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Assessment of Non-Occupational Exposure to Chemicals

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ECETOC

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European Centre for Ecotoxicology and Toxicology of Chemicals

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SUMMARY

The main objective of the work described in this report is to review the assumptions and equations used to assess non-occupational exposure to chemicals. The approach recommended in this report to assess consumer exposure and indirect human exposure has been evaluated for several representative chemicals with different properties and use patterns.

A step-wise approach is recommended to assess consumer exposure. The first step consists of an initial evaluation to establish whether a potential exposure exists. If the substance itself is a consumer product or if the substance is contained in a preparation/article which is a consumer product, direct exposure of the consumer is possible. It is then necessary to estimate the extent, frequency and duration of exposure. The assessment of extent, duration and frequency requires an understanding of the substance and/or product use category and use scenario. Information on the use and function of the substance/product should therefore be provided in the dataset to allow a meaningful exposure assessment. Typical product use scenarios are discussed for common consumer products such as cosmetics, household products, aerosol products, paints and plasticisers. Recommendations are made for typical quantities per application, and frequencies of application. The second step consists of an evaluation of all potential exposure routes (oral, dermal, inhalation) to allow the estimation of the total exposure of the consumer to a particular substance. Comprehensive consumer exposure assessments require measured data to assess the extent of dermal, oral and inhalation exposure to products and their components. Realistic exposure assessments can also be achieved using reasonable calculations and justifiable assumptions for key exposure parameters. In this report some practical approaches are described to predict uptake via oral, dermal and inhalation routes taking into account the bioavailability of the substance. Use of default values in the absence of data may often lead to an overestimation of the exposure dose. A check for realism in the exposure assessment is therefore recommended to ensure that the final assessment is realistic and not overly conservative.

Similarly to the consumer exposure assessment, a step-wise approach is recommended to assess indirect human exposure. The first step (screening phase) consists of an initial evaluation to establish whether air, water or soil compartments are likely to be exposed to the substance (i.e. environmental exposure assessment) and whether human exposure via air, water, soil and food intake is likely to occur (i.e. indirect exposure). It is recommended that if environmental exposure occurs at a regional level, indirect exposure of the public can be expected and should be assessed. Environmental exposure can be estimated if it is known how and in what quantity a substance enters the environment and how it is subsequently distributed and transformed in these receiving

compartments (i.e. air, water, soil). The proposed environmental exposure scheme to obtain release estimations and environmental concentrations for water, air and soil at the regional level has been discussed in detail in ECETOC Technical Report No. 51 "Environmental Hazard Assessment of Substances" (1993a) and is further developed in a forthcoming ECETOC Technical Report on "Environmental Exposure Assessment" (1994a).

If indirect exposure is likely to occur, then it is necessary to estimate the relation between the concentration in each contact medium (air, water, soil) and transfer to food products and drinking water. In addition, it is necessary to assess dietary characteristics and food sourcing for the average individual. Comprehensive indirect exposure assessments (investigative phase) require measured concentration data for air, water, soil and food products, and measured data on ingestion (food, water, soil) and inhalation rates. In the absence of measured data, some practical approaches (screening phase) are described to predict the concentrations in air, water and soil at a regional level, and to assess transfer of chemicals from these media to drinking water and food products. Quantitative structure activity relationships (QSARs) are discussed to relate partition between water, soil and plants, and between animal diet, lipid tissue, and food product. In addition, average food baskets for all EC member countries have been compiled to estimate the potential dose to which the average adult or child may be exposed.

The total non-occupational exposure (consumer and indirect) or resulting total estimated intake for the average individual can then be used in the human health risk assessment and compared with intake criteria, such as acceptable and tolerable daily intakes.

SECTION 1. INTRODUCTION

In recent years there has been growing concern about environmental contamination and exposure of the general population to chemicals. Many substances are released to receiving environmental compartments due to losses in production, processing, formulation and use, or due to losses from waste treatment and recycling processes.

The development of risk assessment procedures for chemicals has received considerable attention from regulators, academia and industry. Impending changes in EEC legislation have accelerated the need to define the principles and consider the practical details of exposure, effect and hazard assessment.

A scientifically-based risk assessment strategy for substances requires a comprehensive and integrated assessment of local and regional emissions, transport, distribution and transformation processes (ECETOC, 1993a). The environmental exposure can be estimated if it is known how and in what quantity a substance enters the environment and how it is subsequently distributed and transformed in the receiving compartments (e.g. air, water, soil). The effect of transport and transformation processes on the distribution and concentration of substances in the different environmental compartments may be predicted by using mathematical models (OECD, 1989; Braat *et al*, 1991; OECD, 1991; ECETOC, 1992a), assessed in experimental laboratory simulation models, or possibly measured in actual environments if specific analytical techniques have been developed for the substance of interest. The end product of an environmental exposure assessment is typically a predicted or measured concentration for ambient air, surface water, ground water, surface soil, and root-zone soil at the local (PEC_{local}) or regional ($PEC_{regional}$) scale.

When contaminants enter the environment, man may be exposed through multiple exposure pathways. The link between man, environment and chemical exposure is through inhalation, ingestion, and dermal contact as visualised in Figure 1.

The prediction of a potential dose to which human populations are exposed through air, water, soil and food throughout a lifetime is often referred to as indirect exposure assessment. The average daily dose is dependent on the concentration in each contact medium (air, water, soil, food) and the intake or uptake factor for each contact medium. This implies that the environmental exposure assessment of substances will be linked to an estimation of human exposure through food consumption. Transfer functions and food consumption patterns will need to be assessed to predict this exposure. It should be pointed out that although each individual step in the exposure

Figure 1 The Link Between Man, The Environment and Chemical Exposure

assessment relies on justifiable assumptions, the potential dose must be interpreted with care. Error and uncertainty may propagate through the assessment and the potential dose is therefore only an approximate value at screening level.

Direct exposure of the consumer to a substance can be expected if the substance itself is a consumer product or if the substance is contained in a preparation or article available on the market. Exposure to the substance of interest leads to a dose which is the quantity of the substance received via the relevant exposure routes i.e. via dermal contact, ingestion or inhalation. To establish this dose, it is necessary to understand the variety of uses (and foreseeable misuses) of the substance itself or the substance in a preparation/article, the quantity of substance typically used in such scenarios and the frequency and duration of substance use. Only when such data are available, an estimation of the total realistic exposure for the consumer to the substance of interest is feasible for all possible routes.

The total human exposure can be estimated for each target population (e.g. workers, consumers, public) for which exposure to the substance can be reasonably foreseen. When a new substance is initially introduced to the market place, it is more likely that the exposure is direct rather than indirect. The new substance is often a part of an article or product and exposure can result from migration, evaporation, and/or leaching and is influenced by the physico-chemical characteristics of the substance and specific consumer habits. For existing substances it may be appropriate to investigate direct and indirect exposure.

The difficulty in exposure assessment lies in the complex nature of the transfer pathways. ECETOC therefore formed a Task Force with the following terms of reference:

- define the principles and practical considerations for evaluating direct and indirect human exposure to substances,
  - to which consumers are exposed,
  - which are released into the environment from diffuse and localised sources;
- Review critically the approach used by regulators in assessing consumer exposure and indirect exposure to man for well-documented representative substances;
- Recommend possible practical procedures for assessing the probability and magnitude of direct and indirect human exposure.

The main objective of this report is to review the assumptions and equations used to assess consumer and indirect human exposure to substances. Occupational exposure i.e. exposure of workers is not considered in this report.

The recommended approach and equations have been compiled in the software package HAZCHEM (ECETOC, 1994b) in order to allow an initial evaluation of indirect exposure. This is illustrated with representative case studies. The concept as discussed in this report is applicable to all substances, whether 'new' or 'existing'.

SECTION 2. BACKGROUND

2.1 LEGISLATION

The 7th Amendment of Directive 67/548/EEC (EEC, 1992) came into force on 31st October 1993. Article 3.2. requires that risk assessment be carried out according to principles to be laid down in a Commission Directive on Risk Assessment of New Substances (93/67/EEC) which was adopted in April 1993. The specific guidance on how to conduct exposure and effect assessment and risk characterisation has been described in Technical Guidance Documents. The purpose of these Technical Guidance Documents is to assist the notifier and the assessor in the risk characterisation and, if necessary, in deciding on what further testing would be required and its timing. This guidance is to be used in conjunction with the Risk Assessment Directive (93/67/EEC). Technical Guidance Documents were adopted on 31st October 1993.

The EC Council Regulation on the evaluation and control of the environmental risks of existing substances (EEC, 1993) requires competent authorities to evaluate the risks to man and environment of existing substances. This regulation was adopted on 23rd March 1993, and came into force on 4th June 1993. Its implementation requires a Commission Regulation on priority setting and risk assessment of Existing Substances. This Directive will refer to a large extent to the Commission Directive on Risk Assessment of New Substances, and its respective Technical Guidance Documents.

2.2 SCIENTIFIC DEVELOPMENTS

The protection of man and the environment has generated numerous activities in the fields of toxicology, industrial hygiene, occupational safety, epidemiology, environmental impact assessment, environmental quality and engineering-reliability studies. In the past decade, risk characterization, risk analysis, risk assessment and risk management have grown to new and exciting 'risk' disciplines. Risk assessment methods are developed to address a wide range of health and environmental risk situations, including air pollution, occupational exposure to chemicals or radiation, consumer exposure, disposal or hazardous waste sites, hazardous substances in the food chain, and introduction of new substances or technologies.

Industry has widely used risk analyses to determine the environmental and health associated implications of both existing and new production technologies. Risk assessment methods are systematically applied to assist the decision making process, i.e. set management priorities by

assessing the magnitude of the risks involved. The methods for the evaluation and control of existing and new substances within the framework of EC Council Regulation on Existing Substances and the 7th Amendment of Directive 67/548/EEC will be further developed to allow an integrated human and environmental risk characterisation of the substance.

In this context, the Dutch National Institute of Public Health and Environmental Protection (RIVM) has developed on behalf of the Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM) and the Ministry of Welfare, Health and Cultural Affairs (WVC) a risk assessment software package USES (Uniform System for the Evaluation of Substances) which integrates DRANC (Dutch Risk Assessment New Chemicals), PRISEC (Priority Setting Existing Chemicals) and ESPE (Evaluation System Pesticides) (RIVM, VROM, WVC, 1994; see also Vermeire *et al*, 1992). DRANC was used in The Netherlands to evaluate risks to man and the environment for New Chemicals, but was replaced by USES in 1994. PRISEC is a regional multi-media model which assumes steady-state conditions but not equilibrium between compartments. It is a "level-3" model in the classification scheme of Mackay (1979) and was developed as software package to prioritise chemicals which should undergo risk assessment. Similarly, activities within Health and Welfare Canada and the Californian EPA have resulted in the development of software packages used for the evaluation of risk to both environment and man (Mackay *et al*, 1991; McKone, 1993).

SECTION 3. CONSUMER EXPOSURE

3.1 INTRODUCTION

External exposure for the consumer may be defined as the quantity of a substance to which an individual is potentially exposed via the oral, inhalation or dermal route. The internal exposure or uptake can be defined as the quantity of the substance which has been absorbed into the systemic circulation per unit bodyweight. Consumers can be exposed via preparations, for example, cosmetic products, aerosol products, household cleaning products etc. Consumers can also be exposed via articles, for example, through skin contact with textiles from which substances may be leached. Exposure of consumers to substances in a typical consumer product is not easy to quantify. Estimation of the exposure requires a knowledge of the approximate concentration of the substance in the product which may occasionally be obtained from the label or directly from the manufacturer. Exposure estimates also require an understanding of the product use scenarios and the route(s) of exposure. The estimated exposure level can then be used as part of a meaningful risk assessment process by comparing it with the No Observed Adverse Effect Level (NOAEL) of the substance. The margin of safety for the consumer exposed to the substance of interest can then be calculated. In the absence of measured data, maximum predicted exposure is generally used as a default. If the safety margins appear small, it is very important to strive towards developing a realistic estimate of each potential exposure whenever possible using real life data. This is to ensure that the exposure estimate is not grossly exaggerated as a result of using maximum default values.

A step-wise approach is advocated to assess the exposure to man. The first step in the process is an initial evaluation to establish whether a potential exposure exists. It is then necessary to estimate the intensity, frequency and duration of exposure to the hazardous agent.

3.2 DURATION OF EXPOSURE

An estimate of the duration of exposure is important when preparing a consumer exposure assessment. Consumers may be exposed for varying lengths of time when using preparations or articles. Depending on the normal use or reasonably foreseeable misuse of the actual preparation or article, the exposure may consist of a single dose of a substance over a short period of time or of repeated doses of the substance over a longer time period. Consumers may experience acute exposure to a substance through a single low-frequency event e.g. the use of a paint-stripping solvent in the home. Accidental misuse of a product can also lead to acute and often high

Table 1 Definitions of Symbols Used in Consumer Exposure Calculations

U	= estimated total uptake	(mg/kg)
U_{oral}	= estimated oral uptake	(mg/kg)
I_{oral}	= amount of substance ingested	(mg/kg)
B_{oral}	= bioavailability for oral exposure (default = 1)	
I_{inh}	= amount of substance inhaled	(mg/kg)
C_{air}	= average concentration of substance in air	(mg/m^3)
V_{inh}	= ventilation rate of an adult (default = $0.8m^3/h$)	(m^3/h)
t	= duration of exposure	(h)
BW	= bodyweight of an adult	(kg)
U_{inh}	= estimated uptake of substance by lungs via inhalation	(mg/kg)
B_{inh}	= bioavailability for inhalation exposure (default =0.75; Linders, 1990)	
E_{derm}	= amount of substance in contact with the skin surface	(mg)
C_{derm}	= average concentration of substance in skin surface layer	(mg/cm^3)
T_{derm}	= thickness of surface layer (default = 0.01; Vermeire *et al*, 1993)	(cm)
S_{derm}	= surface area of exposed skin	(cm^2)
U_{derm}	= estimated uptake via the skin	(mg/kg)
J	= flux of substance through the skin (permeation rate)	($mg/cm^2/h$)
D_{derm}	= diffusion coefficient of substance in stratum corneum	(cm^2/h)
d_{derm}	= thickness of stratum corneum (default = 0.0025cm)	(cm)
K_m	= partition coefficient of substance (stratum corneum/water)	
K_p	= skin permeability coefficient of substance ($Kp = D_{derm} \cdot K_m / d_{derm}$)	(cm/h)
Mw	= molecular mass of substance	(g/Mol)
K_{ow}	= octanol/water partition coefficient	
Lt	= lag time	(h)
UPS	= uptake before saturation	(mg/cm^2)
A	= amount of substance deposited per unit area on dishes	(mg/cm^2)
FA_{oral}	= fraction of deposited substance ingested	
S_{dish}	= area of dishes in contact with substance	(cm^2)
dS/dt	= release of solvent per unit time	(g/h)
R	= evaporation rate	($g/m^2/h$)
a	= area painted per unit time	(m^2/h)
A_p	= surface area to painted	(m^2)
A_{ev}	= evaporating surface of wet paint	(m^2)
M	= mass of solvent applied per unit area	(g/m^2)
t_d	= drying time between one element being painted and being completely dry (= M/R)	(h)
t_a	= time required to paint total area (A_p/a)	(h)
S(t)	= release rate as function of time	
V1	= volume of room of consumer product application	(m^3)
V2	= remaining volume of house	(m^3)
V1 +V2	= volume of house	(m^3)
C1	= average concentration of substance in the room of consumer product application	(mg/m^3)
C2	= average concentration of substance in remaining house	(mg/m^3)
ACH	= room air changes per hour (default = 1)	
Q21 = Q12	= exchange rate between V1 and V2 (SCIES, 1991)	(m^3/h)
Q10	= exchange rate between V1 and the outside air	(m^3/h)
Q20	= exchange rate between V2 and the outside air	(m^3/h)