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OECD SERIES ON EMISSION SCENARIO DOCUMENTS
Number 19

COMPLEMENTING GUIDELINE FOR WRITING EMISSION SCENARIO DOCUMENTS: THE LIFE-CYCLE STEP "SERVICE-LIFE"

English - Or. English

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OECD Environment, Health and Safety Publications

Series on Emission Scenario Documents No. 19

COMPLEMENTING GUIDELINE FOR WRITING EMISSION SCENARIO DOCUMENTS: THE LIFE-CYCLE STEP “SERVICE-LIFE”

IOMC

INTER-ORGANISATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS

A cooperative agreement among
UNEP, ILO, FAO, WHO, UNIDO, UNITAR and OECD

Environment Directorate

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Paris, 2008

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**OECD Environment Directorate,
Environment, Health and Safety Division**

**2 rue André-Pascal
75775 Paris Cedex 16
France**

Fax: (33-1) 44 30 61 80

E-mail: ehscont@oecd.org

FOREWORD

This document is a complement to the Guidance Document on Emission Scenario Documents (OECD Series of Emission Scenario Documents No 1) by focusing emission during service-life of articles. This document was developed by Sweden and reviewed by the OECD Task Force on Environmental Exposure Assessment.

This document is published on the responsibility of the Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology of the OECD.

TABLE OF CONTENTS

1 INTRODUCTION

This document is a complement to the Guidance Document on Emission Scenario Documents (OECD Series of Emission Scenario Documents No 1, ENV/JM/MONO(2000)12). The purpose of the document is to help writers of emission scenario documents (ESDs) to identify whether emissions during service-life may be of importance and therefore need to be included. It will also give an orientation on key aspects connected to such releases that need to be considered in an exposure assessment.

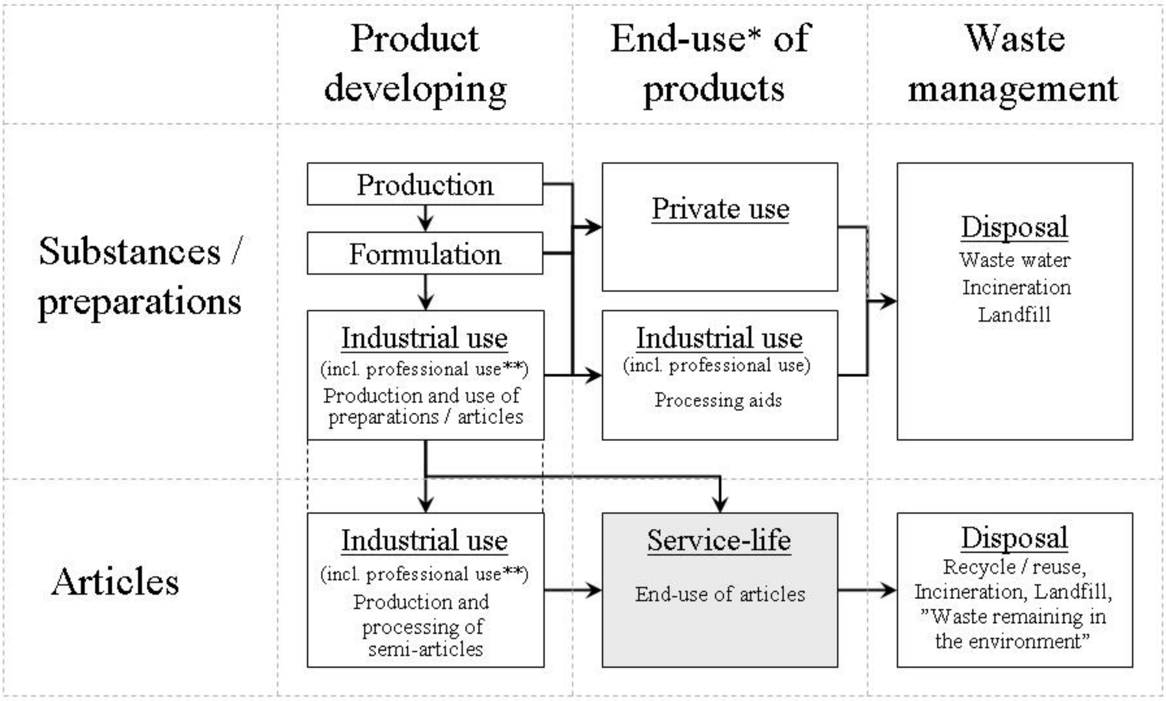
2 BACKGROUND

In an ESD the life-cycle of a substance has been divided into several stages, Production, Formulation, Industrial use/Professional, Private use, Service-life, and Disposal (see Figure 1). The life-cycle step “Service-life” for a substance refers to the end-use of articles containing the substance. Such activities include, for example, wearing and maintenance of textiles, housing, using and maintenance of vehicles, use and maintenance of sport articles. The checklist in Appendix 4 helps to identify whether emissions during Service-life should be considered in an ESD.

The type of chemical dispersal attracting most attention in society has long been industrial point sources where emissions to the environment take place in more or less controlled forms. Over the years, industrial life-cycle stages have been analysed and action has been taken to deal with these releases. The subsequent life-cycle stages, including consumption and disposal, are less managed. Its contribution to the overall chemical exposure will, however, increase as the industrial sources decrease. The further down in the life-cycle one goes, the greater the tendency for point source emissions to change to diffuse emissions. Volatile substances normally leave the product rapidly while the less volatile ones have a tendency to continue to emit. Another tendency is for raw materials to be worked into increasingly complex constructions. The result is that the users most often are unaware of the chemical content or emissions from the articles they use.

"Service-life" is one important part of the life-cycle during which various chemicals in building materials and consumer articles are released into society and the environment. Chemicals can leak out (be emitted) at varying rates. These releases are also known as “diffuse emissions”. Knowledge of diffuse emissions today is limited. A further complicating factor in assessing emissions during service-life is that they are often long lasting in both time and space.

Figure 1: Chemical flow (mass transport) through the chemical life-cycle stages.



* The last use stage of a substance before the waste management
** Includes also the private use of non-end-use products (e.g. paint, insulation material, plastic sheets)

3 SPECIFIC ASPECTS OF EMISSIONS DURING SERVICE-LIFE

Compared to emissions from industrial point sources diffuse emissions from products/articles require knowledge about several additional factors. This section gives:

- the general mechanisms of diffuse emissions.
- an understanding of the accumulation of long-living articles in the society.
- the relationship between the service-life and the other stages in the life-cycle chain (see Figure 1).

3.1 Emission mechanisms from articles

3.1.1 General

Diffuse emissions can arise from virtually any type of material, such as plastics, rubber, leather, textile, glass, concrete and metal based on the physical/chemical properties of the chemical, the matrix that the chemical is formulated into and/or adhered to, and the article's attributes. For example, a pair of shoes may emit chemicals from the rubber in the soles, adhesives, cloth and/or leather uppers.

The way in which chemicals can be emitted varies. Diffuse emissions can be classified into four different groups:

- Release into surrounding **air** (by evaporation)
- Release into surrounding **water** (leaching, usually by water)
- Release into surrounding **solid material** (by diffusion)
- Release in the form of **material particles** to various surroundings (e.g. due to wear)

In the first three groups, the chemical is emitted in molecular form (see also Figure 2). In the fourth group the chemical is emitted in the form of particles of material. The particles may be assumed to have the same composition as the original material.

Figure 2: Example of molecular emission from a material in different environmental compartments.

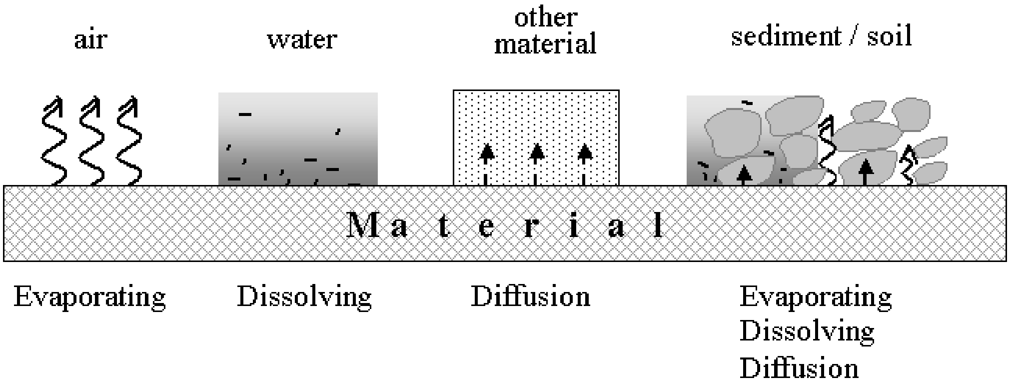
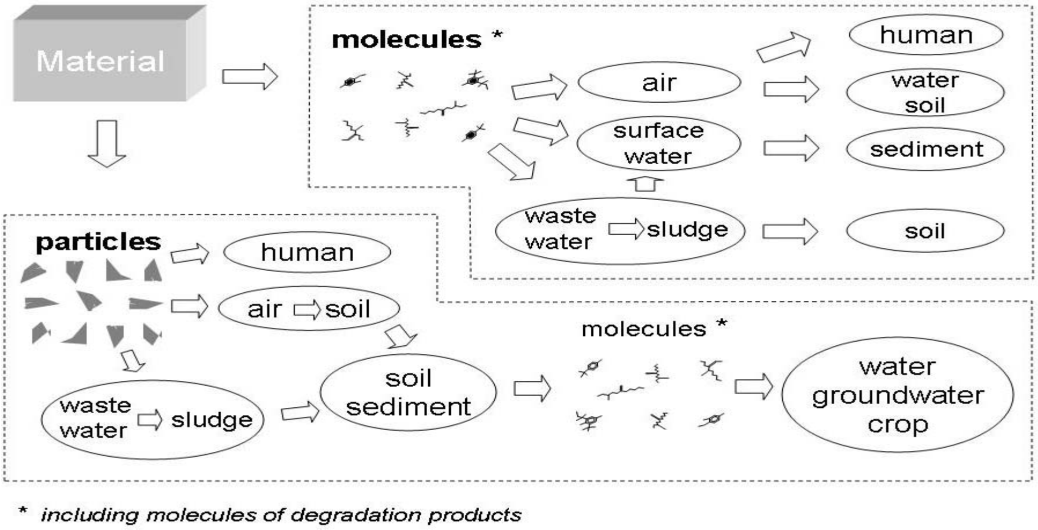


Figure 3 shows various environmental distribution routes depending on whether the release is in molecular or particulate form. Since the emission type strongly influences the distribution of a chemical in the environment this should, if it is known, be included in the ESD.

Figure 3: Various chemical distribution pathways from a material during service-life, divided into molecular and particulate distribution forms.



3.1.2 Molecular emissions

Unlike chemical products and preparations, chemicals in other types of articles are in most cases bound considerably more tightly to a solid matrix. The degree of binding varies according to the combination of chemical and material, from being loosely inserted into a polymer structure to having a strong chemical bond. In more readily mobile cases where the matrix is often organic, smaller molecules can move around the material by diffusion. Examples of chemicals with such behaviour are plasticisers, flame retardants and biocide agents in various plastics. The force driving diffusion is that the chemical is striving for an even concentration in the whole material. If the concentration of an added chemical falls locally in a part of the material, e.g. through evaporation from the surface, this can lead to migration of the chemical in the material to restore the concentration equilibrium. Chemicals in liquid form are generally more mobile than solid ones.

For many chemicals the molecular emission will be enhanced if the temperature increases. There are several situations where high temperatures occur, e.g. places exposed to sunlight, area around motor engine, heat insulation. There are also situations where materials are temporarily heated to temperatures high enough to cause release of gasified chemicals, e.g. during welding, melting together.

The diffusion rate can be estimated for homogeneous materials. It has been found, however, that when plastic ages, for example by sunlight or heat, the diffusion properties of the polymer can undergo significant changes. This affects the material surface in particular. For PVC, sunlight causes the chemical in the material to diffuse more easily, whereas high temperatures can lead to the opposite. These phenomena can be partly counteracted by various stabilising chemicals. These manifestations can vary for different types of polymers. The impact of ageing may also vary considerably with the surrounding environment. This makes it more difficult to generalise.

The chemicals of the matrix may also be subjects of an exposure assessment. It is useful to have a clear understanding of what type of binding occurs when assessing emissions from a solid material. No molecular emission normally occurs for the most strongly bound chemical fraction, usually polymers themselves. There are, however, exceptions where materials over the course of time are spontaneously broken down to more mobile forms. Processes of this kind may also arise through various types of effects, e.g. heating and exposure to light (see the text above). This phenomenon can be utilized to create a controlled release of a chemical from a material. One important example is biocides covalently bound to a polymer matrix. A predesigned degradation of the polymer will then cause a continuous release of the biocide during the whole service-life of the material.

Pure metals and alloys have a more homogeneous composition. No significant mobility occurs inside the material. The emission is therefore oriented towards the surface, for example through corrosion or wear.

Chemicals that are added to material with a long life are often characterised by low solubility in water and low vapour pressure. If the material is not to be exposed to water, however, water-soluble additives may be used. Examples of this are certain colorants in paper. This is of special interest for the recovery and waste disposal of such materials.

Another important molecular emission during service-life is when a chemical slowly transfers (diffuses) from one material into another. This occurs particularly when materials are joined tightly together. A common area where this is relevant is components in adhesives and jointing compounds that can migrate to the material that is bonded together. To take an example, PCB’s in sealing material for building materials have migrated into surrounding concrete to a significant extent. This process is also relevant to foods, where chemicals can migrate from packaging material to the food. It is obviously important to be aware that a chemical can behave in this way when assessing chemical risks. Workers involved with the handling of waste in particular need to be informed that apparently non-hazardous material may have become contaminated, not just from the point of view of hazards in the working environment but also to avoid recycling the material which could give rise to new diffuse sources of emission.

3.1.3 Particulate emissions

Chemical additives in a material (e.g. polymer) may be dispersed to the surroundings if the material has been wholly or partially degraded during its service-life so that particles of material are formed. This often happens in connection with processing, wear (e.g. brake pads), natural ageing of the material or corrosion.

A type of handling of articles that locally can result in significant formation of particles is the processing of building materials. Particles may be formed here for instance in cutting, sawing, welding, grinding and drilling of various types of materials consisting of metal, wood, concrete, plastic, glass etc. Particle size is generally larger in new construction than in maintenance work, where the grinding of larger surfaces in particular is more common. Besides for industrial/professional uses of materials this emissions scenario is also relevant for repairing and refurbishing of articles by the public at large (see Figure 1).

The mechanisms for this type of emission differ substantially from what applies to molecular emission. Here physical factors in the material play a significantly greater role than the inherent properties of the chemical.

Chemicals enclosed in particles of a material are largely isolated from the surroundings, at least temporarily. This has the consequence that they are not equally biologically available and more persistent. It can generally be said that such chemicals have lower bioavailability and consequently a reduced acute toxic effect. Bioavailability may, however, change if surrounding environmental factors affect the material particle so that it erodes, corrodes or is dissolved. The smaller the particles are, the more rapid the chemical can escape from the particle matrix because the surface to area ratio increases. The increase in area can be estimated if information on the particle sizes is available.

When the outer endurance limit of the material starts to be reached, an increase in emissions can be expected. Examples are corrosive metals, crumbling cladding on buildings, peeling paints and worn-off particles (from plastic floor, paint, brake pad, road surface etc.).

If particle release can be foreseen the size of particles should be discussed in an ESD. The physical form may influence mobility, emission rate, and degradation of chemical additives. Some exposure related aspects on particulate emissions are addressed in table 1.

Table 1: Characterisation of particulate emissions

Mobility	Emission rate	Degradation	Emission scenario
- Will the particle float on the water or sink to the sediment? - Is the particle small enough to be carried by the wind?	- Is the relative surface area large or small? - Can large particles in the environment be assumed to erode to smaller units?	- Is the chemical in the particle available for biodegradation (e.g. in a waste water treatment plant)?	- Does the particle size lead to deposition in lungs?* - Does the particle size lead to increased oral uptake by water organisms?

* Respirable particles: Aerodynamic diameters <100 μm have the potential to be inhaled. Diameters 5-100 μm have the greatest probability of settling in the nasopharyngeal region. Diameters <1 μm are most likely to settle in the tracheobronchial or pulmonary regions (TGD 2003, part II, p. 266).

Release of nano sized particles (<100 nm) is of particular concern. Especially releases from “nano-materials” and articles treated with “nano particles” since they are designed to be active….

3.1.4 Emission rate

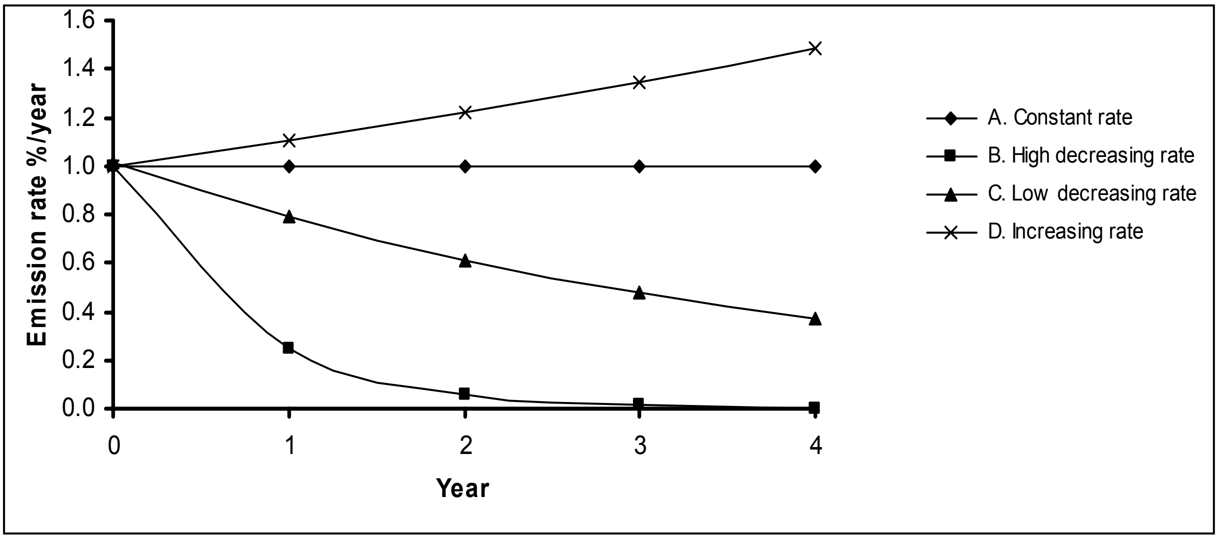
An emission rate is used to quantify a release. Default values normally reflect an average for the whole life time. This is acceptable as long as the emission rate is expected to be more or less constant over time. However, a constant emission rate is probably a less common situation. In many cases the rate changes (see Figure 4). For most additives the rate will decrease over time. Decreasing rates occur for more or less volatile additives or residues in a material. Emission of phthalates from plastic is an example of a slowly decreasing emission rate (curve C in Figure 4), while formaldehyde emission from a fibreboard shows a fast decreasing emission rate (curve B in Figure 4).

Emission of material particles (e.g. abrasion) can in many cases be expected to be constant over time (curve A in Figure 4). When the material breaks down, the emission rate may increase with time for both particles and additive (curve D in Figure 4). Corrosion of metals and biodegradation of wood are two examples.

If the material is coated with a protected surface layer the emission rate will probably be reduced. A polyurethane layer on PVC floor, or a paint film on impregnated wood, are two examples. The protection layer will not only change the molecular release rate. The physical wearing of the underlying material will not start until the protected layer is worn-out.

In the calculation in section 4.6.1, the emission rate is assumed to be constant over time to make the equation simple. Knowledge of varying rates should normally be handled qualitatively in the emission assessment. It is then important to know how the emission rate is derived. If it is calculated by dividing the total life-time loss with the service-life, any variance during service-life will be included. If the rate is based on a short term measurement the variance is probably not included. In the latter case the assessor needs to ensure that the emission rate is representative for the whole service-life for which it will be used. In the calculation example in section 4.6.2 the emission rates are assumed to decreasing exponentially.

Figure 4: Changes of emission rate over time for a chemical in an article.



3.1.5 Emissions of degradation products

In some cases a chemical additive in a material degrades to some extent during service-life. One example is when a stabilizer in PVC, such as a metal salt of an organic acid, will react with the polymer degradation product hydrogen chloride (formed due to excessive heat or much sunlight to the PVC). This may cause a considerable reduction of the content of the chemical. In the ESD a correction term should be provided in such cases. Also, it may cause an increase in the content of a harmful degradation product.

The material matrix itself may break down and form release of degradation products. For example, scientists are studying the potential for degradation of perfluorinated compounds and brominated flame retardants during use of consumer products. This will provide data needed to determine whether degradation products are produced during use of consumer products which could result in potential exposures that need to be further addressed (Begley *et.al.* 2005; Bradley *et.al.* 2007; Kajiwara *et.al.* 2008; Mandalakis *et.al.* 2008; Washburn *et.al.* 2005).

Degradation in a material may arise as a result of a number of causes such as:

- High temperatures.
- Reaction with other substances in the material:
    - …that are present from the start.
    - …that have been formed through degradation processes.
    - …that have transferred to the material over the course of time (water, oxygen, etc.).
- Effect of light or other radiation.
- Biological breakdown (in more open material structures).

Degradation may also occur as a spontaneous reaction. If such situations can be foreseen to occur during the service-life this should be highlighted in the ESD.

3.2 The accumulated amounts of articles in the society

In classical exposure assessment methodology the exposure for a specific substance use is often calculated from the annually consumed amount. This applies when emissions occur close together in time (within about one year from the time of production). This is often the case for point sources. If the residence time of a chemical use in society is longer than one year, an accumulation arises in principle, i.e. the actual quantity of the chemical in society is greater than the quantity added annually. The greater the residence time, the greater the accumulation. Without considering such accumulation the exposure level will be underestimated, at least for regional environmental exposures. Since the emission is greatly influenced by the total quantity article in the society it is important to be able to estimate the accumulated level of chemicals that show diffuse emissions.

If an article has been in use for a prolonged period of time, with fairly constant consumption (with regard to volumes and areas of use), it is likely that the maximum cumulative chemical quantity has had time to become established. At this stage, the annual quantity of the chemical removed (by waste incineration, degradation etc.) is just as high as the quantity added annually. It is usually said that the chemical flow in society then has reached an overall equilibrium ("steady state"). If the total release during service-life is low the cumulative quantity can be estimated in a simplified manner by multiplying the quantity added by the residence time of the chemical in years. When the release levels increases the cumulative quantity level will decrease which may needs to be compensated (see section 4.6.1).

When a specific use of a chemical in a long-life article is identified in an ESD it would be useful to know if it has reached steady state. A rough estimate of the year of introduction for that type of use should normally be enough. This is necessary in understanding whether an assessed exposure level relates to the present or future. It is also important in assessing whether recently measured concentrations are also valid in a future perspective. The more recently a diffusely emitted chemical has been brought on the market, the more likely it is that steady state has not yet been established.

New chemicals usually take time before they reach their optimum niche in the market, sometimes several decades. During this period they first have to out-compete old chemicals and/or build up completely new areas of use.

An accumulation of material that may easily be forgotten, but can lead to significant diffuse emissions, is waste that is not caught by the waste-management system but stays in the environment for a considerable time ("waste remaining in the environment"). It is not the quantity of the annual addition that is determinant but the fact that the residence time for this type of waste is very long. This means in a long-term perspective that significant quantities of chemicals can be stored in the environment more or less loosely bound in materials. If available information does not indicate otherwise, it should be assumed that this can constitute a potential source of emission. If possible the primary recipient for such releases should be identified in the ESD (e.g. waste water, storm water, urban soil, urban sediment).

Quantitative data on "waste remaining in the environment" is probably available for some articles. This may be the case for old tyres, which are used to keep agricultural plastic sheeting in place or just dumped illegally. Such figures may also be derived indirectly from (mass) balancing. From data on recycled materials and articles the quantity missing may be estimated. This might be possible for beer cans or bottles, e.g.

3.3 Disposal of articles

This guidance document will not specifically focus on the disposal stage. However, some parts are tightly connected to the service-life stage and therefore a general orientation is needed. These are reuse/recycling of articles and the formation of "waste remaining in the environment".

Reuse/recycling may cause considerable diffuse emissions depending on the technique used. For example, recycling electronic equipment can include shredding significant amounts of material. These operations may result in generating large quantities of waste dust, containing a variety of chemicals that are released to the local environment. Such releases of materials can normally be assessed today as having a marginal impact on the overall diffuse emissions, but when recycling over the course of time increases, these routes of dispersal will become increasingly important. This is because many countries strive to tighten up the regulations for waste in order to increase recycling of material gradually.

"Waste remaining in the environment" is materials from articles with their content of chemicals, which will end up in the environment. At least three different release routes can be identified.

- Pieces of articles, which are released during service-life and remain in the environment. An example is rubber particles from automobile tyres.
- Whole articles that are left in the environment at the end of use. Examples are ground cables and road construction materials.
- Pieces of articles in wastes recycled into the environment. Examples are demolished building material used as fillings, and particles in sewage treatment sludge used as a soil improvement agent.

These three release scenarios are more or less connected to particulate emissions, which are discussed in Section 3.1.3.

4 EMISSION ESTIMATION

4.1 General considerations

The emission from articles can be assumed to be proportional to the surface area. Then an emission rate per area can be used (e.g. [$g.m^{-2}.yr^{-1}$]). It is, however, not always possible to find such data. Weight based emission factors should then be used (e.g. [$g.tonne^{-1}.yr^{-1}$]). If also weight based factors are unavailable a qualitative estimation should at least be considered (in this case potential environmental destinations need to be identified for monitoring studies).

For the molecular emission of additives from long-life materials, the emission can be expected to be highest in the beginning of the use period (due to diffusion mechanisms). The opposite situation occurs for materials that disintegrate during service-life, e.g. solid metal products. It is necessary to be aware that the emission factors are normally an average for the whole service-life. Leaching of water-soluble chemicals may also occur. This takes place throughout the service-life of the material.

During use a material ages and emissions often occur in the form of particles. Particulate emissions will have different fate and behaviour properties compared to molecular emissions, e.g. lower bioavailability and longer persistence (see also Figure 3). However, in the absence of more detailed data concerning adsorption/bioavailability/persistence, a default assumption should be that the substance content in small particles can be handled as if it was distributed in molecular form. There is no definition available of “small particles”. This therefore has to be considered on case by case basis.

In the case of processing of material emissions can be expected at maintenance, repairing and refurbishing of articles, which should be considered under service-life in the ESD. Both particle emissions and molecular can be assumed to occur (see Section 3.1).

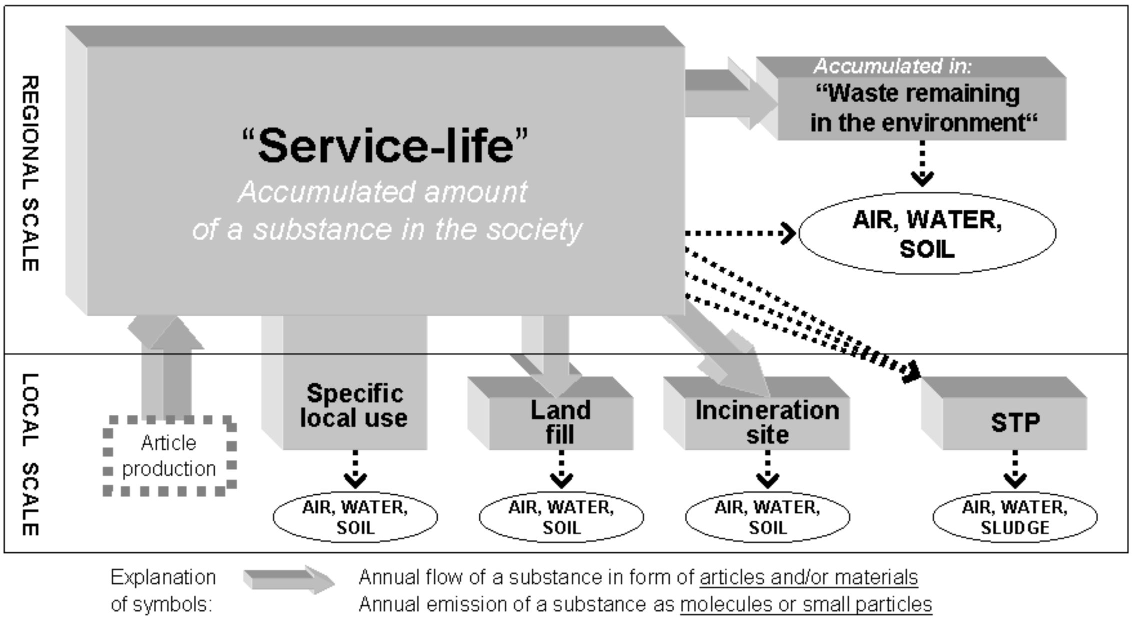
The emissions from long-life articles can be expected to be highest at steady state (i.e. when the flow of an article into society equals the outflow, see Figure 5). Estimating such emissions therefore often requires some knowledge of the substance use pattern in the preceding years.

4.2 Types of emission scenarios

The emissions during service-life usually cause exposure on a “regional” scale (see Figure 5). In some cases, however, local exposure scenarios should also be considered. Examples of local scenarios are use of biocides in articles, e.g. wood preservatives. Another local situation is the discharges from a STP (air, surface water and agricultural soil). Here diffuse emissions from many article users are concentrated to a single release point. Urban soil around traffic routes is a third type of emission scenario (“line sources”), where due to abrasion particles are released (e.g. from tyres).

Since people are present in many emission scenarios the potential for human exposure is obvious. The development of an emission scenario should therefore, when it is suitable, be designed to also be useful for human exposure calculations. Especially the Indoor air pollution can be an important source as most people spend a majority of their time indoors. The potential for direct human exposure to articles during use should also be considered. Human exposure pathways should also be considered in regional scenarios such as outdoor urban air.

Figure 5: Different emission scenarios of long-life article during service-life.



For a chemical emitted from a long-living material/article the time dimension needs to be defined. If accumulation is expected then the reliability of available service-life times should be assessed. An average value can be based on data showing a large range between minimum and maximum. In such cases emission may also have to be calculated as a range.

If the service-life is very long, e.g. for building materials (>50 years), it is important to define if the use in society has reached steady state (see Section 3.2). If the steady state has not been reached, monitoring data from today will probably show an underestimation of the maximum level. Such comparisons should therefore be made with caution.

If an ESD covers uses with very long service lives a rough historical market review on that type of use would be helpful. At least an indication should be made for those applications that probably have reached steady state.

4.3 Incorporation of article recovery in an emission calculation

The service-life time of an article can be defined as the average lifetime of the article. If a significant proportion of an article/material/substance is re-used or recycled leading to a second service-life this should be considered in the exposure assessment. Depending on the re-use/recycle pattern this can be handled in different ways (Source: TGD 2003):

- If the recycling of an article leads to a second service-life with the same or a similar use as the first service-life this can be accounted for by adequately prolonging the first service-life.
- If the recycling of an article leads to a second service-life different from the first service-life, emissions from both service lives are calculated separately.
- If the substance/material is recovered and used as raw material for production of new articles this amount should be added to the appropriate life-cycle stage (formulation, industrial/professional use), if not already accounted for.

4.4 Principal estimation steps

The calculations of emissions from long-life articles can be performed as follows (Source: TGD 2003):

1) Estimation of the service-life of the article.
2) Consider the emission type (molecular and/or particulate).
3) Consider the waste strategy (destruction, recycling, waste left in the environment).
4) Estimation of emission factors for the substance from the actual material (e.g. fraction/tonnes or mg.m^{-2} surface area). If emission data are missing:
   a) Compare with similar articles described in other ESD's;
   b) Search for data in the literature;
   c) Use a worst-case assumption or if necessary request an emission study.
5) Calculation of the total releases of substance from articles at steady state (Section 4.6).
6) Calculate the regional releases representing a densely populated area (section 4.6).

4.5 Use pattern indicating emissions

Besides inherent chemical properties the use pattern influences the emission during service-life. There are several standards for use categorisation. The following standards are used internationally:

-	Use Categories	(UC)	according to TGD 2003
-	Function Categories	(ChemUSES)	according to US-EPA 1980
-	Use Categories Nordic	(UCN)	a new standard in the Nordic product registers
-	Industrial Categories	(IC)	according to TGD 2003 and OECD/IUCLID
-	Main Categories	(MC)	according to TGD 2003 and OECD/IUCLID

- NACE codes	(NACE)	European standard for industry classifications

In the cases that such categories occur in an ESD, these should be used to identify the possibility for a chemical to remain in an end product.

Articles are in focus in Service-life. Defining article groups can therefore be a useful complement to defining a Service-life use pattern. The most common international standard is the OECD nomenclature (Harmonised System), which is developed for trade statistics.

In Appendix 2, use categories relating to the service-life of an article are listed. The indications are based also on the occurrence of a chemical as a residue in a material. Such residues may cause initial emission if the chemical is mobile. Examples are semi-volatile solvents, water-soluble surfactants, excesses of unreacted binder, surface-treatment waxes, oils, catalysts and accelerators. The emission of residues is mainly in molecular form and decline normally with time (within weeks to months).

If available information does not support the indications in Appendix 2 this should be commented on the ESD. Reason for differences can be:

- **Emission cannot be excluded even if data are missing.** This should be handled as an increased uncertainty and be included in the overall precision of the ESD.
- **Emission does occur, however, it can be expected to be insignificant compared to other sources for the same exposure scenario.** This should then be stated in the ESD.
- **Emission does not occur. The indication in Appendix 2 is invalid.** This should only be commented when it's not obvious.

4.6 Recommended equations/variables/parameters/symbols relevant for "Service-life" calculation

Compared to a point source are the releases during service-life of long-living articles are much more difficult to quantify. Release mechanisms are in many cases complicated or just unknown. The time frame for releases is prolonged which demand corrections for accumulation effects in the society. Further, an emission scenario will often need to be geographically extended to address diffuse background levels (regional concentrations). Data necessary for quantification are normally difficult to obtain. In many cases the assessment then has to be qualitative or semi-quantitative. This section will, however, give examples on calculation methods when detailed data are available.

4.6.1 Large scale releases to the environment

Assuming constant annual input of the substance and a constant emission factor the equation for the releases to a specific compartment and for the total of all compartments can be written as (for explanation of symbols, see below):

$$RELEASEtot\_steady\ state_{i,j,k} = F_{i,j} * Qtot\_accum\_steady\ state_{k} \qquad (1)$$

and:

$$RELEASEtot\_steady\ state_{i,k,total} = F_{i,total} * Qtot\_accum\_steady\ state_{k} \qquad (2)$$

The formula for the amount accumulated as product k in society at the end of service-life (Steady State) can be written as:

$$Qtot\_accum\_steadystate_k = Qtot_k * \sum_{y=1}^{Tservice_k} (1 - F_{i,total})^{y-1} \qquad (3)$$

For the situation when the emission factor is low (< 1% per year) the emissions and accumulation at steady state (eq. 1-3) can be simplified as:

$$RELEASEtot\_steady\ state_{i,k,j} \ = \ F_{i,j} \ * Qtot_k * Tservice_k \qquad (4)$$

$$RELEASEtot\_steady\ state_{i,k,total} \ = \ F_{i,total} \ * Qtot_k * Tservice_k \qquad (5)$$

$$Qtot\text{-}accum\_steady\ state_k \ = \ Qtot_k * Tservice_k \qquad (6)$$

This simplification may not be valid for products with a very long service-life.

Explanation of symbols:

$F_{i,j}$	Fraction of tonnage released per year (emission factor[3]) during life cycle stage *i* (service-life) to compartment *j*.	[yr $^{-1}$]	data set[1]
$F_{i,total}$	Fraction of tonnage released per year (emission factor[3]) during life cycle stage *i* (service-life) to all relevant compartments .	[yr^{-1}]	data set[2]
$RELEASEtot\_steady\ state_{i,k,j}$	Annual total release in life-cycle stage *i* to compartment *j* after the 1st service-life period ("steady state") for product *k*.	[tonnes.yr^{-1}]	
$RELEASEtot\ steady\ state_{i,k,total}$	Annual total releases in life-cycle stage *i* to all relevant compartments after the 1st service-life period ("steady state") for product *k*.	[tonnes.yr^{-1}]	
$Qtot_k$	Annual input of the substance in product *k*.	[tonnes.yr^{-1}]	data set
$Qtot\text{-}accum\_steady\ state_k$	Total quantity of the substance accumulated in product *k* after the 1st service-life period ("steady state").	[tonnes]	
$Tservice_k$	Service-life of product *k*.	[yr]	data set

1) Alternatively use equation 10; 2) Alternatively use equation 11; 3) Or measurement.

The annual total amount that will end up as waste from product *k* at the end of service-life at steady state can be written as (assuming no degradation within the article):

$$QWASTEtot\_steady\ state_k \ = Qtot_k \ - \ RELEASEtot\_steady\ state_{i,k,total} \qquad (7)$$

Explanation of symbols:

$QWASTEtot\_steady\ state_k$	Total quantity of the substance in product k ending up as waste after the 1st service-life period ("steady state").	[tonnes.yr^{-1}]	
$Qtot_k$	Annual input of the substance in product *k*.	[tonnes]	data set
$RELEASEtot\_steady\ state_{i,k,total}$	Annual total releases in life-cycle stage *i* to all relevant compartments after the 1st service-life period ("steady state") for product *k*.	[tonnes.yr^{-1}]	eq. (2)

The total release for a whole country should be scaled down to at a "regional" release representing a densely populated area. A default realistic worst case assumption is that 10% of the total release is released into 1% of the total area of the country (default used in EU). Calculation of the annual **regional** release from article *k* to compartment *j* and for the total of all compartments can then be written as:

$$RELEASEreg\_steady\ state_{i,k,j} = RELEASEtot\_steady\ state_{i,k,j} * 0.1 \qquad (8)$$

and:

$$RELEASEreg\_steady\ state_{i,k,total} = RELEASEtot\_steady\ state_{i,k,total} * 0.1 \qquad (9)$$

Explanation of symbols:

$RELEASEreg\_steady\ state_{i,k,j}$	Annual regional release in life-cycle stage *i* to compartment *j* after the 1st service-life period ("steady state") for product *k*.	[tonnes.yr^{-1}]	
$RELEASEreg\_steady\ state_{i,k,total}$	Annual regional release in life-cycle stage *i* to all relevant compartments after the 1st service-life period ("steady state") for product *k*.	[tonnes.yr^{-1}]	
$RELEASEtot\_steady\ state_{i,k,j}$	Annual total release in life-cycle stage *i* to compartment *j* after the 1st service-life period ("steady state") for product *k*.	[tonnes.yr^{-1}]	eq. (1/4)
$RELEASEtot\_steady\ state_{i,k,total}$	Annual total releases in life-cycle stage *i* to all relevant compartments after the 1st service-life period ("steady state") for product *k*.	[tonnes.yr^{-1}]	eq. (2/5)

These regional diffuse releases are then added to the regional emissions calculated from non-diffuse emissions. Regional concentration for different environmental compartments can then be calculated with a multimedia fugacity model (e.g. EUSES).

If an emission factor is available as release per surface area, it can be converted to a product specific "fraction of tonnage released" ($F_{i,j}$ and $F_{i,total}$):

$$F_{i,j}\ (\text{product specific}) = \frac{\text{EMISSIONarea}_{i,k,j}}{\text{THICK}_k * \text{CONC}_k * 1000} \tag{10}$$

and:

$$F_{i,total}\ (\text{product specific}) = \frac{\text{EMISSIONarea}_{i,k,total}}{\text{THICK}_k * \text{CONC}_k * 1000} \tag{11}$$

Explanation of symbols:

$F_{i,j}$	Fraction of tonnage released per year (emission factor) during life cycle stage *i* (service-life) to comparment *j* from product *k*	[yr^{-1}]	
$F_{i,total}$	Fraction of tonnage released per year (emission factor) during life cycle stage *i* (service-life) to all relevant compartments from product *k*	[yr^{--1}]	
$CONC_k$	Concentration of substance in product *k*	[$kg.dm^{-3}$]	data set
$EMISSIONarea_{i,k,j}$	Annual amount of substance emitted in life-cycle stage *i* per area from product *k* to compartment *j*	[$g.m^{-2}.yr^{-1}$]	data set
$EMISSIONarea_{i,k,total}$	Annual total of amount substance emitted in life-cycle stage *i* per area from product *k*	[$g.m^{-2}.yr^{-1}$]	data set
$THICK_k$	Thickness of the emitting material in product *k*	[mm]	data set

If the area based emissions can be expected to decrease with decreasing concentration in the product the equations 1-2 above are used. If the emission is expected to be independgent of the remaining amount of the substance in the product, e.g. corroding metals, the simplified equations 4-5 are used.

If the amount of a substance in use in the society has not reached steady state and the accumulation is still ongoing, the calculated PEC (Predicted Environmental Concentration) will represent a future situation. If this is the case this should be considered when comparing PEC with monitoring data.

Releases from articles will normally only contribute to the regional releases. The emissions from indoor uses can be released to waste water and therefore be regarded as a point source. Also outdoor uses may cause releases to STP (Sewage Treatment Plant) if the storm water system is connected to the STP. This has to be considered case by case.

Quantitative methods for estimating emissions from “waste remaining in the environment” are currently very limited. Therefore such releases have to be considered case by case. As for substances in long life articles, substances in "waste remaining in the environment" will also accumulate. As a simplification the emissions at steady state can be assumed to be equal to the annually formed amount of "waste remaining in the environment" (see Figure 5). If the degradation rate of the substance in the waste material is known, this should be taken into consideration. When the emission of a substance from “waste remaining in the environment” is very slow steady state will take a long time to be reached. In that case the calculated emissions may reflect a future situation.

As for emissions from articles, releases from "waste remaining in the environment" will contribute mainly to the regional releases. Releases from "waste remaining in the environment" can be assumed to be distributed mainly to the Urban/Industrial soil compartment.

It should be noted that if an additive is used in more than one type of product then a total release at steady state should be estimated for each product type.

All releases during different life-cycle stages can be presented together in a flowchart. One example is presented in Figure 6. The detailed calculation behind the life-cycle stage service-life in Figure 6 is presented below.

Calculation example: Use of a plastic additive in a polymer coated roofing material.

Input data
Life-cycle stage: Service-life.
Use description: End-use of polymer coil coated roofing material.
Total annual quantity consumed (*Qtot*): 4 940 tonnes.yr^{-1}
Regional release fraction (of total) 0.1 (default).
Concentration in the product (*CONC*): 25 weight%, → 0.25 kg.dm^{-3} (density ca. 1).
Film characteristics: The thickness of the polymer film is 0.15 mm (*THICK*); One side is exposed to the environment.
Emission factors – molecule form: Air: 0.38 g.m^{-2}.yr^{-1}; Water: 0.75 g.m^{-2}.yr^{-1}; Land: 0.8 g.m^{-2}.yr^{-1}.
Emission factors – particle form: 0.080 yr^{-1} of the material is lost to soil during use.
Service-Life ($T_{service}$): 10 years.

Step 1: Calculate total fraction of tonnage annually released to all environmental compartments:
a) Molecular releases …(equation 10):
…to air: $F_{air} = 0.38 / (0.15 * 0.25 * 1\,000) = 0.010\ \text{yr}^{-1}$
…to water: $F_{water} = 0.75 / (0.15 * 0.25 * 1\,000) = 0.020\ \text{yr}^{-1}$
…to land: $F_{soil} = 0.75 / (0.15 * 0.25 * 1\,000) = 0.020\ \text{yr}^{-1}$
b) Particulate release to soil: $F_{soil} = 0.08\ \text{yr}^{-1}$
c) $\mathbf{F_{total}} = F_{moleculear} + F_{particulate} = 0.01+0.02+0.02+0.08 = \mathbf{0.13}\ \text{yr}^{-1}$

Step 2: Calculate accumulated quantity at steady-state. The equation 1 is used since the total release is greater than 1%:

$$Q_{tot\_accum\_steadyState} = 4\,940 * [(1-0.13)^{10-1}+(1-0.13)^{10-2}+(1-0.13)^{10-3}+(1-0.13)^{10-4}+(1-0.13)^{10-5}+(1-0.13)^{10-6}+(1-0.13)^{10-7}+(1-0.13)^{10-8}+(1-0.13)^{10-9}+(1-0.13)^{10-10}] = \mathbf{28\,907}\ \text{tonnes}$$

Step 3: Total annual releases at steady-state… (equation 4):
…to air (molecular): RELEASEtot_steady state$_{air}$ 0.010 * 28 907 = **289** tonnes.yr^{-1}
…to water (molecular): RELEASEtot_steady state$_{water}$ 0.020 * 28 907 = **578** tonnes.yr^{-1}
…to land: RELEASEtot_steady state$_{soil}$,molecular + particulates = (0.020 + 0.080) * 28 907 = **2 891** tonnes.yr^{-1}

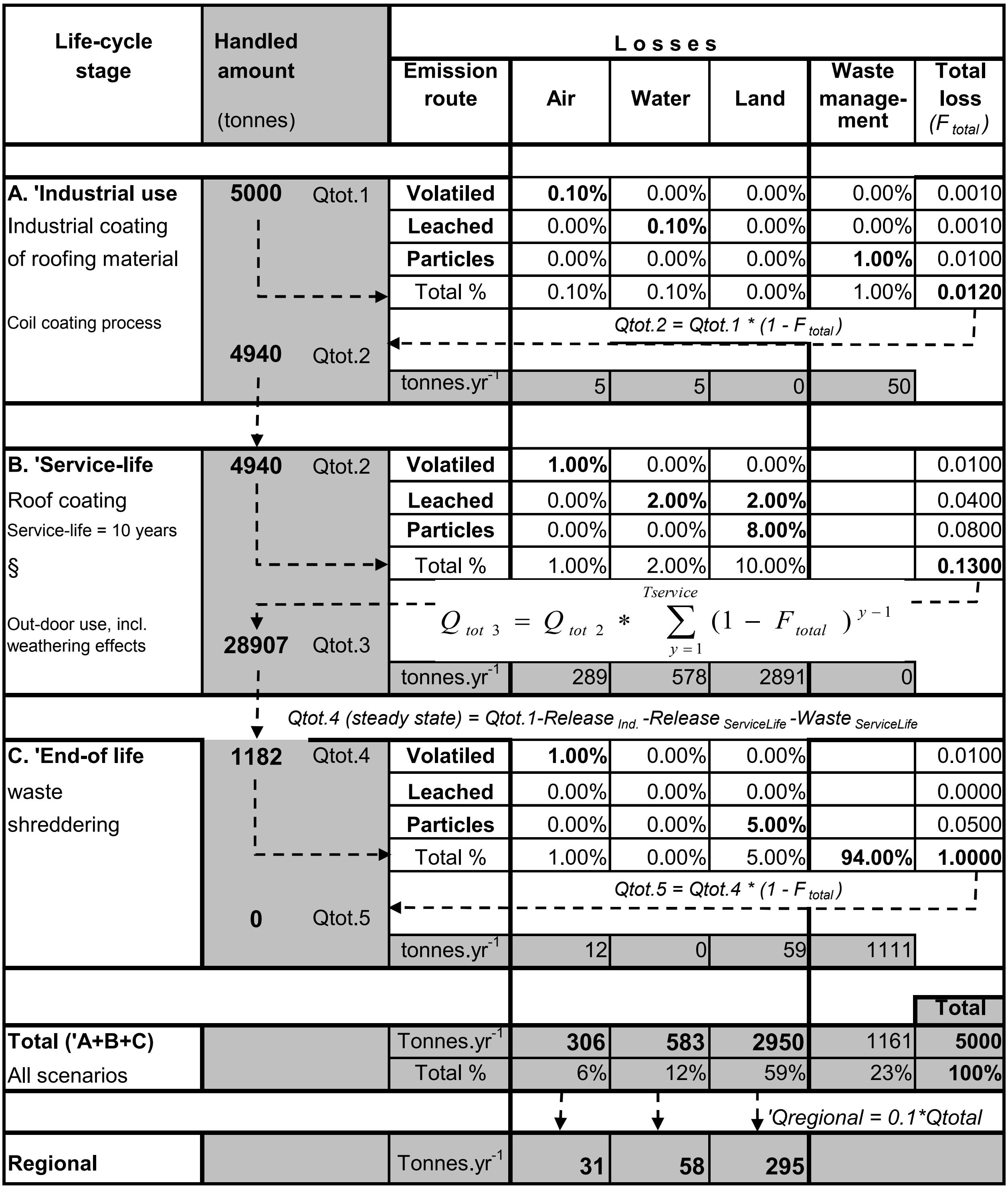
Step 4: Add losses from other relevant life-cycle stages (see figure 6):

…from:	Industrial use	Disposal	Service life		Total life-cycle
…to air:	5	12	289	→	**306** tonnes.yr^{-1}
…to water:	5	0	578	→	**583** tonnes.yr^{-1}
…to soil:	0	59	2 891	→	**2 950** tonnes.yr^{-1}

Step 5: Regional releases… (equation 8):
…to air: RELEASEreg_steady state$_{air}$ 306 * 0.1 = **31** tonnes.yr^{-1}
…to water: RELEASEreg_steady state$_{water}$ 583 * 0.1 = **58** tonnes.yr^{-1}
…to soil: RELEASEreg_steady state$_{soil}$ 2 950 * 0.1 = **295** tonnes.yr^{-1}

Step 6: Calculate Regional Predicted Environmental Concentrations (PECregional)
Additional tool and input data needed:
- A fugacity model (level III)
- Geographic size data (including STP data).
- Substance specific data (chemical/physical, biodegradation rates, adsorption coefficients).

Figure 6: Example of a flowchart used to determined emission estimates during different life-cycle stages.



Life-cycle stage	**Handled amount** (tonnes)		**Losses**					
			Emission route	**Air**	**Water**	**Land**	**Waste manage-ment**	**Total loss** (F_{total})
A. 'Industrial use	**5000**	Qtot.1	**Volatiled**	**0.10%**	0.00%	0.00%	0.00%	0.0010
Industrial coating			**Leached**	0.00%	**0.10%**	0.00%	0.00%	0.0010
of roofing material			**Particles**	0.00%	0.00%	0.00%	**1.00%**	0.0100
			Total %	0.10%	0.10%	0.00%	1.00%	**0.0120**
Coil coating process	**4940**	Qtot.2		Qtot.2 = Qtot.1 * (1 - F_{total})				
			tonnes.yr^{-1}	5	5	0	50	
B. 'Service-life	**4940**	Qtot.2	**Volatiled**	**1.00%**	0.00%	0.00%		0.0100
Roof coating			**Leached**	0.00%	**2.00%**	**2.00%**		0.0400
Service-life = 10 years			**Particles**	0.00%	0.00%	**8.00%**		0.0800
§			Total %	1.00%	2.00%	10.00%		**0.1300**
Out-door use, incl. weathering effects	**28907**	Qtot.3	$Q_{tot\ 3} = Q_{tot\ 2} * \sum_{y=1}^{Tservice} (1 - F_{total})^{y-1}$					
			tonnes.yr^{-1}	289	578	2891	0	
	Qtot.4 (steady state) = Qtot.1-Release $_{Ind.}$ -Release $_{ServiceLife}$ -Waste $_{ServiceLife}$							
C. 'End-of life	**1182**	Qtot.4	**Volatiled**	**1.00%**	0.00%	0.00%		0.0100
waste			**Leached**	0.00%	0.00%	0.00%		0.0000
shreddering			**Particles**	0.00%	0.00%	**5.00%**		0.0500
			Total %	1.00%	0.00%	5.00%	**94.00%**	**1.0000**
	0	Qtot.5		Qtot.5 = Qtot.4 * (1 - F_{total})				
			tonnes.yr^{-1}	12	0	59	1111	
								Total
Total ('A+B+C)			Tonnes.yr^{-1}	**306**	**583**	**2950**	1161	**5000**
All scenarios			Total %	6%	12%	59%	23%	**100%**
						'Qregional = 0.1*Qtotal		
Regional			Tonnes.yr^{-1}	**31**	**58**	**295**		

4.6.2 Indoor releases (the Wall Paint Exposure Model, WPEM)

Chemical emission information from items such as office furniture, wall paint, caulk, etc. can be found in the indoor air literature and from EPA's Office of Research and Development. In some specific cases, models may be available to estimate rates. For example, the Wall Paint Exposure Model (WPEM), developed by the EPA, can provide estimated emission rates for chemicals based on their molecular weight and vapor pressure.

The Wall Paint Exposure Model was designed to estimate the exposure of workers and consumers to chemicals emitted to indoor air from interior wall paint during and after use. WPEM does not estimate regional or local (city-wide) exposures, but individual exposures. WPEM provides exposure estimates such as Lifetime and Average Daily Doses, Lifetime and Average Daily Concentrations, and peak concentrations.

Indoor air models for products are developed by first collecting emission data using a small chamber test method developed by the U. S. EPA (U.S. EPA, 1989) and in the *ASTM Standard Guide for Small Scale Environmental Chamber Measurements of Organic Emissions from Indoor Materials/Products*, Designation ASTM D5116 (ASTM, 1997). As these methods are general, much work was done to develop specific testing protocols for wall paints (ARCADIS, 1998). In general, either alkyd or latex paint was applied in a controlled manor onto a piece of gypsum wall board. The wall board was then placed into a small stainless steel chamber. The small chamber has been engineered to control the air exchange rate, humidity, air turbulence, and air temperature. Air samples are collected at various times as required by testing protocol. The air concentrations over time were used along with other factors to develop mathematical models for latex and alkyd paint.

Indoor-air concentrations in one or two zones are predicted in WPEM by implementing a deterministic, mass-balance equation. The modelled concentration in each zone is a function of the time-varying emission rate in one or more zone, the zone volumes, the airflow rates among zones and between each zone and outdoors, losses to indoor sinks, and (if a reversible sink model is used) re-emissions from indoor sinks.

Consumer products such as paints that are applied to surfaces are best represented by an incremental source model. This model assumes a constant application rate over time, coupled with an emission rate for each instantaneously applied segment that declines exponentially. The mathematical expression for the total emission rate resulting from the combination of constant application rate and exponential emission rate for each applied segment has been developed by Evans (1994).

The model requires the conservation of pollutant mass as well as the conservation of air mass. WPEM uses a set of differential equations whereby the time-varying concentration in each zone is a function of the rate of pollutant loss and gain for that zone. These relationships can be expressed as follows:

Pollutant Mass Balance

(Change in Pollutant Mass) / (Change in Time) = Production ± Transport - Removal ± Reactions

Neglecting reactions:

$$(d\,Mass) / (dt) = \Sigma\,Sources + \Sigma\,Mass\ in - \Sigma\,Mass\ out \pm \Sigma\,Sinks \tag{12}$$

Or:

$$(Vi\ dCi) / (dt) = \Sigma\,Sources + \Sigma\,Cj{*}Qji - \Sigma\,Ci{*}Qij \pm \Sigma\,Sinks \tag{13}$$

where C refers to an air concentration, Q refers to a flow rate, i and j refer to zones (there are up to two indoor zones plus outdoors), and the ± for sinks accounts for the possibility that they may be reversible.

Air Mass Balance

Flows into a zone = Flows out of a zone

Or:

$$\Sigma\,Qji = \Sigma\,Qij \tag{14}$$

where Q, i and j are defined as above. The flow rates are input as constants. The pollutant mass balance is used in conjunction with the flow rates to predict the time-varying pollutant concentration in each indoor zone.

The differential equations can be solved by a variety of numerical solution techniques. The fourth-order Runge-Kutta method (also referred to as the Kutta-Simpson formula) is used for temporal integration (Matthews, 1992). Although this method is not as computationally efficient as some others, it is very stable, self-starting, and accurate. The formula takes the following form:

$$C\ (t + delta\ t) = C\ (t) + 1/6\ [K1 + 2{*}K2 + 2{*}K3 + K4] \tag{15}$$

where:

$K1 = dC/dt * (delta\ t)$, evaluated at $time = t$, $C = C\ (t)$

$K2 = dC/dt * (delta\ t)$, evaluated at $time = t + (delta\ t)/2$, $C = C\ (t) + K1/2$

$K3 = dC/dt * (delta\ t)$, evaluated at $time = t + (delta\ t)/2$, $C = C\ (t) + K2/2$

$K4 = dC/dt * (delta\ t)$, evaluated at $time = t + (delta\ t)$, $C = C\ (t) + K3$.

The Runge-Kutta technique has been evaluated for stability over a wide range of values for time step, zone volumes, and flow rates.

Within WPEM there are default scenarios:

- RESDIY - Two do-it-yourself (DIY) painters are exposed to a chemical in paint while painting an entire house.

- RESADULT - An adult located in the non-painted part of the house is exposed to a chemical in paint while a bedroom is painted by a professional painter.

- RESCHILD - A child located in the non-painted part of the house is exposed to a chemical in paint while a bedroom is painted by a professional painter.

- RESPROF - Two professional painters are exposed to a chemical in paint while painting an entire apartment.

- OFFADULT - An office worker is exposed to a chemical in paint after an entire floor of a low-rise office building is painted by ten professionals over a weekend.

- OFFPROF - Ten professional painters are exposed to a chemical in paint while painting an entire floor of a low-rise office building over a weekend.

The name associated with each scenario refers to a file that can be loaded to access that scenario. Such files, provided with the model, are located in the directory from which WPEM is executed and have an extension of .wem. For example, to access the scenario called RESDIY, the user can open the file named resdiy.wem, using the AOpen a File@ button on the toolbar near the top of the screen. Alternatively, one can click on File at the top left of the screen, then Open, to access the files with default scenarios.

Each file contains defaults for entries such as the type and percent of building painted, the amount of primer and paint applied, the application rate and painting duration, the type of exposed individual and location during the painting event, and the number of lifetime exposure events. There are certain arbitrary selections common to each default scenario, such as painting of walls only, application of one coat each of primer and paint, selection of latex flat paint, selection of the first chemical on the drop-down list, and selection of non-specific gender for the exposed individual. These and other default entries should be reviewed by the user, and changed as needed using appropriate edit buttons, before executing the model.

Table 2 summarizes input values used for each of the default scenarios. Exposure descriptors for each scenario follow the table.

Table 2: Summary of Inputs for Default Scenarios

Input	**Default Scenario**					
	RESDIY	**RESADULT**	**RESCHILD**	**RESPROF**	**OFFADULT**	**OFFPROF**
Type of Building	House	House	House	Apartment	Low-rise office	Low-rise Office
Percent Painted	One bedroom (10 %)	One bedroom (10 %)	One bedroom (10 %)	Entire building (100 %)	Entire floor (50 %)	Entire floor (50 %)
Painted Surface	Walls only	Walls only	Walls only	Walls only	Walls only	Walls only
Painted Area	452 ft^2	452 ft^2	452 ft^2	2,131.5 ft^2	20,000 ft^2	20,000 ft^2
Number of Coats	0 primer 1 paint	1 primer 1 paint	1 primer 1 paint	1 primer 1 paint	1 primer 1 paint	1 primer 1 paint
Paint Coverage	200/400 ft^2/gal (primer/paint)	200/400 ft^2/gal (primer/paint)	200/400 ft^2/gal (primer/paint)	200/400 ft^2/gal (primer/paint)	200/400 ft^2/gal (primer/paint)	200/400 ft^2/gal (primer/paint)
Number of Painters	1 DIY	1 professional	1 professional	2 professional	10 professional	10 professional
Application Rate per Painter	0.33 gal/hr	0.85 gal/hr	0.85 gal/hr	0.85 gal/hr	0.85 gal/hr	0.85 gal/hr
Priming vs. Painting	N/A	Paint same day	Paint same day	Paint same day	Paint same day	Paint same day
Total Duration	3.42 hours	3.99 hours	3.99 hours	9.4 hours	17.65 hours	17.65 hours
Type of Paint	Latex flat	Latex flat	Latex flat	Latex flat	Latex flat	Latex flat
Chemical	TMPD-MIB	TMPD-MIB	TMPD-MIB	TMPD-MIB	TMPD-MIB	TMPD-MIB
Weight Fractions	0.01 primer 0.01 paint	0.01 primer 0.01 paint	0.01 primer 0.01 paint	0.01 primer 0.01 paint	0.01 primer 0.01 paint	0.01 primer 0.01 paint
Exposed Individual	DIY painter	Adult occupant	Child occupant	Professional painter	Adult occupant	Professional painter
Gender	Non-specific	Non-specific	Non-specific	Non-specific	Non-specific	Non-specific
Location during Painting	In painted area	In building, not in painted area	In building, not in painted area	In painted area	Not in building	In painted area
Total Exposure Events	37.5	50	10	3988	10	2125
Years in Lifetime	75	75	10	75	75	75
Body Weight	71.8 kg	71.8 kg	20.3 kg	71.8 kg	71.8 kg	71.8 kg
Length of Model Run	20 days	20 days	20 days	2 days	20 days	3 days

5 STRUCTURE OF THE ESD WITH REFERENCES TO SERVICE-LIFE

If service-life is relevant in an ESD the following structure is recommended for this section:

5. Emission scenarios

5.1 Production
5.2 Formulation
5.3 Industrial use
5.4 Professional use
5.5 Private and consumer use

5.6 Service-life of product/article

Standard phrase when articles use…:
- …is not relevant: “No article applications are known.”
- …can be expected but data are missing: “Data on article uses are missing.”
- A summary of all relevant end-use applications, complemented with a table with assumed service-lives (see Appendix 3).

5.6.1 Use of XXXXX *(only if service-life is a relevant life-cycle stage)*

- Description of the use XXXXX.
- When service-life > 1 year: Discuss accumulation in society. If possible, estimate if steady state has been reached or not (based on data in 5.6.1.2).

5.6.1.1 Release estimation from service-life of XXXXX

(See Section 4 above)

5.6.1.2 Trends and technology in XXXXX application

Comments: This is important for the estimation if the article use has reached steady state or not. It is also useful to define if the ESD needs to be revised soon.

5.6.2 Use of YYYYY

5.6.2.1 Release estimation from service-life of YYYYY

5.6.2.2. Trends and technology in YYYYY application

5.6.3 etc.

…

…

5.6.4 Summary of releases during service-life

- *Only if there are several article applications which need to be included in the same exposure scenario (i.e. regional exposure of the environment; local exposure of water recipient from a municipal waste water treatment plant.*

- *Summary tables for:*
    - *local emissions to waste water treatment plants.*
    - *regional emissions to environmental compartments.*

- *Different release forms (molecular or particles) should be presented separately if it is expected to influence the environmental fate of the chemical.*

5.7 Recovery; and waste disposal

...

6 DATA GATHERING – ARTICLE USES

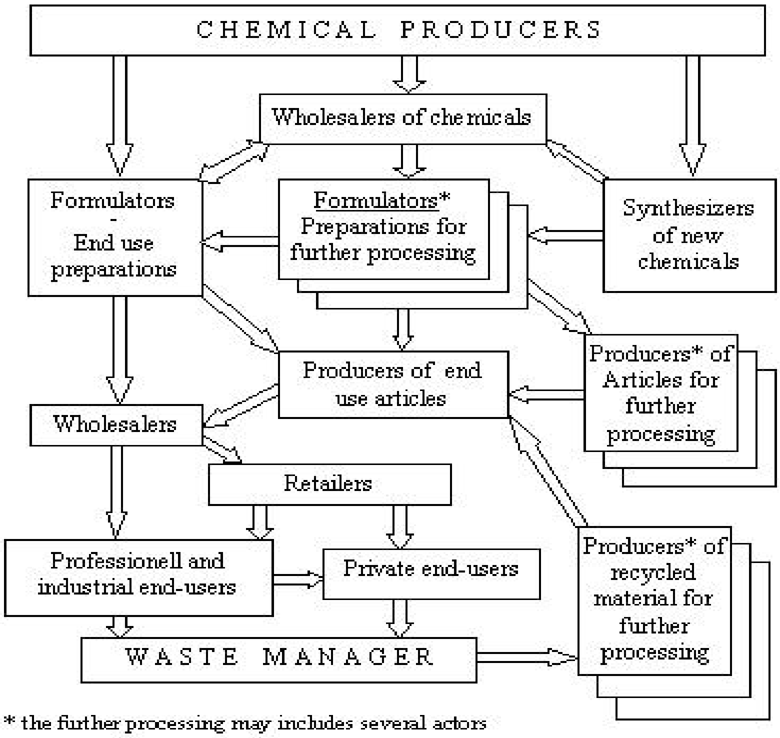
An important reason for the use of articles in an emission scenario being inadequately described stems from the lack of suitable sources of information. When the manufacturing of articles has to be covered, there is generally a need to go further down in the production chain to analyse downstream users (see Figure 7). It is not always obvious for the manufacturer if a specific article may cause considerable chemical releases. The checklist in Appendix 4 can then be used.

Although the chemical manufacturer knows of the use of its chemicals in articles, it is far from certain that there will be access to quantitative data, as these data are generally sensitive marketing information. Confidential statistics may, however, be made available in many cases by structuring or reformulating the data.

Other significant sources of information are organisations that work on life-cycle analysis (LCA, LCIA), material-flow analyses (MFA) and positive eco-labelling. National and international sector organisations may also be sources of information.

For long-living articles guidance should be obtained on how the quantities vary over the course of time. It is often possible to obtain a historical picture (see Sections 3.2 and 4.2). On the other hand, it is not as easy to forecast future development.

Figure 7: Down stream users of chemicals.



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APPENDIX 1: GLOSSARY / DEFINITIONS

It is recommended to have a glossary in the ESD. In this table words relevant to the service-life are collected.

WORD	EXPLANATION
Articles	Can be defined in various ways. The term is used here to mean man-made objects whose function is based more on its special shape, surface or condition than its chemical composition.
Chemical product	Individual chemicals and mixtures of chemicals (normally in the form of liquids or powder).
Consumers	This means people who are end-users of products/articles.
Diffuse emission	An emission that cannot be traced to a specific point source. For articles, the emission is often spread over the greater part of the period of use.
Diffuse exposure	This term can be interpreted in various ways. On the basis of a time dimension, it can be interpreted as an exposure of an object over a prolonged period of time (i.e. regardless of the type of emission source). On the basis of a space perspective, it can be interpreted as exposure from one or more *diffuse sources.*
Diffuse source	A source that lacks a specific point of emission.
Emission (of chemical substances)	Release of substances from an object. It may be either a material that releases chemicals from the surface or a structure that releases substances from a point (for example from a vehicle exhaust). A substance can be considered to be emitted when it is no longer inside the material. If it is in readily available form on the material surface, it is thus emitted. A borderline case is the formation of metal oxides on a metal surface. If the oxide can be removed easily, it can be regarded as emitted.
End-users	This means people who use products/articles at the stage before disposal.
Flow (of chemicals)	This means the intentional mobility of a chemical in society (e.g. transport, trade). Molecular/particulate emission is not included.
Long-life article/material	An article/material having a service-life longer than one year.
Molecular emission	When a chemical is dispersed from a material in molecular form.
Particulate emission	When a chemical is dispersed from a material in the form of a piece of material. This can arise as a result of wear and weathering. The pieces may

WORD	EXPLANATION
	be anything from microscopic powder to macroscopic pieces. The material may either consist of a concentrate of the chemical (e.g. metal) or be a mixture of different chemicals (e.g. plastic additive + polymer).
PEC	Predicted Environmental Concentration
Private end-users	This means people who do not need to take account of in-depth considerations of chemical safety in using products/articles.
Professional end-users	This means people who particularly in exercising their profession use products/articles in such a way that it may require in-depth consideration of chemical safety.
Service-life (of an article)	The average period of time that a product (an article such as a piece of clothing, painted surface, plastic toy) is expected to be used – out of economical, physical-chemical, performance of fashion perspectives or else – for the purpose for which it was manufactured, measured in years.
Steady state (of the use of a product/article)	When the flow of a product/article into society is equal to the flow of the same type of product/article out of society.
STP	Sewage Treatment Plant
TGD	Technical Guidance Document in support on Risk assessment in support of Commission Directive 93/67/EEC on Risk Assessment for new notified substances, Commission Regulation (EC) No 1488/94 on Risk Assessment for existing substances, and Directive 98/8/EC of the European Parliament and of the Council concerning of biocidal the placing of biocidal products on the market. Drawn up within the framework of the EU's risk assessment work (Council Regulation (EEC) 793/93). Can be downloaded from the website of the European Chemical Bureau, "http//ecb.ei.jrc.it/".
WPEM	The Wall Paint Exposure Model, developed by the US-EPA. The User's Manual from the WPEM is available at http://www.epa.gov/oppt/exposure/pubs/wpemman.pdf.

APPENDIX 2: POTENTIAL EMISSIONS OF CHEMICALS FROM ARTICLES

The estimations are based on the following chemical use information:

Use Categories (UC)	Table 1
Industrial Categories (IC)	Table 2

Table 1: Use categories (UC). In TGD 2003 there is a list of synonyms for use categories according to ChemUSES (US EPA, 1980) (TGD 2003, Part II, Appendix I).

UC*	**Explanation**	**Release duration****		**Release Aspects**
		Short	**Long**	
2	Adhesives, binding agents		X	Into matrix
6	Anti-set-off and anti-adhesive agents	X		On surface
7	Anti-static agents	X		On surface
10	Colouring agents***	X		Into matrix, residues
12	Conductive agents		X	Into matrix
13	Construction materials additives		X	Into matrix
14	Corrosion inhibitors***		X	On surface
17	Electroplating agents		X	On surface
20	Fillers		X	Into matrix
21	Fixing agents*	X		Into matrix
22	Flame retardants and fire preventing agents***		X	Into matrix
25	Foaming agents*	X		Into matrix
30	Hydraulic fluids and additives		X	Continuous release Into construction
31	Impregnation agents***	X	X	Into matrix and/or on surface

UC*	Explanation	Release duration**		Release Aspects
		Short	Long	
32	Insulating agents		X	Into construction
33	Intermediates***	X		Residues, Into matrix
35	Lubricants and additives***		X	Into construction
36	Odour agents*	X		Into matrix or on surface
39	Pesticides, non-agricultural (Biocides)	X	X	Into matrix
42	Photochemicals	X	X	Into matrix or on surface
43	Process regulators***	X	X	Residues. Into matrix
45	Reprographic agents		X	Into matrix or on surface
46	Semiconductors		X	Into matrix
47	Softeners: Subcategory coalescing agents; bates (leather technology); emollients; swelling agents; plasticisers.	X	X	Into matrix
49	Stabilisers***		X	Into matrix
51	Tanning agents	X	X	Residues. Into matrix.
52	Viscosity adjusters:*** Sub-categories : pour point depressants; thickeners; thixotropic agents; turbulence suppressors; viscosity index improvers.	X		Residues. Into matrix of coatings.
53	Vulcanising agents	X		Residues. Into matrix.
54	Welding and soldering agents	X	X	Into matrix

* Reference to TGD 2003; ** Short: days-weeks; Long: weeks-years; *** Only for IC = 7,8,11,12,13,14 and 15.

Table 2: Industrial categories (IC). Examples of chemicals potential for release during service-life.

IC*	Explanation	Example
4	Electrical/electronic engineering industry	Electrolytes; semiconductors
7	Leather processing industry	Dyestuffs; tanning auxiliaries
8	Metal extraction industry, refining and processing industry	
10	Photographic industry	Antifogging agents; sensitizers
11	Polymers industry	Stabilisers; softeners; antistatic agents; dyestuffs
12	Pulp, paper and board industry	Dyestuffs; toners
13	Textile processing industry	Dyestuffs; flame retardants
14	Paints, lacquers and varnishes industry	Solvents; viscosity adjusters; dyestuffs; pigments
15	Engineering industry: civil and mechanical	Agents used in construction work; agents used in automobile, aircraft and ship building

* Reference: TGD 2003.

APPENDIX 3: FORMAT ON THE SERVICE-LIFE TABLE

Service-life is here defined as the time an article is used in society. The time during which the article is put aside until it goes for disposal or re-use is sometimes also included. If the re-use relates to the same type of use, this should also be included in the original service-life. If the material is recycled in a different type of use ("recovered"), this is normally not included in the original service-life. A new service-life is obtained for a new use instead.

When an ESD covers several products/articles with a service-life >1 year a summary table with all service-life years should be considered. Average values should be used if the ranges between minimum and maximum are small. In other cases a range should be presented.

If a range is very large the definition of the sub group should be reconsidered. Maybe the subgroup consists of two distinct different use patterns. Such subgroups should then be divided into different subgroups or at least be commented in Table 1 below.

Table 1: Example table for service-life data for different article groups.

Article group	Article sub group	Service-life (years) time		
		Min.	Max.	Average
Textiles	Awning			2
Textiles	Bedding (mattress)			10
Textiles	Carpets	8	20	
Textiles	Clothes on contact with skin			1
Textiles	Household linen	5	10	
Textiles	Others clothes and bed linen	2	5	
Textiles	Sunblind	8	15	
Textiles	Tents	5	20	
Textiles	Wall-to-wall carpet	5	30	
Plastics	Agriculture	2		
Plastics	Building and construction			>10
Plastics	Domestic appliances i.e. brown goods	5	10	
Plastics	Domestic appliances i.e. white goods	5	10	
Plastics	Electrical	10	20	
Plastics	Electronic	0	5	
Plastics	Furniture	5	10	
Plastics	House wares	0	5	
Plastics	Marine			>10
Plastics	Miscellaneous	0	10	
Plastics	Packaging			2
Plastics	Sports	0	5	
Plastics	Transport and automotive	10	20	

APPENDIX 4: CHECKLIST – DIFFUSE EMISSIONS

Appendix 4: Checklist to help in identifying whether diffuse emissions are an important component in an assessment situation.