# A CHLORINE BALANCE FOR THE NETHERLANDS, PART 111:
# BACKGROUND DOCUMENTS, APPENDICES AND PEER-REVIEW.
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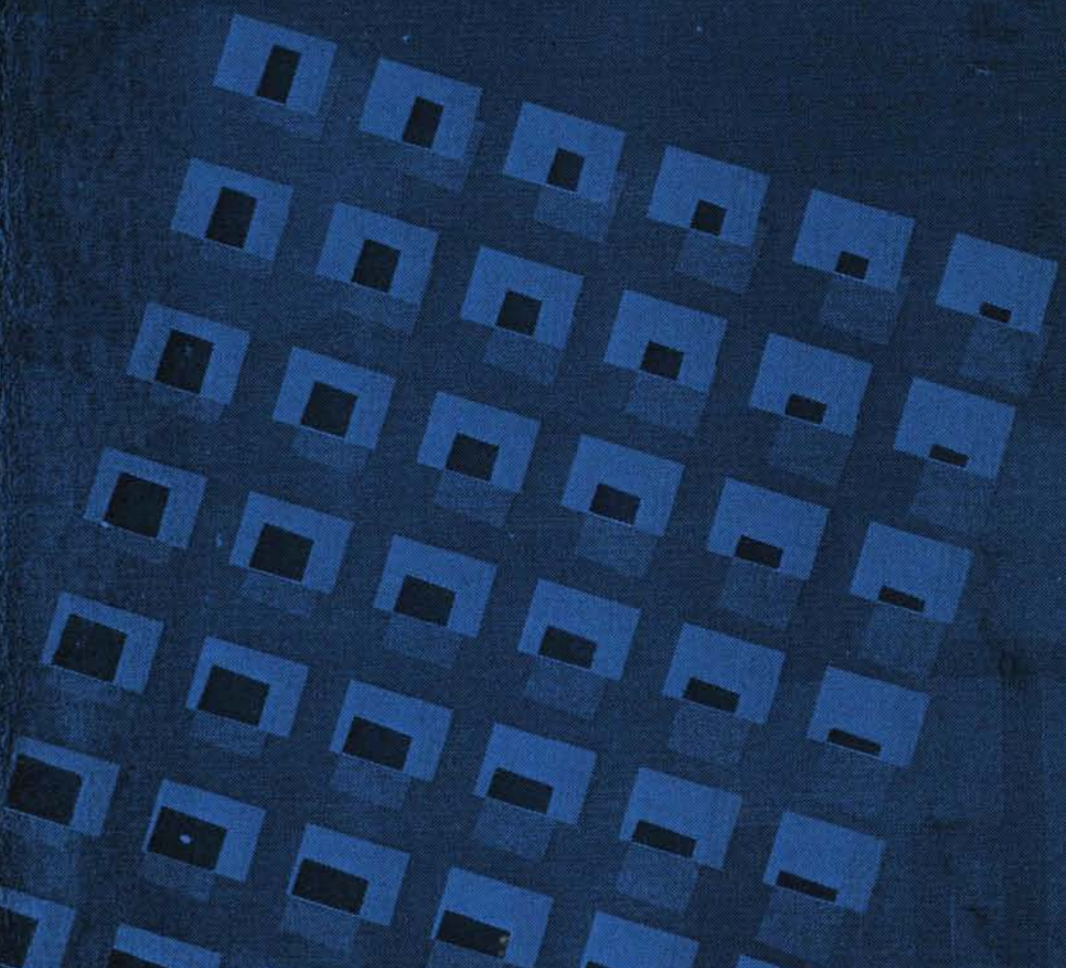
# A CHLORINE BALANCE FOR THE NETHERLANDS

## Part III: Background documents, appendices and peer-review

Final report



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*TNO-report*
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# A CHLORINE BALANCE FOR THE NETHERLANDS

Part III: Background documents, appendices and peer-review

Final report

Commissioned by the Ministries of Housing, Spatial Planning and the Environment (VROM), Economic Affairs and Transport, Public Works and Water Management

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# A CHLORINE BALANCE FOR THE NETHERLANDS

## PART III:

## BACKGROUND DOCUMENT

**Final Report - November 1995**

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APPENDICES

# *1 EMISSION ASSESSMENT (THEORETICAL ASPECTS)*

## 1.1 INTRODUCTION

One of the objectives of the study is to "estimate the risks to humans and the environment due to losses from the chlorine chain". To make a comparison based on risks to humans and the environment the emissions will be assessed on the basis of their potential contribution to specified environmental problems. Such an assessment can be divided into three stages:

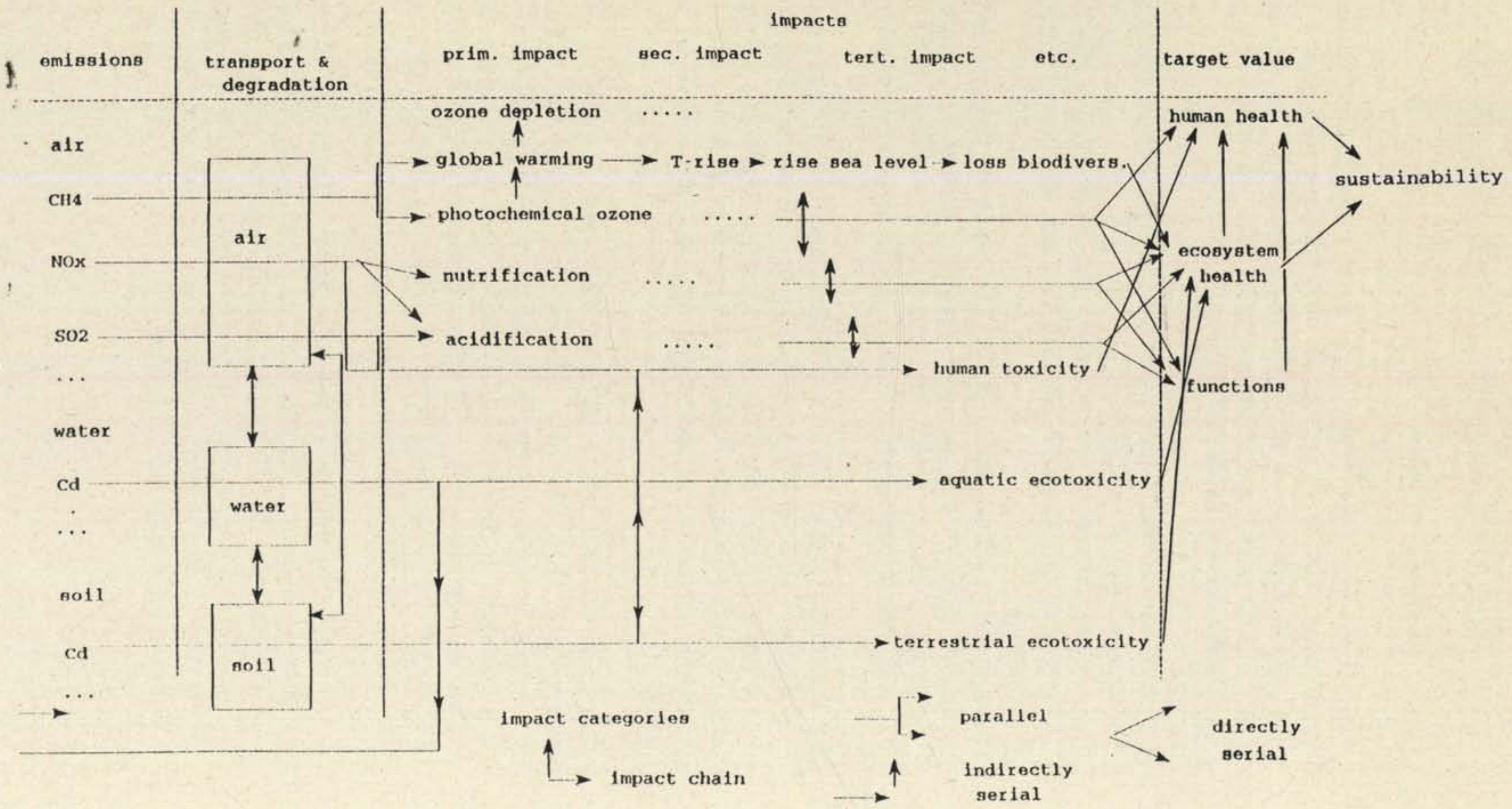
1. *inventory analysis* of the emissions and environmental impacts caused by the system being investigated;
2. *classification* of the environmental impacts by type of effect or environmental problem, followed by *quantification* of the contribution of this type of problem;
3. optionally, *normalisation* of the effect scores by expressing them as a fraction of the overall magnitude of the problem in a defined period in a region, and an *evaluation* in which the effect scores, whether normalised or not, are weighted and then combined to a single environmental index.

In this study "Losses from the chlorine chain" are defined as emissions into the environment. In other words, waste streams only become leaks once they reach the environment. Landfilling is deemed to be an emission into the environment. Waste streams which are incinerated are considered as streams which remain within the economic system while incinerator emissions are considered as leaks from the chain.

There is a complex relationship between emissions and environmental interventions and their eventual impact in terms of reduced sustainability. Substances are released, dispersed, are converted and are absorbed by ecosystems and humans. Figure 1.1.1 illustrates these relationships for a variety of environmental interventions (based on Guinée [1994]). This figure clearly shows that a single environmental intervention can contribute to environmental problems in a variety of ways [Guinée, 1994]:

- in parallel: a single emission can amplify a range of problems;
- directly in series: the emission of a substance may amplify a number of problem types at different stages of the emission-effects chain;
- indirectly in series: a single emission may amplify a problem type through a metabolite or through an impact on a problem type which then leads to an impact on another problem type.

Figure 1.1.1: Relationships between emissions and target values (based on: Guinée, 1994)



In short, environmental interventions should not be considered in isolation - they interact, leading to an impact network. Hence, a number of classification systems have been developed. For example, Table 1.1.1 describes the classification of environmental problems given in the CML/TNO/B&G LCA manual and the classification later developed by the Netherlands Ministry of Housing, Spatial Planning and Environment (VROM) to monitor the effects of environmental policies [Heijungs, 1992; Adriaanse, 1993]. Recently, a third classification method was developed under the Eco-indicator project [Goedkoop, 1995], which is also included in the table.

*Table 1.1.1: Comparison of the classification systems based on the VROM themes, Eco Indicator Project and the CML Guide*

| Eco Indicator Project | CML Guide | VROM themes |
|---|---|---|
| Heavy metals in the atmosphere | Human toxicity | Dispersion |
| Heavy metals in water | | |
| Carcinogens | | |
| Pesticides | Aquatic ecotoxicity | |
| | Terrestrial ecotoxicity | |
| Acidification | Acidification | Acidification |
| Depletion of the ozone layer | Depletion of the ozone layer | Theme: climate<br>Sub-theme: ozone depletion |
| Enhanced greenhouse effect | Enhanced greenhouse effect | Climate change |
| Summer smog | Smog formation | - |
| Winter smog | | |
| - | Odour nuisance | Disturbance |
| - | Noise nuisance* | |
| - | Space use | Disposal |
| Eutrophication | Eutrophication* | Eutrophication |
| - | Resource depletion* | Squandering |
| - | Misc. other categories* | - |

* Not relevant in the context of this study

The classification system has to be selected with some regard to its application. As the evaluation often requires some form of multicriteria analysis the following requirements are often imposed on the classification scheme [Heijungs, 1994b; Assies, 1994; Tukker, 1994b; Finnveden, 1994; Udo de Haes, 1995]:

- the problem types should be homogenous whenever possible (i.e. they should cover environmental interventions causing the same impacts);
- there should be the greatest possible independence between the problem types and they should not overlap.

Figure 1.1.1 clearly shows that in practice, it is almost impossible to select a classification scheme which fulfils all these requirements. For practical reasons the scheme described in the CML manual was adopted for this study. Given the above criteria the CML classification is also somewhat more attractive than the classification based on the various VROM themes which combine a wide variety of impacts (e.g. odour, noise and various toxic effects) into one parameter. This results in an implicit weighting within the confines of the various themes.

The sections below cover the classification, normalisation and evaluation steps of this study. As chlorine compounds do not contribute to environmental issues like nitrification and eutrophication the assessment is only based on a subset of the categories of environmental problems listed in the CML manual. This subset is identified in Table 1.1.1.

## 1.2 CLASSIFICATION

### *1.2.1 Introduction*

The survey of the environmental interventions is followed by the calculation of their quantitative contribution to a given environmental theme. The weighting is based on one of the available methods:

- the equivalence or classification factors from the Product Life Cycle Assessment method [Heijungs, 1991]. The predecessors of these classification factors were earlier used in the McKinsey study "Integrated Substance Chain Management" [VNCI/McKinsey, 1991];
- the theme indicators developed within the environmental policy indicators [Adriaanse, 1993];

LCA classification factors have been developed for all environmental themes mentioned above. Theme indicators have been developed for five of the six themes; there is no separate theme indicator for photochemical smog formation. This is included under the theme indicator acidification.[1]

The LCA classification factors are closely related, and sometimes identical to the theme indicators used as environmental policy indicators [Adriaanse, 1993]. Both quantify the burden on the environment. However, a major difference between them is that the theme indicators express the *actual burden* on the environment in the Netherlands while the classification factors express the *potential contribution* of emissions to a given environmental problem. For the purposes of this study it was decided to consider these issues in an international context. This approach was also taken towards the economic streams. Thus, the emissions in the Netherlands are considered irrespective of the location of their actual impact. The classification factors used for each environmental impact type are introduced below.

### *1.2.2 Enhanced greenhouse effect*

A number of models have been developed for the enhanced greenhouse effect, to quantify the contribution of emissions of various substances to this effect. *Global warming potentials* (GWP) were developed to compare greenhouse gas emission scenarios. The GWP of a substance is the ratio of the heat absorption due to the instantaneous (i.e. impulse) emission of 1 kg of a greenhouse gas integrated over time compared to the heat absorption of a 1 kg carbon dioxide ($CO_2$) emission. This study used the GWPs specified by the Intergovernmental Panel on Climate Change (IPCC) [Houghton et al., 1992] which are widely accepted internationally. The method used to calculate the GWPs indicates that they depend on the time horizon used. This study is based on GWPs based on a 100-year horizon: $GWP_{100}$. The effect score of a given emission in terms of the enhanced greenhouse effect is calculated with the formula:

$$\textit{enhanced greenhouse effect} = \sum_i GWP_i \times m_i \tag{1}$$

where:

*enhanced greenhouse effect* is the number of $CO_2$ equivalents in kg/y;
$m_i$ is the atmospheric emission in kg substance per year;
*GWP* is the Global Warming Potential relative to $CO_2$ (dimensionless).

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[1] However, the contribution of compounds ozone-forming substances to acidification is not quantified in Adriaanse [1993].

In the context of this theme there is no significant difference between the theme indicators and the LCA classification factors [Heijungs 1992; Adriaanse 1993].

### *1.2.3 Depletion of the ozone layer*

Ozone depletion potentials (ODP) have been defined for substances which deplete the ozone layer; these are defined similarly to the GWPs. The ODP is defined as the ratio between the equilibrium ozone depletion due to the annual release (flux in kg/y) of a given quantity of a substance into the atmosphere and the equilibrium ozone depletion due to the same quantity of CFC-11. This study used the widely accepted ODPs determined by the Scientific Assessment Panel [WMO, 1989] which includes all leading scientists in this field. The ozone depletion effect score is calculated with the formula:

$$\textit{depletion of the ozone layer} = \sum_i ODP_i \times m_i \tag{2}$$

where:

*depletion of the ozone layer* = CFC-11 equivalents in kg/y;
$m_i$ = emissions to air, in kg substance per year;
*ODP* = ozone depletion potential, dimensionless.

There is no significant difference between the theme indicators for this theme and the LCA classification factors [Heijungs, 1992; Adriaanse, 1993].

### *1.2.4 Human toxicity*

A range of models has been developed to determine the contributions of various substances to the theme of human toxicity. The Guide for the Environmental Life Cycle Assessment of Products is based on a provisional model using HCAs, HCWs and HCSs - human toxicological classification factors for air, water and soil. A disadvantage of these factors is that the environmental fate of substances, i.e. their distribution and transformation, is not considered in the calculations [Heijungs, 1992].

To offset these disadvantages, Guinée and Heijungs [1993] proposed a toxicity model for use in the LCA method. This includes distribution and decomposition in the calculations of the Human Toxicity Potentials (HTP). The proposed method is very similar to that used in the Uniform System for the Evaluation of

Substances (USES). USES was developed by the RIVM (National Institute of Public Health and Environmental Protection) for rapid, general human toxicological and ecotoxicological risk assessments of a wide range of compounds. USES determines the ratio between a calculated *Potential Environmental Concentration* (PEC) and the *No-Effect Intake* (NEI). The distribution of an emission between the environmental media, environmental transformations and resulting PEC are calculated using Level III Mackay models [Mackay, 1991]. The NEI is calculated on the basis of toxicological standards. In the envisaged LCA model exposure is also calculated with Level III Mackay models, similar to the PEC in PRISEC. The effects are also calculated on the basis of the same toxicological standards. One difference is that in LCAs the location and duration of the emission are not known which necessitates the introduction of a reference substance in the calculations[2]. However, there is no need to introduce a reference substance in the calculations for this study, thus the PEC/NEI ratio can be used as the emission weighting factor.

Level III Mackay models, as used in USES, have not yet been implemented in the LCA method. It would have been possible to implement such models directly in this study on chlorine. However, apart from the emission data the model needed other input such as a considerable data volume on substance properties and the physical environment in the Netherlands and elsewhere. Although a level III Mackay model tailored to the situation in the Netherlands became available when USES was introduced in 1994, at present there is no database with the properties of each substance. A survey to provide these properties of the substances covered by this study would have increased the scale of this study by 30 to 40%. After consultation with the client it was therefore agreed that the current LCA method would be used, at least initially. Chapter 2 of this volume describes how the limitations associated with toxicity assessment using the LCA method were dealt with. A description of the development of the classification factors referred to in the LCA Guide follows below [Heijungs, 1992].

*Provisional classification factor for air:*
The provisional classification factor is the product of the provisional exposure factor and the provisional effects factor. Thus, the provisional *human toxicological classification factor for air* (HCA) is:

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[2] Guinée and Heijungs defined the HTP as: a classification factor describing the potential contribution of a given quantity of a defined substance to the human toxicity, relative to an equal quantity of a reference substance released into a reference environmental medium. The atmospheric emission of phenol is used as the reference emission.

$$HCA = B_a \times E_a = \frac{\dot{V}_a \times W \times M}{V_a \times (ACA \text{ c.q. } AQG) \times \dot{V}_a} \text{ c.q. } \frac{\dot{V}_a \times W}{V_a \times (TDI \text{ c.q. } ADI)} \quad (3)$$

Where:

HCA is the provisional classification factor for air (kg body weight · $kg^{-1}$ substance);
$\dot{V}_a$ is the human respiratory volume (= 20 $m^3$ air · $day^{-1}$ · $person^{-1}$);
*W* is the world population (= $5 \cdot 10^9$);
*M* is the human body weight (= 70 kg · $person^{-1}$);
*ACA* is the Acceptable Concentration in air (kg substance per $m^3$ air);
*AQG* is the Air Quality Guideline (kg substance per $m^3$ air);
*TDI* is the Tolerable Daily Intake (kg substance · $day^{-1}$ · $kg^{-1}$ body weight);
*ADI* is the Acceptable Daily Intake (kg substance · $day^{-1}$ · $kg^{-1}$ body weight).

*Provisional classification factor for water:*
The provisional *human toxicological classification factor for water* (HCW) is calculated similarly to that for air:

$$HCW = B_w \times E_w = \frac{\dot{V}_w \times W}{V_w \times (TDI \text{ c.q. } ADI)} \quad (4)$$

where:

*HCW* is the provisional classification factor for water (kg body weight · $kg^{-1}$ substance);
$\dot{V}_w$ is the human water consumption (2 l water · $day^{-1}$ · $person^{-1}$);
*W* is the world population (= $5 \cdot 10^9$);
$V_w$ is the water volume in the world model ($3.5 \cdot 10^8$ l);
*TDI* is the Tolerable Daily Intake (kg substance · $day^{-1}$ · $kg^{-1}$ body weight);
*ADI* is the Acceptable Daily Intake (kg substance · $day^{-1}$ · $kg^{-1}$ body weight).

*Provisional classification factor for soil*
The provisional *human toxicological classification factor for soil* (HCS) is calculated with the formula:

$$HCS = B_s \times E_s = \frac{M \times W \times N}{V_s \times C\ value-} \qquad \textbf{(5)}$$

where:

$HCS$ is the provisional classification factor for the soil (kg body weight · $kg^{-1}$ substance);

$M$ is the human body weight (= 70 kg body weight);

$W$ is the world population (= $5 \cdot 10^9$);

$N$ is the uncertainty reduction factor for the TDI;

$V_S$ is the soil mass in the world model ($2.7 \cdot 10^{16}$ kg dry matter).

*Calculation of the effect score*

The provisional human toxicological classification factors for the environmental media air, water and soil are listed in a table in Appendix B to the LCA Guide. The sources of the toxicity data were: Vermeire *et al.* [1991], FAO/WHO [1990], Staarink & Hakkenbrak [1985 and 1987], WHO [1987], Kleijn & Van der Voet [1991], Van den Berg [1991] and Van den Berg & Roels [1991].

When undertaking a practical study the effect score of each substance is calculated by multiplying the emissions into the various environmental media per functional unit by the relevant provisional classification factors. The effect scores of the emissions into air, water and soil are added to produce the overall effect score for human toxicity:

$$human\ toxicity = \sum_i ((HCA_i \times m_{a,i}) + (HCW_i \times m_{w,i}) + (HCS_i \times m_{s,i})) \qquad \textbf{(6)}$$

where:

*human toxicity* is the contaminated body weight (kg body weight);

$m_{a,i}$ is the emission into air (kg substance $i$);

$m_{w,i}$ is the emission into water (kg substance $i$);

$m_{s,i}$ is the emission into the soil (kg substance $i$);

$HCA_i$ is the provisional human toxicological classification factor for air (kg body weight · $kg^{-1}$ substance $i$);

$HCW_i$ is the provisional human toxicological classification factor for water (kg body weight · $kg^{-1}$ substance $i$);

$HCS_i$ is the provisional human toxicological classification factor for the soil(kg body weight · $kg^{-1}$ substance $i$).

This can be interpreted as the total human body weight contaminated up to the maximum acceptable limit by the functional unit. As the exposure factors used are only *provisional* it is emphasised that the effect score should only be considered as an indication. Once the envisaged model for the classification of toxic substances [Guinée and Heijungs, 1992] has been implemented, a more accurate analysis will be possible.

The theme indicator "dispersion" is calculated by dividing the annual emissions of the relevant substance by its MAC and multiplying the result by a factor depending on the half-life of the substance [Adriaanse 1993]. The disadvantages of this indicator are:

- like the HCA, HCW and HCS, this theme indicator has little or no relationship to the environmental fate of the substance;
- MAC values rather than standards such as TDIs and ADIs are used to weight the effects;
- there is no separate ecotoxicity score.

### *1.2.5 Ecotoxicity*

As for human toxicity, this theme was also based on the provisional classification factors for the LCA method [Heijungs et al., 1992]. The ecotoxicological classification factor for aquatic ecosystems (ECA) is:

$$ECA = B_a \times E_a = \frac{1}{MTC_{EPA}} \tag{7}$$

where:

*ECA* is the provisional ecotoxicological classification factor for aquatic ecosystems ($m^3$ water · $mg^{-1}$ substance);

$MTC_{EPA}$ is the maximum tolerable concentration determined using the EPA method for the relevant environmental medium (mg substance · $m^3$ water).

The ecotoxicological classification factor for terrestrial ecosystems (ECT):

$$ECT = B_t \times E_t = \frac{1}{MTC_{EPA}} \tag{8}$$

where:

*ECT* is the provisional ecotoxicological classification factor for terrestrial ecosystems (kg soil · mg$^{-1}$ substance);

$MTC_{EPA}$ is the maximum tolerable concentration determined using the EPA method for the relevant environmental medium (mg substance · kg$^{-1}$ soil).

*Calculation of the effect scores*

The provisional ecotoxicological classification scores for the environmental media water and soil are listed in the relevant table in Appendix B of the Guide [Heijungs 1992]. When a practical study is undertaken the effect score of each substance is calculated by multiplying the emissions to the affected environmental media due to the functional unit by the relevant provisional classification factors. The effect score for aquatic ecotoxicity can be calculated with the formula:

$$aquatic\ ecotoxicity = \sum_i ECA_i \times m_{w,i} \qquad \textbf{(9)}$$

where:

*aquatic ecotoxicity* is the volume of the contaminated aquatic ecosystem (m$^3$ water);

$m_{w,i}$ is the emission into water (mg substance);

*ECA* is the provisional ecotoxicological classification factor for aquatic ecosystems (m$^3$ water · mg$^{-1}$ substance).

The effect score for terrestrial ecotoxicity is calculated with the formula:

$$terrestrial\ ecotoxicity = \sum_i ECT_i \times m_{t,i} \qquad \textbf{(10)}$$

where:

*terrestrial ecotoxicity* is the volume of the contaminated terrestrial ecosystem (kg water);

$m_{t,i}$ is the emission into the soil (mg substance);

*ECT* is the provisional ecotoxicological classification factor for terrestrial ecosystems (kg soil · mg$^{-1}$ substance).

The units of the resulting *terrestrial ecotoxicity* and *aquatic ecotoxicity* values are kg soil and m$^3$ water, which may be interpreted as the volume of terrestrial or aquatic material contaminated to the $MTC_{EPA}$. Thus, the *critical volumes* approach is also used for ecotoxicity classification in this provisional method. Again, given the fact that *provisional* exposure factors are used the effect score should only be considered as an indication. Once the envisaged model for the classification of toxic substances [Guinée and Heijungs, 1992] has been implemented a closer approximation will be feasible. You are also referred to the discussion related to human toxicity, in the preceding section.

The potential effects due to exposure are calculated using toxicological standards, the *No (adverse) Effect Concentrations* (NEC). NECs are derived by extrapolation from toxicity data for specific species. A variety of extrapolation methods may be used. For this study the method developed by the US *Environmental Protection Agency* (EPA) was selected. Although this method is not the most advanced available, it has the advantage of providing data on the greatest number of substances.

The envisaged model for the calculation of Terrestrial EcoToxicity Potentials (TETPs) and Aquatic EcoToxicity Potentials (AETPs) [Guinée and Heijungs, 1993] for the LCA method closely resembles the calculation method used in PRISEC. Exposure is calculated with Level III Mackay models, similar to PEC in PRISEC. The effects are also calculated using the same toxicological standards. However, in LCA the location and duration of the emission are not known which requires the introduction of a reference substance in the calculations[3].

However, in this study the terrestrial ecotoxicity scores of the substances were found to be very low. To some extent this is due to the lack of classification factors. For this reason, only the aquatic ecotoxicity was calculated.

There is no separate theme indicator for ecotoxicity [Adriaanse, 1993].

### *1.2.6 Formation of photochemical oxidants*

To be able to assess different emission scenarios for volatile organic compounds (VOCs), POCPs were developed which are similar to GWPs and ODPs [Derwent and Jenkins, 1990]. A UNECE defines POCP: the POCP of a specified emission

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[3] *Terrestrial EcoToxicity Potentials* (TETPs) and *Aquatic EcoToxicity Potentials* (AETPs) can be derived, similarly to HTPs [Guinée and Heijungs, 1993]. TETPs and AETPs are defined as: a classification factor which specifies the potential contribution of a given quantity of a substance to the terrestrial or aquatic ecotoxicity, relative to the same quantity of a reference substance, emitted to a reference environmental medium. Again, the atmospheric release of phenol is used a the reference emission.

is the ratio between the change in ozone concentration due to the emission of one kg of that substance and the change due to the emission of 1 kg of ethene. The UNECE uses a model to calculate PCOPs. However, important aspects of this model require improvement. As the UNECE provides a relatively comprehensive list of POCPs, and in view of the international context in which these values have to be placed, this list was used for this study. The effect score for photochemical oxidant formation is calculated with the formula:

$$\textit{photochemical oxidant formation} = \sum_i POCP_i \times m_i \qquad \textbf{(11)}$$

where:

*photochemical oxidant formation* is the number of ethene equivalents (kg/y);
$m_i$ is the emission to air (kg substance/y);
*POCP* is the Photochemical Ozone Creation Potential (-).

This approach is identical to that used for the LCA classification factors. However, photochemical smog formation is not included in the theme indicators; Adriaanse included the effects under the acidification theme but did not quantify them.

### *1.2.7 Acidification*

The $H^+$ release potential relative to sulphur dioxide ($SO_2$) is the measure of acidification. Thus, the acidification potential (AP) is a measure of the relative contribution of a substance to acidification, relative to the reference substance, $SO_2$. This is similar to the GWPs and ODPs. The effect score for acidification is calculated with the formula:

$$\textit{acidification} = \sum_i AP_i \times m_i \qquad \textbf{(12)}$$

where:

*acidification* is the number of $SO_2$ equivalents (kg/y);
$m_i$ is the emission air (kg substance/y);
*AP* is the acidification potential.

This theme indicator is significantly different from the LCA classification. The theme indicators are based on the $H^+$ *deposition* based on measurements, rather than *emissions*.

### *1.2.8 Landfilling and space use*

Waste streams are not always leaks in the chain. One process's waste stream may be another process's feedstock, as in recycling. Furthermore, a significant proportion of the waste streams is incinerated. The resulting emissions contribute to the environmental problems discussed above and are quantified as such. The resulting "leak" consists of the waste streams which are landfilled. One of the effects of landfilling is space use, which can be expressed in m³ or in tonnes. Additionally, landfilling will lead to emissions into the environment. The scale of these emissions depends on the landfilling methods used and is not estimated in this study. However, for practical reasons the landfilling volume is introduced, expressed in kg chlorine.

### *1.2.9 Odour*

Emissions of odorous substances are classified using a *critical volumes* method in which the emission of a potentially odorous substance is divided by the odour threshold of the substance. For the time being, a distinction will have to be made between aquatic and atmospheric emissions of potentially odorous substances. Thus, the odour thresholds are also separately defined for these two environmental media. This is expressed in the following formulas:

$$odorousair = \sum_i \frac{m_{i,\mathrm{air}}}{OT_{i,\mathrm{air}}} \qquad \textbf{(13)}$$

$$odorous\ water = \sum_i \frac{m_{i,\mathrm{water}}}{OT_{i,\mathrm{water}}} \qquad \textbf{(14)}$$

where:

*odorous air* is the volume of air contaminated to the odour threshold (m³);
$m_{i,\ air}$ is the emission of substance $i$ into air (kg);
$OT_{i,\ air}$ is the odour threshold of substance $i$ in air ($kg \cdot m^{-3}$);
and where *odorous water*, $m_{i,\ water}$ and $O_{i,\ water}$ are the corresponding parameters for water.

Again, this provisional approach is essentially a worst case method which does not consider dispersion and degradation processes, which greatly depend on the substance concerned[4] .

The provisional approach described here was only partly implemented in the Guide. This is due to the fact that there is no consistent odour threshold for most substances. Van Gemert and Nettenbreijer [1977] provided a comprehensive bibliography of substances and their odour thresholds. For many substances, the tests may be as long ago as 1900 and over ten different values may have been found. It appears that the odour threshold is highly dependent on the questions and measuring methods. Van Gemert and Nettenbreijer made a distinction between the detection threshold and the recognition threshold. For many of the measured values it is unclear which of these two is meant. Furthermore, the purity of the substance, rate at which the concentration rises, number of test persons, etc. are all factors which affect the measured odour threshold. Thus, there are extremely large differences between the various values[5]. For atmospheric emissions, however, there is a comprehensive list of odour thresholds determined using uniform methods. This list is used for the provisional classification of potentially odorous emissions into the atmosphere. At present there is no similar list for aquatic releases.

In the theme indicators [Adriaanse, 1993], odour and noise are combined and indicated by the percentage of the population which suffers noise and odours.

### *1.2.10 Unspecified classification factors*

The Guide [Heijungs et al., 1992] does not provide classification factors for some emissions. For example, CFC emissions are not always specified in terms of their various components. In such cases the average of the classification factors for

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[4] Indirect odour emissions cannot be assessed with the critical volumes method. For example, ozone is a potentially odorous substance. Direct ozone emissions are negligible, particularly when compared to the volume of ozone which may be formed due to the photochemical reactions of volatile organic compounds and $NO_x$. See also the section on the formation of photochemical oxidants. At present these indirect ozone emissions cannot be quantified in absolute terms and be incorporated in the classification of odour emissions. The problem is probably comparable to the enhanced greenhouse effect due to the indirect formation of $CO_2$ and $O_3$ due to photochemical reactions of volatile organic compounds and $NO_x$ (see above). This problem might be solved by the development of *smell creation potentials* (Saps), similar to GWPs, which consider these reactions.

[5] Two examples: two determinations of the detection limit of $H_2S$, in 1924 and 1930, resulted in values of 0.0001 and 0.18 mg · $kg^{-1}$; menthol: 0.0004 and 0.9 mg · $kg^{-1}$.

various CFCs was used. For human toxicity classification factors for some substances were derived from the MACs:

- chlorine;
- epichlorohydrine;
- allylchloride.

The MACs had to be converted to ACAs using the formula:

$$ACA = \frac{MAC}{Sf} \times \frac{hours\ per\ week}{hours\ per\ working\ week} \tag{15}$$

where:

$ACA$ is the acceptable concentration in air (kg substance $\cdot$ $m^{-3}$ air);
$MAC$ is the maximum acceptable concentration - time weighted average (kg $\cdot$ $m^{-3}$);
*hours per working week* = 40;
*hours per week* = 168;
$S_f$ is the safety factor, 10.

This calculation introduces a safety factor of 10 as the MACs were defined to protect adult employees, while the ACAs are also supposed to protect vulnerable groups.

## 1.3 NORMALISATION

### *1.3.1 Introduction*

To provide more information about the significance of various effect scores they can be divided by the overall magnitude of the relevant problems expressed in identical scores. This step, normalisation, was developed for LCA. Normalisation can provide information about the extent to which the problem under consideration contributes to the overall magnitude of the environmental issues. It can also uncover differences in this area between the various effect scores [Guinée, 1995]. This can be expressed in a formula:

$$N_i = S_i / A_i \tag{16}$$

where:

$N_i$ is the normalised score;
$S_i$ is the score of the system under consideration (e.g. the chlorine chain) on theme i;
$A_i$ is the overall annual score of all activities in a specified area on theme i.

Normalisation may be undertaken at various levels of scale. Given the non-location-specific nature of studies of this type, normalisation for LCAs is often carried out at the global scale.

For the purposes of this study it was decided to implement normalisation for the Netherlands only as this study of the chlorine chain covers the Netherlands and emissions from the chlorine chain in the Netherlands. Given the geographical delineation of the system the obvious choice is to use the overall emissions in the same geographical system (i.e. the Netherlands) for comparison. Thus, all emissions are expressed as a percentage of the overall emissions in the Netherlands. The disadvantage of this approach is that, should a given release in the Netherlands contribute little to a theme on a global scale but also be the only release in the Netherlands its score would be 100%. However, this situation was not encountered during this study.

### *1.3.2 Data for normalisation*

A report written in the context of the development of the LCA method [Guinée, 1993] provides a base for the data needed for normalisation. This publication provides *world totals* for the environmental themes addressed in this study, with the exception of landfilling volumes. Later, Guinée modified the totals [Guinée, 1995]. These modified world totals are included in the table below. Guinée based his world emissions of greenhouse gasses and ozone depleting substances on publications by the Intergovernmental Panel on Climate Change [IPCC; see Houghton et al., 1991]. The world emissions of other substances are unknown. For these substances, Guinée made rough estimates of the world totals by multiplying emissions in the Netherlands, based on the Dutch Emission Record system, with the equivalence factors to obtain the totals for the Netherlands, which were then multiplied by a factor of 100. This factor is the ratio between the world GNP and the Netherlands GNP.

For the purposes of this study, normalisation was carried out at the level of the Netherlands. The totals for the Netherlands are listed in Table 1.3.1. They were determined as follows:

*Enhanced greenhouse effect*
The Netherlands total for the enhanced greenhouse effect is based on the environmental indicators developed by Adriaanse [Adriaanse, 1993].

*Depletion of the ozone layer*

Adriaanse also provided a total for the Netherlands of substances depleting the ozone layer. However, his calculations did not include emissions of tetrachloromethane (carbon tetrachloride), 1,1,1-trichloroethane and HCFCs. Hence, his total is not comprehensive. The Netherlands' total depletion of the ozone layer was therefore based on the Netherlands 1990 *consumption* of substances which deplete the ozone layer [CFC Committee, 1993]. As only part of the consumption in a given year will lead to the actual *emission* of substances depleting the ozone layer, the emission of such substances in 1990 will have been lower than the consumption. The total for the Netherlands is therefore an overestimate, thus the contribution of emissions from the chlorine chain (expressed as a % of the Netherlands total) to this theme is too low in relative terms.

*Acidification*

For acidification, the overall Netherlands 1992 emission of $NH_3$, $NO_x$ and $SO_2$, as specified in the National Environmental Survey 3, was used as the basis for the overall Netherlands score [RIVM, 1993b]. The overall emissions were multiplied by the corresponding equivalence factors given in the LCA Guide [Heijungs et al., 1991] to produce the overall Netherlands score given in the table below.

*Landfilling*

The Netherlands total volume of landfilled material in 1990 was obtained from the National Environmental Survey 3 [RIVM, 1993].

*Other themes*

The totals provided by Adriaanse [1993] and the National Environmental Survey 3 [RIVM, 1993] cannot be used for the themes human toxicity, aquatic ecotoxicity, photochemical oxidant formation and odour. This is because these themes are classified differently, or the totals are calculated differently from the LCA classification used here. You are therefore referred to the comparisons made in the preceding sections of this chapter. For these reasons, the normalisation of these themes was based on the totals calculated by Guinée [1995] which were again revised in the context of this study. Firstly, the scores of substance emissions based on world emissions were replaced by emission scores based on the Netherlands emission records. For the scores in the Netherlands Guinée used the individual emission records (ER-I) which only provide data on process emissions. For this study the scores from the collective emission records (ER-C) were added to include emissions from diffuse sources in the totals [Pulles and v.d. Most, 1992]. This data was obtained from the fourth round ER, based on 1988 as the datum year. In the context of this study it was not possible to replace the data for all 600 substances by the data from the fifth round ER (1990 datum) which has since been published. Thus, the Netherlands totals for 1988 were used for human toxicity, ecotoxicity, smog formation and odour. In general, emissions will have fallen in the period between 1988 and 1990. Thus, the 1988 totals are likely to be higher than the 1990 totals. This will lead to a minor underestimate of the contributions of the chlorine emissions to these problems.

### *1.3.3 Uncertainties in the Netherlands total scores*

Given the way they were determined, the Netherlands totals used here are only provisional. The reliability margin of the totals for acidification, depletion of the ozone layer and enhanced greenhouse effect is probably at most several tens of %. This concerns a limited number of substances whose emissions are accurately known and for which there is not a major lack of classification factors. The total for landfilled waste was based on several records. The uncertainty band would appear to be within several tens of %.

The Netherlands total for ecotoxicity may have been underestimated by a factor of 2 to 3, possibly more. Guinée only included a limited number of pesticides in his calculation of the total for the Netherlands, as the emissions or emission factors of the others were not known. During this study, reasonable information about *chlorine-containing pesticide emissions* was obtained. Although equivalence factors were only available for about one quarter of these agents, they were responsible for 12% of the 1990 Netherlands total determined by Guinée (see also Part 1, section 4.3 and Appendix 4). In view of the use of non-chlorine containing pesticides and the lack of equivalence factors it would not be surprising if a thorough study of the Netherlands ecotoxicity total resulted in a figure several times higher than that initially proposed by Guinée[6].

Given the data from this study, it would appear that the Netherlands ecotoxicity total is not significantly affected by the scores of pesticides. Errors in the Netherlands ecotoxicity total may have occurred in the event that major emissions are excluded from the ER-I and ER-C, or if substances do not contribute to the scores due to the unavailability of classification factors. However, the list of equivalence factors for these themes would appear to be less incomplete than for ecotoxicity (see also Appendix 4). It may also be expected that ER-I and ER-C combined provide reasonable information about the total emissions in the Netherlands. A similar analysis applies to odour and smog formation.

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[6] In his thesis Guinée gave specific reservations about the totals derived by him.

Despite these uncertainties in the totals normalisation is still useful. It provides a greater appreciation of the contribution to the Netherlands total, although for a theme such as ecotoxicity this is only in terms of the order of magnitude. This step is also required to add the scores for various themes using the weighting method to be discussed below. This is because the effect scores for the various themes are expressed in different units which would otherwise be impossible to compare.

*Table 1.3.1: 1990 overall scores per environmental theme, the Netherlands and the world.*

| THEME | WORLD | NETHERLANDS | UNIT |
|---|---|---|---|
| human toxicity | $3.24\ 10^{11}$ | $1.25\ 10^{9}$ | kg $bw.y^{-1}$ |
| aq. ecotoxicity | $9.08\ 10^{14}$ | $9.08\ 10^{12}$ | $m^3.j^{-1}$ |
| acidification | $2.86\ 10^{11}$ | $1.02\ 10^{9}$ | kg $SO_2.j^{-1}$ |
| ozone depl. | $1.00\ 10^{9}$ | $1.13\ 10^{7}$ | kg CFC $11.j^{-1}$ |
| enh. greenhouse eff. | $3.77\ 10^{13}$ | $2.44\ 10^{11}$ | kg $CO_2.j^{-1}$ |
| smog formation | $3.74\ 10^{9}$ | $5.73\ 10^{7}$ | kg $ethene.j^{-1}$ |
| odour | $6.28\ 10^{17}$ | $6.68\ 10^{15}$ | $m^3.j^{-1}$ |
| landfill volume | - | $1.67\ 10^{10}$ | $kg.j^{-1}$ |

## 1.4 DISTANCE TO TARGET WEIGHTING FACTORS

### *1.4.1 Introduction*

Classification and normalisation result in scores for each theme which are expressed as fractions of the overall score for each environmental theme in a given period in a defined region. These scores have to be weighted if they are to be expressed in a uniform unit. There are a number of options for weighting environmental themes [Lindeijer, 1995][7]:

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[7] Other weighting methods are based on the costs or exergy needed to prevent an intervention. In this case assumptions have to be made about the prevention techniques used. In these methods, the evaluation is not based on a valuation of the environment at such, instead, they focus on "utility" in terms of costs or exergy requirements.

1. panel methods;
2. monetary methods based on the cost of the damage;
3. methods based on target levels for the various themes.

The first method was used in the VNCI/McKinsey study. A panel was asked to assign weights to various environmental themes [VNCI, McKinsey, 1991]. The second method assumes that the score on a given environmental theme can be expressed in terms of damage (i.e. costs). In essence, this method continues the emission-impact chain to the actual impact and its costs. These are then used for weighting. In the last method it is assumed that a weighting factor is a function of the current load level and a target level on a given theme. The assumption is that a major discrepancy from the target level is relatively serious and therefore means that a relatively high weight is assigned to the theme.

At present, the Netherlands Ministry of Housing, Spatial Planning and Environment (VROM) is investigating whether the third method should be adopted as a standard in the Netherlands [RMB, 1994]. The CE used this method to determine weighting factors for the VROM policy themes [Sas, 1994]. Hence, this method was also adopted for the present study.

### *1.4.2 Distance to target principle*

The distance to target principle (DTT) assumes that the weighting factor for a theme is a function of the current load level and a target level. Such a function can be described by a wide range of formulas (e.g. [Heijungs, 1994], [Tukker, 1994a and 1994b], [Mueller Wenck, 1995] and [SETAC-WIA, 1994]). A widely used formula, which has been proposed by VROM for adoption as a standard is [Adriaanse, 1993; Sas, 1994; RMB, 1994]:

$$W_i = \frac{A_i}{T_i} \tag{17}$$

Where:

$W_i$ is the weight of theme i;

$A_i$ is the current total score in the Netherlands on theme i (in 1990);

$T_i$ is the target for the total score in the Netherlands on theme i (e.g. a level of sustainability or policy objective in the year 2000).

The extent to which the intrinsic magnitude of a given environmental problem is expressed in a DTT weighting factor is currently under discussion. In Formula 17 above, it is assumed that at the target level the seriousness of the environmental problems with respect to theme A are equal to those with respect to theme B. In that case the weighting factors for themes A and B will both be equal to 1. This assumption can be defended if it is assumed that the intrinsic seriousness of an environmental problem is incorporated in the policy targets. It is assumed that a stricter standard will be imposed on intrinsically serious problems than on problems which are intrinsically less serious. In addition to the DTT weighting factor the CE uses an intereffect factor of 1 for the intrinsic seriousness of a given environmental problem. This factor was adopted because VROM considers all policy themes to be equally important [Sas, 1994]. According to Guinée [1995] the intereffect factors are currently not available and determining them would require a separate study. For this reason he used an intereffect factor of 1 for all environmental problems. This approach was also adopted in this study.

The distance to target approach can be used to determine a large number of weighting sets. The basis for the selection of the target level can vary, e.g. a policy objective or level of sustainability. Alternatively, a range of geographical levels at which the current and target levels are compared could be chosen. Recently, the Council for Environmental Management proposed the use of levels of sustainability as a basis for the weighting process. However, this has not yet been put into practice in terms of proposed weighting factors or levels of sustainability [RMB, 1994]. For practical reasons it was therefore decided to use the weighting factors based on the Netherlands policy objectives for the year 2000, as developed in the study "Verwijdering Huishoudelijk Kunststofafval" (Disposal of domestic plastics wastes) [Sas, 1994]. Given that the level of scale of this present study is that of the Netherlands, the adoption of the objectives at this level is an obvious choice.

### *1.4.3 Provisional distance to target weighting factors for the CML classification*

The CE has developed weighting factors for the VROM policy themes. These are not always in line with the classification used in the CML LCA Guide [Heijungs, 1992] which was adopted for this study. Furthermore, the CE did not develop weighting factors for the depletion of the ozone layer and odour. These issues have been approached as follows:

*Human toxicity and ecotoxicity*

The CE developed a weighting factor for a single, integrated theme "dispersion". The 1990 VROM policy indicator "dispersion" was 242 · $10^{17}$ kg polluted environment. The 2000 target is 139 · $10^{17}$ kg [Adriaanse, 1993; Sas, 1994]. VROM has not set policy objectives in terms of scores for human toxicity and ecotoxicity in accordance with the CML Guide. Given the lack of better alternatives, the weighting factor for the policy indicator dispersion calculated by CE was applied to both human toxicity and ecotoxicity. As a single VROM policy theme was divided into two themes, the intereffect factor for both themes was set to 0.5. Otherwise, the division would lead to the theme being included twice in the calculations. The current policies envisage a reduction of both themes by 43%.

This approach is not satisfactory and was only taken in the absence of any alternative. The VROM theme indicator dispersion is based on a weighted total of the environmental pollution due to 505 pesticides, 11 radioactive substances and 34 priority substances. The reduction target for the theme is essentially based on the policy target for pesticides. It would have been better to have surveyed the reduction targets of each substance for the themes human toxicity and ecotoxicity and calculate the expected LCA score for the year 2000. However, this went beyond the scope of this study.

*Acidification*
The 1990 score was $1.02 \cdot 10^9$ $SO_2$ equivalents. The objective for the year 2000 is $396 \cdot 10^6$ $SO_2$ equivalents [VROM, 1993e; Sas, 1994]. The policy objective is a reduction of 60% between 1990 and 2000. The data used here is identical to that used by Sas [1994].

*Depletion of the ozone layer*
The CE weighting factor for climate change only covers the enhanced greenhouse effect, not depletion of the ozone layer. Thus, for the purposes of this study, Formula 17 was used to determine a provisional DTT weighting factor. The CFC emission reduction objective for the year 2000 for CFCs, halons, tetrachloromethane and 1,1,1-trichloroethane is 100% [VROM, 1993e]. The production limit for HCFCs on 1 January 1996 is the sum of 2.6% of the ODP of the 1989 CFC production and the 1989 HCFC consumption [CFC Committee, 1994; EU, 1994]. The total CFC consumption in 1989 amounted to 9.65 kt (kilotonnes) ODP [CFC Committee, 1994]. The target for the HCFC consumption in 1995 is therefore 0.25 kt ODP. In 1989 the HCFC consumption amounted to 0.13 kt ODP. Hence, the resulting HCFC ceiling for 1995 was set at 0.38 kt ODP. According to the EU regulation on substances which deplete the ozone layer, emissions should be reduced from 1995, down to zero in 2015. The emission reduction in 2005 should be 35% [EU, 1995]. For the purposes of this study it was assumed that the emission reductions between 1996 and 2005 will develop linearly, thus the reduction in the year 2000 would be 16%. This is therefore considered as the target for that year. Given 0.38 kt ODP in 1995 the corresponding target is 0.32 kt ODP in 2000. The 1990 consumption was 11.3 kt ODP (see Table 1.3.1). Although the actual emissions were lower due to accumulation in society, this will also apply to the value calculated for the year

2000. It is assumed that these effects will cancel each other out. The resulting DTT weighting factor is 11.3/0.32 = 35.3 The policy target is to reduce emissions by 97% between 1990 and 2000.

*Enhanced greenhouse effect*

The 1990 score for the enhanced greenhouse effect was 244 · $10^9$ kg $CO_2$ equivalent [Adriaanse, 1993]. This score is higher than that used in the CE study, as that study did not include the impact of CFCs and HCFCs. The policy target for the year 2000 is 195 · $10^9$ kg $CO_2$ equivalent [Adriaanse, 1993; Sas, 1994]. This figure does not include the impact of HCFCs. Given the assumptions made in the context of the discussion of the depletion of the ozone layer, the HCFC consumption in 2000 will be approximately 7000 kt. On the basis of the average GWP of HCFC-22 and HCFC-142b, i.e. 1,700 kg $CO_2$ equivalent per kg, the revised score is approximately 205 · $10^9$ kg $CO_2$ equivalents. Thus, the emission reduction target for the period 1990-2000 is 16%.

*Smog formation*

There is no policy target for smog formation. Thus, the CE based the policy target for smog formation on the policy target for VOC's and acidification (447 kt VOC in 1990 and 194 kt VOC in 2000). This approach was also adopted in the present study. Hence the emission reduction target for the period 1990-2000 is 57%. The VROM policy target is not expressed in the same units as the scores based on the CML method. Thus, the 1990 smog formation data given in Table 1.3.1 cannot be compared with the VOC emissions listed here.

*Odour*

The CE did not calculate a weighting factor for odour. According to Adriaanse [1993], the policy target for the year 2000 is that the number of persons affected by odour should be halved. It is assumed that this *immission* objective can be linearly converted to an *emission* objective, in which case the emission reduction target and the DTT weighting factor are set at 2.

*Landfill volume*

In 1990 landfilled waste amounted to 15.5 Mt [Adriaanse, 1993] or 16.7 Mt [RIVM, 1993b]. The policy target for the year 2000 is a 70% reduction to 5 Mt.

The weighting factors are listed in Table 1.4.1. The weighted, integrated total score of an emission on all eight themes is calculated with the formula:

$$X_e = \Sigma_{i=1..n} G_i * N_{i,e} \qquad (18)$$

where:

$X_e$ is the weighted total score of a substance (e), integrated into a single measure over themes 1 through n (also known as the environmental index);

$G_i$ weight of theme i;

$N_{i,e}$ is the normalised score of the emission of substance (e) on theme i.

*Table 1.4.1: Distance to target weighting factors, intereffect factors and the resulting total weights per theme*

| THEME | LEVEL 1990[1] | TARGET 2000[1] | DTT FACTOR | INTEREFF. FACTOR | WEIGHT | WEIGHT REL. TO GREEN-HOUSE EFF. |
|---|---|---|---|---|---|---|
| hum. toxicity | $242\ 10^{17}$ | $139\ 10^{17}$ | 1.7 | 0.5 | 0.85 | 0.7 |
| aq. ecotoxicity | id. | id. | 1.7 | 0.5 | 0.85 | 0.7 |
| acidification | $1.02\ 10^{9}$ | $396\ 10^{6}$ | 2.6 | 1 | 2.6 | 2.2 |
| ozone depl. | $11.3\ 10^{6}$ | $0.32\ 10^{6}$ | 35.3 | 1 | 35.3 | 30 |
| greenhouse eff. | $2.44\ 10^{11}$ | $2.05\ 10^{11}$ | 1.2 | 1 | 1.2 | 1 |
| smog formation | $447\ 10^{6}$ | $194\ 10^{6}$ | 2.3 | 1 | 2.3 | 1.9 |
| odour | 1 | 0.5 | 2.0 | 1 | 2.0 | 1.8 |
| landfill | 15.5/16.7 | 5.0 | 3.1 | 1 | 3.1 | 2.6 |

[1] Units: see main text

### *1.4.4 Weighting factors in other studies*

Another approach was recently used to develop weighting factors for environmental themes in the Eco Indicator project [Goedkoop et al., 1995]; these are listed in Table 1.4.2. In this study the European overall score on a given theme was converted to the impacts at later stages in the emission-impact chain. The impacts considered were:

- number of fatalities per million persons per year;
- % ecosystem degradation.

One fatality per million per year was deemed to be equivalent to 5% ecosystem degradation.

The reduction factors for each theme to reach an objective of 1 fatality per million per year or 5% ecosystem degradation were calculated. In essence, this also refers to a distance to target, but now with an objective for each theme based on a standard of 1 fatality per million per year or 5% ecosystem degradation.

*Table 1.4.2: Weighting factors used in the Eco Indicator project*

| ENVIRONMENTAL THEME | WEIGHT | WEIGHT REL. TO GREENHOUSE EFFECT |
|---|---|---|
| various substances with human toxic effects: | | |
| - heavy metals in air | 5 | 2 |
| - heavy metals in water | 5 | 2 |
| - carcinogens | 10 | 4 |
| pesticides | 25 | 10 |
| acidification | 10 | 4 |
| ozone depletion | 100 | 40 |
| greenhouse effect | 2.5 | 1 |
| smog formation | | |
| - summer smog | 2.5 | 1 |
| - winter smog | 5 | 2 |
| odour | - | - |
| landfill volume | - | - |

The Eco Indicator project used a slightly different classification of the environmental themes than that in the LCA Guide. Hence, only a few of the resulting weighting factors can be compared with those in the preceding section. The weighting factors are listed in Table 1.4.2. A comparison of Tables 1.4.1 and 1.4.2 shows that the weighting factor for ecotoxicity in the current project is less than one-tenth that in the Eco Indicator project. Despite the different method used to determine the weighting factors, the others differ by no more than a factor 2 to 3.

## 1.5 BENCHMARKING THE ENVIRONMENTAL PERFORMANCE OF A TARGET GROUP

### *1.5.1 Introduction*

To assess whether a target group does well or poorly in environmental terms its environmental performance has to be compared with that of other target groups. Such a benchmarking system provides a correction for the fact that large-scale activities will naturally have a greater environmental impact than small-scale activities. Thus, a way has to be found to provide a link between the environmental impact of a target group and the scale of its economic activities. A number of allocation systems could be used:

- added value of the production;
- number of employees;
- use of raw materials;
- physical production (e.g. expressed in tonnes of materials).

This issue is even more complex in the study of the chlorine chain since this study assessed the chain only in terms of chlorine. Only chlorine-containing releases were surveyed and other activities and releases which are intimately associated with the chain were disregarded. Furthermore, the production volume, added value or number of employees of companies which process chlorine are not all related to chlorine. For example, the raw materials for the production of PVC are chlorine and ethene. In essence, another allocation key has to be defined, i.e. a key for the allocation of the production volume, added value or number of employees to the incoming raw materials, chlorine and ethene.

When dealing with such allocation problems various extreme positions could be taken. For example only the chlorine emissions of a production plant could be allocated to the chlorine chain - this is an obvious choice on the basis of causality. If the overall added value or employees in the plant are then allocated to the chlorine chain the environmental impact per employee or unit of added value will be relatively low.

The opposite approach is also possible: it could be argued that all emissions from the plant (including non-chlorine emissions) are caused by the process in which chlorine is used and should therefore be allocated to the chlorine chain. If the economic performance is then allocated to another raw material used, the chlorine chain would have extremely high emissions per unit of added value.

Such extreme approaches may be used as ammunition in polemic discussions but are both unrealistic. The development of LCA methods has provided several approaches to deal with the allocation problems associated with multiple input and multiple output processes. The most important are allocation based on causality or based on mass or the economic value of the inputs or outputs.

The advantage of selecting the *raw material input* as the primary allocation key is that this avoids the need to continue the allocation discussion at the process level. The chlorine throughput in the chain, and therefore the individual processes, provides a measure of the economic activities. This leaves the question of which emissions of a given plant should be allocated to chlorine. In view of the principle of causality it may be argued that only chlorine-containing emissions, not other emissions, should be allocated to the chlorine chain.

Naturally, the selected basis for comparison will always leave some room for discussion. Such allocation methods are also inflexible. Conceivably, each target group might be assessed on the basis of an average, acceptable environmental impact. Taken to extremes, the production of drinking water or steel might be compared with the average water or steel consumption in the Netherlands economy. In macroeconomic terms it might be more useful to permit defined sectors a higher or lower environmental impact on a given theme than average, depending on their function. This is similar to the differences between capital-intensive and labour-intensive industries. The essence is that the policy targets (or alternatively, the levels of sustainability) are not exceeded at the macro level. A Pareto optimum may be found between these limits, at which the impact on each theme varies greatly between the target groups.

### *1.5.2 A benchmark for the chlorine chain*

The overall chlorine throughput of the Netherlands society is 939 kt/y. The total material throughput of Dutch society is approximated by the Netherlands throughput of the most important bulk materials, listed in Table 1.5.1. The total volume is 210,000 kt. Hence, chlorine accounts for approx. 0.4% of the total use of materials in the Netherlands. This can be considered as an environmental impact benchmark.

This estimate of the total production of bulk materials is likely to be too low. Thus, 0.4% is likely to be too high. Given the method by which this percentage was determined it should be considered to be a provisional, indicative figure.

Another approach confirms that the order of magnitude of this figure provides a reasonable estimate of the scale of the production of the chlorine chain relative to all production in the Netherlands. The Netherlands national product is over 500 billion guilders [CBS, 1992]. The 1992 turnover of the Akzo chemicals groups, before the merger with Nobel, was over 5 billion guilders [Akzo, 1992]. These figures include the extensive activities in other countries and the activities in the chemicals group which are not based on the use of chlorine as a raw material. Examples include the sales of caustic soda, which is produced together with chlorine. The allocation issues associated with PVC production, referred to earlier, should also be considered. Akzo is by far the largest operator in the chlorine chain in the Netherlands. If it is assumed that the other activities in the chlorine chain in the Netherlands are of a similar order of magnitude as the activities of the Akzo chemicals group which cannot be allocated to the Netherlands or chlorine, the amount of 5 billion guilders gives some indication of the turnover of the chlorine chain, i.e. that its order of magnitude is around 1% of the Netherlands national product.

*Table 1.5.1: Production-related flow of materials in the Netherlands*

| BULK MATERIAL | Production in the Netherlands, kt/y |
|---|---|
| crude oil | 67000 |
| natural gas | 34986 |
| concrete/cement | 16451 |
| paper | 12973 |
| food/fodder | |
| - animal | 16000 |
| - vegetable | 19000 |
| - grass | 9000 |
| chemical industry | 18500 |
| metal | 16000 |
| TOTAL | 209910 |

Source: CBS, 1991b ; EZ, 1993

## 1.6 PROBLEMS IN SUSTAINABILITY ASSESSMENTS

### *1.6.1 Introduction*

In principle, a benchmarking procedure of the type described in section 1.5 could be used to assess the performance of a target group in terms of sustainability.

Sustainability levels would have to be set for each environmental theme which would then be allocated to the target group using an allocation key [see Buise, 1993; Buitenkamp, 1992]. A comparison with the actual scores for these themes would then provide an indication of the extent to which the target group exceeds its sustainability limits. This section will address the problems currently associated with this method.

### *1.6.2 Levels of sustainability*

At present there are no generally accepted sustainability limits at the level of the Netherlands or the world. However, there are policy objectives in the Netherlands which have been accepted by political fora. These were used as the basis for the weighting method discussed in section 1.4. The levels of sustainability proposed by various authors for the themes relevant to the present study are discussed below. Generally, these levels were determined by setting a zero or negligible impact at the end of the chain and then backtracking through the chain to determine the emission limits. There are significant normative aspects associated with determining levels of sustainability [WRR; 1994; Weterings and Opschoor, 1994]. These are not limited to selecting negligible impact levels but also include choices related to backtracking to the emission limits.

*Human toxicity and ecotoxicity*
The LCA human toxicity score is based on the number of kg bodyweight contaminated up to the TDI. A related target, derived by Guinée [1995] is that the score should not exceed the combined weight of the world population. For the Netherlands this corresponds to 70 kg/person * $15 \cdot 10^6$ persons = $1.05 \cdot 10^8$ kg/y. For aquatic toxicity the LCA method results in a score indicating the volume of the contaminated fresh water ecosystem. Guinée has proposed the total volume of water, or fresh water, as a potential objective. Adriaanse [1993] and Boekelman [1995] have provided widely differing estimates of the volume of fresh water in the Netherlands. Hence, it was decided not to use this method to determine the sustainability level for the Netherlands. Adriaanse used a similar method when determining the level of sustainability for the VROM theme dispersion. He defined the sustainability level as the total environmental volume (water, atmosphere and soil) which can be contaminated to the maximum acceptable concentrations based on the MARs [Adriaanse, 1993]. A third approach could be based on the risk policy for substances: the negligible risk could be selected as the threshold below which sustainable development is safeguarded. In effect, in this study this is the criterion that we used in the assessment, see Chapter 2 of this volume. This criterion may be more demanding than that used by Adriaanse and Guinée. Firstly, their limit value is similar to the MAR, 100 times higher than the negligible risk,

and secondly they base their approach on the *average* contamination of the entire environment up to this level. Where possible, the assessments in the present study were based on *local* exceedance of negligible risk levels. On the other hand, the risk-based policy accepts contamination of the same environmental entity by *several substances* up to the negligible risk level or NR, in contrast to the method used by Guinée and Adriaanse.

### *Acidification*

The Netherlands policy objective is a deposition of 2400 acid equivalents per hectare per year in the year 2000. The long term objective is a deposition of 1400 acid equivalents per hectare per year, in 2010. This level will prevent the occurrence of the most serious effects, even on woodlands on poor sandy soil. The complete avoidance of all environmental damage requires a deposition level of approximately 400 acid equivalents per hectare per year. Adriaanse [1993] used this *immission* level as a starting point for calculating the sustainable *emission* level. He multiplied this deposition by the area of the Netherlands to obtain a maximum emission of $1.5 \cdot 10^6$ kg $H^+$, which corresponds to $4.8 \cdot 10^7$ kg $SO_2$ equivalents per year. Kortman et al. [1994] took the same approach but based on 1400 acid equivalents per hectare per year and calculated the maximum emissions as approximately $18 \cdot 10^7$ kg $SO_2$ equivalents per year. This approach ignores the fact that acidification is at least partly a problem affecting entire continents as emissions in one location will lead to deposition elsewhere. For example, Van der Loo [1994b] has indicated that given the prevalent westerly winds across Europe the reduction of acid emissions in France is more important than the reduction of similar emissions in Scandinavia. Thus, allocation keys other than those set by Adriaanse and Kortman could be used.

### *Depletion of the ozone layer*

According to Adriaanse [1993] a no-effect atmospheric concentration of substances which deplete the ozone layer could be determined, at least in principle. This could be used to determine a sustainable emission level, similar to that for the greenhouse gasses discussed below. However, at present, the actual concentration is well above the no-effect concentration. In essence, the available environmental capacity has been used by previous generations. Thus, the sustainability level would amount to zero emissions of substances affecting the ozone layer. Due to the long persistence of these gasses in the atmosphere, even zero emissions will not lead to the no-effect concentration until well into the 21st century. Kortman et al. [1994] have proposed a method which could be used to determine a no-significant- adverse-effect level, based on the emission of CFC substitutes which will not have a significant effect on the reduction of the atmospheric halogen concentration. They arrived at a permissible global emission of $18 \cdot 10^6$ kg ODP per year. If this was allocated to the Netherlands on the basis of its area or GNP (see below) the resulting emission budget would be 5 to $120 \cdot 10^3$ kg ODP.

*Enhanced greenhouse effect*

The IPCC has drawn up a range of scenarios for the worldwide emissions of greenhouse gasses. A no-adverse- effect level was defined, assuming that a temperature rise of 0.1°C per decade, up to a maximum of 2°C above the preindustrial level, will not lead to adverse effects. This would allow ecosystems sufficient time to adapt. This dual objective has been converted to permissible concentrations of greenhouse gasses in the atmosphere and total permissible emissions. Given the long persistence of greenhouse gasses in the atmosphere the permissible emissions are expressed as an accumulated figure for the period 1985-2100. This emission budget has to be allocated over time and to each country. The IPCC has determined a time allocation in its accelerated policy scenario which is reasonably consistent with the objective referred to [v.d. Elzen, 1993]. This scenario assumes that there will be a relatively limited emission reduction in the short term, followed by a major reduction in the long term. Guinée [1995] adopted the final emission in the year 2100 based on the IPCC accelerated policy scenario, expressed in $CO_2$ equivalents, calculated by Adriaanse [1993], as the sustainable level. Given the current emission distribution between the various countries this means that the emissions from the Netherlands would be $1.55 \cdot 10^{11}$ kg $CO_2$/y. Van der Loo [1994] used a calculation by Krause et al. [1990] which has a similar basis, but which focuses on the $CO_2$ emission budget. Van der Loo used identical emission budgets for each year. He identified a number of methods to allocate these emissions to countries, the resulting budgets for the Netherlands vary more than twenty fold (in brackets: % of global emissions allocated to the Netherlands):

- historical entitlements (as used in Adriaanse [1993]) (0.72%);
- gross national product (0.69%);
- land area (0.03%);
- current population (0.29%);
- cumulative population in the period 1985-2000 (0.20%).

Another option, mentioned by Van der Elzen [1993] would be to include the *used* emission budgets of each country in the discussion.

Adriaanse [1993] distanced himself from this approach based on an acceptable temperature increase. According to him, this will lead to a completely new situation on earth, incomparable with that during previous centuries. In his view, the sustainable greenhouse gas emission level should be equal to the preindustrial emissions. He calculated these as $0.1 \cdot 10^{11}$ kg $CO_2$ equivalent per year for the Netherlands.

*Smog*

According to Kortman et al. [1994] it is uncertain whether a no-significant-adverse-effect level for smog can be converted to a clear emission limit. Guinée [19950 used the Netherlands *policy objective* as the basis for determining his target level.

*Odour and landfilled waste*

The LCA score for odour is expressed in units of air contaminated to the odour threshold. In analogy with human toxicity, Guinée [1995] based the odour objective on the world air volume. For the situation in the Netherlands this amounts to $6.23 \cdot 10^{14}$ $m^3/y$ [Adriaanse, 1993]. However, given the local nature of odour nuisance, it is doubtful whether such an approach will be satisfactory. Adriaanse [1993] did not set a specific sustainability level but suggested, in accordance with the general objectives in the Netherlands National Environmental Policy Plan (NEPP) that emission reductions of 70 to 90% would be desirable. He applied the same criterion to landfilling, which resulted in a total of 3 Mt landfilled waste per year. We are not aware of other proposals relating to landfilling, although, in principle, a situation in which no waste at all was landfilled would be desirable [Gielen, 1992].

### *1.6.3 Conclusions*

Table 1.6.1 provides a comparison on each theme between the Netherlands policy objectives and some proposed levels of sustainability and indicates that there are major differences between them. The proposed sustainability levels for acidification and the enhanced greenhouse effect are more demanding than the policy objectives. As discussed above, the situation with respect to human toxicity and ecotoxicity may be the reverse.

To summarise, given the current state of the social and political discussions, an assessment framework based on levels of sustainability lacks the robustness to be practical for use in this study. This is quite apart from the discussion in section 1.5 on the allocation key to be used to allocate the Netherlands emission limits to relevant target groups. For acidification and the enhanced greenhouse effect the assessment would also include an unfair element: the tentatively derived levels of sustainability are so strict compared to the policy objectives that at present few target groups in society are likely to meet them.

*Table 1.6.1: A comparison between policy objectives and some proposed levels of sustainability*

| THEME | LEVEL 1990 | TARGET 2000 | PROPOSED SUSTAINABILITY LEVELS | | UNIT |
|---|---|---|---|---|---|
| | | | Option 1 | Option 2 | |
| hum. toxic. | 12,5 $10^8$ | - 43 % (7.1 $10^8$)* | 1.05 $10^8$ (a) | {All substances, | kg lbw/y |
| aq. ecotox. | 9.08 $10^{12}$ | - 43 % (5.2 $10^{12}$)* | ? (a) | {everywhere: NR | $m^3$/y |
| acidificat. | 1020 $10^6$ | 396 $10^6$ | 48 $10^6$ (b) | 180 $10^6$ (c) | kg $SO_2$-eq./y |
| ozone dep. | 113 $10^5$ | $0^d$ | 0 (b) | 0.05-1,2 $10^5$ (c) | kg CFC-11/y |
| greenh.eff. | 2.44 $10^{11}$ | 2.05 $10^{11}$ | 1.55 $10^{11}$ (a) | 0.1 $10^{11}$ (b) | kg $CO_2$-eq./y |
| smog | 5.73 $10^7$ | - 70 % (1.72 $10^7$)* | - 70 % (a) | | kg ethene/y |
| odour | 66.8 $10^{14}$ | - 50 % (33.4 $10^{14}$)* | 6.23 $10^{14}$ (a) | - 80 % (13.4 $10^{14}$) (b) | $m^3$/y |
| landfill | 15.5/16.7 | 5.0 | 3.0 (b) | | Mton/y |

* The structure of the VROM policy themes is not fully in-line with the classification used in the CML Guide. The objectives for the CML themes marked "*" are converted from the objectives for the VROM policy themes (see section 1.4).

a) Based on Guinée [1995], converted to the level of the Netherlands.

b) Adriaanse [1993].

c) Based on Kortman et al. [1994].

d) Objective for 2015.

# 2 *ASSESSMENT OF THE TOXICITY OF SELECTED SUBSTANCES AGAINST THE BACKGROUND OF THE NETHERLANDS POLICY ON RISKS*

## 2.1 INTRODUCTION

As discussed in sections 1.2.4 and 1.2.5 in Part III, the use of the LCA method to determine human toxicity and ecotoxicity for the purposes of the present study has some major limitations. The distribution of substances between the environmental media and transformations in the environment, such as the formation of metabolites, are not considered. Furthermore, this method does not consider any synergistic or antagonistic effects due to exposure to more than one substance. Given these limitations the score based on the LCA method is not appropriate to determine the seriousness of the potential toxic effects of a substance. This chapter discusses an assessment of toxicity risks of chlorinated compounds which obtained an above-zero score on human toxicity and ecotoxicity using the LCA classification method.

Not all substances were included in the additional assessment. Twenty-three of the more than 50 substances, not including pesticides, which were found to be released had a score for human toxicity or ecotoxicity (see Appendix 4). The other 27 substances did not score on these themes. Six of the 23 substances have been phased out or will be phased out when the envisaged policies are implemented. These are CFC-12, PCP, 1,1,1-trichloroethylene, PCBs, HCBd and tetrachloromethane. The remaining 17 substances are discussed here in detail. Atrazine, the pesticide with the highest human toxicity score, and the three pesticides with the highest ecotoxicity scores, i.e. dichlorvos, MCPA and MCPP, were also included. The full list includes:

- chlorobenzenes (4 substances with an above-zero score);
- EDC;
- PER;
- chloroform;
- dioxins;
- dichloromethane;
- trichloroethene;
- VCM;
- ECH;
- AC;
- MCPP;
- MCPa;
- dichlorvos;
- atrazine;
- chlorine.

## 2.2 MOTIVATION OF THE METHOD AND ASSESSMENT FRAMEWORK

### *2.2.1 Introduction*

Toxicity risks can be assessed by various methods. The objective of this study was to use available, operational assessment methods. Developing a new method specifically for the study was beyond the scope of the project. The three methods most relevant to this study were:

- calculating the scores of substance emissions for the themes human toxicity and ecotoxicity using the LCA Guide (see sections 1.2.4 and 1.2.5);
- assessing substance emissions using more sophisticated multimedia models such as the Level III Mackay models used in USES;
- assessing the risks posed by substances on the basis of the *actual* concentrations in the environment, such as in the recent report "Aandachtstoffen in het Nederlandse milieubeleid" [The place of substances demanding special attention in the Netherlands environmental policies] [Janus et al., 1994].

The advantages and disadvantages of these methods are discussed below. Section 2.2.5 lists the reasons for choosing the selected method.

### *2.2.2 Option 1: LCA scoring method*

The use of the LCA method to determine a score for the human and ecotoxicity of substance emissions was discussed in sections 1.2.4 and 1.2.5 of this part of the report. The advantages and disadvantages of this method are:

- The distribution between environmental media is disregarded.
- Environmental transformations are disregarded.
- In view of the above, the emission data identified in this study are not effectively translated to potential exposures.
- The assessment is general: it is based on an average potential exposure, disregarding any local differences.
- The assessment disregards potential antagonistic or synergistic effects due to combined exposure.
- The method can be applied directly. Emission data can be used to calculate scores as the classification factors of most substances are known.
- This method has already been used to calculate a total score for all emissions (including those not containing chlorine) in the Netherlands. This makes it possible to compare the toxicity score of the chlorine chain with other emissions in the Netherlands.

### 2.2.3 *Option 2: USES or Level III Mackay models*

Toxicity assessment based on Level III Mackay models, as used in USES, was discussed in sections 1.2.4 and 1.2.5. The advantages and disadvantages of this method are:

- The distribution between environmental media is taken into account.
- Environmental transformations are (partially) considered.
- In view of the above, the emission data identified in this study are more effectively translated to potential exposure than in the LCA method.
- USES includes an Operational atmospheric transport model for Priority Substances (OPS) which is used to calculate long-term average concentrations near point sources.
- The assessment is general: it is based on an average potential exposure, disregarding any peak emissions.
- The assessment disregards potential antagonistic or synergistic effects due to combined exposure.
- The method cannot be applied immediately. A large number of substance properties may have to be surveyed to be able to calculate a score based on emission data. Furthermore, the OPS module would have to be used for calculations for each point source, which would also take too long.
- This method has not yet been used to calculate an overall score for all emissions in the Netherlands (including those not containing chlorine). This makes it impossible to compare the toxicity score of the chlorine chain with other emissions in the Netherlands.

### 2.2.4 *Option 3: policy approach based on substances demanding special attention*

Method

The RIVM (National Institute of Public Health and Environmental Protection) recently published the first comprehensive report on "substances demanding special attention". These substances are listed in the Order on the Designation of Substances Demanding Special Attention, under the Chemical Substances Act 1992 [Netherlands Government Gazette 138, 21 July 1992]. This report assessed the actual environmental risks of substances on the basis of the knowledge and data available at the time. The main objectives were:

1. Providing an overview of current or completed studies on substances demanding special attention.
2. Guiding and prioritising new research on these substances.

3. Providing recommendations on the progress of substances through the activities in this area and the removal of substances from the list of substances demanding special attention.

For each substance or group of substances demanding special attention the report includes a list of the most important data on emissions, occurrence in environmental media and food, current environmental quality objectives and requirements, research (monitoring and measuring programmes and other studies relevant to the activities related to substances demanding special attention) and policy development and measures.

Environmental quality objectives and requirements are toxicological recommended values and values determined as part of the policy process. The most important toxicological recommended values are the maximum acceptable risk level (MAR) and the negligible risk level (NR). For substances where a clear concentration limit can be determined below which no effects occur (threshold), the maximum acceptable risk to humans is set at this level. However, MARs should also protect ecosystems, in practice it is assumed that 95% of species should be protected. However, often there is no concentration limit below which no effects occur. In such cases even extremely low cases pose a low risk of adverse effects. The MAR of such substances is set at the concentration at which it is assumed, on the basis of linear interpolation, that there would be one fatality per million per year (a risk of $10^{-6}$/y). The Negligible Risk (NR) is the concentration of the substance below which the occurrence of adverse effects is considered to be negligible. The NR is set at 1% of the MAR.

Values determined in policy processes include target, guide and limit values. The target values are equal to Nrs. Target values provide compensation for simultaneous exposure to multiple substances. Limit values and guide values are essentially intermediate targets on the way to reaching the target values. They are used for substances whose concentrations will only be reduced down to the target value in the long terms. Limit values may not be exceeded while the exceedance of guide values should be avoided whenever possible.

The report included a risk assessment for humans and the environment, based on the MARs and NRs and the most up to date exposure data, generally based on *measured* environmental concentrations. Where possible, the RIVM considers worst case situations, such as exposure to local, relatively higher concentrations in the vicinity of sources or in the indoor environment. This assessment framework is in line with the outcome of the parliamentary discussions on the risk policy related to substances. On the basis of this assessment the RIVM made recommendations on each substance about its continued inclusion or removal from the list of substances demanding special attention. Enforcement recommendations indicate further activities considered to be important.

Advantages and disadvantages

The advantages and disadvantages of this method are:

- The distribution between environmental media and environmental transformations are, implicitly, included as the method is based on measured concentrations in the environment.
- The emission data from the chlorine study cannot be linked directly to the concentrations of substances in the environment which the RIVM used as the basis of its assessment.
- This assessment is highly specific: in principle, the RIVM considers vulnerable groups and local, relatively high exposures.
- To some extent, the inclusion of the NR in the assessment anticipates possible synergistic or antagonistic effects due to combined exposure.
- The method can be applied directly. The RIVM has completed the assessment and published a report.
- This method has not been used to calculate an emission score for all emissions (including those not containing chlorine) in the Netherlands. Thus, the chlorine chain cannot be compared to other emissions in the Netherlands in terms of toxicity.

### 2.2.5 *Motivation of the selected method and development*

The above indicates that the LCA scoring method has major shortcomings when assessing toxicity risks for the purposes of this study. The application of USES or a similar Level III Mackay model has fewer shortcomings but requires considerably greater efforts to obtain a data set of substance properties. This was expected to require additional work amounting to about 30% of the current commitment to the study. Even so, a model of this type would not provide the detail of information in the RIVM report on substances demanding special attention. For example, the RIVM's assessments consider specific situations such as the indoor environment, exposure of vulnerable groups such as nursing babies and exposure in the vicinity of sources. In principle, although this level of detail could be obtained through model-based calculations it would probably exceed the scale of the current chlorine study several times. None of the methods takes sufficient account of the impact of combined exposure to different substances and the formation of metabolites.

The major disadvantage of the use of the RIVM material is that the RIVM generally uses the actual concentrations of substances in the environment, generally around or even before 1990. These cannot be linked directly to the emission data obtained for the chlorine study. Generally emissions were falling at the end of the '80s [VROM, 1993e]. The present study also indicates that the emissions of most chlorinated compounds will be reduced, sometimes greatly, if the envisaged policies are implemented. It may be assumed that emissions reductions will lead to lower concentrations in the environment. It would appear to be acceptable to assume that the emission situation after the implementation of the envisaged policies will lead to lower substance concentrations than those used as the basis of the RIVM assessment.

In consultation with the RIVM and VROM it was therefore decided to base the risk assessment on the report on substances demanding special attention. The sections below contain summaries of the relevant parts of this report on the 21 substances listed above. The last section of this chapter also contains a summary of the discussion of other chlorinated compounds in the RIVM report. The RIVM study did not cover ECH and AC. TNO and CML drew up an analysis based on criteria documents and other materials. With the exception of sections 2.17 and 2.18, the entire chapter including both the sections taken from the RIVM report and the new material, were submitted to the RIVM for comment before publication of the final report.

## 2.3 CHLOROBENZENES

### *2.3.1 Problem definition and risk assessment*

Chlorobenzenes form a group of 12 organic compounds which are used as raw materials and solvents for the production of pesticides and pharmaceuticals. For example, 1,4-dichlorobenzene is used in toilet blocks and mothballs for institutional and domestic use. The major sources of emissions are the pesticides industry, pharmaceutical industry and, to a lesser extent, the textile industry. Emissions are to all environmental media, mostly into the atmosphere. Most emissions concern 1,4-dichlorobenzene [Slooff, 1991]. The pharmaceuticals and bandages industry is a major indirect industrial emission source which affects the surface water. This sector is responsible for more than 50% of the overall emissions into the surface water in the Netherlands [Senhorst, 1994]. The information below is focused on dichlorobenzenes (DCB) and hexachlorobenzene (HCB) as most of the emissions concern these substances (DCB), their relatively high toxicity (HCB) and the availability of exposure data.

In some locations the HCB limit is exceeded in sediment. At some locations the HCB and DCB target values are exceeded in the soil or groundwater. The current annual average concentrations of HCB and DCB in national waterways are several hundred times, or more, below the MAR [Slooff, 1991; CCRX, 1993]. The risks to aquatic ecosystems are therefore considered to be negligible. The annual average atmospheric concentrations are similar.

With respect to inhalation exposure it is concluded that the risk to the population at large is probably negligible at the current chlorobenzene concentrations. A reservation should be made with respect to 1,4-DCB exposure in the indoor environment. The negligible risk level may be exceeded considerably in many dwellings, at least by comparison with the measured concentrations.

3,4-DCB concentrations in the indoor atmosphere are also relatively high. However, there is no MAR for this substance. Estimates were made of the daily intake of HCB, the most toxic chlorobenzene. The average and maximum intakes are 100 and 30 times lower than the TDI (tolerable daily intake) of this compound.

There is no data available on the intake of other chlorobenzenes. However, it is likely that the intake levels of these substances will be lower than those of HCB. In view of this data the risk of oral exposure to chlorobenzenes is considered to be negligible.

### *2.3.2 Recommendations for further research and conclusions*

Further research should be carried out on the health hazards of exposure to 1,4-DCB in the indoor environment.

Although the data available for some of the chlorobenzenes is limited it would appear that the desired environmental quality level has largely been reached, at least in terms of the risk posed to humans and the environment. In some locations the limits (HCBS, sediment) or targets (HCB and DCB, soil and groundwater) are still exceeded but the targets and limits are generally lower than the NR or MAR of the relevant environmental media. The risks to humans and the environment associated with the current exposure levels are considered to range from "limited" to "negligible". The concentrations will continue to fall in the future due to unrelated developments. The RIVM has proposed removing chlorobenzenes as a group from the list of substances demanding special attention, with the exception of 1,4-DCB. This substance should remain on the list given the indoor air quality issue as the negligible risk level in the indoor environment is frequently exceeded. 3,4-DCB may also be relevant in the context of the indoor environment issue, but there is no MAR for this substance. TNO and CML observed that no policies have been defined to reduce exposure in the indoor environment to 1,4-DCB and 3,4-DCB.

Table 2.3.1 lists the Netherlands environmental quality targets and requirements for this substance [Janus, 1994].

## *Table 2.3.1 Environmental quality objectives and requirements: targets and limits (T,L), negligible risk levels/maximum acceptable risk levels (NR, MAR) and soil remediation intervention values (SI)*

| Substance | Surface water<br>Total<br>μg/l | | Dissolved<br>μg/l | | Sediment (newly deposited)<br>mg/kg dm | Soil / Sediment<br>mg/kg dm | | Groundwater (dissolved)<br>μg/l | | Atmosphere<br>μg/m$^3$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chlorobenzenes (total) | S | G | S | G | L | T | SI | S | SI | T | L |
| | - | - | - | - | - | - | 30 | - | - | - | - |
| | NR | MAR | NR | MAR | MAR | NR | MAR | | | NR | MAR |
| | - | - | - | - | - | - | - | | | - | - |
| Monochlorobenzene | T | L | T | L | L | T | SI | T | SI | T | L |
| | - | - | - | - | - | -$^{c}$ | - | 0.01$^{b}$ | 180 | - | - |
| | NR | MAR | NR | MAR | MAR | NR | MAR | | | NR | MAR |
| | - | - | 6.9 | 690$^{d}$ | 7.6$^{h}$ | 0.076 | 7.6$^{h}$ | | | 0.42 | 42$^{n}$ |
| Dichlorobenzenes | T | L | T | L | L | T$^{a}$ | SI | T | SI | T | L |
| | - | 2 | - | - | - | 0.01 | - | 0.01$^{b}$ | 50 | - | - |
| | NR | MAR | NR | MAR | MAR | NR | MAR | | | NR | MAR |
| | - | - | 2.5 | 250$^{d,e}$ | 5.5$^{i}$ | 0.004 | 0.4$^{j,k}$ | | | 0.6-6.7 | 60-670$^{o}$ |
| Trichlorobenzenes | T | L | T | L | L | T$^{a}$ | SI | T | SI | T | L |
| | - | 0.4 | - | - | 0.3 | 0.01 | - | 0.01$^{b}$ | 10 | - | - |
| | NR | MAR | NR | MAR | MAR | NR | MAR | | | NR | MAR |
| | - | - | 0.67 | 67$^{d,f}$ | 6.7$^{i}$ | 0.0024 | 0.24$^{j,l}$ | | | 0.04 | 4$^{p}$ |
| Tetrachlorobenzenes | T | L | T | L | L | T$^{a}$ | SI | T | SI | T | L |
| | - | 0.2 | - | - | 0.3 | 0.01 | - | 0.01$^{b}$ | 2.5 | - | - |
| | NR | MAR | NR | MAR | MAR | NR | MAR | | | NR | MAR |
| | - | - | 0.24 | 24$^{d,g}$ | 7.2$^{i}$ | 7.2E-4 | 0.072$^{j,m}$ | | | 0.016 | 1.6$^{q}$ |
| Pentachlorobenzenes | T | L | T | L | L | T$^{a}$ | SI | T | SI | T | L |
| | - | - | - | - | 0.3 | 0.0025 | - | 0.01$^{b}$ | 1 | - | - |
| | NR | MAR | NR | MAR | MAR | NR | MAR | | | NR | MAR |
| | - | - | 0.075 | 7.5$^{d}$ | 3.0$^{i}$ | 0.003 | 0.3$^{j}$ | | | 0.08 | 8$^{r}$ |
| Hexachlorobenzene | T | L | T | L | L | T$^{a}$ | SI | T | SI | S | G |
| | - | - | - | - | 0.004 | 0.0025 | - | 0.01$^{b}$ | 0.5 | - | - |
| | NR | MAR | NR | MAR | MAR | NR | MAR | | | NR | MAR |
| | - | - | 0.024 | 2.4$^{d}$ | 1.3$^{h}$ | 0.013 | 1.3$^{h}$ | | | 0.023 | 2.3$^{s}$ |

a Target value for standard soil and sediment

b Detection limit.

c Target value below detection limit (no numerical target in MILBOWA).

MARs: all indicate and other MARs in the table are listed in reference 4. The information in the footnotes below about the determination of these MARs are largely based on the reports used for reference for, i.e. references 2 and 3. You are referred to these reports for further details.

d MAR surface water, all substances: QSAR method, based on the minimum toxicity (narcotic effect)$^{2}$.

Combined value, based on v.d. Plassche [1993b]. Based on 210 μg/l for 1.3-DCB, 260 μg/l for 1.4-DCB and 270 μg/l for 1.2-DCB, from v.d. Plassche [1993a].

f Combined value, based on v.d. Plassche [1993b]. Based on 64 μg/l for 1.2.3-TCB, 79 μg/l for 1.2.4-TCB and 57 μg/l for 1,3,5-TCB, from v.d. Plassche [1993a]

g Combined value, based on v.d. Plassche [1993b]. Based on 23 μg/l for 1.2.3.4-TeCB, 22 μg/l for 1.2.3.5-TeCB and 26 μg/l for 1.2.4.5-TeCB, from v.d. Plassche [1993a],

*pm1. In the criteria document, based on the results of the modified EPA method, using NOEC and L(E)C50 values for the individual substances, the following MARs were determined for chlorobenzenes in surface water: 30 μg/l for MCB, 20 μg/l for DCB, 10 μg/l for TCB, 5 μg/l for TeCB, 2.5 μg/l for PeCB and 0.2 μg/l for HCB. The fact that toxicity generally increases with the level of chlorination was taken into account$^{1}$.*

*pm2. In reference 20 an MAR for surface water was derived for 1.2.4-TCB amounting to 44 μg/l· "refined effect assessment" method (conf. Aldenberg and Slob, 1991), based on NOEC values for fresh water organisms.*

h MAR sediment and MAR soil/sediment (MCB; HCB): indicative values (equilibrium partition method, based on the MAR for surface water).

i MAR sediment (DCB, TCB, TeCB, PeCB): indicative values (equilibrium partition method, based on the MAR for surface water).

j MAR soil (DCB, TCB, TeCB, PeCB): indicative values (modified EPA method, based on the L(E)C50 for soil organisms)

k Combined value, from v.d. Plassche [1993b]. Deemed to be equal to the value for 1.4-DCB, from v.d. Plassche [1993a].

l Combined value, from v.d. Plassche [1993b]. Based on 0005 mg/kg for 1.2.3-TCB, 0.1 mg/kg for 1.2.4-TCB and 0.6 mg/kg for 1.3.5-TCB, from v.d. Plassche [1993a].

m Combined value, from v.d. Plassche [1993b]. Based on 0.2 mg/kg for 1.2.3.4-TeCB, 0.007 mg/kg for 1.2.3.5-TeCB and 0.01 mg/kg for 1.2.4.5-TeCB, from v.d. Plassche, 1993a].

*pm The indicative MARs for soil for the various chlorobenzenes based on the toxicity data for soil-dwelling organisms are identical to the values in the criteria document.*

n MAR atmosphere (MCB) = indicative MAR$_{human}$ = 42 µg/m$^3$, based on mammalian inhalation studies; Indicative MAR$_{eco}$ = 1.900 µg/m$^3$ (modified EPA method, based on mammalian data)$^3$.

o MAR atmosphere (DCB):

1.2-DCB: indicative MAR$_{human}$ = 60 µg/m$^3$, based on mammalian inhalation studies; indicative MAR$_{eco}$ = 1.900 µg/m$^3$ (modified EPA method, based on mammalian data)$^3$.

*pm In reference 15 an ACA (equivalent to MAR$_{human}$) for 1.2-DCB was derived of 600 µg/m3.*

1.4-DCB: indicative MAR$_{human}$ = 670 µg/m$^3$, based on mammalian inhalation studies; indicative MAR$_{eco}$ = 300 µg/m$^3$ (modified EPA method, based on mammalian data)$^3$.

*pm In reference 15 an ACA (equivalent to MAR$_{human}$) for 1.4-DCB was derived of 1,200 µg/m3.*

p MAR atmosphere (TCB): indicative MAR$_{human}$ = 4 µg/m$^3$, based on mammalian inhalation studies; the relevant isomer was not identified); no MAR$_{eco}$ was derived for TCB$^3$

q MAR atmosphere (TeCB) = indicative MAR$_{human}$ for 1.2.4.5-TeCB = 1.6 µg/m$^3$, based on the NOAEL from an oral exposure study using mammals; no MAR$_{eco}$ was derived for TeCB$^3$.

r MAR atmosphere (PeCB) = indicative MAR$_{human}$ = 8, no MAR$_{eco}$ was derived for PeCB$^3$.

s MAR atmosphere (HCB): indicative MAR$_{human}$ = 2.3 µg/m$^3$, based on the NOAEL from an oral exposure study using mammals; no MAR$_{eco}$ was derived for HCB $^3$.

pm v.d. Plassche [1994] derived the following indicative MARs and NRs for pentachlorobenzene (PeCB) and hexachlorobenzene (HCB), based on indirect effects (toxic effects through the food chain):

| | |
|---|---|
| PeCB: | |
| MAR or NR water: | 0.03 or 0.0003 µg/l (250 times lower than the corresponding value in the table) |
| MAR or NR sediment: | 0.012 or 0.00012 mg/kg dm (250 times lower than the corresponding value in the table) |
| MAR or NR soil: | 0.12 or 0.0012 mg/kg dm (2.5 times lower than the corresponding value in the table) |
| HCB: | |
| MAR or NR water: | 0.0021 or 0.000021 µg/l (1.100 times lower than the corresponding value in the table) |
| MAR or NR sediment: | 0.0012 or 0.000012 mg/kg dm (1.100 times lower than the corresponding value in the table) |
| MAR or NR soil: | 0.028 or 0.00028 mg/kg dm (50 times lower than the corresponding value in the table) |

## 2.4 DICHLOROETHANE

### *2.4.1 Problem definition and risk assessment*

1,2-dichloroethane is manufactured in the Netherlands and is used in the chemical industry as an intermediary in vinylchloride production. This substance is also used in the pharmaceutical (drugs and bandages) and rubber industries. Until recently, dichloroethane was used for cleaning electronic components and as a soil sterilisation agent (nematodicide). Its use as a scavenger in leaded petrol is falling. At present most of the emissions are due to the chemical industry, including the pharmaceutical industry (approx. 10 sources). In the period 1981-1988 the atmospheric emissions due to point sources rose by a factor of about 3.

According to the 1984 criteria document the NR$_{atmosphere}$ is occasionally exceeded by a factor of 10 in the vicinity of industrial point sources and petrol stations and in cities. The MAR$_{atmosphere}$ is never exceeded in the indoor or outdoor environment. The calculated annual concentrations for 1984 in the vicinity of EDC production plants slightly exceeded the NR at a distance of 4 km and exceeded it by more than 10 times at a distance of 1 km.

There is insufficient information on the concentrations in the soil and groundwater to assess environmental risks. However, given the volatility of 1,2-dichloroethane it is to be expected that the concentrations will not be high. The average concentrations in the surface water are below the detection limit. There are no targets and limits for surface water. It is likely that the MAR is not exceeded. There is no recent data on the presence of 1,2-dichloroethane in watercourse sediments.

There is sufficient evidence of the carcinogenicity and genotoxicity of 1,2-dichloroethane in laboratory animals, although there is no data on human effects. 1,2-dichloroethane should be considered as a potential human carcinogen after inhalation or oral exposure. Exposure is generally by inhalation. The intake through water and, probably, through food is relatively low. The acceptable daily intake is not exceeded.

### *2.4.2 Recommendations for further research, and conclusions*

There are a limited number of old measurements of 1,2-dichloroethane concentrations. Thus, the current environmental quality is uncertain. It would be advisable to investigate exposure concentrations in the vicinity of the emission sources. The target for atmospheric concentrations is exceeded in the vicinity of industrial point sources. The atmospheric MAR concentration is not exceeded. As the recommended limit is not exceeded, the risks to humans are considered to be limited. In the view of the RIVM, 1,2-dichloroethane should be maintained as a priority substance in view of the exceedance of targets and NR levels.

The report on substances demanding special attention suggests that the continuing emissions from the chemical industry could be reduced through the environmental licensing procedures. TNO and CML concluded that emissions from the most important point sources have been reduced considerably by comparison with 1990 and that further reductions for the year 2000 have been agreed within the IMT framework. Within the constraints of the present study it was not possible to investigate whether such measures will ensure that the NR will not be exceeded in the future.

Table 2.4.1 lists the Netherlands environmental quality objectives and requirements for this substance [Janus, 1994].

*Table 2.4.1: Environmental quality objectives and requirements: targets and limits (T,L), negligible risk levels/maximum acceptable risk levels (NR, MAR) and soil remediation intervention values (SI)*

| Substance | Surface water<br>Total<br>µg/l | Dissolved<br>µg/l | Sediment (newly dep.)<br>mg/kg dm | Soil/ Sediment<br>mg/kg dm | Groundwater (dissolved)<br>µg/l | Atmosphere<br>µg/m$^3$ |
|---|---|---|---|---|---|---|
| 1,2-dichloroethane | T L<br>- -<br>NR MAR<br>- - | T L<br>- -<br>NR MAR<br>7[c] 700[c] | L<br>-<br>MAR<br>1.5[d] | T SI<br>-[a] 4<br>NR MAR<br>0.015 1.5[d] | S SI<br>-[a] 400 | T L<br>1[b] -<br>NR MAR<br>0.48 48[e] |

a. below the detection limit
b. annual average
c. indicative harmonised MAR based on the QSAR approach and a factor of 20
d. derived from MAR$_{surf}$/NR$_{surf}$
e. MAR$_{human}$ from the criteria document, based on animal experiment data, concentration corresponding to a cancer risk of 1.10$^{-4}$ during live[1]. This MAR was also used by Vermeire et al.[14]. The Health Council[15] proposed a value of 100 µg.m$^{-3}$ (corresponding to a cancer risk of 1.10$^{-4}$), based on epidemiological studies.
Rademaker et al. (1993) derived an indicative MAR$_{eco}$ of 20 µg.m$^{-3}$ using a modified EPA method based on a NOAEL of 0.2 mg.m$^{-3}$ (not 2 mg.m$^{-3}$ as listed in Table 4.2) for rates. The final INS report included the MAR suggested by the Health Council (100 µg.m$^{-3}$)[15]. In the INS framework you are referred to Guinée and Blom (1993).

## 2.5 PER

### 2.5.1 Problem definition and risk assessment

PER is widely used in the Netherlands for degreasing metals, in dry cleaning shops, in the graphics industry and in households. PER (tetrachloroethane) emissions are almost exclusively into the atmosphere. In 1990 over 90% of emissions were due to its use for degreasing and cleaning in the mechanical and electrical engineering industries and its use in dry cleaning. PER is considered to contribute to smog forming but its direct human toxicity and ecotoxicity is low. In the soil, PER may be converted anaerobically, via trichloroethylene, to vinylchloride [BUA, 1991].

The average outdoor concentrations of PER in 1991 ranged from 0.18 µg/m$^3$ (rural area) to 0.78 µg/m$^3$ (street)[3] and are therefore considerably below the target and the MAR$_{atmosphere}$. The MAR is exceeded at some locations, mostly near dry cleaning shops and the peak concentrations may be as high as 50 mg/m$^3$ (1984)[6]. It is estimated that in 1984 approximately 10,000 people in the vicinity of dry cleaning shops were exposed to an annual average concentration of 1000 µg/m$^3$ during 8 hours per day, with peak concentrations of up to 50 mg/m$^3$. The TDI (tolerable daily intake) of tetrachloroethane is 16 µg/kg bodyweight·day. The estimated maximum daily exposure of 1.8 µg/kg$_{bodyweight}$ through the atmosphere, water and food did not exceed the TDI. There is no data on concentrations in the vicinity of other emission sources such as the graphics and engineering industries. The MAR is not exceeded in the indoor environment. Phosgene is an important atmospheric degradation product of PER. This substance is extremely toxic and is an initiator of photochemical processes which lead to smog forming and the enhanced greenhouse effect.

Relatively minor emissions into water are caused by metal cleaning operations, deposition and discharges from public sewage works. Since 1986 the PER concentrations in the surface water of the Maas at Eijsden and the Rhine at Lobith have fallen to below 0.4 and 0.2 µg/l [CCRX, 1993]. This does not exceed the NR level. The average measured groundwater concentrations are below the target level. However, there are high local exceedances due to soil contamination. Such historic contamination is beyond the scope of the present study of the chlorine chain.

### 2.5.2 *Recommendations for further research and conclusions*

In the view of the RIVM, PER should continue to be considered as a priority substance as the atmospheric MAR is exceeded, particularly in the vicinity of dry cleaning shops. There is no data on the situation in the vicinity of other emission sources such as the graphics and engineering industries. Further research should provide exposure data obtained near these sources.

The policy on PER is currently being implemented. TNO and CML have concluded that considerable emission reductions relative to 1990 will be realised at the major point sources. This will be due to the Order in Council on Dry Cleaning Shops and the IMT framework for the electrical and mechanical engineering industries. Within the constraints of the present study it was not possible to determine whether such measures will prevent future exceedances of the NR and MAR.

Table 2.5.1 lists the Netherlands environmental quality objectives and requirements for this substance [Janus, 1994].

*Table 2.5.1:* *Environmental quality objectives and requirements: targets and limits (T,L), negligible risk levels/maximum acceptable risk levels (NR, MAR) and soil remediation intervention values (SI)*

| Substance | Surface water<br>Total<br>µg/l | | Dissolved<br>µg/l | | Sediment (newly dep.)<br>mg/kg dm | Soil / Sediment[a]<br>mg/kg dm | | Ground water (dissolved)<br>µg/l | | Atmosphere<br>µg/m³ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| tetrachloroethene | S | G | S | G | S | S | SI | S | SI | S | G |
| | - | - | - | - | - | 0.01 | 4 | 0.01[g] | 40 | 25[e] | 2000[e]<br>8300[f] |
| | NR | MAR | NR | MAR | MAR | NR | MAR | | | NR | MAR |
| | - | - | 3.3[b] | 330[b] | 4.0[h] | 0.0016[c] | 0.16[c] | | | 25 | 2500[d] |

a. Target value and MAR for standard soil (10% organic matter)
b. Indicative MAR and NR based on the QSAR method.
c. Indicative MAR and NR based on the modified EPA method1.
d. MAR human ("effect-based limit value") from the criteria document; based on a NO(A)EC of 135 mg/m$^3$ for humans when exposed at work, divided by an uncertainty factor of 50 (10 intra; 5 (rounded) for the conversion to continuous exposure). Rademaker et al.[1993](INS) derived an indicative MAR human of 6.2 µg/m$^3$ based on the LO(A)EL of 62 mg/m$^3$ and a 30 day inhalation study with mice (continuous exposure) divided by an uncertainty factor of 10.000. It should be noted that Table 5.1 of lists an incorrect indicative MAR of 62 µg/m$^3$.
The indicative MAR$_{eco}$ is 1.200 µg/m$^3$ and is based on the modified EPA method on the basis of the NOAEL for mice. The final report of the INS uses the MAR for the atmosphere, from the criteria document.
The Health Council [1986] also recommended a MAR for the atmosphere of 2500 µg/m$^3$. The NO(A)EC of 135 mg/m$^3$ was converted to continuous exposure (135 • 0.14 = 32 mg/m$^3$). On the basis of a "log resultant variation factor" of 12.8 this resulted in a MAR of 25 mg/m$^3$.
e. Annual average.
f. 98th percentile (hour average)
g. Detection limit
h. Indicative MAR from MAR[illegible] (using Kp 12 l/kg)$^1$

## 2.6 CHLOROFORM

### 2.6.1 *Problem definition and risk assessment*

Most trichloromethane (chloroform) is used for the production of chlorofluorocarbons (CFCs). It is also used as a solvent in the pharmaceutical and bandages industries and as an intermediate in the production of paints and pesticides. The chlorination of swimming pools and drinking water also leads to the formation of trichloromethane. Trichloromethane is also formed by the decomposition of 1,2-dichloroethane in the exhaust fumes of motor vehicles and the decomposition of trichloroethene in the atmosphere. Atmospheric emissions account for the largest part of the overall emissions. The chemical industry in particular is responsible for trichloromethane emissions.

The annual average concentrations in the vicinity of industrial point sources and in swimming pools exceed the MAR. There is no data on local concentrations. It is therefore difficult to assess the actual risks. The target level is frequently exceeded in laboratories, production plants, dwellings, restaurants and shops. A recent risk assessment of chloroform in swimming pools concluded that the TDI (30 µg/kg$_{bodyweight}$·day) was only exceeded in a small group of leading swimmers. Even in these cases it was only exceeded by a factor of 1.5 to 2. As such exposure is only likely to occur during a short period in their lives it is unlikely that it will adversely affect health. Inhalation of the air in swimming pools is the most important form of exposure.

Epidemiological studies suggest a link between bowel cancer in humans and exposure to the by-products of the disinfection of drinking water, which include chloroform, but this cannot be attributed to chloroform. There are no indications of genotoxicity. The average daily exposure in the Netherlands was estimated at 0.4 µg/kg$_{body\ weight}$ [Vermeire, 1991] and the TDI is not exceeded. Recently, a TDI of 15

$\mu g/(kg_{bodyweight} \cdot day)$ was derived in an Environmental Health Criteria document. The average overall intake of the world population was estimated to be at most 2 $\mu g/kg_{bodyweight}$[13]. It was noted that exposure may be higher in the vicinity of industrial point sources, due to increased concentrations in the indoor environment and due to high concentrations in food.

The available data about trichloromethane in the soil is insufficient for a risk assessment. The average concentrations measured during the past 10 years in the Rhine at Lobith and in the Maas at Eijsden ranged between 0.1 and 1.0 µg/l. The NR was not exceeded. The concentrations did not exhibit any discernible trend. There are insufficient recent measurements of the concentration in sediment to assess the risk.

### *2.6.2 Recommendations for further research and conclusions*

The estimated average exposure of the population in the Netherlands and other countries does not exceed the TDI. However, data from other countries suggests that some foodstuffs may contain high trichloromethane concentrations, which may lead to the recommended values being exceeded. Furthermore, the target value, and possibly the MAR, are frequently exceeded in the vicinity of industrial point emission sources and in the indoor environment. The TDI may be exceeded in a very small group of leading competitive swimmers. However, this is unlikely to pose any health risks as the exceedance is limited and does not extent to a full lifetime. Given the above, the RIVM recommends that trichloromethane is maintained as a priority substance.

The application of chloroform in consumer products was prohibited in June 1995 when EC Directive 94/60 on the marketing of dangerous substances and regulations was issued. Within the constraints of the present study it was not possible to investigate whether such measures will prevent the exceedance of the NR and MAR in the future.

Table 2.6.1 lists the Netherlands environmental quality objectives and requirements for this substance [Janus, 1994].

*Table 2.6.1:* *Environmental quality objectives and requirements: targets and limits (T,L), negligible risk levels/maximum acceptable risk levels (NR, MAR) and soil remediation intervention values (SI)*

| Substance | Surface water | | | | Sediment (newly dep.) mg/kg dm | Soil / Sediment mg/kg dm | | Ground water (dissolved) µg/l | | Atmosphere µg/m³ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total µg/l | | Dissolved µg/l | | | | | | | | |
| trichloromethane | T | L | T | L | L | T | SI | T | SI | T | L |
| | - | - | - | - | - | $0.001^e$ | $10^f$ | $0.01^d$ | 400 | 1 | - |
| | NR | MAR | NR | MAR | MAR | NR | MAR | | | NR | MAR |
| | - | - | $5.9^a$ | $590^a$ | $1.9^b$ | $0.019^b$ | $1.9^b$ | | | 1 | $100^c$ |

a. The QSAR method was used by v.d. Plassche et al.[1993b] (INS) to derive a MAR and NR for surface water of 5900 and 59 µg/l. To harmonise the parameters, the final INS[17] report used a "modification factor" of 10, resulting in a MAR and NR for surface water of 590 and 5.9 µg/l

b. A MAR and NR are derived in the final report of the INS [v.d. Plassche 1993b] for soil/sediment and sediment, based on the harmonised MAR and NR surface water.

c. $MAR_{human}$ (criteria document) based on a chronic NO(A)EL for rats using a safety factor of 1.000[1]. Rademaker et al.[1993] (INS) derived an indicative $MAR_{human}$ of 13 µg/m³ based on the same NOAEL for rats, but with a conversion to continuous exposure (safety factor 1.000)[7]. However, the final INS report uses a MAR of 100 µg/m³. The indicative $MAR_{eco}$ is 430 µg/m³, also based on a NOAEL for rats (modified EPA method)[7].

d. Equal to the detection limit

e. Target value for standard soil (10% organic matter)

f. Intervention value for standard soil (10% organic matter, 25% argillaceous material)

## 2.7 DIOXINS

### 2.7.1 *Problem definition and risk assessment*

The major emission sources in the Netherlands of halogenated dibenzodioxins and dibenzofurans (dioxins) are chemical waste incinerators, cable burning operations, evaporation from wood treated with pentachlorophenol and the primary metals industry.

At the current exposure levels neither children nor adults are expected to suffer adverse effects due to dioxin intake with food or other local sources. The recommended value is exceeded in nursing babies. However, at present there is insufficient data for an effective assessment of the risks posed by dioxin in breast milk. At the current exposure levels the risks to ecosystems are considered to be limited, except locally in heavily polluted ports. Bioaccumulation is viewed as the most critical effect as predators might suffer adverse effects.

No environmental quality standards for air have been set. The MAR ecosystem for the soil is not exceeded anywhere in the Netherlands. The MAR for nematode eating predators corresponds to the background level in the Netherlands and Europe. In the vicinity of waste incinerators and locations where cable is illegally burned to remove insulation the MAR for predators is locally exceeded by a factor of 8-80 or 300. Regionally and locally (near waste incinerators) there are probably unacceptable risks to predators feeding on nematodes. However, there are uncertainties in the MAR for predators and uncertainty that contaminated areas correspond to the areas where predators feed.

The concentration in sediment is not regularly monitored. Generally, the MAR for ecosystems is not exceeded in the Netherlands, except in some heavily polluted docks. In 1983-1985 the MAR for predators feeding on fish was exceeded in the sediment of most watercourses. In the estuaries and marine environment in the period 1987-1990 the concentrations were around the MAR for predators. Nationally and locally there may be an unacceptable risk to predators feeding on fish. However, the uncertainties are the same as those with respect to nematode eating predators, as discussed above.

As discussed in the problem definition, the recommended level is exceeded during the period that babies are breast fed. The RIVM has stated that the TDI is exceeded by a factor of 15. However, according to the WHO, the TDI is not applicable during short-term exposure. In its report on substances demanding special attention the RIVM stated that, at present, there is insufficient data for an effective assessment of the potential risks of dioxins in breast milk [Janus et al., 1994]. The Health Council saw no reason to advise against breast-feeding, but it also considered further epidemiological studies into the effects of dioxins on nursing babies to be necessary.

TNO and CML concluded that in the near future considerable emission reductions relative to 1990 will be made at the major point sources. Within the constraints of the present study it was not possible to study to what extent such measures will affect the risk assessment above.

### 2.7.2 *Recommendations for further research, and conclusions*

According to the RIVM, dioxins should continue to be considered as priority substances. The TDI is not exceeded in children and adults. Given the outcome of recent studies it may be necessary to re-evaluate the tolerable daily intake of dioxins. According to the RIVM there is insufficient information available at present to assess the potential risk of dioxins in breast milk [Janus, 1994]. The MAR for terrestrial and aquatic ecosystems is hardly exceeded. However, it is likely that there are risks to predators feeding on nematodes or fish given the exceedance of the $MAR_{predator}$ in the soil and sediment. Further research should be carried out to determine the risks related to the exposure of nursing babies, emission reduction technology and determining the potential effects on ecosystems.

Table 2.7.1 lists the Netherlands environmental quality objectives and requirements for this substance [Janus, 1994].

*Table 2.7.1: Environmental quality objectives and requirements: targets and limits (T,L), negligible risk levels/maximum acceptable risk levels (NR, MAR) and soil remediation intervention values (SI)*

| Substance | Surface water<br>Total<br>ng/l | | Dissolved<br>ng/l | | Sediment<br>(newly dep.)<br>mg/kg dm | Soil /<br>Sediment<br>mg/kg dm | | Ground water<br>(dissolved)<br>µg/l | Atmosphere<br>µg/m³ |
|---|---|---|---|---|---|---|---|---|---|
| 2,3,7,8-TCDD [f] | T | L | T | L | L | T | SI | T SI | T L |
| | - | - | - | - | - | - | - | - - | - - |
| | NR | MAR | NR | MAR | MAR | NR | MAR | | NR MAR |
| | 1.2E-4 | 1.2E-2[a] | 1.2E-5 | 1.2E-3[a] | 3.8E-4[c] | 5E-3 | 0.5[a] | | - - |
| | 5E-6 | 5E-4[e] | 5E-7 | 5E-5[b] | 1.5E-5[d] | 3E-8 | 3E-6[b] | | |

a. indicative MAR ecosystem, calculation based on the EPA method
b. indicative MAR predator, calculated cf. Romijn et al. (1991) and as described in RIVM (1993)
c. indicative MAR sediment: equilibrium partition method - based on MAR ecosystem (dissolved fraction).
d. indicative MAR sediment: equilibrium partition method - based on MAR predator (dissolved fraction) 1
e. based on MAR ecosystem (dissolved), Kp= 315000 l/kg and 30 mg suspended matter/l
f. for other PCDD and PCDF a conversion can be made with the I-TEF to the I-TEQ concentration

## 2.8 DICHLOROMETHANE

### 2.8.1 *Problem definition and risk assessment*

Dichloromethane (DCM) is used as a propellant in spray cans, solvent, paint stripper, degreasing agent, extraction agent and cleaning agent. It is also used in fibre production and surface treatment of plastics. The major industrial sources are the chemical and pharmaceutical industries. Diffuse releases of dichloromethane are related to the use of spray cans and paint strippers.

Locally, in the vicinity of 5 to 10 plants, the annual average DCM concentrations exceed the target value [BKH, 1993]. In recent years the concentrations around these plants have remained constant. It is likely that the number of plants releasing DCM will fall. Between 1984 and 1988 the atmospheric releases of dichloromethane fell by about 50%. This was largely due to emission reductions in industry related to the measures referred to earlier. However, diffuse emissions are likely to rise in the coming years due to the replacement of CFCs by DCM in plastic foam manufacturing under the CFC Action Programme. The substance will also increasingly be used as a replacement for other chlorinated hydrocarbons[2].

In the indoor environment, during paint stripping operations, maximum concentrations of 3000 $\mu g \cdot m^{-3}$ to 9000 $\mu g \cdot m^{-3}$ have been measured [10]. These exceeded the $MAR_{air}$ and the 5-minute average MAR of 490 $mg \cdot m^{-3}$ and the MAC of 350 $mg \cdot m^{-3}$ (8-hour average). Local, increased concentrations may also occur when spray cans are used in hairdressing salons and at home [BKH, 1993].

A significant quantity of DCM enters the environment through sewage sludge and the use of paint strippers by DIYers. However, no data is available about the concentrations which occur in soil and groundwater. It is not possible to make a risk assessment. Dichloromethane emissions to surface waters and sediment are very low, less than 3% of the total emissions. From 1985 to 1988 emissions to water were reduced by about 50%. In 1990 the concentrations measured by the RIWA were all below the target of 0.5 $\mu g \cdot l^{-1}$. The highest values measured in 1980 were 5 $\mu g \cdot l^{-1}$ [BKH, 1993]. There is little data on the expected risks.

Acute human toxicity is low. Exposure to dichloromethane reduces the oxygen-carrying capacity of the blood. The central nervous system may also be affected. The TDI according to the criteria document was 60 µg per kg bodyweight. Dichloromethane intake will largely be by inhalation. The daily intake is estimated at 18 µg per kg bodyweight, the TDI is not exceeded [Vermeire, 1991].

### *2.8.2 Recommendations for further research, and conclusions*

The RIVM proposed that further research should be carried out into:
- indoor use of DCM, resulting concentrations and exposure periods, effects of ventilation and alternatives to DCM, particularly in spray cans;
- cumulative effects of DCM and substances acting similarly, on the basis of which emission reduction measures might be considered in view of the low costs and limited economic impact;
- it is considered desirable to investigate the effect of the Hydrocarbons 2000 project and the CFC action programme on the emissions of chlorinated hydrocarbons.

The environmental risks of CDM are considered to be minor, except in the indoor environment and possibly in the vicinity of sources. In the indoor environment the $MAR_{air}$ is exceeded due to the use of spray cans and paint strippers (diffuse sources). No policy has been drawn up on paint strippers. There is an emission reduction target for spray cans. The $NR_{air}$ is exceeded in the vicinity of sources. Within the frameworks of various IMTs reduction targets amounting to reductions of approx. 80% relative to 1985 have been set. Within the constraints of the present study it was not possible to determine whether or not these measures will prevent exceedance of the NR and MAR in future. The RIVM is of the opinion that dichloromethane should remain on the list of priority substances.

In the view of the RIVM the overall atmospheric emission reduction target of 80% will not be reached without the introduction of further measures.

Table 2.8.1 lists the Netherlands environmental quality objectives and requirements for this substance [Janus, 1994].

*Table 2.8.1:* *Environmental quality objectives and requirements: targets and limits (T,L), negligible risk levels/maximum acceptable risk levels (NR, MAR) and soil remediation intervention values (SI)*

| Substance | Surface water<br>Total<br>μg/l | | Surface water<br>Dissolved<br>μg/l | | Sediment (newly dep.)<br>mg/kg d.s. | Soil / Sediment<br>mg/kg d.s. | | Ground water (dissolved)<br>μg/l | | Atmosphere<br>μg/m$^3$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| dichloromethane | T<br>-$^a$<br>NR<br>- | L<br>-$^a$<br>MAR<br>- | T<br>-<br>NR<br>200$^f$ | L<br>-<br>MAR<br>20.000$^f$ | L<br>-<br>MAR<br>36$^g$ | T<br>-$^b$<br>NR<br>0.36$^g$ | SI<br>20<br>MAR<br>36$^g$ | T<br>0.01$^c$ | SI<br>1000 | T<br>20$^d$<br>NR<br>17 | L<br>MAR<br>1,700$^e$ |

a In "Stoffen en Normen", based on the target value in the atmosphere (20 μg.m$^{-3}$), a limit and target for surface water was derived of 0.5 μg.m$^{-3}$ [VROM, 1993f]

b target value below detection limit

c detection limit

d annual average

e MAR derived from a chronic inhalation study with rats by applying a safety factor of 100 to the NOAEL of 173 mg.m$^{-3}$ $^{1}$. In Rademaker et al. [1993] (INS) reference is made to an indicative MAR$_{human}$ of 300 μg.m$^{-3}$. This MAR was based on the same NOAEL, but a correction was made for continuous exposure. The indicative MAR$_{eco}$ is 12 mg.m$^{-3}$ and is based on a NOAEL for mice, using the modified EPA method. The final report of INS$^{14}$ used the MAR in the criteria document (1700 μg.m$^{-3}$).

f QSAR method

g derived from MAR$_{water}$/NR$_{water}$

## 2.9 TRICHLOROETHENE

### 2.9.1 Problem definition and risk assessment

The primary source of trichloroethene emissions to the atmosphere is its use as a cleaning and degreasing agent in the metal and plastics industries. The second large emission volume is its use in textile finishing operations. Prolonged exposure to trichloroethene may affect the human central nervous system. Trichloroethene may lead to odour nuisance. Trichloroethene has a low toxicity to aquatic organisms and is easily degraded in the environment. However, it is still found after decades at former dry cleaning shops. In the soil this substances can be converted anaerobically to vinylchloride.

The average atmospheric concentrations measured in 1991 ranged from 0.18 µg/m³ (rural) to 0.95 µg/m³ (street in Apeldoorn). It was calculated that in 1984 some 14,000 persons in the vicinity of the largest point source were exposed to average concentrations of 10 µg/m³ with peaks of 10 mg/m³. There is no recent information on concentrations in the vicinity of plants emitting this substance. Calculations show that the target value (annual average) is not exceeded in the vicinity of large plants. At smaller plants it is not clear if, and to what extent, the target value is exceeded in the vicinity of smaller plants. The MAR is not exceeded in dwellings. During degreasing operations, employees may be exposed to concentrations ranging from tens to hundreds of mg/m³. The MAC is 190 mg/m³. The odour threshold is approximately 50 mg/m³.

In 1987 the highest trichloroethene concentrations in groundwater were 500 times the target value. This was probably due to local soil contamination. Such historical emissions lie outside the scope of this study. In a recent study, the RIVM stated that without the introduction of additional policies, the diffuse soil contamination due to this substance will be such that the limit value for soil will be exceeded. This pollution is largely due to deposition, some of which comes from other countries [Lijse, 1995]. There is no measurement data obtained after 1987. Emissions into the water environment are relatively limited. The annual average concentrations in the Rhine at Lobith and the Maas at Eijsden in 1991 were lower than 1 µg/l. As far as we are aware the limit value and MAR were not exceeded. Risks to humans and the environment are considered to be low.

A large proportion of the trichloroethene inhaled by humans is exhaled, the remainder is metabolised and excreted through the kidneys. The central nervous system is affected after prolonged exposure to higher concentrations. The average daily intakes through drinking water, food and air are estimated at 2, 1-7 and 13 µg per day. On average, the TDI of 540 µg per kg bodyweight per day is not exceeded.

### *2.9.2 Recommendations for further research and conclusions*

The risks to the population associated with trichloroethene are considered to be low. New data will have to be obtained on exposure in the vicinity of emission sources. Without the introduction of supplementary policies the limit value for soil will be exceeded due to diffuse pollution.

TNO and CML concluded that in the near future considerable emission reductions relative to 1990 will be made at the major point sources. Part of this emission reduction will be due to the various IMTs. Within the constraints of the present study it was not possible to determine whether such measures will ensure that future exposure levels remain below the NR and MAR. According to the RIVM, trichloroethene should remain on the list of priority substances.

Table 2.9.1 lists the Netherlands environmental quality objectives and requirements for this substance [Janus, 1994].

*Table 2.9.1: Environmental quality objectives and requirements: targets and limits (T,L), negligible risk levels/maximum acceptable risk levels (NR, MAR) and soil remediation intervention values (SI)*

| Substance | Surface water Total µg/l | | Surface water Dissolved µg/l | | Sediment (newly dep.) mg/kg dm | Soil / Sediment mg/kg dm | | Ground water (dissolved) µg/l | | Atmosphere µg/m³ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| trichloroethene | S | G | S | G | S | S | SI | S | SI | S | G |
| | - | 2 | - | - | - | 0.001$^d$ | 60 | 0.01$^g$ | 500 | 50$^e$ | 50$^{e,f}$ |
| | NR | MAR | NR | MAR | MAR | NR | MAR | | | NR | MAR |
| | - | - | 24$^a$ | 2400$^a$ | 13$^b$ | 0.13$^b$ | 13$^b$ | | | 19 | 1900$^c$ |

a. Indicative MAR and NR, based on the QSAR method.
In Emans [1992], a MAR surface water of 2,100 $\mu g/m^3$ was derived: "refined effect assessment-"method (cf. Aldenberg and Slob, 1991, based on NOEC values for fresh water organisms.

b. Indicative MAR and NR sediment, derived from $MAR_{surf}$ and $NR_{surf}$ using the equilibrium partition method (Kp 5.5 l/kg)[7,17].

c. $MAR_{human}$ from the criteria document; derived on the basis of an NO(A)EL of 189 $mg/m^3$ from inhalation studies with various species (continuous exposure for 90 days) and a safety factor of 100. Rademaker et al.[6] (INS) derived an indicative $MAR_{human}$ of 190 $\mu g/m^3$, based on the same NOAEL for animal experiments, but using an additional safety factor of 10 for conversion from subchronic exposure to chronic exposure
The indicative $MAR_{eco}$ (INS)[6] is 7600 $\mu g/m^3$ and was derived on the basis of the modified EPA method based on an LC50 for mice. In the final report of the INS[17], a MAR for the atmosphere of 5 $mg/m^3$ was used, obtained from a memorandum by Guinée and Blom [1993].
On the basis of epidemiological studies the Health Council set a recommended value of 5 $mg/m^3$ for the outdoor atmosphere (annual average). An NO(A)EL of 270 to 540 $mg/m^3$ was derived from epidemiological studies. Conversion to continuous exposure resulted in 64 $mg.m^3$. This concentration was divided by "log resultant variation factor" of 12.8 to obtain 5 $mg/m^3$.

d. standard soil (10% organic matter).

e. annual average.

f. The limit value, 98th percentile, is 300 µg/m3

g. detection limit.

## 2.10 VINYLCHLORIDE

### *2.10.1 Problem definition and risk assessment*

In the Netherlands vinylchloride is used in the production of polyvinylchloride (PVC). Emissions are almost exclusively into the atmosphere. There is no recent concentration data. In 1984, the target value for the atmosphere was locally exceeded, in the vicinity of industrial point sources. Under anaerobic conditions vinylchloride may be formed in the soil, from trichloroethene or tetrachloroethane.

There is no recent data on vinylchloride concentrations in the Netherlands. Data from 1984 showed that at a distance of 1 to 5 km from the three industrial point sources the annually averaged concentrations were at least 12.5 times lower than the MAR.

The national average background concentration of 0.2 μg/m³ is a factor 5 below the NR and the target value. 90% of the background concentration is due to sources outside the Netherlands.

Emissions into the water environment are negligible. There is no indication that the presence of vinylchloride in environmental media other than the atmosphere could affect health or the environment [BKH, 1993].

Vinylchloride is a genotoxic carcinogen. It is not possible to set a threshold below which the risk of carcinogenicity can be ruled out. The carcinogenic effect occurs after inhalation or oral exposure [Vermeire, 1991]. The average daily oral exposure to vinylchloride is estimated at 59 . The concentration at which there is a risk of one additional cancer per 10,000 persons (lifelong oral exposure) is 3,510 ng/($kg_{bodyweight}$·day) [Vermeire, 1991]. Given this data the public health risks associated with oral and inhalatory exposure (see also *the atmosphere*) are considered to be minor.

### *2.10.2 Recommendations for further research and conclusions*

The risks to the population at large and the environment due to vinylchloride are considered to be minor. In 1984 the atmospheric target level was only exceeded in the vicinity of three industrial point sources. The background concentration is well below the target value and is largely due to sources in other countries. A wide range of measures has been taken to reduce vinylchloride emissions and the use of PVC products. Hence, the RIVM recommends that vinylchloride is removed from the list of priority substances. The study by TNO and CML indicated that by the year 2000 the emissions from the three point sources will be considerably reduced relative to those in 1990.

Table 2.10.1 lists the Netherlands environmental quality objectives and requirements for this substance [Janus, 1994].

*Table 2.10.1:* *Environmental quality objectives and requirements: targets and limits (T,L), negligible risk levels/maximum acceptable risk levels (NR, MAR) and soil remediation intervention values (SI)*

| **Substance** | **Surface water**<br>**Total**<br>**µg/l** | | **Dissolved**<br>**µg/l** | | **Sediment**<br>**(newly dep.)**<br>**mg/kg dm** | **Soil / Sediment**<br>**mg/kg dm** | | **Ground water**<br>**(dissolved)**<br>**µg/l** | | **Atmosphere**<br>**µg/m$^3$** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Vinylchloride | **T** | **L** | **T** | **L** | **L** | **T** | **SI** | **T** | **SI** | **T** | **L** |
| | - | - | - | - | - | - | 0.1[d] | 0.01[c] | 0.7 | 1[e] | - |
| | **NR** | **MAR** | **NR** | **MAR** | **MAR** | **NR** | **MAR** | | | **NR** | **MAR** |
| | - | - | 8.2 | 820[b] | 1.4[f] | 0.014 | 1.4[f] | | | 1 | 100[a] |

a. MAR human proposed by the Health Council, concentration for a risk level of 1.10$^{-4}$ during life (calculation based on epidemiological data). This MAR was also sued by Vermeire et al.[1991], partly in view of the fact that, based on epidemiological data, the WHO also derived a risk of 1.10$^{-4}$ for lifelong exposure to 100 µg.m$^{-3}$. Rademaker et al.[1993] (INS) derived an indicative MAR$_{eco}$ of 600 µg/m$^3$ based on an NO(A)EL of 6 mg/m$^3$ for animal experiments and a safety factor of 10 (modified EPA method). The final report of the INS[12] used a MAR of 100 µg.m$^{-3}$ (in the context of INS reference is made to Guinée and Blom, 1993).
(To avoid any misunderstandings: the MAR in the criteria document i.e. 3.5 µg.m$^{-3}$ (risk level 1.10$^{-4}$) is outdated.

b. V.d. Plassche et al. [1993b] (INS) derived an <u>indicative</u> MAR and NR for surface water of 8200 and 82 µg/l, determined with the QSAR method In view of parameter harmonisation, an "adaption factor" of 10 was used in the final report of the INS which resulted in the above <u>indicative</u> harmonised MAR and NR.

c. Target value below detection limit

d. Standard soil (10% organic matter)

e. Annual average

f. V.d. Plassche et al.[1993b] derived an <u>indicative</u> MAR for soil/sediment of 14 mg/kg dm, based on the MAR$_{surf}$ with Kp 1.7 l/kg$^2$. In view of the harmonisation an "adaption factor" of 10 was used in the final report of the INS[12], resulting in the above MAR and NR. The MAR for sediment (newly deposited) was deemed to be equal to that for soil/sediment.

## 2.11 Epichlorohydrine (ECH)

### *2.11.1 Problem definition and risk assessment*

Epichlorohydrine is largely used as an intermediate in epoxy resin manufacturing. It is produced at one location in the Netherlands. Until recently, ECH was also used in the Netherlands as a raw material in glycerin production, but this use was phased out in the '80s. ECH is manufactured from chlorine and propene. The substance is highly toxic. Animal experiments and limited human exposure data indicate effects on the eyes and skin, central nervous system, alimentary canal, liver and blood. Although the limited epidemiological studies did not support an increased risk of human cancers, one of the studies suggested that there might be a potential risk of lung cancer in employees exposed to ECH. Epichlorohydrine is quickly absorbed through the skin and the alimentary canal and, after inhalation, through the lungs. This is followed by the rapid distribution of the substance throughout the body [Bessemer, 1984].

There is only outdated information about the risks of current emissions to human health. There is no data on the ecotoxicological risks of current emissions. The average daily intake in the Netherlands, based on 1981 emission data, is estimated at less than 1 µg per day. This corresponds to an average atmospheric concentration of less than 0.05 μg/m³. No NR or MAR is known for this substance. Lifelong exposure to 2 μg/m³ will lead to a risk of at most 1 in $10^6$ additional cancers [Besemer et al., 1984].

### *2.11.2 Recommendations for further research and conclusions*

With respect to human health it may be concluded that the general risks are probably low given the minor risks associated with the emissions in 1981 and the fact that emissions have roughly been halved since that time. There is no data on ecotoxicological risks. However, one should be aware that there is no NR or MAR and the available information is out of date. Furthermore, given the available data it is not possible to draw any conclusions with regard to local risks in the vicinity of emission sources.

## 2.12 ALLYLCHLORIDE (AC)

### *2.12.1 Problem definition and risk assessment*

Allylchloride is an intermediate in the manufacture of ECH, the main raw material for epoxy resins. ECH is manufactured at one location in the Netherlands. Allylchloride is a severe irritant to the eyes and respiratory system.

Given a comparison between the NOAEL of 31 mg/m³ and the exposure calculated with USES there could be some cause for concern for human health due to indirect exposure. However, specific data from the plant in Pernis indicates that there is no cause for concern with respect to human health.

General ecotoxicity calculations carried out with USES indicate that there is a potential risk to aquatic organisms (OEC/PNEC ratio of 59). However, specific data on the plant in Pernis indicates that the risk to aquatic organisms is negligibly low (PEC/PNEC ratio < 0.006).

### *2.12.2 Recommendations for further research and conclusions*

Given the data provided by the RIVM it may be concluded that the risks to humans and the environment are low, even in the vicinity of the source [Van Koten-Vermeulen et al., 1994].

## 2.13 MECOPROP (MCPP)[8]

### *2.13.1 Problem definition and risk assessment*

Mecoprop is a systemic herbicide, taken up through the leaves, which is mostly used in grassland, cereal and fruit growing. The active component is Mecoprop-P. The use of the racemic mixture has been prohibited since February 1990, at present only the application of the Mecoprop-P isomer is permitted.

On several occasions, Mecoprop was detected in groundwater near the surface, at a maximum concentration of 2.2 µg/l. On one occasion it was detected in the deep groundwater, at 0.1 µg/l. According to the PESTLA model, Mecoprop does not accumulate in the soil [Linders et al., 1994]. According to this model Mecoprop is leached into the groundwater near the surface, resulting in concentrations up to 100 µg/l [Tuinstra and Linders, 1991]. Mecoprop is regularly detected in the groundwater near the surface where the concentrations are at or below the indicative NR of Mecoprop in surface water. Hence the risk to groundwater organisms is considered to be negligible. (There is no NR or MAR for groundwater.)

In 1992 and 1993 Mecoprop was repeatedly detected in a number of fresh water and saltwater surface waters, both regional and national waterways. In regional waters the indicative NR level was exceeded up to 4-29 times [Maenhout, 1992, cited in Teunissen-Ordelman et al., 1994; Geenen and Van der Geest, 1995; Hoogheemraadschap van Rijnland, 1993]. In national waterways the NR level was exceeded by a factor 2 at most [Van Meerendonk et al., 1994; Geenen et al., 1995]. The indicative MAR for surface water was never exceeded. Mecoprop has been detected in rainwater [average: 0.23 µg/l, max. 1 µg/l; Heemraadschap Fleverwaard, cited in RIZA, 1994; Teunissen-Ordelman et al., 1994]. Given both the vapour pressure and the Henry coefficient its evaporation is limited [Tuinstra and Linders, 1991]. Occasional tests for the presence of Mecoprop in sediment have been carried out (e.g. in Flevoland), but the substance was never detected [Teunissen-Ordelman et al, 1994]. There is no acceptable daily intake (ADI) for Mecoprop or Mecoprop-P. However, the RIVM/ACT has undertaken a toxicological evaluation. A further assessment of the risk to humans is not possible given the lack of exposure date. Given the pesticides approval procedure the risk to humans is considered to be low to negligible.

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[8] Janus et al., 1995.

### *2.13.2 Recommendations for further research and conclusions*

The RIVM suggested that Mecoprop-P should continue to be considered as a substance demanding special attention as the desirable environmental quality has not yet been realised, at least not in surface waters. The indicative NR level is exceeded, particularly in regional watercourses. It is recommended that further research is undertaken on the occurrence and fate of Mecoprop in the soil (groundwater) and atmosphere (rainwater). In the context of groundwater, its suspected main metabolite, 2-methyl-4-chlorophenol, should also be considered. The MAR for surface water should be better supported, at present only an indicative value has been obtained. The current surface water (national and regional watercourses) and groundwater monitoring programmes should be continued and should be supplemented with measurements in regional watercourses in the Province of Limburg where the substance is used extensively. Given the fact that the indicative NR level in surface water is exceeded and the need for national policies (based on its use in the Netherlands) and international policies (transfrontier influx) to reach the required surface water environmental quality it is proposed that Mecoprop-P should be included on the national list of priority substances. If the current policies, such as the Multi-Year Crop Protection Plan, lead to sufficient emission reductions it will not be necessary to place this substance on the list of priority substances.

## 2.14 MCPA[9]

### *2.14.1 Problem definition and risk assessment*

MCPA is a systemic herbicide, taken up through leaves and roots, which is mostly used in grassland farming. This herbicide is also used in cereal and potato production, fruit and asparagus growing and for the maintenance of public greenery.

There are no measurements of MCPA levels in the soil. According to the PESTLA model, MCPA can accumulate in the soil to concentrations equivalent to at most 0.2% of the dose applied and may leach to the groundwater near the surface in concentrations of at most 5 µg/l [Linders et al., 1994]. The presence of MCPA in deep groundwater has occasionally been investigated, it was only detected on a few occasions, the maximum concentration was 0.8 µg/l [Teunissen-Ordelman et al, 1994; Tas and Tibosch, 1995]. This maximum concentration remains below the indicative NR level of MCPA in surface waters. The risk it poses to groundwater organisms is therefore considered to be negligible. There is no MAR or NR level for groundwater.

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[9] Janus et al., 1995

In 1992 tests on MCPA in the deep groundwater were undertaken at several locations, the substance was never detected [Boland et al, 1994].

In 1992 and 1993 MCPA was repeatedly detected in a number of fresh water and saltwater surface waters, both regional and national waterways [Van Meerendonk et al., 1994; Geenen et al., 1995; Geenen and Van der Geest, 1995; Hoogheemraadschap van Rijnland, 1993; Hoogheemraadschap van Rijnland, 1994; Van Beersum, 1990; cited in RIZA, 1994; Teunissen and Ordelman, 1994]. In regional waters the indicative NR level was exceeded up to 2-12 times (with outliers of up to 80 times, in ditches adjacent to sprayed land). In national waterways the NR level was exceeded by a factor 2 at most, at locations where regional waterways joined national waterways. The indicative MAR for surface water was never exceeded. MCPA has been detected in rainwater (max. 0.2 µg/l). There have been some investigations for the presence of MCPA in sediment (Flevoland), the substance was never detected [Teunissen and Ordelman, 1994].

The RIVM determined the acceptable daily intake of MCPA as 0.0015 mg/kg bodyweight per day (documentation RIVM/ACT). The risks to humans could not be assessed due to the lack of exposure data. Given the pesticides approval procedure this risk is considered to be low to negligible.

### *2.14.2 Recommendations for further research and conclusions*

The RIVM suggested that MCPA should continue to be considered as a substance demanding special attention as the desirable environmental quality has not yet been realised, at least not in surface waters. The indicative NR level is exceeded in regional watercourses. It is recommended that further research is undertaken on the occurrence and fate of Mecoprop in the soil and groundwater. Its suspected main metabolite, 2-methyl-4-chlorophenol, should also be considered. The MAR for surface water should be better supported, at present only an indicative value has been obtained. The current surface water (national and regional watercourses) and groundwater monitoring programmes should be continued and should be supplemented with measurements in regional watercourses in Limburg and the Noordoostpolder where the substance is used extensively. Given the fact that the indicative NR level in surface water is exceeded and the need for national policies (based on its use in the Netherlands) and international policies (transfrontier influx) to reach the required surface water environmental quality it is proposed that MCPA should be included on the national list of priority substances. If the current policies, such as the Multi-Year Crop Protection Plan, lead to sufficient emission reductions it will not be necessary to place this substance on the list of priority substances.

## 2.15 DICHLORVOS

### *2.15.1 Problem definition and risk assessment*

Dichlorvos is an agricultural pesticide (greenhouses, mushroom and chicory production). It is also used as a veterinary medicine. Compared with 1990 and 1991, dichlorvos was measured much more frequently and in higher concentrations in 1992. The concentrations measured in 1992 ranged from 0.01 to 0.7 µg/l. There is no information on its occurrence in the soil. The few measurements of groundwater did not indicate the presence of dichlorvos. The atmospheric deposition in the Netherlands part of the Rhine area is roughly estimated at 0.4 t per year. It is estimated that 36% of this comes from other countries. Dichlorvos has also been detected in rainwater specimens.

The WHO determined the ADI for dichlorvos as 4 µg/kg bodyweight per day. Routine measurements by water companies indicate that the intake of dichlorvos with drinking water is less than 3 ng per kg bodyweight per day. Routine measurements on a range of food crops by the Commodity Inspectorate indicated that dichlorvos is occasionally found in concentrations above the limit set pursuant to the Commodities Act. It is likely that exposure to dichlorvos through food or drinking water does not pose a health hazard to the population in general.

As dichlorvos is not routinely monitored by water quality managers, no data is available. Dichlorvos is included on the list of recommendations requesting water quality managers to regularly monitor a range of pesticides. Dichlorvos is included on List I of the Third Policy Document on Water Management.

MARs and NRs for surface water, sediment and the soil will be determined in 1994, as part of the Integrated Standards project. At a later stage these values could be used to revise the limit and target values.

### *2.15.2 Recommendations for further research and conclusions*

The RIVM proposes that dichlorvos should continue to be considered as a substance demanding special attention as a risk assessment is not feasible given the lack of NR and MAR levels and the limited exposure data (except on surface waters). Initially, further activities will be limited to monitoring surface waters (national and regional watercourses) and soil survey measurements (soil and groundwater), while awaiting the definition of MAR levels. Atmospheric surveys may also be desirable.

Table 2.15.1 lists the Netherlands environmental quality objectives and requirements for this substance [Janus, 1994].

*Table 2.15.1:* *Environmental quality objectives and requirements: targets and limits (T,L), negligible risk levels/maximum acceptable risk levels (NR, MAR) and soil remediation intervention values (SI)*

| Substance | Surface water |  |  |  | Sediment (newly dep.) | Soil / Sediment |  | Ground water (dissolved) |  | Atmosphere |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Total<br>µg/l |  | Dissolved<br>µg/l |  | mg/kg dm | mg/kg dm |  | µg/l |  | µg/m³ |  |
| dichlorvos | T | L | T | L | L | T | SI | T | SI | T | L |
|  | - | 0.002 | - | - | - | < d.l.[a] | - | < d.l.[a] | - | - | - |
|  | NR | MAR | NR | MAR | MAR | NR | MAR |  |  | NR | MAR |
|  | - | - | - | - | - | - | - |  |  | - | - |

a) VROM [1992] listed target values: < d.l. (below the detection limit; not numerically defined) for soil/sediment and ground water.

## 2.16 ATRAZINE

### 2.16.1 Problem definition and risk assessment

Atrazine is a herbicide used in agriculture, specifically in maize production, but also in vegetable, bulb and fruit production. At some locations the indicative MAR level is slightly exceeded in the soil. Atrazine is found in the groundwater near the surface and in deeper groundwater, particularly where maize is grown on sandy soil. Although the intervention value for soil is not exceeded, there are some locations where the target value is exceeded. Measurements in the major rivers (Rhine, Schelde) suggest that there is an influx of the substance across the border. However, at the border even the highest concentrations only exceed the NR level. Measurements by RIZA/RIKZ, RIWA and measurements in the framework of SIVECOM in 1990, 1991 and 1992 did not indicate exceedance of the MAR level in national watercourses, but the NR level was frequently exceeded. The few measurements of atrazine in regional watercourses indicate that the MAR level is occasionally exceeded. To data atrazine has not been detected in watercourse sediments. However, the substance has been detected in rainwater.

Its metabolites, desethyl-atrazine and desisopropyl-atrazine, have been detected in the soil and in groundwater. In addition to these two metabolites, desethyl-desisopropyl-atrazine, another metabolite, has also been detected in groundwater. One should be aware that desethyl-atrazine and desisopropyl-atrazine are also simazine metabolites.

Atrazine was recently detected in rainwater, the average concentrations ranged from 0.05 to 0.4 µg/l, the maximum was 0.7 µg/l. In the 1991 "Milieudiagnose" the average deposition was estimated at 8.1 g per hectare.

Vermeire et al. [1991] derived a generic TDI for triazines of 2 µg per kg bodyweight per day, based on data on simazine. It should be noted that there are toxicity data which could be used to determine the specific TDI of atrazine but that this was not done by Vermeire et al. for practical reasons. Routine measurements by drinking water companies indicate that the intake of atrazine with drinking water is less than 3 ng per kg bodyweight per day. Routine tests on a range of food crops by the Commodity Inspectorate indicate that atrazine is only occasionally found in concentrations exceeding the limits set pursuant to the Commodities Act (Residues Order). It is likely that exposure to atrazine through food and drinking water does not pose a health hazard to the general population.

### *2.16.2 Recommendations for further research and conclusions*

The RIVM proposes that atrazine should continue to be considered as a substance demanding special attention as the desired environmental quality has not been reached. This certainly affects surface waters and the soil and possibly other media. The NR level is exceeded in both these media and the MAR level is exceeded in regional watercourses. There is also an influx of the substance across the national border. Further monitoring of these environmental media is desirable, particularly in view of the revision of the MARs in 1994. Survey measurements of its occurrence in the atmosphere may be desirable as the substance is found in rainwater. In view of the above and the need for national and international policies the RIVM has recommended that this substance is included on the list of priority substances.

Table 2.16.1 lists the Netherlands environmental quality objectives and requirements for this substance [Janus, 1994].

*Table 2.16.1: Environmental quality objectives and requirements: targets and limits (T,L), negligible risk levels/maximum acceptable risk levels (NR, MAR) and soil remediation intervention values (SI)*

| Substance | Surface water<br>Total<br>µg/l | | Dissolved<br>µg/l | | Sediment (newly dep.)<br>mg/kg dm | Soil / Sediment<br>mg/kg dm | | Ground water (dissolved)<br>µg/l | | Atmosphere<br>µg/m$^3$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| atrazine | T | L | T | L | L | T | SI | T | SI | T | L |
| | 7.5E-3 | 0.1 | 7.5E-3 | 0.1 | 0.002 | 0.5E-4 | 6 | 7.5E-3 | 150 | - | - |
| | NR | MAR | NR | MAR | MAR | NR | MAR | | | NR | MAR |
| | - | - | 2.2E-2 | 2.2[a] | 5.2E-3[b] | 6.5E-4 | 6.5E-2[c] | | | - | - |

a) MAR surface water: Aldenberg & Slob [1991], based on direct effects on fresh water organisms, see [Emans, 1992]. According to v.d. Meent [1990]: MAR water (0.75, NR 7.5E-3) based on method GR-mod2. The latter MAR and NR are therefore outdated.

b) MAR sediment (indicative value): method GR-mod2/EP (this MAR sediment was based on the MAR surface water using a method which was since revised. Thus, the MAR sediment should also be revised, this will be done in 1994 as part of the INS). It is not clear whether this refers to newly deposited sediment.

c) MAR soil (indicative value): modified EPA method.

## 2.17 CHLORINE

The RIVM report on substances demanding special attention did not address chlorine. Chlorine obtains a positive score in the LCA method on the basis of its acute toxicity. As chlorine is highly reactive its atmospheric residence time under normal conditions may be expected to be short. This is only considered to a limited extent in the LCA method, hence the score may be an overestimate of the actual risk.

In practice, the discussions concern external safety around plants rather than the risks posed by regular chlorine emissions. This study does not address external safety. There is a statutory evaluation of external safety risks which includes an NR of $10^{-8}$ fatalities per year and an MAR of $10^{-6}$ fatalities per year. The MAR for existing plants is $10^{-5}$.

An adequately supported conclusion cannot be drawn on the basis of this information. However, in view of the above it would not be unreasonable to assume, for the time being, that the actual risks related to regular, limited chlorine emissions are low.

## 2.18 OTHER ASSESSMENTS IN THE REPORT ON SUBSTANCES DEMANDING SPECIAL ATTENTION

The report on substances demanding special attention covered other chlorine compounds in addition to those discussed above. When subjected to the LCA assessment their score on toxicity themes is zero or low at the surveyed quantities emitted. The RIVM's conclusions with respect to these substances were as follows:

*Chlorophenols*

The RIVM proposes that these substances be removed from the list of substances demanding special attention, with the exception of PCP. At some locations the MAR for surface water may be exceeded due to leaching from wood treated with PCP. Environmental risks are considered to be low, human risks are considered to be negligible. However, the occurrence of PCP in the indoor environment may have to be considered.

*Chlorotoluenes*

Most of the data required for risk assessments is not available. The RIVM recommends that these substances remain on the list of substances demanding special attention until the publication of the scoping document.

*Chloroanilines*

Monochloroanilines (MCA) and dichloroanilines (DCA) are the only substances in this group which are used in the Netherlands, albeit in small quantities. The public health risk is considered to be acceptable to minor, as is the risk to aquatic ecosystems, with the possible exception of some locations. The RIVM recommends that the chloroanilines, with the exception of MCA and DCA, are removed from the list of substances demanding special attention. The RIVM also concluded that there is too little information on MCA and DCA for an effective risk assessment and that it would therefore be desirable to update the information on these substances.

*Chloronitrobenzenes*

Most of the information required for risk assessment is not available. The RIVM recommends that this substance remains on the list of substances demanding special attention until the publication of the scoping document. These substances are not produced in the Netherlands and they are probably not used either.

*Hexachloronaphthalenes*

It is likely that these substances are not manufactured or used in the Netherlands. The RIVM proposes that they are removed from the list of substances demanding special attention.

*PCBs*

The limit value for watercourse sediments is still exceeded. The concentrations in fish may also pose a risk to humans. These substances will be finally phased out in the year 2005, in the opinion of the RIVM there is no need for supplementary policies.

*Tetrachlorobenzyltoluenes (e.g. Ugilec 121 and 141)*
These substances are banned in the Netherlands. The RIVM recommends that these substances are maintained on the list of substances demanding special attention as there may be an influx through the rivers.

*Tetrachloromethane*
At present the NR level is frequently exceeded, however the MAR level is not exceeded, not even near industrial sources. This substance is being phased out.

*1,1,1-trichloromethane*
The direct effects of this substances are considered to be minor to negligible, with the possible exception of the indoor environment. This substance was finally phased out on 1 January 1995.

*Hexachlorobutadiene*
It is likely that this substance is neither used in the Netherlands nor imported. The RIVM proposes that this substance is withdrawn from the list of substances demanding special attention.

*Chloroparaffins*
Most of the data required for risk assessment is not available. The RIVM recommends that these substances remain on the list, there are suggestions that PARCOM recommended the phasing out of short chain chloroparaffins.

*Other pesticides*
It is recommended that some chlorinated agents, such as γ-HCH, remain on the list of substances demanding special attention as the desired environmental quality has not been reached. However, this conclusion is not specific to chlorinated agents, it also applies to other pesticides.

With the possible exception of chloroparaffins these descriptions provide no reasons for identifying further substances for inclusion in the chlorine chain study.

## 2.19 RISK ASSESSMENT SUMMARY

Table 2.19.1 summarises the risk assessment. It identifies the substances covered by the chlorine study, those assessed on exceedance of the NR or MAR levels using the RIVM study, and the substances demanding special attention covered by the RIVM report whose emissions were not surveyed in the chlorine study. Some emissions are due to a single company, in which event they are only given as "x" rather than numerical information, for reasons of confidentiality.

*Table 2.19.1:* *Evaluation of the exceedance of the NR/MAR of each substance, based on the RIVM study on 'Substances demanding special attention', excl. (H)CFCs and pesticides [Janus et al., 1994]*

| Substance | Emissions (t Cl) | | RIVM's assessment based on the environmental concentrations in the listed year | | | Comments |
|---|---|---|---|---|---|---|
| | 1990 | After policy implementation | Year | MAR exceedance | NR exceedance | |
| VCM | 152 | 45 | 1984 | - | At point sources | |
| trichloroethene | 708 | 294 | - | - | Soil | Based on calculations of diffuse pollution |
| tetrachloromethane | 385 | 29 | ? | - | At chloromethanes production | Production greatly reduced since 1990 |
| dioxins (in grammes) | 619 g. | 56 gram | >1990 | TDI nursing babies, nematode eating predators near incinerators | | MAR not applicable to short exposures. the Health Council does not recommend against breast-feeding but wants further epidemiological studies |
| PER | 1887 | 658 | 1984 | At dry cleaning shops | | |
| PCP | 13 | 9 | ? | Locally | | PCP is now banned, pollution due to leaching from treated wood |
| PCBs | 0,078 | 0,018 | 1991 | - | In sediment, due to fish consumption | To be banned 2005; some release from old, diffuse applications |
| MCB | 44 | 44 | - | - | - | RIVM mostly analyses other chlorinated benzenes |
| HCB (in grammes) | 195 g. | 149 gram | 1991? | - | Locally, in soil or sediment | |
| ECH | 24 | 23 | 1984 | -, locally? | -, locally? | TNO/CML analysis; no local data available |
| DCM | 5490 | 2823 | 1990? | When used indoors | Near point sources | |
| chloroform | 163 | 38 | ? | In swimming pools | At chloromethanes production | TDI only exceeded by keen swimmers due to exposure in swimming pools |
| chlorine | 24 | 17 | - | - | - | TNO/CML analysis |
| AC | x | x | - | -, locally? | -, locally? | TNO/CML analysis; no local data available |
| 1,4 DCB | 40 | 40 | ? | - | Indoor environment | |
| 1,3 DCB | x | x | 1986 | - | - | Possibly local NR exceedance |
| 1,2 DCB | 10 | 10 | 1986 | - | - | Possibly local NR exceedance |
| 1,2,4 TCB and 1,2,3 TCB | 3,4 | 3,4 | - | - | - | RIVM mostly analyses other chlorinated benzenes |
| 1,2 EDC | 920 | 287 | 1984 | - | At EDC/VCM production sites<br>Near point of use in pharmaceutical industry | EDC/VCM production - emission reduction 90 %; reduction in pharmaceutical manufacturing unknown |
| HCBd (in grammes) | 42 g | 0 | 1985 | Inc. in sediment | Occasionally, in sediment | RIVM suggests removal from list |
| dichlorotoluene | x | x | - | ? | ? | Insufficient data |
| 1,1,1 tri | 4162 | 2 | n.a. | n.a. | n.a. | Banned, one process emission remaining |
| TCPE and HPPE | x | x | - | * | * | Not included in the RIVM study |
| MCA | x | x | - | * | * | ditto |
| Methylchloride | 249 | 242 | - | * | * | ditto |
| Ethylchloride | x | x | - | * | * | ditto |
| 2-chloropropane | x | x | - | * | * | ditto |
| 2,3 dichl.propene | x | x | - | * | * | ditto |
| 1-chloropropane | x | x | - | * | * | ditto |
| 1,3-dichl.propene | 8 | 6 | - | * | * | ditto |
| 1,3-dichl.propanol | x | x | - | * | * | ditto |
| 1,2-dichl.propane | 4 | 3 | - | * | * | ditto |
| 1,2,3 trichl.propane | x | x | - | * | * | ditto |
| 1,1 dichloroethene | 1 | 0 | - | - | - | Plant closed |
| 1,1,2 trichl.ethane | 1 | 0 | - | - | - | Plant closed |
| chl.phenols, excl.PCP | ** | ** | misc. | - | ? | RIVM proposes removal from list |
| chloroanilines | ** | ** | 1988 | ? | Occasionally in water, probably due to emissions in other countries | Insufficient recent data |
| chl.nitrobenzenes | ** | ** | - | ? | ? | Probably not used in the Netherlands |
| hexachl.naphthalenes | ** | ** | - | ? | ? | Probably not used in the Netherlands, RIVM proposes removal from list. |
| tetrachl.benzyltol. | ** | ** | - | - | - | Banned in the Netherlands, concentration increasing due to river influx |
| chloroparaffins | ** | ** | | ? | ?<br>- | Insufficient data, it is suggested that PARCOM favours phasing out short-chain CPs |

* Not a substance demanding special attention; not discussed in the RIVM report. Estimated contribution, total approx. 10% of the LCA score for human toxicity.

** Substances demanding special attention discussed in the RIVM report - no emissions found in the Chlorine chain study

x Confidential: emission due to a single plant.

# 3 *SFINX: A COMPUTER PROGRAM FOR SUBSTANCE FLOW ANALYSES*

## 3.1 GENERAL FRAMEWORK AND OBJECTIVE

The integrated analysis of all flows of a substance or group of substances in the economy and the environment of a given system has proved to be an effective instrument to support the definition of substance-specific policies. The SFINX (Substance Flow InterNodal eXchange) computer program is a tool to assist in substance flow analyses. It can be used as a:

1. record keeping system: it provides a framework for sorting, processing and presenting data on a given substance or group of substances to provide an overview of the flows and accumulations of the substance or group in a specified system (generally the Netherlands) during a specified period (generally one year).
2. model: for example, to assess the effect of envisaged policies, including the shift of any problems which might result.

Each of these objectives requires the use of a clearly defined and systematic system, free of any inconsistencies, to ensure that the outcome can be verified and to ensure that analyses undertaken at different times are comparable. A complete specification of all substance flows in a system is also needed for more than elementary applications. The flows, particularly those in the economy, of some substances are extremely complex. At present CML uses the SFINX (Substance Flow InterNodal eXchange) model which is still being refined. At present, SFINX users can:

- obtain an overview of all flows of a single substance or group of substances within a delineated system;
- check the consistency and completeness of basic data;
- make estimates of any unavailable data through defined relationships within the system;
- present the data and outcome of the calculations in various formats, depending on user requirements;
- calculate the long-term effects of various assumptions such as trends and policy measures.

In future SFINX should also provide the following facilities:

- undertaking problem analyses;
- specifying links between the SFINX files of substances;
- provide estimates of the short-term effects of certain trends or measures (dynamic operation).

## 3.2 STRUCTURE OF THE MODEL

SFINX is written in PROLOG and runs under DOS. Substance flow models can be created one step at a time. A menu is used to specify nodes (i.e. nodes in substance flows, e.g. economic processes, agriculture as a whole, or environmental media), connections between nodes (the substance flows), to quantify known flows as tables and to specify the relationships between substance flows through formulas. The calculation of the magnitude of the substance flows is handled by a mathematical program, Mathematica, currently one of the standard programs in this field. SFINX handles the communication between itself and Mathematica.

To use SFINX as a record keeping program the flows are quantified using literature data, statistical information and measurement data which is entered into tables. Quattro tables can be imported into SFINX. Similarly, SFINX tables can be exported to Quattro.

When SFINX is used as a model it is important to ensure that substance flows are entered with their interdependencies where possible, using formulas. In this way, the substance flows within the system can be derived from the smallest possible set of basic data. The remaining fixed data should be selected with great care.

The results of the calculations can be presented in several formats. The basic output (general view) is a list of all nodes and the related substance balances of the input and output flows for each node. Users can also define special views by selecting groups of flows and creating separate lists with totals.

## 3.3 APPLICATION OF SFINX IN THE CHLORINE CHAIN STUDY

During this study, SFINX was used as an accounting program. The collected data was entered into the program and used to generate overviews of the chlorine flows in the Netherlands.

Each SFINX file is a network of interconnected nodes. Each node represents a defined process. Supplies to and from other nodes provide the connections, all of which form the network. A balance of the inflow, outflow and accumulation of each node can be drawn up. The system is automatically balanced as the balance has to be correct for each node. In reality this may be an illusion: accumulation means that there is an imbalance between input and output. When SFINX is applied as an accounting program this is solved by treating accumulation as an outflow to stock. As the economic chlorine system in the Netherlands is exceedingly complex it was decided to use modules. Elements of the chain are included in separate SFINX files. These files are then linked by an umbrella file containing both the primary chlorine production (i.e. the common source) and waste processing (common sink). This not only closes the balance of each node and system but also that of the overall chlorine system. This provides a comprehensive and fairly detailed overview of the chlorine system in the Netherlands: inflow, outflow, throughput, accumulation and losses (emissions and waste) - both of the entire system and of its component chains. All flows are expressed as weight units of chlorine (kilotonnes chlorine). In this way all balances can be closed and different chlorine compounds can be addressed together.

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# A CHLORINE BALANCE FOR THE NETHERLANDS

## APPENDICES

## *APPENDIX 1: REFERENCES*

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# *APPENDIX 2: CHLORINE FRACTIONS AND MOLECULAR MASSES OF CHLORINE COMPOUNDS*

| | C | H | Cl | F | Br | O | N | Na | mol. weight | fraction Cl |
|---|---|---|---|---|---|---|---|---|---|---|
| HCl | | 1 | 1 | | | | | | 36.46064 | 0.97236 |
| Methylchloride | 1 | 3 | 1 | | | | | | 50.48752 | 0.70221 |
| Methylenechloride | 1 | 2 | 2 | | | | | | 84.93228 | 0.83485 |
| Chloroform | 1 | 1 | 3 | | | | | | 119.37704 | 0.89094 |
| Tetrachloromethane | 1 | | 4 | | | | | | 153.82180 | 0.92192 |
| CFC 13:chlorotrifluoromethane | 1 | | 1 | 3 | | | | | 104.45891 | 0.33939 |
| CFC 12:dichlorodifluoromethane | 1 | | 2 | 2 | | | | | 120.91321 | 0.58642 |
| CFC 11:trichlorofluoromethane | 1 | | 3 | 1 | | | | | 137.36750 | 0.77426 |
| HCFC 21:dichlorofluoromethane | 1 | 1 | 2 | 1 | | | | | 102.92274 | 0.68892 |
| HCFC 22:chlorodifluoromethane | 1 | 1 | 1 | 2 | | | | | 86.46845 | 0.41001 |
| Halon 1211:bromochlorodifluoromethane | 1 | | 1 | 2 | 1 | | | | 165.36451 | 0.21439 |
| Monochloroethane | 2 | 5 | 1 | | | | | | 64.51440 | 0.54953 |
| Dichloroethane | 2 | 4 | 2 | | | | | | 98.95916 | 0.71651 |
| Trichloroethane | 2 | 3 | 3 | | | | | | 133.40392 | 0.79726 |
| Tetrachloroethane | 2 | 2 | 4 | | | | | | 167.84868 | 0.84487 |
| Pentachloroethane | 2 | 1 | 5 | | | | | | 202.29344 | 0.87627 |
| Hexachloroethane | 2 | | 5 | | | | | | 236.73820 | 0.89853 |
| Vinylchloride | 2 | 3 | 1 | | | | | | 62.49852 | 0.56726 |
| PVC | 2 | 2 | 1 | | | | | | 61.49058 | 0.57655 |
| Dichloroethene | 2 | 2 | 2 | | | | | | 96.94328 | 0.73141 |
| Trichloroethylene | 2 | 1 | 3 | | | | | | 131.38804 | 0.80950 |
| Perchloroethylene | 2 | | 4 | | | | | | 165.83280 | 0.85514 |
| CFC 115:chloropentafluoroethane | 2 | | 1 | 5 | | | | | 154.46672 | 0.22952 |
| CFC 114:1.2-dichlorotetrafluoroethane | 2 | | 2 | 4 | | | | | 170.92101 | 0.41484 |
| CFC 113:1.1.2-trichloro-1.2.2-trifluoroethane | 2 | | 3 | 3 | | | | | 187.37531 | 0.56762 |
| HCFC 123:1.1-dichloro-2.2.2-trifluoroethane | 2 | 1 | 2 | 3 | | | | | 152.93055 | 0.46364 |
| HCFC 124:1-chloro-1.2.2.2-tetrafluoroethan | 2 | 1 | 1 | 4 | | | | | 136.47625 | 0.25977 |
| HCFC 141b:1.1-dichloro-1-fluoroethane | 2 | 3 | 2 | 1 | | | | | 116.94962 | 0.60629 |
| HCFC 142b:1-chloro-1.1-difluoroethane | 2 | 3 | 1 | 2 | | | | | 100.49533 | 0.35278 |
| 1-chloro-1.2.2-trifluoroethene | 2 | | 1 | 3 | | | | | 116.46991 | 0.30439 |
| 1-chloro-1.2.2.2-tetrafluoroethane | 2 | 1 | 1 | 4 | | | | | 136.47625 | 0.25977 |
| Monochloropropane | 3 | 7 | 1 | | | | | | 78.54128 | 0.45139 |
| Dichloropropane | 3 | 6 | 2 | | | | | | 112.98604 | 0.62756 |
| Trichloropropane | 3 | 5 | 3 | | | | | | 147.43080 | 0.72141 |
| Allylchloride | 3 | 5 | 1 | | | | | | 76.52540 | 0.46328 |
| Dichloropropene | 3 | 4 | 2 | | | | | | 110.97016 | 0.63896 |
| 2-chloro-1.1.1.3.3.3-hexafluoropropane | 3 | 1 | 1 | 5 | | | | | 186.48406 | 0.19011 |
| Epichlorohydrine | 3 | 5 | 1 | | | 1 | | | 92.52480 | 0.38317 |
| Monochlorobutane | 4 | 9 | 1 | | | | | | 92.56816 | 0.38299 |
| Dichlorobutane | 4 | 8 | 2 | | | | | | 127.01292 | 0.55825 |
| Dichlorobutene | 4 | 6 | 2 | | | | | | 124.99704 | 0.56726 |
| Trichlorobutene | 4 | 5 | 3 | | | | | | 159.44180 | 0.66707 |
| hexachlorobutadiene | 4 | | 5 | | | | | | 260.76020 | 0.81575 |
| Chloroprene | 4 | 5 | 1 | | | | | | 88.53640 | 0.40043 |
| Hexachlorocyclohexane | 6 | 6 | 5 | | | | | | 290.82984 | 0.73141 |
| Monochlorobenzene | 6 | 5 | 1 | | | | | | 112.55840 | 0.31497 |
| Dichlorobenzene | 6 | 4 | 2 | | | | | | 147.00316 | 0.48234 |
| Trichlorobenzene | 6 | 3 | 3 | | | | | | 181.44792 | 0.58616 |
| tetrachlorobenzene | 5 | 2 | 4 | | | | | | 215.89268 | 0.65686 |
| pentachlorobenzene | 6 | 1 | 5 | | | | | | 250.33744 | 0.70810 |
| hexachlorobenzene | 6 | 0 | 6 | | | | | | 284.78220 | 0.74694 |
| monochloroethanol | 2 | 5 | 1 | | | 1 | | | 80.51380 | 0.44033 |
| Trichloroethanol | 2 | 3 | 3 | | | 1 | | | 149.40332 | 0.71189 |
| 1,3-dichloro-2-propanol | 3 | 6 | 2 | | | 1 | | | 128.98544 | 0.54972 |
| monochloroacetate | 2 | 2 | 1 | | | 2 | | | 93.48936 | 0.37922 |
| Na-monochloroacetate | 2 | 2 | 1 | | | 2 | | 1 | 116.47915 | 0.30437 |
| trichloroacetate | 2 | 0 | 3 | | | 2 | | | 162.37890 | 0.65500 |
| Na-trichloroacetate | 2 | 0 | 3 | | | 2 | | 1 | 185.36867 | 0.57377 |
| Monochlorocresols | | | | | | | | | 0.00000 | ERR |
| 4-chloro-2-methylfenoxyacetic acid | | | | | | | | | 0.00000 | ERR |
| (MCPA) | | | | | | | | | 0.00000 | ERR |
| 4-chloro-2-methylfenoxypropionic acid | | | | | | | | | 0.00000 | ERR |
| (MCPP) | | | | | | | | | 0.00000 | ERR |
| PPHE | 9 | 15 | 5 | | | 1 | | | 316.48100 | 0.56011 |
| TCPE | 6 | 10 | 4 | | | 1 | | | 239.95560 | 0.59099 |
| | | | | | | | | | 0.00000 | ERR |
| | | | | | | | | | 0.00000 | ERR |
| Other organochlorocompounds | | | | | | | | | 0.00000 | ERR |

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## *APPENDIX 3: BASIC LIST OF 150 SUBSTANCES AND THE LIST OF 40 SUBSTANCES*

TNO and CML compiled a list of 40 substances to assist in tracing substances through the various chains. The intention was to obtain a list of substances to be used to search for emitted substances in the ER-I (emission records) and WIER (RIZA system for the registration of discharges into water). These released substances would be included in the study.

The initial reduction of the thousands of chlorinated substances was made on the basis of the judgement of TNO and CML experts and the literature, to compile an initial list of chlorinated substances which might be relevant in the Netherlands chlorine industry. This list is included in Table B3.2 and includes some 150 substances. These substances were selected because they are included on the list of priority substances, the black list and the grey list, or because they were considered to be important in other studies [ECOTEC 1991, Bremmer 1988, Alwast 1993, IJC 1993, Kleijn 1990, VROM 1991, BKH 1994]. The basic list was then reduced to some 40 substances which would certainly have to be considered in this study. The reduction of the initial list was undertake as follows:

- 24 organic compounds were selected as bulk chemical products, based on slightly dated information [Bremmer 1988];
- in principle, inorganic chlorides (salts) were not included, however, hypochlorite was included in view of its possible by-products;
- substances included both on the black list and the list of priority substances were also included [BKH 1993];
- the overall emissions of the other substances were obtained from the individual emission records. The contribution of each substance to the environmental themes were then calculated using the LCA classification factors. After prioritisation the number of substances was increased to 50. The total contribution of the rejected substances to the overall score of the chlorine on each environmental theme was less than 5%.

Initially, the intention was to select only five pesticides for the study. However, during the implementation it was found that there were accessible data on the overall pesticide use in the Netherlands. For this reason all, about 60, chlorine-containing pesticides in the Netherlands were included. Table B3.1 lists the substances eventually selected for this project, excluding the pesticides. The subheadings in the list indicate the criteria for the selection of the substances.

*Table B3.1: List of 40 substances*

ORGANIC BULK CHEMICALS

*C1*

monochloromethane (methylchloride)
dichloromethane (methylenechloride)
trichloromethane (chloroform)
tetrachloromethane (tetra)
trichloromonofluoromethane (CFC-11)
dichlorodifluoromethane (CFC-12)
monochlorodifluoromethane (HCFC-22)

*C2*

monochloroethane
1,2-dichloroethane (1,2-DCE)
1,1,1-trichloroethane (1,1,1-tri)
monochloroethene (vinylchloride)
1,1-dichloroethene (vinylidene)
trichloroethene (tri)
tetrachloroethene (per)
trichlorotrifluoroethane (CFC-113)
dichlorotetrafluoroethane (CFC-114)

*C3*

1,2-dichloropropane
1,3-dichloropropene
3-chloropropene (allylchloride)
epichlorohydrine

*C4*

2-chloro-1,3-butadiene (chloroprene)

*Miscellaneous*

α-chlorotoluene (benzylchloride)
PVC
phosgene

INORGANIC BULK CHEMICALS

chlorine
hydrochloric acid
sodium hypochlorite (bleach)
titaniumtetrachloride

BLACKLISTED AND PRIORITY SUBSTANCES

hexachlorocyclohexane
chloroanilines
chlorobenzenes
chlorophenols
dioxins
PCBs and PCTs

ER-I SUBSTANCES

monochloroacetic acid
trichloroacetic acid
polychloropropylethers
HCFC 133
HCFC 124
HCFC 226

# *Table B3.2: Basic list of 150 substances*

## ORGANIC CHLORINE COMPOUNDS

### C1

monochloromethane (methylchloride)
dichloromethane (methylene chloride)
trichloromethane (chloroform)
tetrachloromethane (tetra)
trichloromonofluoromethane (CFC-11)
dichlorodifluoromethane (CFC-12)
monochlorotrifluoromethane (CFC-13)
monochlorodifluoromethane (HCFC-22)

### C2

monochloroethane
1,2-dichloroethane (1,2-DCE)
1,1-dichloroethane
1,1,1-trichloroethane (1,1,1-tri)
1,1,2-trichloroethane
1,1,2,2-tetrachloroethane
1,1,1,2-tetrachloroethane
pentachloroethane
hexachloroethane
monochloroethene (vinylchloride)
1,1-dichloroethene (vinylidene)
1,2-dichloroethene
trichloroethene (tri)
tetrachloroethene (per)
pentachloromonofluoroethane (CFC-111)
trichlorotrifluoroethane (CFC-113)
dichlorotetrafluoroethane (CFC-114)
monochloropentafluoroethane (CFC-115)
1,1-dichloro-2,2,2-trifluoroethane (HCFC-123)
1,1-dichloro-1-fluoroethane (HCFC-141b)
1-chloro-1,1,difluoroethane (HCFC-142b)
1-chloro-2-propanol(propylenechlorohydrine)

### C3

1-chloropropane
2-chloropropane
1,2-dichloropropane
1,3-dichloropropane
1,2,3-trichloropropane
1,1,1-trichloropropane
1,1,2-trichloropropane
1,2,2-trichloropropane
tetra- octachloropropanes
3-chloropropene (allylchloride)
1,3-dichloropropene
other chloropropenes
epichlorohydrine

### C4

1-chlorobutane
tert-butylchloride
1,4-dichlorobutane
1,4-dichloro-2-butene
3,4-dichloro-1-butene
2-chloro-1,3-butadiene (chloroprene)
other C4

### CYCLIC, NONAROMATIC

hexachlorocyclohexane (HCH)
other cyclic, nonaromatic

### CHLOROBENZENES

monochlorobenzene
o-dichlorobenzene
m-dichlorobenzene
p-dichlorobenzene
1,2,4-trichlorobenzene
1,2,3-trichlorobenzene
1,3,5-trichlorobenzene
tetrachlorobenzenes
pentachlorobenzene
hexachlorobenzene

### CHLOROTOLUENES

o-chlorophenol
p-chlorophenol
α-chlorotoluene (benzylchloride)
2,4-dichlorotoluene
3,4-dichlorotoluene
α,4-dichlorotoluene (p-chlorobenzylchloride)
p-chlorobenzalchloride
α,α,α-trichlorotoluene (benzotrichloride)
α,α,α,4-tetrachlorotoluene (p-chlorobenzotrichloride)

### CHLOROPHENOLS

o-chlorophenol
p-chlorophenol
2,4-dichlorophenol
2,6-dichlorophenol
2,4,6-trichlorophenol
pentachlorophenol

### CHLOROCRESOLS

4-chloro-o-cresol

### CHLOROANILINES

### CHLORONITROBENZENES

o,m,p chloronitrobenzene

### PHENYLCHLOROSILANES

### CHLOROPARAFFINS

### CHLOROCARBOXYLIC ACIDS

monochloroacetic acid
dichloroacetic acid
trichloroacetic acid
chloroacetic acid-Na-salt
trichloroacetic acid-Na-salt
2-chloropropionic acid
2,2-dichloropropionic acid

### PVC

chloroprene (neoprene)

### PCBs

### DIOXINS

### MISCELLANEOUS

phosgene
chlorcyanide
bromochlorodifluoromethane (halon 1211)
polivinylidenechloride
chlorinated polyolefins
terephthaloyldichloride
methylchloroacetate
cholinechloride

### PESTICIDES

DDT
triphenylphosphine
4-chloro-2-methyl-phenoxyacetic acid (MCPA)
4-chloro-2-methyl-phenoxybutanoic acid (MCPB)
Mecoprop (MCPP)
2,4-dichlorophenoxypropionic acid (2,4 dichloroprop; 2,4-DP)
2,4-dichlorophenoxyacetic acid (2,4-D)
2,4-dichlorophenyl-4'-nitrophenylether (nitrofen)
dichlofop-methyl
bifenox
4-(2,4-dichlorophenoxy-butyric acid) (2,4-DB)
prothiophos
dichlorofention
chloroacetic acid methylester
chloroacetamide
chloroacetic acidethylester
3,3'-dichlorobenzidine
o-chloronitroanisol
4,4'-dichloro-2-nitro-diphenylether
4,4'-dichloro-2-amino-diphenylether
chlorfenson
triadimefon (cl ?)
fenson (cl ?)
chloroacetylchloride
methyldichloroacetate
benzoylprop-ethyl (cl ?)
2-chloropropionicacidethylester
polychloroprene
2,4,6-trichloro-1,3,5-triazine (cyanuric chloride)
trichloroalkylphosphate
dichlorophosphoric acid ethylester
O,O-dimethylthiophosphoric acid chloride
O,O-diethylthiophosphoric acid chloride
trimethylphosphite
triethylphosphite
triphenylphosphine

Note: the above list of pesticides is incomplete, see also Table 37.1 in segment?? 37

## INORGANIC CHLORINE COMPOUNDS

chlorine
chlorate
chlorite
iron chloride
hydrochloric acid
titanium tetrachloride
sodium hypochlorite (bleach)
phosphortrichloride
phosphorpentachloride
phosphoroxychloride

phosphorsulfochloride

## *APPENDIX 4: OVERALL SUBSTANCE EMISSIONS AND THEME SCORES*

Tables B4.2 - B4.5 list the overall emissions of each substance and the scores on the various themes. However, nonagricultural pesticides as their volumes are confidential. Emissions to the soil, water and atmosphere are not specified separately. As *emissions* do not have a landfill volume score there is correspondingly no column for this theme. (Only PVC waste, waste processing residues and some process waste streams had an above-zero score on this theme.) As the only pesticide scores relate to human toxicity and ecotoxicity, only these themes were specified for these substances. Scores are given for the situation in 1990 and the situation after implementation of the policies envisaged on 1 January 1995.

After normalisation based on the total Netherlands DTT (Distance-to-target) the scores on each theme were weighted and added to obtain a single parameter. This procedure was not applied to the table for pesticides. Using the same procedure, the total Netherlands scores on the themes were integrated into a single parameter, which may be considered as the total environmental pollution in the Netherlands across the eight themes. The integrated pollution of each substance is expressed as a percentage of the overall integrated environmental pollution in the Netherlands. The same procedure was repeated to obtain the last column, however the integration was limited to *seven* themes, depletion of the ozone layer was not considered.

For example, the table for 1,1,1-trichloroethylene *indicates* that this substance contributes approximately 4.2% to the overall, integrated environmental problems in the Netherlands (i.e. to the eight themes). This is largely due to the high ODP of 1,1,1,-trichloroethylene and the high weighting factor for the ozone depletion theme (see Part III). If the depletion of the ozone layer is not included, this substance only contributes 0.0056% to the overall environmental problem in the Netherlands (integrated across the eight themes).

The table also indicates for which substances equivalence factors are not available, although they are required. Generally speaking the scores in columns acidification, depletion of the ozone layer and global warming are zero because the equivalence factors of the substances are zero. It is likely that there are no smog and odour equivalence factors missing for substances which a high score per emitted unit. The ecotoxicity scores are clearly uncertain. There are human toxicity equivalence factors for most of the important toxic substances such as 1,2 EDC and dioxins. If the CFCs and HCFCs are excluded from the considerations, there are 17 organochlorine compounds which have a possibly unwarranted zero score due to the lack of equivalence factors. Pesticides were also excluded from these considerations. This is both because the discussion of ecotoxicity already showed that the LCA assessment of these substances suffers from clear uncertainties and because there is already an approval procedure for pesticides. The uncertainty due to the lack of equivalence factors for the remaining 17 substances is tentatively indicated here. Table B4.1 lists the most important substances without scores, both in 1990 and in future. The table shows that 1,1,1-trichlorethane and monochloromethane are most important in terms of volume. Other substances account for an emission of 0.1 kt chlorine. The possible order of magnitude of the score of the missing substances was estimated as follows:

- the NRs and MARs derived for 1,1,1-trichloroethane are comparable with those for trichloroethene [Janus, 1994]. As a working hypothesis, the equivalence factor for trichloroethene were also used for *1,1,1-trichloroethane*;
- *methylchloride* is released in large quantities by natural processes (e.g. volcanoes and marine processes). According to some estimates, anthropogenic emissions amount to only 4% of the emissions from natural sources [Ecotec, 1991]. Given the lack of a better alternative, the equivalence factor used is of the same order of magnitude as DCM, trichloroethene and PER;
- table B4.2 shows that 1 kt of a substance results in a score of approx 0.1 (DCM) to over 3 (1,2-EDC), except for PCBs, ECH, hexachlorobenzene and dioxins. As a working hypothesis it was assumed that there are no highly toxic substances without equivalence factors. Consequently, the equivalence factors of the *other substances* ranges from 0.1 to 3.

It should be noted that the above estimate was based on an assumed, average human toxicity classification factor for the atmosphere, water and soil. In 1990 the "missing" score may have amounted to 0.32 to 0.61, on an overall human toxicity score of more than 7 kt/y. In the future, the missing score may amount to 0.03 to 0.31, on an overall human toxicity score of 2 kt/y. Thus, the score for 1990 may have been underestimated by 5-10% and that for the future situation by 2-15%.

*Table B4.1: Tentative analysis of the uncertainty in the human toxicity score due to unavailable equivalence factors*

| Substance | Tentative equivalence factor (tonne/tonne chlorine) | 1990 | | Policies implemented | |
|---|---|---|---|---|---|
| | | Emissions (kt Cl/y) | Score (kt/y) | Emissions (kt Cl/y) | Score (kt/y) |
| 1,1,1 tri-chloroethane | 0.07 | 4.16 | 0.29 | 0.003 | 0.0 |
| methyl-chloride | 0.08 | 0.25 | 0.02 | 0.25 | 0.02 |
| other substances | 0.1 - 3 | 0.1 | 0.01-0.3 | 0.1 | 0.01-0.3 |
| Total | | | 0.32-0.61 | | 0.03-0.31 |

*Table B4.2:* *Total emissions and scores for chlorine compounds in 1990, excluding pesticides (some emission figures are not shown for reasons of confidentiality)*

| | Quantity kton Cl | HumToxA kton | AqEcoTox 1000 m3 | Acidific kton | OzonDep. kton | GlobWarm kton | OzonFrm. kton | OdorFrm. 1000 m3 | DTT | DTT ex ozon |
|---|---|---|---|---|---|---|---|---|---|---|
| vinylchloride | 0,152816 | 0,32378 | 0 | 0 | 0 | 0 | 0 | 0 | 4,725E-04 | 4,725E-04 |
| trichloroethene | 0,7078916 | 0,0501551 | 2669,672 | 0 | 0 | 0 | 0,053895 | 209090 | 5,285E-03 | 5,285E-03 |
| trichlorobenzene | 4,1E-07 | 0 | 0,581 | 0 | 0 | 0 | 0 | 0 | 1,167E-07 | 1,167E-07 |
| tetrachloromethane | 0,3858654 | 0,7927765 | 14,3056 | 0 | 0,45013 | 540,8 | 0 | 0 | 3,024E+00 | 6,392E-03 |
| TEQ | 6,186E-07 | 2,0357259 | 0 | 0 | 0 | 0 | 0 | 0 | 2,971E-03 | 2,971E-03 |
| TCPE | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| PPHE | | 0 | 0 | 0 | 0 | 0 | | 0 | 0,000E+00 | 0,000E+00 |
| PER | 1,8872836 | 0,107226 | 510,9503 | 0 | 0 | 0 | 0,0109108 | 262499,14 | 1,241E-03 | 1,241E-03 |
| pentachlorophenol | 0,0133 | 0,022 | 0 | 0 | 0 | 0 | 0 | 0 | 3,210E-05 | 3,210E-05 |
| PCB | 7,8E-05 | 0,02886 | 0 | 0 | 0 | 0 | 0 | 0 | 4,211E-05 | 4,211E-05 |
| monochlorobenzene | 0,0440896 | 0,015337 | 0 | 0 | 0 | 0 | 0 | 0 | 2,238E-05 | 2,238E-05 |
| monochloroacetic acid+salt | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| methylchloride | 0,249 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| hexachlorobutadiene | 4,2E-08 | 0 | 0,566 | 0 | 0 | 0 | | 0 | 1,137E-07 | 1,137E-07 |
| hexachlorobenzene | 1,951E-07 | 1,492E-06 | 13,87 | 0 | 0 | 0 | 0 | 13,870002 | 2,791E-06 | 2,791E-06 |
| HCl | 6,7047592 | 0 | 0 | 6,08563 | 0 | 0 | 0 | 0 | 3,115E-02 | 3,115E-02 |
| HCFC 22 | 0,67 | 0 | 0 | 0 | 0,0899 | 2615 | 0 | 0 | 6,280E-01 | 2,530E-02 |
| HCFC 21 | 0,000342 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| HCFC 142b | 0,086 | 0 | 0 | 0 | 0,0158 | 439 | 0 | 0 | 1,102E-01 | 4,247E-03 |
| HCFC 133b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| HCFC 124 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| HCFC 123 | 0,012575 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| Halon 1211 | 0,0454 | 0 | 0 | 0 | 0,898 | 0 | 0 | 0 | 6,020E+00 | 0,000E+00 |
| ethylchloride | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| epichlorohydrin | 0,0241422 | 0,07737 | 0 | 0 | 0 | 0 | 0 | 0 | 1,129E-04 | 1,129E-04 |
| dichlorotoluene | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| dichloromethane | 5,490334 | 0,454034 | 0 | 0 | 0 | 98,159 | 0,065444 | 10227,9 | 7,251E-03 | 7,251E-03 |
| chloroform | 0,1630821 | 0,2166719 | 397,83 | 0 | 0 | 4,5161 | 0 | 0 | 4,398E-04 | 4,398E-04 |
| chlorine | 0,024004 | 0,0508702 | 0 | 0 | 0 | 0 | 0 | 0 | 7,423E-05 | 7,423E-05 |
| CFC 13 | 0,00612 | 0 | 0 | 0 | 0 | 235 | 0 | 0 | 2,273E-03 | 2,273E-03 |
| CFC 12 | 0,59222 | 0,0222382 | 0 | 0 | 1,00932 | 7162 | 0 | 0 | 6,835E+00 | 6,932E-02 |
| CFC 115 | 0,024 | 0 | 0 | 0 | 0,0523 | 732 | 0 | 0 | 3,577E-01 | 7,082E-03 |
| CFC 114 | 0,0538 | 0 | 0 | 0 | 0,1039 | 909 | 0 | 0 | 7,053E-01 | 8,794E-03 |
| CFC 113 | 0,784571 | 0 | 0 | 0 | 1,47011 | 6185,5 | 0 | 0 | 9,915E+00 | 5,984E-02 |
| CFC 11 | 2,036617 | 0 | 0 | 0 | 2,6306 | 8939 | 0 | 0 | 1,772E+01 | 8,648E-02 |
| allylchloride | | 0,136 | 0 | 0 | 0 | 0 | 0 | 0 | 1,985E-04 | 1,985E-04 |
| 2-chloropropane | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 2-chloro-1,1,1,3,3,3-hexafluor | 0,0308 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 2,3-dichloropropene | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1-chloropropane | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1-chloro-1,2,2,-trifluoroethene | 0,0543 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1-chloro-1,2,2,2-tetrafluoroeth | 0,116 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1,4-dichlorobenzene | 0,040092 | 0,0079753 | 0 | 0 | 0 | 0 | 0 | 0 | 1,164E-05 | 1,164E-05 |
| 1,3-dichloropropene | 0,00764 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1,3-dichlorobenzene | | 2,7E-05 | 0 | 0 | 0 | 0 | 0 | 142 | 6,221E-08 | 6,221E-08 |
| 1,3-dichloro-2-propanol | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1,2-dichloropropane | 0,003893 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1,2-dichloroethane | 0,920584 | 3,0708455 | 3,68 | 0 | 0 | 0 | 0 | 0 | 4,482E-03 | 4,482E-03 |
| 1,2-dichlorobenzene | 0,00972 | 0,0037812 | 0 | 0 | 0 | 0 | 0 | 0 | 5,518E-06 | 5,518E-06 |
| 1,2,4-trichlorobenzene | 3E-06 | 2,92E-05 | 0 | 0 | 0 | 0 | 0 | 0 | 4,261E-08 | 4,261E-08 |
| 1,2,3-trichloropropane | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1,1-dichloroethene | 0,00103 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1,1,2-trichloroethane | 0,00143 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1,1,1-trichloroethane | 4,16289 | 0 | 119,04 | 0 | 0,62154 | 518,464 | 0,0051846 | 976830 | 4,172E+00 | 5,643E-03 |

*Table B4.3:* *Total emissions and scores for chlorine compounds (excluding pesticides) after the implementation of the envisaged policies (some emission figures are not shown for reasons of confidentiality)*

| | Quantity kton Cl | HumToxA kton | AqEcoTox 1000 m3 | Acidific kton | OzonDep. kton | GlobWarm kton | OzonFrm. kton | OdorFrm. 1000 m3 | DTT | DTT ex ozon |
|---|---|---|---|---|---|---|---|---|---|---|
| vinylchloride | 4,552E-02 | 0,09638 | 0 | 0 | 0 | 0 | 0 | 0 | 1,406E-04 | 1,406E-04 |
| trichloroethene | 2,937E-01 | 0,0219243 | 158,52 | 0 | 0 | 0 | 0,023724 | 92162 | 2,122E-03 | 2,122E-03 |
| trichlorobenzene | 4,100E-07 | 0 | 0,581 | 0 | 0 | 0 | 0 | 0 | 1,167E-07 | 1,167E-07 |
| tetrachloromethane | 2,936E-02 | 0,0583121 | 13,1297 | 0 | 0,03249 | 39,06 | 0 | 0 | 2,183E-01 | 4,656E-04 |
| TEQ | 5,590E-08 | 0,1821929 | 0 | 0 | 0 | 0 | 0 | 0 | 2,659E-04 | 2,659E-04 |
| TCPE | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| PPHE | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| PER | 6,584E-01 | 0,0372292 | 161,3936 | 0 | 0 | 0 | 0,0038059 | 91769,11 | 4,293E-04 | 4,293E-04 |
| pentachlorophenol | 9,300E-03 | 0,0154 | 0 | 0 | 0 | 0 | 0 | 0 | 2,247E-05 | 2,247E-05 |
| PCB | 1,800E-05 | 0,00349 | 0 | 0 | 0 | 0 | 0 | 0 | 5,093E-06 | 5,093E-06 |
| monochlorobenzene | 4,405E-02 | 0,0153244 | 0 | 0 | 0 | 0 | 0 | 0 | 2,236E-05 | 2,236E-05 |
| monochloroacetic acid+salt | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| methylchloride | 2,420E-01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| hexachlorobutadiene | 0,000E+00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| hexachlorobenzene | 1,490E-07 | 1,14E-06 | 10,6 | 0 | 0 | 0 | 0 | 10,600001 | 2,133E-06 | 2,133E-06 |
| HCl | 5,098E-01 | 0 | 0 | 0.46143 | 0 | 0 | 0 | 0 | 2,362E-03 | 2,362E-03 |
| HCFC 22 | 8,390E-02 | 0 | 0 | 0 | 0,0113 | 327 | 0 | 0 | 7,891E-02 | 3,163E-03 |
| HCFC 21 | 2,540E-04 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| HCFC 142b | 0,000E+00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| HCFC 133b | 4,140E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| HCFC 124 | 8,820E-02 | 0 | 0 | 0 | 0.00747 | 149 | 0 | 0 | 5,152E-02 | 1,441E-03 |
| HCFC 123 | 1,160E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| Halon 1211 | 0,000E+00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| ethylchloride | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| epichlorohydrin | 2,305E-02 | 0,0738738 | 0 | 0 | 0 | 0 | 0 | 0 | 1,078E-04 | 1,078E-04 |
| dichlorotoluene | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| dichloromethane | 2,823E+00 | 0,2336105 | 0 | 0 | 0 | 50,511 | 0,033714 | 5266,4 | 3,734E-03 | 3,734E-03 |
| chloroform | 3,800E-02 | 0,0489835 | 327,2827 | 0 | 0 | 1,01553 | 0 | 0 | 1,470E-04 | 1,470E-04 |
| chlorine | 1,729E-02 | 0,0351809 | 0 | 0 | 0 | 0 | 0 | 0 | 5,134E-05 | 5,134E-05 |
| CFC 13 | 6,120E-03 | 0 | 0 | 0 | 0 | 235 | 0 | 0 | 2,273E-03 | 2,273E-03 |
| CFC 12 | 1,040E-02 | 0,0003906 | 0 | 0 | 0,017787 | 126,09 | 0 | 0 | 1,205E-01 | 1,220E-03 |
| CFC 115 | 0,000E+00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| CFC 114 | 0,000E+00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| CFC 113 | 8,880E-04 | 0 | 0 | 0 | 0.00167 | 7,04 | 0 | 0 | 1,126E-02 | 6,811E-05 |
| CFC 11 | 3,546E-01 | 0 | 0 | 0 | 0,45832 | 1551,95 | 0 | 0 | 3,087E+00 | 1,501E-02 |
| allylchloride | | 0,0741 | 0 | 0 | 0 | 0 | 0 | 0 | 1,081E-04 | 1,081E-04 |
| 2-chloropropane | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 2-chloro-1,1,1,3,3,3-hexafluoropropane | 2,370E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 2,3-dichloropropene | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1-chloropropane | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1,4-dichlorobenzene | 4,009E-02 | 0,0079753 | 0 | 0 | 0 | 0 | 0 | 0 | 1,164E-05 | 1,164E-05 |
| 1,3-dichloropropene | 5,760E-03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1,3-dichlorobenzene | | 2,71E-05 | 0 | 0 | 0 | 0 | 0 | 143 | 6,251E-08 | 6,251E-08 |
| 1,3-dichloro-2-propanol | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1,2-dichloropropane | 3,013E-03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1,2-dichloroethane | 2,872E-01 | 0,9476466 | 6,03 | 0 | 0 | 0 | 0 | 0 | 1,384E-03 | 1,384E-03 |
| 1,2-dichlorobenzene | 9,720E-03 | 0,0037812 | 0 | 0 | 0 | 0 | 0 | 0 | 5,518E-06 | 5,518E-06 |
| 1,2,4-trichlorobenzene | 3,000E-06 | 2,92E-05 | 0 | 0 | 0 | 0 | 0 | 0 | 4,261E-08 | 4,261E-08 |
| 1,2,3-trichloropropane | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000E+00 | 0,000E+00 |
| 1,1,1-trichloroethane | 2,620E-03 | 0 | 0 | 0 | 0,000394 | 0,328 | 3,28E-06 | 520 | 2,545E-03 | 3,555E-06 |

*Table B4.4:* *Total emissions and scores for agricultural pesticides in 1990*

| | HumTox (kton) | AqEcoTox (1000 m3) | TerEcoTx (kton) |
|---|---|---|---|
| lindane | 0,065459 | 482 | 24800000 |
| 2,4-D | 4,51E-07 | 11,9 | 1740000 |
| chlortolurol | 0 | 0 | 0 |
| dichlorovos | 0,000274 | 773000 | 497000 |
| linuron | 0 | 4400 | 0 |
| monolinuron | 0 | 0 | 0 |
| chloorprofam | 0 | 0 | 0 |
| simazin | 0,00148 | 1050 | 0 |
| trichlorofon | 4,72E-06 | 16300 | 22500 |
| chlofentezin | 0 | 0 | 0 |
| vinchlozolin | 4,55E-05 | 0 | 0 |
| hexythiazox | 0 | 0 | 0 |
| tolclofos-methyl | 0 | 0 | 0 |
| tolylfluanide | 6,97E-05 | 0 | 0 |
| tri-allaat | 0 | 0 | 0 |
| tridimefon | 2,64E-07 | 0 | 1020 |
| triadimenol | 3,88E-06 | 0 | 0 |
| triforine | 3,33E-06 | 0 | 0 |
| anilazin | 5,98E-05 | 0 | 0 |
| atrazin | 0,54598 | 8600 | 25500000 |
| bifenox | 0 | 0 | 0 |
| captan | 0,000109 | 71500 | 1790000 |
| chloorbromuron | 0 | 0 | 0 |
| chlorfenvinphos | 0,000143 | 0 | 7790 |
| chlormequat | 8,98E-05 | 0 | 390000 |
| chloropyrifos | 0,000254 | 0 | 78900000 |
| chlorthalonil | 0,000576 | 0 | 0 |
| cyanazin | 0,000496 | 0 | 0 |
| cypermethrin | 1,71E-07 | 735 | 0 |
| dichlofluanide | 7,54E-09 | 0 | 0 |
| dichloropropene | 0 | 0 | 0 |
| dicofol | 3,36E-06 | 0 | 0 |
| dienofchloor | 0 | 0 | 0 |
| diflubenzuron | 2,84E-06 | 0 | 0 |
| diuron | 0 | 0 | 0 |
| ethefon | 0 | 0 | 0 |
| etridiazool | 0 | 0 | 0 |
| fenarimol | 0 | 0 | 0 |
| fenvalerate | 2,04E-06 | 0 | 0 |
| fluroxypyr | 0 | 0 | 0 |
| heptenofos | 0 | 0 | 0 |
| iprodione | 2,39E-05 | 0 | 0 |
| MCPA | 0 | 42300 | 0 |
| MCPP | 0 | 68800 | 0 |
| metazachloor | 0 | 0 | 0 |
| metolachloor | 0 | 0 | 0 |
| metoxuron | 0 | 0 | 0 |
| penconazool | 0 | 0 | 0 |
| pencycuron | 0 | 0 | 0 |
| permethrin | 2,69E-06 | 33500 | 0 |
| prochloraz | 0,000193 | 0 | 0 |
| procymidon | 2,57E-06 | 0 | 0 |
| propachloro | 0 | 7120 | 0 |
| propazin | 0,000447 | 0 | 0 |
| propiconazool | 8,73E-06 | 0 | 0 |
| propyzamide | 0 | 0 | 0 |
| pyridaat | 0 | 0 | 0 |
| quintozene | 0,000113 | 0 | 0 |
| Total | 0.61584775 | 1027798,9 | 133648310 |

*Table B4.5:* *Total emissions and scores for agricultural pesticides after implementation of the envisaged policies*

| | HumTox (kton) | AqEcoTox (1000 m3) | TerEcoTx (kton) |
|---|---|---|---|
| lindane | 0,039235 | 289 | 14900000 |
| 2,4-D | 2,71E-07 | 7,13 | 1040000 |
| chlortolurol | 0 | 0 | 0 |
| dichlorovos | 0,000165 | 464000 | 298000 |
| linuron | 0 | 2640 | 0 |
| monolinuron | 0 | 0 | 0 |
| chloorprofam | 0 | 0 | 0 |
| simazin | 0,000886 | 633 | 0 |
| trichlorofon | 2,83E-06 | 9760 | 13500 |
| chlofentezin | 0 | 0 | 0 |
| vinchlozolin | 2,73E-05 | 0 | 0 |
| hexythiazox | 0 | 0 | 0 |
| tolclofos-methyl | 0 | 0 | 0 |
| tolylfluanide | 4,18E-05 | 0 | 0 |
| tri-allaat | 0 | 0 | 0 |
| tridimefon | 1,58E-07 | 0 | 610 |
| triadimenol | 2,33E-06 | 0 | 0 |
| triforine | 2E-06 | 0 | 0 |
| anilazin | 3,59E-05 | 0 | 0 |
| atrazin | 0,327588 | 5160 | 15300000 |
| bifenox | 0 | 0 | 0 |
| captan | 6,55E-05 | 42900 | 1070000 |
| chloorbromuron | 0 | 0 | 0 |
| chlorfenvinphos | 8,59E-05 | 0 | 4680 |
| chlormequat | 5,39E-05 | 0 | 234000 |
| chloropyrifos | 0,000152 | 0 | 47300000 |
| chlorothalonil | 0,000345 | 0 | 0 |
| cyanazin | 0,000298 | 0 | 0 |
| cypermethrin | 1,02E-07 | 441 | 0 |
| dichlofluanide | 4,52E-09 | 0 | 0 |
| dichloropropene | 0 | 0 | 0 |
| dicofol | 2,02E-06 | 0 | 0 |
| dienochloor | 0 | 0 | 0 |
| diflubenzuron | 1,7E-06 | 0 | 0 |
| diuron | 0 | 0 | 0 |
| ethefon | 0 | 0 | 0 |
| etridiazool | 0 | 0 | 0 |
| fenarimol | 0 | 0 | 0 |
| fenvalerate | 1,22E-06 | 0 | 0 |
| fluroxypyr | 0 | 0 | 0 |
| heptenofos | 0 | 0 | 0 |
| iprodione | 1,44E-05 | 0 | 0 |
| MCPA | 0 | 25400 | 0 |
| MCPP | 0 | 41300 | 0 |
| metazachloor | 0 | 0 | 0 |
| metolachloor | 0 | 0 | 0 |
| metoxuron | 0 | 0 | 0 |
| penconazool | 0 | 0 | 0 |
| pencycuron | 0 | 0 | 0 |
| permethrin | 1,61E-06 | 20100 | 0 |
| prochloraz | 0,000116 | 0 | 0 |
| procymidon | 1,54E-06 | 0 | 0 |
| propachlor | 0 | 25100 | 0 |
| propazin | 0,000268 | 0 | 0 |
| propiconazool | 5,24E-06 | 0 | 0 |
| propyzamide | 0 | 0 | 0 |
| pyridaat | 0 | 0 | 0 |
| quintozene | 6,79E-05 | 0 | 0 |
| Total | 0,3694666255 | 637730,13 | 80160790 |

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## *APPENDIX 5: ABBREVIATIONS*

| | |
|---|---|
| ADI | Acceptable Daily Intake |
| AMvB | Algemene Maatregel van Bestuur *[Order in Council]* |
| AOO | Afvaloverlegorgaan *[Waste Consultancy Body]* |
| AP | Acidification Potential |
| AVI | Afvalverbrandingsinstallatie *[Waste incineration plant]* |
| AWZI | Afvalwaterzuiveringsinstallatie *[effluent treatment plant]* |
| BMP | Bedrijfsmilieuplan *[Corporate environmental plan]* |
| BSA | Bouw- en sloopafval *[Building and demolition waste]*; (TNO-)Beleidsstudies en Advies |
| CBS | Centraal Bureau voor Statistiek *[Central Bureau of Statistics]* |
| CML | Centrum voor Milieukunde Leiden *[Centre for Environmental Science Leiden]* |
| CWZ | Centrale Waterzuiveringsinstallatie *[Central water treatment plant]* |
| ECA | Ecotoxicologische classificatiefactor voor aquatische ecosystemen *[Ecotoxicological classification factor for aquatic ecosystems]* |
| ECT | Ecotoxicologische classificatiefactor voor terrestrische ecosystemen *[Ecotoxicological classificaiton factor for terrestrial ecosystems]* |
| EG, EC, EU | Europese Gemeenschap/Unie *[European Community/Union]* |
| EPA | Environmental Protection Agency |
| ER | Emissieregistratie *[Emission Records]* |
| EZ | Ministerie van Economische Zaken *[Ministry of Economic Affairs]* |
| GEP | General Electric Plastic |
| GWP | Global Warming Potential |
| HTP | Human Toxicity Potential |
| IBC | Isoleren, Beheersen, Controleren *[Isolate, Control, Monitor]* |
| IMA | Informatie- en meldpunt afvalstoffen *[Information and notification centre for waste substances]* |
| IMT | Integrale Milieutaakstelling *[Integrated Environmental Target]* |
| IPCC | International Panel on Climate Change |
| KWD | Kantoor-, winkel- en diensten afval *[Office, shop and services waste]* |
| LCA | Levenscyclusanalyse *[Life-cycle assessment]* |
| LMA | Landelijk Meldpunt Afvalstoffen; sinds 1994: IMA *[National Notification Centre for Waste Substances; since 1994: IMA*] |
| LVM | Limburgse Vinyl Maatschappij |
| MAC | Maximaal Aanvaarde Concentratie *[Maximum Acceptable Concentration]* |
| MAR | Maximum acceptable risk level (= MTR) |
| MER | Milieu Effectenrapportage *[Environmental Impact Report]* |
| MJP-G | Meerjarenprogramma Gewasbescherming *[Multi-Year Crop Protection Programme]* |
| MJP-H | Meerjarenplan voor bestrijdingsmiddelen buiten de landbouw *[Multi-Year Programme for non-agricultural pesticides]* |

| | |
|---|---|
| MTR | Maximaal toelaatbaar risiconiveau *[Maximum Tolerable Risk level]* |
| M-YCP | Multi-year Crop Protection Programme |
| NEC | No (adverse) Effect Concentration |
| NEFYTO | Nederlandse Vereniging voor Fytofarmacie *[Netherlands Associaiton for Phytopharmaceuticals]* |
| NEI | No-effect Intake |
| NER | *Nederlandse Emissierichtlijnen [Netherlands Emissions Guidelines]* |
| NR | Negligible Risk level (=VR) |
| NVZ | Nederlandse Vereniging van Zeepfabrikanten *[Netherlands Association of Soap Manufacturers]* |
| ODP | Ozone depletion potential |
| PBT's | Persistente, bioaccumulerende en toxische stoffen *[Persistent, bioaccumulating and toxic substnaces]* |
| PEC | Predicted Environmental Concentration |
| RAP/NAP | Rijn- en Noordzeeaktieprogramma *[Rhine and North Sea Action Programmes]* |
| RIVM | Rijksinstituut voor Volksgezondheid en Milieuhygiëne *[National Institute of Public Health and Environmental Protection]* |
| RIZA | Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwater *[Institute for Inland Water Management and Waste Water Treatment]* |
| RGR | Rookgasreinigingsresidu *[Flue gas treatment residue]* |
| RWZI | Rioolwaterzuiveringsinstallatie *[sewage plant]* |
| SNC | Shell Nederland Chemie |
| SNM | Stichting Natuur en Milieu *[Foundation for Nature Conservation and Environmental Protection]* |
| SNR | Shell Nederland Raffinaderij |
| SPIN | SamenwerkingsProject Industriele procesbeschrijvingen in Nederland *[Collaborative Project for the Description of industrial processes in the Netherlands]* |
| TDI | Tolerable Daily Intake |
| TEQ | Toxiciteitsequivalent *[Toxicity equivalent]* |
| TETP | Terrestrial EcoToxicity Potential |
| TNO | Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek *[Netherlands Organisation for Applied Scientific Research]* |
| UBS | Uniform beoordelingssysteem stoffen *[= USES]* |
| USES | Uniform system for the evaluation of substances |
| V en W | Ministry of Transport and Public Works |
| VHCP | Vereninging van Handelaren in Chemische Produkten *[Association of Traders in Chemical Products]* |
| VNCI | Vereniging van Nederlandse Chemische Industrie *[The Netherlands' Chemical Industry Association]* |
| V.O.F. | Vennootschap onder firma *[a partnership under Dutch law]* |
| VR | Verwaarloosbaar risiconiveau *[Negligible risk level]* |

| | |
|---|---|
| VROM | Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer *[Ministry of Housing, Spatial Planning and the Environment]* |
| VVVF | Vereniging van Verf- en Drukinktfabrikanten *[Association of Paint and Printing Ink Manufacturers]* |
| WIER | Registratie-stysteem RIZA voor lozingen naar water *[RIZA's registration system for releases to water]* |

*Chemical compounds - abbreviations*

| | |
|---|---|
| AC | Allylchloride |
| AOX | Adsorbable organic halogens |
| BPA | Bisphenolacetone |
| CFC | Chlorofluorocarbons |
| (C)FHC | (Chloro)fluorohydrocarbons |
| CHC | Chlorinated hydrocarbons |
| CMC | Carboxymethylcellulose |
| DADPM | Diaminodiphenylmethane |
| DCB | Dichlorobenzene |
| DCH | Dichlorohydrine |
| DCM | Dichloromethane |
| DD | Dichloropropane and dichloropropene |
| ECH | Epichlorohydrine (chloropropylene oxide) |
| EDA | Ethylenediamine |
| EDC | Ethylenedichloride |
| EOCl | Extractable organic chlorine |
| EOX | Extractable organic halogens |
| FGZ | Phenyl-glycylchloride |
| HCB | Hexachlorobenzene |
| HCBd | Hexachlorobutadiene |
| HCFC | Hydrochlorofluorocarbon |
| HCPX | Hexachloro para-xylene |
| HFP | Hexafluoropropene |
| HHC | Halogenated hydrocarbons |
| HC | Hydrocarbons |
| MCA | Monochloroacetic acid |
| MCB | Monochlorobenzene |
| MCPA | 4-Chloro-2-methyl-phenoxyacetic acid |
| MCPP | 4-Chloro-2-methyl-phenoxypropionic acid |
| MDI | Methylenediphenyldiisocyanate |
| NMP | N-methylpyrrolidon |
| NNB | Niet nader benoemd/unspecified |
| PCB | Polychlorobiphenyl |

| | |
|---|---|
| PCP | Pentachlorophenol |
| PDA | p-Phenylenediamine |
| PER | Tetrachloroethene |
| PFIB | Perfluorisobutene |
| PTFE | Polyfluorethene |
| PVC | Polyvinylchloride |
| TCB | Trichlorobenzene |
| TCDD | Dioxins |
| T-CMC | CMC, technical grade |
| TCP | Trichloropropane |
| TDC | Terephthalic acid dichloride |
| TET | Tetrachloromethane |
| TFE | Tetrafluoroethene |
| TFZ | Terephthalic acid |
| VCM | Vinylchloride monomer |
| VDCM | Vinylidenechloride |
| VOC | Volatile organic compounds |
| Z-CMC | CMC, pure |

## *APPENDIX 6: SOME DEFINITIONS*

| | |
|---|---|
| Chlorinated micropollutants: | Unidentified emissions which have at present neither been shown to cause harm, nor to be harmless. |
| Emission: | release of a substance from a production process or application, into the environment (soil, water or atmosphere), excluding the flow of chloride (i.e. salt) into the water. |
| Netherlands total score: | score of all emissions in the Netherlands for a given theme (both chlorine-containing and chlorine-free). |
| Netherlands environmental pollution (total integrated) | number calculated by adding the normalised Netherlands total scores for each theme, with or without the use of weighting factors. |
| Normalisation: | expressing the score of an emission for a theme as a fraction of the Netherlands total score on that theme. |
| Outflow: | release into the environment of *any* chlorine-containing compound from a process, including the release of chloride (salt) to water. |
| PBTs: | emissions of persistent, bioaccumulating and toxic substances which were not traced. |
| Process: | production process or application in which a chlorine compounds is used for a single, defined application. |
| Score: | number calculated with the LCA classification method developed by the CML, it the contribution of an emission to the specified environmental theme. |
| Segment group: | cluster of production processes *or* applications in the chlorine chain to indicate the scores in Figures 4.4.4-4.4.11. The clusters were based on overlapping |

| | |
|---|---|
| | environmental effects (e.g. CFCs) or close links between processes (e.g. the production of AC/ECH/epoxy resins). |
| Segment: | production or application (consumption) process, or cluster of linked production or application processes in the chlorine chain, the description in Volume II was based on this structure. |
| Subchain: | all production and consumption processes in the chlorine chain, downstream of the basic chemical containing chlorine, including its production - essentially a branch on the fold-out diagram. |

## *APPENDIX 7: SUPERVISORY COMMITTEE, TECHNICAL WORKING GROUP AND FEEDBACK GROUP*

*Supervisory committee:*

drs. C.J. v. Kuijen (VROM/DGM/SVS), chairman upto October 1994
dr. C.M. Plug (VROM/DGM/SVS), chairman from October 1994
ir. M. Bovenkerk (VROM/DGM/SVS), secretary
ir. V. Bakker (RIZA)
ir. L. Koster (Shell Nederland)
ir. J.L.J. Meersseman (Solvay Chemie B.V., from June 1995)
ing. C.M. Moons (VROM/DGM/B)
ir. W.C.J. Quik (VNCI)
ir. H.J.C. Scheffers (Akzo Nobel, from September 1994)
dr. ir. H.A.C.M. Spaas (DOW Europe N.V.)
ir. J.A. Wesseldijk (Akzo Nobel, up to September 1994)
drs. B.J. Witmont (EZ)

*Technical working group:*

ir. M. Bovenkerk (VROM/DGM/SVS), chairman
ir. G.J. Alders (Akzo Nobel)
ir. M.A.M. Augustijn (Solvay Chemie B.V.)
ir. V. Bakker (RIZA)
ir. W. Blanken (VNCI)
drs. H. Flier (Akzo Nobel)
ir. P. Bogaerts (DOW Benelux; up to July 1994)
P. Ootes (DOW Benelux; from July 1994)
drs. E.T.H. Vink (DOW Benelux; from July 1994)
ir. A.L. Mooiweer (Shell Nederland Chemie)

*DGM internal feedback group:*

ing. M.M.J. Allessie (VROM/DGM/A)
D. v.d. Brand (VROM/DGM/SVS)
drs. M.A. v.d. Gaag (VROM/DGM/DWL)
drs. M.M. de Hoog (VROM/DGM/IBPC)
drs. M.T.V. de Jong (VROM/DGM/IBPC)
ir. H. Wijnen (VROM/DGM/IBPC)
ir. P.T.J. v.d. Zandt (VROM/DGM/SVS)

Members of the feedback group attended certain meetings of the technical working group, depending on the subjects on the agenda. The meetings of the supervisory committee and technical working group were attended by the following representatives of CML and TNO:

drs. ing. R. Kleijn (CML)
drs. A. Tukker (TNO)
drs. E.v.d. Voet (CML)

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## *APPENDIX 8: PEER REVIEW*

Note: the peer review was based on the penultimate version of the report which was sent to the peer review panel on 3 August 1995. The panel did not discuss the text of the review with the research institutes, client or members of the support committee. The review was written independently by the panel and is reproduced here in full.

The consideration given to the comments resulting from the peer review was discussed in the foreword to this report. The review panel was not asked to comment on the revised version of the report.

# Peer review
# Closing the Chlorine Chain
Apeldoorn, the Netherlands
17-18 August 1995

Final version, 19 September 1995

*Peer review committee*
Professor H. A. J. Govers
Professor W. A. Hafkamp
Professor J. H. Koeman (chairman)
Professor A. van der Meiden
H.J.W. Sas

Rapporteur: F.G.P. Corten

*Subject of the peer review:*
A Chlorine Balance for the Netherlands
A. Tukker (TNO), R. Kleijn (CML), E v.d. Voet (CML)
Apeldoorn/Leiden, 1995

# Peer review 'Closing the Chlorine Chain'

## 1 Introduction

The peer review 'Closing the Chlorine Chain' was undertaken on 17 and 18 August 1995. A committee appointed for this purpose assessed the study 'A Chlorine Balance for the Netherlands'.

This report describes the activities of the committee. Chapter 1 lists the members of the committee and describes the subject of the peer review and the associated documents. Chapter 2 describes the committee's brief. Chapter 3 describes the committee's *modus operandi.* Chapter 4 covers the discussion of the study, the comments and the question to be addressed by the study, implementation of the study and formulation of the conclusions. Finally, in Chapter 5 the committee provides some recommendations for a follow-up to the strategic survey.

### Members of the peer review committee

- Professor H. A. J. Govers, Amsterdam University, Department of Environmental and Toxicological Chemistry (Professor of Environmental Chemistry);
- Professor W. A. Hafkamp, Erasmus University Rotterdam, Department of Environmental Studies (Professor of Environmental Studies);
- Professor J. H. Koeman, Agricultural University, Department of Toxicology (Professor of Toxicology);
- Professor A. van der Meiden, Amersfoort (Professor emeritus of Public Relations);
- H.J.W. Sas, Centre for Energy Conservation and Environmental Technology (CE), Delft (senior project manager, materials and waste substances).

F.G.P. Corten, CE, Delft (project manager, policy studies) acted as the rapporteur.

### Subject of the peer review

The peer review concerned phase 1 of a strategic survey of closing the chlorine chain. In March 1993 the Ministry of Housing, Spatial Planning and the Environment made a commitment to the Permanent Committee on Environmental Management of the Lower House that such a survey would be carried out. The objective of the survey would be to provide comprehensive information about the chlorine chain in the Netherlands, the leaks in it and whether or not it is possible to remedy such leaks. The leaks in the chlorine chain were addressed in phase 1 of the survey.

The peer review was based on the final report on phase 1:

**A Chlorine Balance for the Netherlands**
*A. Tukker (TNO Centre for Technology and Policy Studies), R. Kleijn (Centre of Environmental Science, Leiden), E. v.d. Voet (Centre of Environmental Science, Leiden).*
*Final draft for peer review, 31 July 1995*
*Part I Main report*
*Part II Substance documents*
*Part III Backgrounds*
*Errata 14 August 1995*

The committee also read the six appendices to the letters of appointment to its members and to the rapporteur:

1. Agenda and report of the preliminary discussions on 25 April 1995 on the peer review.
2. Initial memorandum on closing the chlorine chain, 27 August 1993, by the department of Substances, Safety and Radiation of the Directorate-General for Environmental Management (DGM) of the Ministry of Housing, Spatial Planning and the Environment (including three appendices).
3. Joint project proposal by TNO and CML 'Closing the Chlorine Chain', a study into leaks in the chlorine chain and the associated risks, 30 July 1993 with a tender dated 2 August 1993.
4. Joint quotation by TNO and CML for 'Intermediate phase of the chlorine chain study', 19 October 1994.
5. Joint quotation by TNO and CML for 'Expansion of the intermediate phase of the chlorine chain study', 24 March 1994 (with annex) and letter of tender of 24 March 1995. This quotation included a chapter on the peer review[1].
6. Guidelines for Life-Cycle Assessment: A 'Code of Practice', first edition, Chapter 7: 'Peer Review' (from the workshop held at Sesimbra, Portugal, 31 March - 3 April 1993).

## 2 Brief of the peer review committee

When appointing the members of the peer review committee the Ministry of Housing, Spatial Planning and the Environment (VROM) referred to the above six appendixes with respect to the brief of the committee. The main elements from these documents which define the brief are included in this chapter.

During the preliminary discussions on 25 April 1995 between the funding body (VNCI), commissioning body (VROM) and the researchers (TNO/CML) and

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[1] This stated, inter alia, that a peer review was recommended to the industrial members of the steering committee to further increase the support for and credibility of the study. TNO and CML recommended that 'the members of the peer review committee should be widely recognised as scientific experts in areas relevant to the chlorine chain study'. They also recommended that 'the members of the peer review committee should be identified with a broad spectrum of views on chlorine chemistry'. It was also stated that the peer review report should be included 'as a clearly separate appendix' to the comprehensive report on phase 1.

two of the proposed members of the peer review committee the brief was defined as:[2]

- To analyse whether or not, in view of the information currently available, the report 'A Chlorine Balance for the Netherlands' (STB/94/054) and its supplement provide adequate answers to the questions for phase 1 in the terms of reference for the study into closing the chlorine chain in the Netherlands (i.e. 'Where are the leaks in the chlorine chain in the Netherlands, what is the magnitude/relevance (preferably expressed in quantitative terms) of the risks associated with those leaks against the background of the risk policy discussed and agreed with the Lower House?').
- To analyse whether the methods (Sfinx/LCA) were appropriately applied and documented and whether appropriate data files were used.
- To analyse whether the conclusions and recommendations from the above report and its supplement are indeed supported by the described data and whether the conclusions and recommendations are consistent and clear to the readers.
- To analyse which material and methodological aspects which may not have been addressed in sufficient detail in phase 1 of the report on the chlorine chain may be developed in further stages of the study.

The following agreements about the operating method are relevant here:

- The peer review panel will appoint its own chairman and will decide on the procedures for the analysis.
- Where appropriate, the peer review panel may use the "Code of Practice", Guidelines for Life-Cycle Assessment, (31 March - 3 April 1993).

## 3 Method

The committee's method of operation is described below. The committee met for two days to assess the study.[3]

Before these sessions, all members thoroughly reviewed the report and its appendices as well as the other documents made available and noted their comments.

Various procedural matters were agreed during the first session. Professor Koeman was appointed by acclamation as chairman. The members introduced themselves and described their backgrounds and expertise. The procedure to be followed was then defined.

The starting point was provided by letter of appointment to the members of the committee, including elements of the 'Code of Practice' for LCA studies. This described an interactive peer review, including the following elements:

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[2] Quoted from the report on the meeting of 25 April 1995.

[3] These sessions were held on Thursday 17 August 1995, from 10:00 to 12:30 and from 13:30 to 17:30 at Apeldoorn and from 20:00 to 21:30 at Beekbergen, and on Friday 18 August 1995 from 9:00 to 12:30 and from 13:30 to 15:30 at Apeldoorn.

- at the beginning of the LCA, to review the goals, scope, boundaries and the data collection planned;
- after initial data collection or modelling, to review the progress and offer advice or comments; and
- at the final report stage, to review the adequacy of the study, and the credibility of the conclusions.'

However, in this case, the committee was asked to undertake a peer review of phase 1 of the chlorine chain study after its completion. Hence, there was no interactive process. However, the committee chose to consider the entire process, from the awarding of the commission to the final result, where this was relevant to phase 1 and future phases of the survey.

The general comments of the committee members were compiled during the first, comprehensive round. This information was used to draw up a schedule with the various aspects to be considered during the peer review (see next page). The comments on the main report were then discussed, page-by-page, starting with the summary (pp. i through xvi) and then the other pages (pp. 1 through 67). Aspects of the various background documents and appendices were selected at random for review, the members focused on sections within their specific area of expertise. Generally the main outlines were assessed, calculations were occasionally checked or facts verified on the basis of readily available information.

The comments of the committee boiled down to several major points, which could be illustrated by examples from the text. These major points were again discussed on Friday afternoon. The committee's final conclusions were unanimous.

The rapporteur kept notes of the various comments. A list of nine technical questions, addressed to the authors of the report, was also drawn up. These questions were discussed with A. Tukker on 18 August, from 12:00 to 12:30 (see appendix 1).

The rapporteur wrote the draft peer review report which was mailed for comment to the members of the committee on 29 August. The second draft was developed on the basis of their comments and sent to them on 8 September. The last comments were then included in the final version of the report in consultation with the chairman.

When reviewing the report the committee focused on some aspects of the implementation of the study. The committee also considered the original brief (question) as defined by the commissioning body of the study. Finally, the extent to which the study provided an answer to the original question and the extent to which the study could provide a basis for the further phases were also included in the review. Table 1 lists the aspects considered by the peer review committee.

**Table 1** **Foci of the peer review committee**

**1. Original question**
Was, given the context of the historical discussion of the environmental aspects of chlorine chemistry and its products, a question defined which was compatible with society's expectations of a survey of the chlorine chain?

**2. Implementation of the study**
When reviewing the implementation of the study the members of the committee considered the following aspects:

- selection of the *modus operandi;*
- justification of the selection of the *modus operandi;*
- application of the method and quality of the data;
- reporting of the results;
- formulation of the conclusions and recommendations.

The committee identified the following components of the implementation of the study:

a. Survey of the chlorine streams and losses due to leaks;
b. Assessment:
    - safety
    - worldwide problems
    - problems related to toxicity
c. Prioritisation of the losses due to leaks

**3. Peer review committee's recommendations**
What recommendations can the committee make on the basis of the peer review?

## 4 Discussion of the report

### 4.1 Major points of the comments

The first round of comments identified some major points. During the second round these were found to be supported unanimously by all members of the committee. These major points are listed below and concern all aspects listed in Table 1. They will be discussed in greater detail in the next section.

1. In the view of the committee the researchers have gathered the data on the chlorine chain very professionally and with great perseverance, both from a range of databases and from the chlorine industry. The data was also processed very accurately.
2. The committee was impressed by the care with which the gaps in the information, uncertainties and inaccuracies in the data were described.

3. In the view of the committee the selection of the methodology of the study was not adequately supported.
4. The committee was aware that, at present, there is no fully adequate method to identify the risks of the introduction of substances (including chlorinated micropollutants) into the environment. However, in the view of the committee, the method selected for the study was inadequate in this area, e.g. with respect to combined exposure to substances. It is also the view of the committee that there are better methods available to consider the environmental fate of substances.
5. In the view of the committee, the uncertainties in the information available about the chlorine chain identified in the report, were insufficiently considered in the conclusions. The uncertainties associated with minor flows may be extremely important, particularly with respect to toxicity. This risk evaluation was not sufficiently transparent.
6. The committee was disappointed by the fact that health risks to employees were not considered in the study.
7. Some of the formulations used in the report appear to amount to a value judgment on the use of chlorine or the environmental impact of the chlorine chain which, in the view of the committee, was not part of the remit of phase 1 and was not supported by the study carried out.
8. The committee recommended that all the observed gaps in knowledge and uncertainties be given priority in a follow-up study or phase 2.
9. It is the view of the committee that the publication of the report should be handled with care.

### 4.2 Detailed examination of the major points

The major points listed above will be considered in detail in this section, on the basis of the aspects in Table 1, and will be illustrated by examples. Several less important comments will also be considered.

#### 4.2.1 Brief

The committee was aware that the discussions in society are mostly focused on the *risks* to humans and the environment associated with the production, transport, use and disposal of chlorine-containing substances. There is an acute awareness that even minor streams may lead to major effects.

The question, defined by the commissioning body, was:

- A substance stream analysis shall be undertaken for chlorine and chlorine-containing substances for the situation in the Netherlands, to include all related emissions, except chlorine salt emissions. This shall cover at least 95% of the chlorine chain.

- The relative magnitude and relevance of the emissions shall be compared with each other against the background of the risk policy discussed and agreed with the Lower House.

In the view of the committee, this question is inadequate to survey the chlorine chain. This is due to the special relevance of the human toxic and ecotoxic effects of the chlorine chain. A quantitative survey (substance flow balance) covering 95% of the chlorine chain is not sufficiently accurate for this purpose and to some extent it is actually irrelevant. It does not include the very limited emissions of chlorinated micropollutants which may have serious adverse effects.

This problem is noted in the report (p. 12, paragraph 4, sentence 1 [Translator's note: all references are to the penultimate, original Dutch version of the report. See also the introduction to this peer review and the preface of this study]). However, the uncertainties and gaps in knowledge resulting from this are not adequately included in the conclusions.

P. ii, paragraph 1 : 'In phase 3 in phase 3, the need for and extent of measures to be taken or the implementation of alternatives would be investigated on the basis of the results of phases 1 and 2; 'Need for' should be replaced by 'desirable'. Phase 1 was undertaken to establish the need.

### 4.2.2 Execution of the research

**Selection of the method and justification of this choice**

In accordance with the brief defined by the commissioning body the researchers proposed a method to provide a comprehensive quantitative overview of the chlorine chain: inputs, outputs, conversion/transformation, etc. A general assessment framework was also proposed, to determine the priorities based on the following environmental aspects which were identified as being essential:

- ozone depletion and global warming;
- ecotoxicity;
- landfilling waste;
- human toxicity;
- smog formation;
- acidification;
- odour[4]

The assessment with respect to these effects was based on the LCA framework developed and documented by the CML. This method was accepted by the commissioning body. However, the report does not provide the grounds for the selection of this method. Similarly, it is not explained why other methods such as MacKay models and other multi-media models were not used in the study.

P. iii, Chapter 2. A method is selected without further justification, i.e. substance flow analysis using an LCA assessment and weighting. Again, in III, p. 7, sub 1.2.4, the selection is not supported and it is suggested that it may be revised in a subsequent phase, which is not correct (paragraph 3: '*In phase I it is therefore ...*'). The committee recommends that the selection should

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[4] [Translator's note: this footnote concerns the use of the Dutch words for 'odour' and 'stench', and is only relevant to the Dutch version of the report.]

be justified and that possible alternatives should be discussed. The effects of the choice on the scope and relevance of the results should also be indicated.

P. iv, paragraph 3 'outflow of inorganic chlorine compounds ... ... was not followed'. Which substances does this refer to? It is recommended that these substances are discussed in qualitative terms, thus stating the reasons not to include them.

P. 45, paragraph 3, line 9 '... measures in the pharmaceutical industry were not surveyed': please indicate why these were not surveyed.

**Application of the method and quality of the data**

The method as such was applied consistently and accurately:

- 99% of the chlorine flows were surveyed, rather than 95%;
- a broad survey of the most relevant data files was undertaken and the data was effectively used;
- great efforts were also made to obtain data from the industry;
- the literature study was extensive;
- the assessment method per se was applied consistently;
- many cross-sections of the chlorine chain were included in the survey;
- the effects of recent policies on emissions were included;
- the constraints of the method used were described such that they can easily be traced.

The committee was disappointed that 1990 data was generally used, rather than more recent data. However, the committee was aware that the researchers had no other option.

**Presentation of the results**

Despite some comments regarding some details the method was considered to be reasonably adequate for the effects *enhanced greenhouse effect*, *depletion of the ozone layer* and *solid waste*. This also applied, albeit to a lesser extent to *formation of photochemical oxidants* (smog).

The method which was defined and applied had serious limitations with respect to the reliable assessment of the themes *ecotoxicity* and *human toxicity*. The reasons for this were:

- potentially relevant chlorine streams (unintentional emissions, product contamination, chains not surveyed, AOX) were excluded due to the selected approach;
- no correlation was made between emissions and environmental concentrations;
- the effects of combined exposure to substances and formation of metabolites were not considered.

The disadvantage of separating safety risks is that the integration, at a later stage, of this aspect with the other aspects may be inadequate.

The researchers indicated most of these shortcomings in their reports. However, the uncertainties are not given sufficient consideration:

- the report does not identify remedying the gaps in the available knowledge as a real priority;
- to some extent it is suggested that the chlorine-chains not considered (10 kt chlorine per annum) are not relevant, although this was not supported in the report;
- it is also suggested that there are no practical, feasible alternatives to the method used in the study, although in the view of the committee such alternatives are available (MacKay-III models and other multimedia models).

Occasionally the limitations were not described in full:

P. iv, paragraph 4. Limitations: add

- exposure to complex mixtures (e.g. including naturally occurring chlorine compounds) was not included in the report;
- occupational safety aspects were not considered.

Occasionally, the results were not supported or only partly supported:

P. ix, items 1-7: the selection of these processes should be supported.

P. ix, item 2: 'the use of pesticides'. Add 'effects of mixtures and the formation of metabolites'.

P. ix, item 3: Landfill. Add 'incineration residues of all chlorinated hydrocarbons which have to be incinerated'.

P ix. item 4: '... and chloromethanes'. Add 'unknown substances, effects of mixtures and the formation of metabolites'.

P. xii, paragraph 4, occupational health risks should be included in the discussion of human toxicity.

P. xiii, paragraph 1, last sentence, the 24% should be divided into organic chlorine compounds and hydrochloric acid.

P. 20, paragraph 2: '... all substances are allocated for 100%' should be replaced by '... all surveyed substances are allocated for 100%'.

P. 23, paragraph 3, item 1: '... and the remaining gaps appear to be reasonably acceptable'. What is this based on and how is this reflected in the conclusions?

P. 47, paragraph 2, line 1: 'Chlorinated pesticides are by far the most important ... would appear to be irrelevant'. This applies within the framework of the selected method and the defined system limits. It is likely that combined exposure to chlorinated substances is the most relevant factor with respect to the ecotoxicity score.

P. 54, paragraph 1, line 11, '... chloride (salt) ... ... generally discharged to salt water'. The committee noted that the harmful effects of the chloride ion depend on the accompanying ion, which may not always be sodium. It would be advisable to investigate which accompanying ions are used and what the resulting environmental impact is. The word 'discharged' suggests an absence of harm, which has not been proven [Translator's note: it concerns the Dutch word the authors used for 'discharged', which is not relevant to the translated document.]

Part III: the environmental concentrations of substances used in Part III of the report are not linked to emission data. Thus, it is impossible to make a link between losses due to leaks and the impact on humans and the environment. The committee was aware that this would also have been difficult if another method had been selected, but even so the absence of any attempt to provide this was considered as an omission.

II/213, sub 3, first sentence: 'is assumed that around 1% ...'. This is an assumption of the researchers. Dispersion (multi-media) models are used for the purposes of establishng policy on pesticides. Please refer to this in a footnote.

II/259, sub 2.1.2, first line: '... approx. 6000 tonnes were processed in other countries'. The main report should clearly state that these emissions were not included in the study as they were beyond the system boundaries.

II/259, paragraph 3, first sentence: 'approx. 3400 tonnes'. Please explain how this number was derived from the basic data.

## Formulation of the conclusions and recommendations

In the view of the committee, the high quality of the implementation of the study and the collection of data were considerably affected by careless and incomplete formulations in the conclusions which do not take the observed uncertainties and missing information sufficiently into account. This also applies with respect to some other parts of the report and formulations which amount to a value judgment. In the view of the committee these elements could have an adverse impact on public opinion when the report is published as fundamental concerns might be raised which would make a carefully considered and differentiated approach of the issue of chlorine in our society, in phases 3 and 4 of the survey, more difficult.

The committee recommended that all substance flows for which insufficient data are available should be included as research priorities in the completion of phase 1 or as priorities in phase 2.

P. vii, last sentence: 'In short, the study explains the trajectory of practically 99% of the 939 ktons of inflowing chlorine'. In the view of the committee, the term 'explains' is too strong. Although the flows in the economy are known, the exact fate of the substances in the environment is not known. The exact pathways by which the substances reach the environment are also unknown.

P. xiii, paragraph 4: 'The number of priorities ... ... is limited'. The first sentence includes a value judgment which is not supported by the facts. The priorities listed on page xiv are incomplete and irrelevant observations about the relative magnitude of some priorities are made. Furthermore, the method for selecting the priorities is not justified. In the opinion of the committee, the following priorities should be added:

6. All substances and substance flows about which insufficient information is available should be given priority in further studies (to complete phase 1) or in phase 2.
7. The remediation of historic emissions should be a priority in phase 2.

The last paragraph of page 29 gives some reasons why the uncertainties in the study are only reflected in the conclusions to a limited extent. The committee does not support these arguments. The study was not intended to be an assessment of sustainability. However, the study was emphatically intended to prioritise chlorine-containing emissions. This should be completed in phase 1.

P. xv, paragraph 6: 'The study does not include emissions from a very limited number of .... 1% of the Netherlands chlorine flow'. This refers to 10 kt chlorine. An unspecified margin of error, not referred to in the report, should be added to the other 99%, thus the proportion will be greater than 1%. It is not known which substances this relates to, nor what the quantities of each substance are, how they are introduced into the enviroment and how they are degraded in the environment. Although the study fulfills the brief, the committee is concerned that nothing at all is known about this issue.

**Value judgments**

Some examples of value judgments which are unwarranted in the view of the committee:

P. i, paragraph 1: 'In this way chlorine has contributed a lot to the prosperity and welfare of toady's society'. In the view of the committee a value judgment of this type is inappropriate in the survey stage.

P. viii, paragraph 3: 'The chlorine chain scores lower on many themes' should be replaced by 'The scores of the chlorine chain are highest on the themes ecotoxicity, depletion of the ozone layer and the greenhouse effect'. In the view of the committee, such a value judgment is not supported by the scores in Figure 2. However, some of the members of the committee considered the 0.4% referred to was a suitable indicator.

P. ix, paragraph 1, line 4 'would be *permitted* to contribute'. 'Permitted' implies a value judgment and should be deleted.

P. ix, paragraph 1 'well above average'. The committee feels this is an inadequate description of an exceedance by a factor of 10 to 20.

P. ix, paragraph 1, last sentence '....relatively....'. The comittee recommends that this sentence be rewritten in more neutral terms. It suggests a 'What you don't know won't hurt you' approach which the committee considers to be inappropriate. The committee would prefer that the precautionary principle was used, as referred to on page 2, paragraph 1 of the report.

P. ix, paragraph 2, line 4: 'It is noticeable that for *almost every* theme' should be replaced by 'It is noticeable that for two of the three themes ...'. This does not apply to ecotoxicity. Similarly:

P. ix, paragraph 2, last sentence: 'So the existing policy has set the right priorities...' should be replaced by 'The current policy therefore defines the right priorities in most areas ...'. P. 50, paragraph 1: ditto.

P. ix, paragraph 2, line 9: 'only a limited number of processes'. Given the many limitations of the study it would be unwarranted to conclude that only a limited number of processes are involved.

P. xvi, paragraph 2, line 3: '... doubtful ...' should be replaced by '... unknown ...', line 5: '... do form ...' should be replaced by '... also form ...'.

P. 16, paragraph 2, line 9: 'that the release of unintentional by-products is possibly not completely covered in all cases'. This sentence does not correspond to the facts, as specific instances are mentioned in the preceding text, which prove unintentional discharges.

P. 39, paragraph 4, last sentence: 'could point to gaps in our knowledge'. This disguises the fact that there is a clear lack of information.

P. 52, paragraph 6, line 4: 'This is an advantage...'. This value judgment is inappropriate in phase 1.

P. 61, paragraph 2, last sentence: 'The segments referred to score...only slightly higher than ....impregnated wood accumulated in society'. The relevance of this comparison, which appears to suggest a value judgment, is unclear to the committee.

III/43, last paragraph: 'The recommended value is exceeded ... ' does not reflect the seriousness of the situation. The recommended value is *considerably* exceeded.

III/43, last paragraph: 'The TDI is not exceeded among children and adults. ... There is insufficient information available at present to assess the potential risk of dioxins in breast milk.' This is incorrect and does not fully acknowledge the seriousness of the situation. The recommended value is considerably exceeded by nursing babies. There is sufficient literature available on the consequences of this.

### 4.2.3 Other comments

**'Publicity-sensitive' aspects**

This report is likely to attract considerable publicity when it is published. The report contains some elements which may easily lead to misunderstanding or unbalanced interpretation when published.

Foreword, paragraph 4, line 5: 'This undoubtedly gives rise to discussions which could in principle have been avoided'. Confidentiality of the data was relevant in roughly one in four segments. In the view of the committee this is likely to have an adverse impact on public discussions. The committee recommends that this sentence is replaced by an explanation of the industry's reasons not to publish data.

P. ii. paragraph 2, last few sentences: please discuss the motivation of the environmental movement elsewhere in the report.

P. 23, paragraph 2, line 10 'the MTR is defined as the concentration as which the mortality rate is one in a million per annum' should be replaced by '... the MTR is defined as the concentration at which it is assumed, on the basis of linear interpolation, that there would be one fatality per million persons per year. Given the lack of better information this method is used to set a limit.'

**Readability of the report**

Although the report is generally easily readable, it contains some unclear elements and typing errors and stylistic errors. The readability would be improved if the whole report was checked on these aspects.

Summary, p. 0, note. The committee recommends that this text should be included as a note where it is first mentioned in the running text.

P. i, paragraph 3, first sentence: confusing. Replace by: 'Although there is a specific policy on certain chlorinated substances, the Netherlands does not have a general policy on chlorine.'

P. vii, paragraph 1, 3rd sentence: poor construction.

Conclusions and recommendations (summary, section 4 and main report, Chapter 5): the conclusions and recommendations in the summary and the main report are almost identical and of the same length. This is not desirable in terms of readability. It is proposed that the part in the summary should be cut considerably, or the text from the main report could be copied in its entirety (which should be noted).

P. xiii, paragraph 3 'This is except ..... accumulated foam'. The meaning of this sentence is unclear.

P. xvi, paragraph 4. This paragraph is irrelevant as a final conclusion is not part of the brief.

P. xvi, paragraph 3, last sentence: not relevant, delete.

P. 23, sub 3, 4th sentence: poor construction.

Pp. 27/28, section 3.4.4, last paragraph: this paragraph does not contain information relevant to the study and is confusing. The last sentence contains a policy judgement which is inappropriate at this phase of the study. The committee recommends that this sentence be deleted.

P. 50, paragraph 5, 'DDT' should be 'DTT'.

P. 51: in the view of the committee, the figures on this page are of little interest to users and may reduce the accessibility of the report.

Despite some errata the contents of section 4.4.5 are still difficult to understand.

P. 57, paragraph 3, line 2: 'essential applications'. What does this concept refer to?

II/213, paragraph 2, second sentence: poor construction.

II?218, last line: 'The quantity of Halon-1301 is outside the scope of the study' should be replaced by 'The quantity of Halon-1301 therefore falls outside the scope of the study.'

III/57, paragraph 4, last sentence: 'it is proposed putting atrazine on the list of priority substances' add: '*the RIVM* proposes that atrazine be added to the list of priority substances."

B/21, paragraph 3, last sentence: '... to the overall score on an environmental theme', add: '... to the overall score *of the chlorine chain* on an environmental theme.'

## 5 Recommendations

1. The committee recommends that all unknown emissions and all emissions whose further environmental effects and impact on living organisms are not sufficiently known should be identified as priorities. This includes:
   - chains not included in the survey;
   - product contamination;
   - unintentional discharge of chlorinated micropollutants[5];
   - formation of metabolites;
   - toxicity of mixtures;
   - historical emissions.

   In the view of the committee the current substance flow analysis and the LCA framework are inadequate for the assessment of the above categories.

   Most of these lacunae in the information are referred to (section 4.3 of the summary and section 5.3 of the main report) but they are not identified as priorities for further research (section 4.2 of the summary and section 5.2.2 of the main report). In the view of the committee this is necessary. In the view of the committee, the precautionary principle will have to be applied (as referred to in the main report, page 2, paragraph 1) if further research provides insufficient information. The remaining gaps in the information should then be designated as priorities for phase 2.

2. The committee recommends a follow-up phase, in addition to phase 1, in which all available methods are used which could help to remedy the identified gaps in the available knowledge.

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[5] E.g. hidden in AOX emissions.

3. The committee would also like to emphasize that the human ability to understand the chlorine streams is limited. This should be considered when defining policies, by excluding uncertainty wherever possible. Where uncertainties cannot be excluded, the policies will have to amount to risk management.

4. With respect to the present report, the committee recommends that the conclusions and sections supporting the conclusions (e.g. 4.4.6) be reformulated. It is also recommends that the text be checked for any value judgments.

   If these changes are made, justice will be done to the comprehensive and high-quality survey made for this study. This would provide a valuable document for the recommended follow-up research and other phases in the study.

5. The committee recommends that special consideration be given to supporting the publication of the report. The material is too sensitive to be dealt with by the normal publication methods. This will require consultation with those affected.

Appendix 1
Questions to A. Tukker, 18 August 1995

1. Main report, foreword, paragraph 4: 'This undoubtedly leads to discussions which could in principle have been avoided'. Question: which discussions are referred to? Answer: discussions about the fact that the industry does not make data publicly available cannot be avoided.

2. P. xiii, paragraph 1, line 8: 'The remaining 24% is organic chlorine compounds or hydrochloric acid'. Q: can the 24% be broken down into organic chlorine compounds and hydrochloric acid? A: this will be done.

3. P. ix, paragraph 3, p. xiv, paragraph 2: 'pesticides'. Q: does this refer to both agricultural pesticides and other pesticides. Q: all pesticides are included in the study.

4. DGM Internal Feedback Group. Q: that what extent were the members of this group involved with the study and did they contribute to it? A: the members were invited to all technical project meetings. They attended some meetings and added to or commented on technical issues.

5. Were the confidential emissions (see II, p. 104) included in the survey? A: yes, they were included.

6. Were emissions in other countries included in the survey? A: the system is limited to the Netherlands. Emissions from and the disposal of exported chlorine-containing products were beyond the scope of the study.

7. Was the impact of the future landfill ban on PVC waste considered, as this will increase the volume of waste to be incinerated? A: this was indeed considered, this aspect will be clarified.

8. Comment to II/211: the CTB does not advise on approval, but decides on it. A: this will be changed. II/213 (emission of approx. 1% into the aquatic environment): Koeman is drafting an alternative text.

9. B/21: comment: it is unclear how the list of substances was drawn up. A: this will be explained in the text.