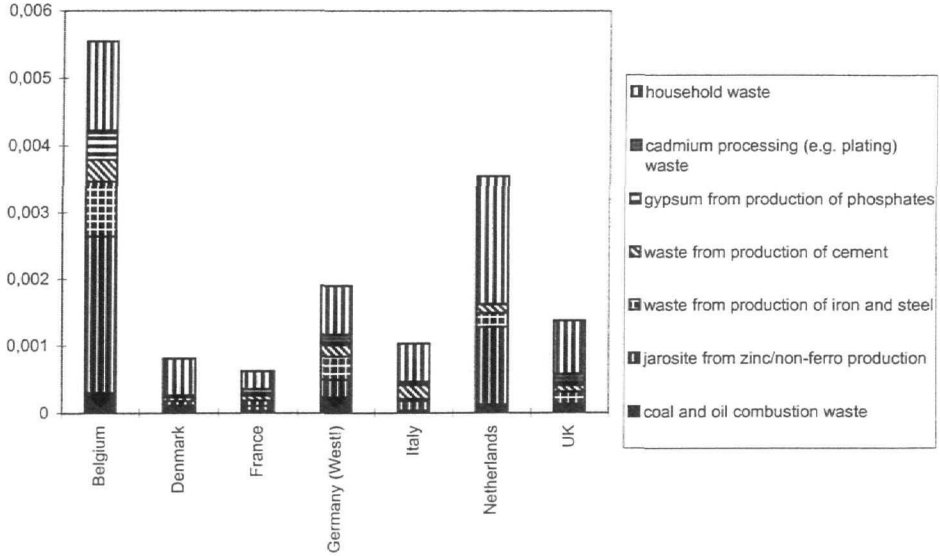
Landfill wastes according to OECD (1994) are built up as follows:

Figure 34: Sources of cadmium landfill loads per km² according to (OECD, 1994) for the Netherlands compared to some other EU member states (kg/yr.km²)



Landfill wastes according to ERL (1990) are built up as follows:

Figure 35: Sources of cadmium landfill loads per km² according to (ERL, 1990) for the Netherlands and some other EU member states (kg/yr.km²)



From figure 34 and 35 it appears that also in the case of landfill waste Belgium has the highest load per unit area. The Dutch load is relatively high too together with the German load. In figure 34 there were no specific data on sources of Dutch cadmium load to landfill; in figure 35 the main sources of the Dutch cadmium load to landfill per unit area are household waste, jarosite and waste from the production of iron and steel. From figure 17 the main sources appeared to be jarosite and household waste.

Note that the jarosite waste flow from the refinery of zinc is quite significant and that different sources give different values for this flow: in the ERL (1990) report this flow is estimated to amount 48 tonnes per year (reference year about 1988), and in the report of Annema *et al.* (1995) the same flow is estimated to be about 82 tonnes per year (reference year 1990).¹ Some sources do not include this waste flow at all (Hutton, 1982).

¹ The jarosite waste flow of about 80 tonnes Cd/yr is quite significant to the total cadmium solid waste flow of the EU which was estimated to be 575 tonnes Cd/yr in 1990 for the at that time 12 members states of the EU (van der Voet, 1996; pp. 260, 262).

Appendix 3 Origins of cadmium loads in the Netherlands and the EU

3a Data concerning direct sources of cadmium load in the Netherlands and the EU (after Annema *et al*, 1995 and van der Voet, 1996)

air (kg/yr.km²)

	NL	EU
production of zinc		0,011
production of iron and steel	0,043	0,010
cadmium applying industry		0,006
electricity production	0,000	0,015
petrochemical industry	0,017	
cement industry		0,003
agricultural soil		0,018
traffic (fuel combustion)	0,007	
waste incineration	0,024	0,010
sewage water treatment		0,001
households (coal & oil combustion)	0,000	
transboundary inflow	0,060	0,009
<i>totaal</i>	0,152	0,083

water (kg/yr.km²)

	NL	EU
production of zinc	0,000	0,003
production of iron and steel	0,001	0,004
production of phosphates	0,089	0,018
Cd applying industry		0,008
sewage treatment plants	0,021	0,031
deposition	0,015	0,001
rinsing from agricultural grounds	0,003	0,003
rinsing from non-agricultural grounds	0,006	0,000
rinsing from landfill		0,012
overstort	0,011	
transboundary inflow	0,383	0,008
<i>totaal</i>	0,527	0,088

soil diffuse (kg/yr.km²)

	NL	EU
fertilizers containing phosphates	0,072	0,189
traffic (car tires)	0,005	
corrosion of zinc	0,010	0,003
deposition	0,137	0,082
sewage sludge	0,009	0,012
animal manure	0,100	0,060
compost use	0,015	0,014
crop residues		0,029
<i>totaal</i>	0,348	0,389

landfill (kg/yr.km2)

	NL	EU
petrochemical industry waste	0,017	
jarosite from zinc/non-ferro production	1,969	0,268
waste from production of iron and steel	0,069	0,137
cement industry		0,120
car waste (shredder dust and plastics)	0,084	
gypsum from phosphate production	0,163	0,062
cadmium applying industry	0,006	0,105
electricity production waste		0,013
sewage sludge	0,014	0,015
household waste	0,592	0,390
incineration slags	0,171	
mud	0,226	
building applications etc. (stabilisers)	0,115	0,113
plastic crates etc.	0,012	
<i>totaal</i>	3,438	1,223

sewage sludge (kg/yr.km2)

	NL	EU
production of zinc		0,005
production of iron and steel		0,007
production of phosphates		0,031
cadmium applying industry	0,004	0,014
waste water from households	0,009	0,004
unknown source to STP	0,011	
traffic	0,003	
water pipes	0,013	
waste incineration	0,008	
deposition	0,006	
<i>totaal</i>	0,053	0,061

3b Data concerning ultimate origins of cadmium load in the Netherlands and the EU (after Annema *et al*, 1995 and van der Voet, 1996)

air (kg/yr.km ²)		
	NL	EU
others		0,005
transboundary inflow air	0,059	0,009
waste from stock in households	0,024	
old iron and steel stock	0,008	
marl extraction		0,003
food and fodder import		
fossil fuels extraction and import	0,024	0,015
iron import	0,036	
P rock and P-fertilizer import		0,012
Cd and Cd products import		0,017
Zn ore extraction, Zn (ore) import		0,021
total load	0,152	0,083

water (kg/yr.km ²)		
	NL	EU
others	0,026	0,020
transboundary inflow air	0,005	0,002
transboundary inflow water	0,395	0,009
marl extraction		0,002
food and fodder import		
fossil fuels import and extraction	0,005	
P rock and P-fertilizer import	0,095	0,037
Cd and Cd products import		0,018
Zn ore extraction, Zn (ore) import		0,001
total load	0,527	0,088

soil diffuse (kg/yr.km ²)		
	NL	EU
others	0,017	0,008
transboundary inflow air	0,070	0,012
waste from stock in households	0,031	
food and fodder import	0,017	
fossil fuels import and extraction	0,028	0,019
iron import	0,042	
P rock and P-fertilizer import	0,122	0,276
Cd and Cd products import	0,007	0,039
Zn ore extraction, Zn (ore) import	0,014	0,035
total load	0,348	0,389

landfill (kg/yr.km2)

	NL	EU
others	0,069	0,037
transboundary inflow water	0,138	
waste from stock in households	1,375	
marl extraction		0,110
P rock and P-fertilizer import	0,172	0,110
Cd and Cd products import	0,172	0,465
Zn ore extraction, Zn (ore) import	1,513	0,501
total load	3,438	1,223

sewage sludge (kg/yr.km2)

	NL	EU
others	0,003	0,002
transboundary inflow air	0,003	
waste from stock in households	0,010	
Cd from unknown source to STP	0,011	
Corrosion from water pipes	0,013	
food import	0,004	
P rock and P-fertilizer import	0,001	0,034
Cd and Cd products import	0,009	0,012
Zn ore extraction, Zn (ore) import		0,014
total load	0,053	0,061

3c Data concerning contribution of products in the cadmium load for the Netherlands and the EU, after Annema *et al*, 1995 and van der Voet, 1996

air (kg/yr.km ²)		
	NL	EU
others		0,003
transboundary inflow air	0,059	0,009
waste from stock in households	0,024	
marl extraction		0,003
fossil fuels	0,024	0,015
iron products	0,044	0,001
P rock and P-fertilizer import		0,012
Synthetics (pigments)		0,008
Synthetics (stabilizers)		0,010
Cd surface coating		0,006
Cd batteries		0,013
Cd alloys		0,001
zinc products		0,001
total load	0,152	0,083

water (kg/yr.km ²)		
	NL	EU
others	0,026	0,011
transboundary inflow air	0,005	
transboundary inflow water	0,395	0,008
marl		0,002
fossil fuels	0,005	
P rock and P-fertilizer import	0,095	0,037
Synthetics (pigments)		0,010
Synthetics (stabilizers)		0,006
Cd surface coating		0,011
Cd batteries		0,003
Cd alloys		
Cd various		
zinc products		0,001
total load	0,527	0,088

soil diffuse (kg/yr.km ²)		
	NL	EU
others	0,017	0,008
transboundary inflow air	0,070	0,012
waste from stock in households	0,031	
fossil fuels	0,028	0,019
iron products	0,042	
P-fertilizer	0,139	0,276
Synthetics (pigments)	0,007	0,019
Synthetics (stabilizers)		0,016
Cd surface coating		0,012
Cd batteries		0,023
zinc products	0,014	0,004
total load	0,348	0,389

landfill (kg/yr.km2)

	NL	EU
others	0,069	0,049
transboundary inflow water	0,138	
marl extraction		0,098
fossil fuels		0,012
iron products		0,012
P rock and P-fertilizer import	0,172	0,098
Cd products (not specified)	1,547	
Synthetics (pigments)		0,257
Synthetics (stabilizers)		0,269
Cd surface coating		0,183
Cd batteries		0,208
Cd alloys		0,012
Cd raw material (export)	1,410	
zinc products	0,103	0,024
total load	3,438	1,223

sewage sludge (kg/yr.km2)

	NL	EU
others	0,003	0,002
transboundary inflow air	0,003	
waste from stock in households	0,010	
Cd from unknown source to STP	0,011	
P fertilizer	0,005	0,034
Synthetics (pigments)		0,009
Synthetics (stabilizers)		0,004
Cd surface coating	0,013	0,010
Cd batteries		0,002
zinc products		0,001
total load	0,053	0,061

Appendix 4

Disposal of municipal waste in the Netherlands and the EU (OECD ENVIRONMENTAL DATA, 1993))

	physical data		landfill	incineration	landfill	inc. waste	landfill	inc. waste
	km2 1988	capita 1988	1000 ton	1000 ton	tons/km2	tons/km2	kg/cap.	kg/cap.
Austria	83900	7,60E+06	1700	310	20	4	224	41
Belgium		9,90E+06						
Denmark	43100	5,13E+06	720	1320	17	31	140	257
France	549100	5,59E+07	9482	7616	17	14	170	136
Finland	337000	4,95E+06	2400	50	7	0	485	10
Germany (West!)	248700	6,15E+07	14842	4742	60	19	242	77
Greece	132000	1,00E+07	2995	1	23	0	299	0
Ireland	70300	3,54E+06	1100		16		311	
Italy	301300	5,75E+07	17990	1262	60	4	313	22
Luxemburg	2600	3,75E+05	51	117	20	45	136	312
Netherlands	41785	1,48E+07	3197	2490	77	60	217	169
Portugal	92389	1,03E+07	821		9		80	
Spain	504800	3,88E+07	9376	606	19	1	242	16
Sweden	449964	8,44E+06	1400	1300	3	3	166	154
UK	244100	5,71E+07	14000	2500	57	10	245	44
EU 1987	3101038	3,46E+08	80074	22314	26	7	232	65

Disposal of waste and the cadmium load to landfill and incineration for the Netherlands and the EU

	Waste per km2		Waste per capita		cadmium load		cadmium content	
	landfill	incineration	landfill	incineration	landfill	incineration	landfill	incineration
	tons/km2	tons/km2	kg/cap.	kg/cap.	kg/km2	kg/km2	kg/ton	kg/ton
The Netherlands	77	60	217	169	3,438	0,395	0,045	0,0066209
EU average	26	7	232	65	1,223	0,078	0,047	0,010801