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HAZARD ASSESSMENT OF CHEMICAL CONTAMINANTS IN SOIL
REVISED APPENDIX 3

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HESP

HUMAN EXPOSURE TO SOIL POLLUTANTS
VERSION 2.00

Technical Report No 40

Revised Appendix 3

THE CONCEPT

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PREFACE

As indicated in the ECETOC Technical Report No. 40 "Hazard Assessment of Chemical Contaminants in Soil" (1990), hazard assessment is a necessary step to evaluate the significance of the presence of contaminants in the environment. Part of the hazard assessment process is the estimation of exposure.

This Appendix 3 of the above mentioned report describes "The Concept of HESP". HESP 2.00 is a computer programme to estimate the exposure of human beings to contaminants in soil and is essentially an updated version of the original Appendix 3 of the ECETOC Technical Report No. 40. As compared to the original version of HESP, the same approach is maintained but a number of formulae and value choices are improved as a result of recent scientific publications and discussions with specialists from the RIVM (Dutch State Institute for Public Health and the Environment) and representatives of BASF, Bayer, DSM and Hoechst.

All assumptions, value choices and formulae to calculate the potential exposure of human beings in specific situations are described in this document. The "HESP User Guide", Version 1.3 by W. Veerkamp, Shell Internationale Petroleum Maatschappij (SIPM), and B.W. Laffoon, Computer Management Group, the Netherlands, describes how to run the userfriendly PC version of the computer programme to estimate human exposure as based on the assumptions and equations of this revised Appendix 3 of ECETOC Technical Report No. 40.

The HESP 2.00 model can be applied to carry out a Preliminary Exposure Assessment in an early phase of the hazard assessment process (see scheme in Fig. 1). In cases where the Preliminary Hazard Assessment indicates the possibility of significant exposure, a Definitive (site specific) Exposure Assessment (which usually includes measurement of exposure concentrations for relevant exposure routes) is required as basis for the Definitive Hazard Assessment.

Only the latter can provide a sound basis for decisions regarding possible measures.

The ECETOC Technical Report No. 40 "Hazard Assessment of Chemical Contaminants in Soil" (1990), presents the full description of the hazard assessment process and indicates the place of HESP in this process.

About this Appendix

This revised Appendix is a guide for the use of the HESP 2.00 programme. It contains the following chapters:

Section 1: Introduction, which gives some background information on the HESP model developed by SIPM and DSM in cooperation with the Dutch governmental authorities (Ministry of Housing, Physical Planning and Environment (VROM) and RIVM) and representatives of BASF, Bayer and Hoechst.

Section 2: Gives a detailed description of all equations used in the programme.

Section 3: Gives a description of the model parameters used in the calculations with a set of default values used for the Dutch situation. The scenario used is called Netherlands 1.00.

Section 4: Conains the literature used for the development of the programme.

Annex I: Alphabetic listing and description of all parameters used in the document are given.

1. INTRODUCTION

Based on a report for a specific site decommissioning by Golder Associates (Reades and Gorber, 1986) a more general approach has been developed to assess the exposure levels of soil contaminants for human beings. The initial set of equations and assumptions has been published in the ECETOC Technical Report No. 40, "Hazard Assessment of Chemical Contaminants in Soil" (ECETOC, 1990). In consultation with DSM (who provided a few modules for the HESP model) and with representatives of BASF, Bayer and Hoechst, and after discussions with representatives of the Dutch governmental authorities the model has been updated, based on the most recently published literature including e.g. the review of v.d. Berg (1991) examining exposure of human beings to soil pollution. The HESP model is directed towards estimating the exposure of man to chemicals, which are present in the environment as soil contaminants. A number of possible exposure routes were identified and subsequently quantified. The main exposure routes taken into account in this model are:

INHALATION,
INGESTION,
DERMAL ABSORPTION.

These main exposure routes can be subdivided on the basis of the intermediate environmental compartment involved. The following subdivision in exposure routes is used throughout the program:

- direct ingestion of soil or dust,
- inhalation of vapours,
- inhalation of particulate matter,
- inhalation during bathing,
- ingestion of garden produce,
- ingestion of drinking water,
- ingestion of meat and dairy products,
- ingestion of fish,
- dermal exposure to soil or dust,
- dermal exposure during bathing,

- dermal exposure during swimming.

Depending on the land use, relevant exposure routes in that particular situation can be selected and included in the calculations.

The HESP model is directed towards estimating the exposure to two types of residents: an adult and a young child. The calculated results, which may be either the total exposure or the concentration in specific compartments represent the greatest cumulative intakes for individuals living at a contaminated site (referred to as "Maximum Average Exposure"), or Predicted Environmental Concentrations (PEC), where "average" indicates the total yearly uptake presented as mg/d independent of the season.

The model assumes that a house is located in the middle of a contaminated site and concentrations of substances are assumed not to change with time.

The programme screens and input are given in the HESP User Guide Version 1.3 by Veerkamp and Laffoon (1992).

2. THE EQUATIONS

2.1. Quantification of direct ingestion

The following equations are used to calculate uptake of a chemical as a result of the direct ingestion of either soil or dust:

$$DU = (\Sigma\ DU_{x,n}) * C_s / W \qquad \text{(eq. 1)}$$

where $DU_{x,n}$ = uptake resulting from direct ingestion of soil or dust per unit body weight per season (mg soil/d),
n = dust or soil,
x = summer or winter,
W = receptor's weight,
C_s = C_t (concentration in the soil top layer).

$$DU_{x,dust} = AID * f_{a,ing} * f_{rs,i} * N_i \qquad \text{(eq. 2)}$$

$$DU_{x,soil} = AID * f_{a,ing} * N_o \qquad \text{(eq. 3)}$$

where AID = amount of soil ingested daily by man (mg/d), based on the average amount ingested on a yearly basis,
$f_{a,ing}$ = fraction of uptake/intake for ingestion,
$f_{rs,i}$ = soil fraction in dust indoors,
N_y = fraction of time spent annually indoor; outdoor; sleeping or absent from location (= $N_{s,y}$ + $N_{w,y}$).

$$N_{x,y} = \Sigma\ tx1_y/24 * (tx2_y/7) * f_x \qquad \text{(eq. 4)}$$

where $tx1_y$ = time spent indoor, outdoor, sleeping or absent from the location in a season in hours per day,

$tx2_y$ = time spent indoor, outdoor, sleeping or absent from the location in a season in days per week,

f_x = fraction of the season,

$N_{x,y}$ = fraction of time spent (indoors, outdoors, sleeping or absent) in season.

2.2. Quantification of dermal absorption

The following equations are used to calculate the dermal absorption of chemicals through skin contact with either contaminated soil or dust:

$$DA = (\Sigma\ DA_{x,n}) * C_s / W \qquad \text{(eq. 5)}$$

where $DA_{x,n}$ = dermal absorption equivalent for soil or dust per day in a season (kg soil/d),

C_s = C_t (concentration in the top soil layer),

$$DA_{x,dust} = A_{exp} * DAE_i * DAR * f_m * f_{rs,i} * N_i * 24 \qquad \text{(eq. 6)}$$

$$DA_{x,soil} = A_{exp} * DAE_o * DAR * f_m * N_o * 24 \qquad \text{(eq. 7)}$$

where A_{exp} = surface of exposed part of the body,

DAE = amount of soil or dust on the skin,

DAR = dermal absorption rate,

f_m = matrix factor,

Outdoors

$$A_{exp} = A_{fh} \quad \text{(adult)} \qquad \text{(eq. 8)}$$

$$A_{exp} = A_{ah} + A_{lf} \quad \text{(child)} \qquad \text{(eq. 9)}$$

Indoors

$$A_{exp} = A_h \quad \text{(adult)} \qquad \text{(eq.10)}$$

A_{exp} = 0.5 * A_{ah} (child) (eq.11)

where A_{ah} = surface area of the arm and hands,
A_{lf} = surface area of the legs and feet,
A_{fh} = surface area of forearm and hands,
A_h = surface area of the hands.

2.3. Quantification of the inhalation of particulate matter

The following equations are used to calculate the inhalation of particulate matter both indoors and outdoors:

$$IP = (\Sigma\ IP_{y,x}) * C_s / W \quad \text{(eq.12)}$$

where IP = inhaled chemical via dust,
$IP_{y,x}$ = inhaled particulate matter per season in soil equivalents (mg soil/d),
y = indoors, outdoors, sleeping or absent,
C_s = C_t (concentration in the top soil layer),

$$IP_{y,x} = VA * TSP_y * f_{rs,y} * f_r * f_{a,inh} * N_y \quad \text{(eq.13)}$$

where f_r = fraction retained in the lung,
VA = volume of air breathed,
TSP_y = total suspended particulates outdoors or indoors,
$f_{a,inh}$ = fraction uptake/intake for the lung,
N_y = N_{sleep} + N_{indoor}.

$$TSP_i = 0.75 * TSP_o \quad \text{(eq.14)}$$

where TSP_i = local suspended particulates indoors,
TSP_o = local suspended particulates outdoors.

2.4. Quantification of the inhalation of vapours

2.4.1. *Calculation of the fugacity*

The following equations are used to calculate the contaminant partition within the soil:

$$Z_a = 1 / (R * T_{soil}) \quad \text{(eq. 15)}$$

$$Z_w = S / P \quad \text{(eq. 16)}$$

where P = vapour pressure at T_{soil},
S_w = solubility in water at T_{soil},
S = solubility in water at T_{soil}
$S = S_w/M$,
Z_a = fugacity capacity constant air,
Z_w = fugacity capacity constant water,
R = gas constant (8.3143),
T_{soil} = temperature of the soil,

OR $$Z_w = 1 / H_s \quad \text{(eq. 17)}$$

WITH $$\ln H_s = \ln H_T + 0.024 (T_{soil} - T) \quad \text{(eq. 18)}$$

AND $$H_T = P / S(T) \quad \text{(eq. 19)}$$

where $P(T)$ = vapour pressure at T,
$S(T)$ = solubility in water at T,
T = temperature related to $P(T)$ and $S(T)$,
H_T = Henry's law constant for temperature T,
H_s = Henry's law constant for T_{soil}.

$Z_s = K_d * SG * Z_w / SN_s$ (eq. 20)

where Z_s = fugacity capacity constant soil,
K_d = partition coefficient soil-water,
SG = specific gravity,
SN_s = volume phase of solid phase.

For organic contaminants:

$K_d = K_{oc} * f_{oc}$ (eq. 21)

$K_{oc} = 0.411 * K_{ow}$ (eq. 22)

$f_{oc} = f_{om} / 1.724$ (eq. 23)

where K_d = partition coefficient soil/water,
K_{oc} = partition coefficient for octanol-water corrected for organic carbon,
f_{oc} = fraction organic carbon,
f_{om} = fraction of organic matter,
K_{ow} = partition coefficient octanol-water.

For inorganic contaminants:

K_d is an input parameter.

$Pa = (Z_a * SN_a) / (Z_a * SN_a + Z_w * SN_w + Z_s * SN_s)$ (eq. 24)

$Pw = (Z_w * SN_w) / (Z_a * SN_a + Z_w * SN_w + Z_s * SN_s)$ (eq. 25)

$Ps = (Z_s * SN_s) / (Z_a * SN_a + Z_w * SN_w + Z_s * SN_s)$ (eq. 26)

where Pa = mass fraction in soil gas phase,
Pw = mass fraction in soil liquid phase (water),
Ps = mass fraction in soil solid phase (absorbed to soil minerals),
SN_a = volume phase of gas fraction (air),
SN_w = volume phase of liquid phase (water),
SN_s = volume phase of solid phase (soil).
$SN_s = 1 - SN_a - SN_w$

2.4.2. *Soil concentration to be used in the calculations*

Outdoors:

IF $C_d \geq C_m$

IF $C_d > C_t$

THEN $C_{s,o} = 0.1 * C_t + 0.5 * C_m + 0.4 * C_d$ (eq. 27)

ELSE $C_{s,o} = C_t$ (eq.27a)

ELSE IF $C_m \geq C_t$

THEN $C_{s,o} = 0.17 * C_t + 0.83 * C_m$ (eq. 28)

ELSE $C_{s,o} = C_t$ (eq.28a)

Where L_c = length of the diffusive path in the soil

Basement:

Construction with an open (direct earth) floor

IF $C_d \geq C_m$

IF $C_d > 0.1 * C_t$

THEN $C_{s,bo} = 0.5 * C_m + 0.5 * C_d$ (eq. 29)

ELSE $C_{s,bo} = C_t$ (eq.29a)

ELSE IF $C_m \geq 0.01 * C_t$

THEN $C_{s,bo} = C_m$

ELSE $C_{s,bo} = C_t$

(In the case C_t is used, the calculations are performed using eq. 40)

Where L_c = length of the diffusive path in the soil,
$C_{s,bo}$ = average soil concentration used in the calculation for the basement air concentration (open).

Construction with a concrete floor

$C_{s,bc} = 0.068 * C_t + 0.340 * C_m + 0.592 * C_d$ (eq. 30)

Where L_c = length of the diffusive path in the soil,
$C_{s,bc}$ = average soil concentration used in the calculation for the basement air concentration (concrete).

2.4.3. *Calculation of the maximum soil concentration*

In those situations, where transport of the chemical from the soil compartment to other compartments is calculated via the porous water, the concentration of the porous water cannot exceed the water solubility. Therefore $C_s = C_{s,max}$

$C_{pw} = C_s * SG * Pw / SN_w$ (eq. 31)

When $C_{pw} > S_w$ then $C_{pw} = S_w$ will be used for the calculations and hence C_s becomes:

$$C_{s,max} = S_w * SN_w / SG * P_w \quad \text{(eq. 32)}$$

$$C_{sa} = C_{s,max} * SG * Pa / SN_a \quad \text{(eq. 33)}$$

where C_s = C_t, C_m or C_d,
C_{sa} = soil air concentration of contaminant,
C_{pw} = soil water concentration of contaminant,
calculation of C_{sa} and C_{pw} depend on the concentrations of the soil compartment (t=top, m=middle and d=deeper layer).

2.4.4. *Vapour flux calculation*

The following equations are used to calculate the upward flux of vapours.

$$D_{sa} = SN_a^{(10/3)} * D_a / (1 - SN_s)^2 \quad \text{(eq. 34)}$$

$$D_{sac} = CN_a^{(10/3)} * D_a / (1 - CN_s)^2 \quad \text{(eq. 35)}$$

$$D_{sw} = SN_w^{(10/3)} * D_w / (1 - SN_s)^2 \quad \text{(eq. 36)}$$

$$D_{ef} = (Pa * D_{sa} / SN_a) + (Pw * D_{sw} / SN_w) \quad \text{(eq. 37)}$$

With

$$D_a = 0.036 * \sqrt{(76 / M)} \quad \text{(eq. 38)}$$

$$D_w = 3.6 * 10^{-6} * \sqrt{(76 / M)} \quad \text{(eq. 39)}$$

where D_{sa} = diffusion coefficient in the gas phase in soil,
D_{sac} = diffusion coefficient in the gas phase in concrete,
D_{sw} = diffusion coefficient in the water phase

in soil,
D_a = diffusion coefficient in free air,
D_w = diffusion coefficient in free water,
D_{ef} = diffusion coefficient in soil,
CN_a = volume phase of gas fraction in concrete,
CN_w = volume phase of liquid phase in concrete,
CN_s = volume phase of solid phase in concrete.

$$J1 = ((D_{sa} / L_c) * (D_{sac} / d_c)/((D_{sa} / L_c) + (D_{sac} / d_c)))* (C_{sa} - C^{o}_{ba}) \qquad \text{(eq. 40)}$$

$$J2 = D_a * (C_{sa} - C^{o}_{ya}) / X_a \qquad \text{(eq. 41)}$$

$$J3 = C_{pw} * Ev / 24 \qquad \text{(eq. 42)}$$

$$J4 = (D_{ef} / L_c) * ((C_{sa} - C^{o}_{ya}) * SN_a / Pa) \qquad \text{(eq. 43)}$$

IF $J3 + J4 < J2$ THEN $J = J3 + J4$ (eq. 44)
ELSE $J = J2$ (eq. 45)

$J < 0$ THEN $J = 0$

Outdoors: $J_{oa} = J$

Basement:

Open floor $J_{ba} = J$ OR $J_{ba} = J1$

Concrete floor $J_{ba} = J1$

where J1 = concrete flux,
J2 = boundary layer flux,
J3 = water evaporation flux,
J4 = diffusion flux water-soil,

Ev = flux of evaporating water,
X_a = height boundary layer,
L_c = length of the diffusion path,
J = total soil flux,
J_{oa} = total flux outdoor air,
J_{ba} = total flux basement air,
C^{o}_{ya} = initial background indoor or outdoor concentration (y = b (basement) or o (outdoor)),
d_c = thickness of the concrete in basement wall.

2.4.5. *Dilution calculation*

The following equations are used to calculate the dilution of outdoor air:

$$Vf = Vg * Sz / L \qquad \text{(eq. 46)}$$

where Vf = dilution velocity,
Vg = mean wind velocity,
Sz = Pasquill dispersion coefficient in vertical direction, weather stability class D, (m)
L = length of contaminated area, (m)

$$Vg = (V_Y + V^*) / 2 \qquad \text{(eq. 47)}$$

V_Y = wind velocity at a height Y,
V^* = friction velocity,

$$V_Y = \ln (Y / sr) * V^* / k \qquad \text{(eq. 48)}$$

IF $sr > Y$ THEN $V_Y = 0$

where Y = breathing height,
sr = surface roughness,
k = Karman constant (0.4),

$$V^{*} = k * V_h / \ln (h / sr) \qquad \text{(eq. 49)}$$

where V_h = wind velocity at a height of h,
h = height (10 m),

$$Sz = Co * 0.2 * L^{0.76} \qquad \text{(eq. 50)}$$

$$Co = (10 * sr)^{(0.53 * L^{-0.22})} \qquad \text{(eq. 51)}$$

where Co = correction factor for roughness length.

2.4.6. *Calculation of contaminant concentration in air*

The following equations are used to calculate the concentration of contaminants in outdoor air, indoor air and basement air:

$$C_{oa} = C^{o}_{oa} + J_{oa} / Vf \qquad \text{(eq. 52)}$$

where C_{oa} = contaminant concentration in outdoor air, (outdoor air concentration should not exceed the soil air concentration, unless the initial concentration is already exceeding the soil air concentration)

$$C_{ba} = C^{o}_{ba} + J_{ba} * A_t / (Vb * R_a) \qquad \text{(eq. 53)}$$

where C_{ba} = contaminant concentration in basement,
R_a = ventilation rate

Open floor:
$A_t = l * w$
$A_t = 2 * 0.25 * (l + w)$

In the case eq. 40 is used.

Concrete floor:

A_t = l * w + 2 * he * (l + w)
V_b = l * w * he

l = length of basement,
w = width of basement,
he = height of basement
(basement air concentration should not exceed the soil air concentration, unless the initial concentration is already exceeding the soil air concentration).

$C_{ba} \leq C_{sa}$ and $C_{oa} \leq C_{sa}$, unless the initial concentrations exceed C_{sa}.

$$C_{la} = f_{bi} * C_{ba} \qquad \text{(eq. 54)}$$

where C_{la} = contaminant concentration in indoor air
f_{bi} = fraction of basement air contributed to indoor air

$$\text{IF} \quad C_{la} < C_{oa} \qquad \text{THEN} \quad C_{la} = C_{oa} \qquad \text{(eq. 55)}$$

2.4.7. *Calculation of the amount of inhaled vapours*

The following equations are used to calculate the amount of chemicals inhaled as vapours in- and outdoors.

$$IV = \Sigma IV_{y,x} / W \qquad \text{(eq. 56)}$$

where IV = total inhaled vapour
$\Sigma IV_{y,x}$ = inhaled vapour in- /outdoor
W = receptor's body weight

$$IV_{o,x} = VA * 1000 * C_{oa} * f_{a,inh} * N_o \quad \text{(eq. 57)}$$

$$IV_{i,x} = VA * 1000 * C_{la} * f_{a,inh} * N_i \quad \text{(eq. 58)}$$

where VA = volume of air breathed,
$f_{a,inh}$ = fraction absorbed,
N_o = fraction spent outdoor,
N_i = fraction spent indoor and sleeping.

2.5. Quantification of the exposure through consumption of garden produces, meat, fish and diary products

The concentration in plants is, in this model, dependent on two processes, namely uptake through the roots with subsequent internal transport and deposition of dust on the leaves with subsequent uptake. Both processes have been separately described below. The total concentration in the plants is defined as the sum of both processes.

The intake by cattle is determined in a similar way as for human beings, taking into account inhalation of vapour and dust, plant consumption, water consumption and soil ingestion. The concentration of contaminants in meat and milk is calculated using a distribution coefficient according to data published by Travis and Arms (1988).

The concentration in fish is calculated using a bioconcentration factor according to Bysshe published in the Handbook of Chemical Properties Estimation Methods (Lyman et al., 1982).

2.5.1. *Calculation of the concentration in plants due to root uptake*

Inorganic substances

Based on experimental data a relationship between the partition coefficient soil/water (K_d) and the bioconcentration factor (= relation between the concentration in tissue of the above ground parts of plants and an environmental compartment; BCF) has been proposed by Baes (1982).

$$\ln BCF_{plant} = 2.67 - 1.12 * \ln K_d \qquad \text{(eq. 59)}$$

Based on data presented by Dijkshoorn and others (Jarvis et al., 1976; Dijkshoorn et al., 1981; 1983a and b; Cataldo et al., 1981; Gerritse et al., 1983 and 1984) a pH correction is introduced for the BCF_{plant} according to the following equation:

$$BCF^*_{plant} = BCF_{plant} * 10^{-0.25 * (pH(soil) - pH(Kd))} \qquad \text{(eq. 60)}$$

where BCF^*_{plant} = corrected BCF for actual pH of the soil

$$C_{pl} = BCF^*_{plant} * C_s \quad \text{(based on dry weight)} \qquad \text{(eq. 61)}$$

where $C_s = C_t$

$C_{stem} = C_{root} = 0.2 * C_{pl}$ (based on fresh weight)

where C_{pl} = concentration in part of the plant,
C_{stem} = concentration in upper parts of the plant,
C_{root} = concentration in root parts of the plant.

Organic substances

Based on data presented by Ryan et al. (1988) a relationship between BCF_{plant} and K_{ow} has been established.

Concentration in the stem

$$BCF_{stem} = ((SG * P_w) / SN_w) * ((10^{(0.95 * \log K_{ow} - 2.05)} + 0.82) * (0.784 * 10^{-0.434((\log K_{ow} - 1.78)^2 / 2.44)})) \quad \text{(eq. 62)}$$

where SG = soil bulk density,
SN_w = soil water content,

$$C_{stem} = BCF_{stem} * C_s \text{ (based on fresh weight)} \quad \text{(eq. 63)}$$

where C_{stem} = the concentration in the stem of the plant,
C_s = total concentration in soil (including water phase) = C_t.

Concentration in the root

$$BCF_{root} = ((SG * P_w) / SN_w) * (10^{(0.77 * \log K_{ow} - 1.52)} + 0.82) \quad \text{(eq. 64)}$$

$$C_{root} = BCF_{root} * C_s \text{ (based on fresh weight)} \quad \text{(eq. 65)}$$

where C_{root} = the concentration in the root of the plant,
C_s = total concentration in soil (including water phase) = C_t.

2.5.2. *Calculation of the concentration in plants due to deposition*

$$C_{dep} = (f_{in} / (Y_v * f_{Ei})) * (1 - (1 - e^{-f_{Ei} * t_e}) /$$

$(f_{Ei} * t_e)) * DR_o * C_{dust}$ (based on *dry weight*)

(eq. 66)

where f_{in} = initial fraction of interception,
Y_v = vegetative productivity,
f_{Ei} = weathering constant,
t_e = crop growth period,
DR_o = deposition rate outside,
C_{dust} = $f_{rs,o} * C_s$ (OR INPUT),
C_s = concentration in the soil = C_t.

2.5.3. *Calculation of the uptake through consumption of garden produce*

$$VI = C_{pt} * Q_{fv} * fh_v * f_{a,ing} / W \qquad \text{(eq. 67)}$$

where VI = vegetable and fruit equivalent uptake in mg/kg-bw.d,
Q_{fv} = fruit and vegetable consumption per day,
fh_v = fraction of consumption of home grown produce,

$$C_{pt} = (C_{stem} + 0.2 * C_{dep}) * f_{l/r} + C_{root} * (1 - f_{l/r})$$

(based on fresh weight) (eq. 68)

where C_{pt} = average concentration in consumed garden produce,
C_{dep} = concentration in plant due to deposition of dust,
$f_{l/r}$ = fraction of leafy products in the garden produce.

2.5.4. *Calculation of the intake of chemicals by cattle*

$$DU_c = C_s * AID_c * f_{ac} * N_{yc} \qquad \text{(eq. 69)}$$

where DU_c = direct ingestion of contaminant through soil ingestion per unit body weight per season,
AID_c = amount of soil ingested daily by cattle,
txo_c = time spent outside per day by cattle,
f_{ac} = absorbed fraction by cattle,
N_{yc} = fraction of days annually this occurs,
y = outdoor,
c = index for cattle,

$$IP_c = C_s * VA_c * TSP_y * f_{rs} * f_{rc} * f_{ac} * N_{yc} \qquad \text{(eq. 70)}$$

where IP_c = Inhaled contaminant through particulate matter for cattle,
VA_c = volume of air breathed by cattle per day,
f_{rc} = fraction retained in the lung,
y = outdoor or indoor,

$$IV_c = VA_c * C_{ya} * f_{ac} * N_{yc} \qquad \text{(eq. 71)}$$

where IV_c = Inhaled vapour by cattle,
y = outdoor or indoor,

$$VI_c = C_{pl} * Q_{pc} * f_{ac} \qquad \text{(eq. 72)}$$

where VI_c = Vegetation intake equivalent,
Q_{pc} = plant consumption,
C_{pl} = concentration in part of the plant, assuming a crop growth period of 30 days ($C_{stem} + C_{dep}$)

$$DU_{wc} = (C_{wp} * (1 - f_{gc} - f_{sc}) + C_{gw} * f_{gc} + C_{sw} * f_{sc}) * Q_{wc} \qquad \text{(eq. 73)}$$

where DU_{wc} = direct ingestion through drinking water,

C_{wp} = average concentration of the contaminant in the drinking water from service pipe,
f_{gc} = fraction of ground water used as drinking water,
f_{sc} = fraction of surface water used as drinking water,
C_{gw} = concentration in ground water,
C_{sw} = concentration in surface water,
Q_{wc} = water consumption,

$$TI_c = DU_c + IP_c + IV_c + VI_c + DU_{wc} \quad \text{(eq. 74)}$$

where TI_c = Total intake of contaminants for cattle.

2.5.5. *Calculation of the concentration in meat, milk and fat*

The following equations (eq. 75 and 80) are based on data presented by Travis and Arms (1988). Equation 77 has been described by Kenaga (1980).

Organic compounds:

Meat

A) $$\log K_{me} = - 7.735 + 1.033 * \log K_{ow} \quad \text{(eq. 75)}$$

$$C_{me,1} = TI_c * K_{me} \quad \text{(eq. 76)}$$

B) $$\log K_{fa} = - 3.457 + 0.500 * \log K_{ow} \quad \text{(eq. 77)}$$

$$C_{me,2} = (TI_c / (AID_c + (IP_c/C_s) + Q_{pc})) * K_{fa} * f_{fme} \quad \text{(eq. 78)}$$

C) $$C_{me,3} = (t_c * TI_c/(W_c * f_{fme} + Q_{mi} * SG_{mi} * t_c * f_{fmi}))*f_{fme} \quad \text{(eq. 79)}$$

Milk

A) $\log K_{mi} = - 8.056 + 0.992 * \log K_{ow}$ (eq. 80)

$C_{mi,1} = TI_c * K_{mi}$ (eq. 81)

B) $C_{mi,2} = (TI_c / (AID_c + (VA_c * TSP_o) + Q_{pc})) * K_{fa} * f_{fmi}$ (eq. 82)

C) $C_{mi,3} = (t_c * TI_c / (W_c * f_{fme} + Q_{mi} * SG_{mi} * t_c * f_{fmi}))*f_{fmi}$ (eq. 83)

where
K_{me} = meat/diet partition coefficient,
K_{mi} = milk/diet partition coefficient,
C_{me} = concentration in the meat products,
C_{mi} = concentration in the milk products,
$f_{f,me}$ = fraction of fat in meat,
$f_{f,mi}$ = fraction of fat in milk,
SG_{mi} = bulk density of milk,

C_z = highest value $C_{z,1}$ or $C_{z,2}$, with a maximum of $C_{z,3}$ (concentration in products from the vicinity of the location).

Inorganic compounds:

$C_{me} = TI_c * t_c * (1 - f_{fme}) / (W_c + Q_{wc} * t_c * f_{ex})$ (eq. 84)

$C_{mi} = (TI_c * t_c * (1-f_{fmi}) / (W_c + Q_{wc} * t_c * f_{ex})) * f_{ex}$ (eq. 85)

where f_{ex} = fraction of metals taken up is excreted.

2.5.6. *Calculation of the uptake through consumption of meat, milk and dairy products*

$MI = (\Sigma (C_z * Q_z * f_z)) * f_a / W$ (eq. 86)

where MI = Equivalent uptake of meat, milk and dairy products,
Q_z = product consumption either milk or meat,
f_z = fraction of cattle product from the location,
z = index indicating meat, milk or aquatic organism.

2.5.7. *Calculation of the concentration in fresh water organisms*

Organic compounds:

$$\log BCF_z = C * \log K_{ow} - D \qquad \text{(eq. 87)}$$

where BCF_z = bioconcentration factor for aquatic organisms,
C = constant,
D = constant.

Inorganic compounds:

BCF = input parameter

$$C_z = C_{sw} * BCF_z \qquad \text{(eq. 88)}$$

where C_z = concentration in aquatic organism,

$$FI = \Sigma(C_z * Q_{fi} * f_z) * f_a / W \qquad \text{(eq. 89)}$$

where FI = Equivalent uptake through consumption of aquatic organisms,
Q_{fi} = aquatic organism consumption,
f_z = fraction of food products from the vicinity of the location (fish, dairy, milk and meat).

2.6. Quantification of the exposure through drinking water

2.6.1. *Calculation of the permeation through plastic service-pipes*

$$C_{wp} = ((2 * D_{pe} * C_{pw} * \delta t)/ r * d_e) * (\pi * r^2 * L / Q_{dw}) \qquad \text{(eq. 90)}$$

where
- C_{wp} = average concentration of the contaminant in the service pipe during the day,
- C_{pw} = concentration in the porous water (based on C_m),
- δt = number of hours that the water is stagnant (24 h),
- D_{pe} = permeation coefficient for polyethene,
- D_{pvc} = permeation coefficient for PVC,
- D_{me} = permeation coefficient for metals or other inorganic materials (D_{me} = 0)
- r = internal radius of the pipe
- d_e = thickness of the pipe wall
- Q_{dw} = total amount of water used per housekeeping

$$C_{dw} = C_{wp} * (1- f_g) + C_{gw} * f_g \qquad \text{(eq. 91)}$$

where
- C_{dw} = drinking water concentration,
- f_g = fraction of groundwater used for drinking water.

2.6.2. *Calculation of the extent of evaporation during showering*

$$kwa = \frac{(((H_{sh}/RT_{sh}) * kL * kG)}{((H_{sh}/RT_{sh}) * kG + kL)) * (Ad/Vd) * t_f} \qquad \text{(eq. 92)}$$

where k_{wa} = extent of evaporation,
kG = gas mass transfer coefficient,
kL = liquid mass transfer coefficient,
A_d = surface area of the droplet,
V_d = volume of the droplet,
t_f = falling time of the droplet,
H_{sh} = Henry's law constant for T_{sh},

$$\ln H_{sh} = \ln H_T + 0.024\ (T_{sh} - T) \quad \text{(eq. 93)}$$

where T_{sh} = temperature of the water during showering,

$$kG = K_g * \sqrt{(18/M)} / 3600 \quad \text{(eq. 94)}$$

$$kL = K_l * \sqrt{(44/M)} / 3600 \quad \text{(eq. 95)}$$

where M = molecular weight,
K_l = liquid phase exchange rate (CO_2),
K_g = gas phase mass transfer coefficient.

2.6.3. *Calculation of the inhaled vapour during showering*

IF $N_{in} + N_{out} = 0$
THEN $N_{exp} = 0$; ELSE $N_{exp} = 1$

$$IV_w = N_{exp} * ((k_{wa} * V_w * C_{dw} / V_{bath}) /2) * VA * (t_s / 24) * N_s * f_{a,inh} / W \quad \text{(eq. 96)}$$

where IV_w = inhaled vapour during showering,
V_w = volume of water used,
V_{bath} = volume of the bathroom,
t_s = duration of showering,
N_s = fraction of days showering occurs,
N_{exp} = exposure while bathing or showering,
k_{wa} = extent of evaporation.

2.6.4. *Calculation of dermal uptake during showering*

$$DA_w = N_{exp} * A_{tot} * f_{exp} * DAR_w * t_s/2 * (1-k_{wa}) * C_{dw} * N_s / W \quad \text{(eq. 97)}$$

where DA_w = dermal absorption through water contact,
f_{exp} = fraction of skin exposed,
A_{tot} = total surface area of skin.

2.6.5. *Calculation of dermal uptake during bathing*

$$DA_w = N_{exp} * C_{dw} * DAR_w * A_{tot} * t_b * N_b / W \quad \text{(eq. 98)}$$

where DAR_w = dermal absorption rate for exposure in water,
t_b = bathing time,
N_b = fraction of days bathing occurs,
N_{exp} = exposure while bathing or showering,

$$P_{erm} = (0.038 + 0.153 * K_{ow}) \quad \text{(eq. 99)}$$

$$DAR_w = ((5000 * P_{erm} / (5000 + P_{erm})) * e^{-0.016 * M}) / 1.5 \quad \text{(eq.100)}$$

DAR_w (inorganic) = 0

P_{erm} (inorganic) = 0

where P_{erm} = dermal absorption rate (m/h).

2.6.6. *Calculation of dermal uptake during swimming*

$$DA_{sw} = C_{sw} * DAR_w * A_{tot} * N_{sw} / W \quad \text{(eq.101)}$$

where DA_{sw} = dermal absorption per kg body weight,
N_{sw} = fraction of days bathing occurs

for the recreational scenario,

$= t_{sw} * (tx2_o/7) * f_x$

t_{sw} = time spent swimming (h/d),

$tx2_o$ = time spent outside (d/wk).

2.6.7. *Calculation of the intake via drinking water*

$$DU_w = ((N_i + N_o)/(1 - N_{sleep})) * C_{dw} * Q_w * f_{a,ing} / W \quad \text{(eq. 102)}$$

where DU_w = direct ingestion through drinking water,

Q_w = water consumption,

f_g = fraction of groundwater used for drinking water.

2.7. Calculation of the concentration in water

2.7.1. *Calculation of ground water concentration*

$$C_{gw} = C_{pw} * L * q_{inf} / (K * d * I + L * q_{inf}) \quad \text{(eq. 103)}$$

where q_{inf} = infiltration rate,

K = hydraulic conductivity of the aquifer,

d = thickness of the mixing zone in the aquifer,

I = hydraulic gradient,

C_{pw} = based on the C_s of the deeper soil layer C_d,

$$q_{inf} = q_{re} * (1 - f_h) / (1 - SN_s) \quad \text{(eq. 104)}$$

where q_{re} = recharge rate,

f_h = fraction of the location covered by housing and/or pavement.

2.7.2. *Calculation of surface water concentration*

$$C_{sw} = (R_o * C_s + Q_{di} * C_{gw}) / (R_o * K_d + Q_{sw}) \qquad \text{(eq. 105)}$$

where R_o = run-off of soil,
Q_{di} = discharge from the aquifer in surface water,
Q_{sw} = mass flow of surface water,
C_s = C_t,
C_{sw} ≤ C_{pw},

$$R_o = SL * L * L_{ws} * SG * (1 - f_h) \qquad \text{(eq. 106)}$$

where SL = soil loss (m/h),
L_{ws} = width of the soil loss zone (is 10% of the width of the location (L_w)),
f_h = fraction of area covered by housing and or growth,

$$Q_{di} = K * d * I * L_w \qquad \text{(eq. 107)}$$

$$Q_{sw} = \overset{o}{Q}_{sw} + Q_{di} - Q_{ev} \qquad \text{(eq. 108)}$$

where $\overset{o}{Q}_{sw}$ = initial mass flow of surface water,
Q_{ev} = amount of water evaporated,
L_w = width of the location (n).

3. MODEL PARAMETERS

The parameters as used in the computer version HESP 2.00 are described in this Section. Input values used for the Dutch situation represent the CSOIL calculations as described by the RIVM (v.d. Berg, 1991). Scenario: Netherlands 1.00

3.1 Fixed Basement Parameters

R_a: 1.25 (1/h) (Ventilation rate) (Fast et al., 1987).
Values range from 0.03 to 7.4. When 0.0 is used $C_{ba} = C_{sa}$.

fbi: 0.1 (-) (fraction from basement-air contributed to indoor-air), assuming a concrete floor of the living room (Fast et al., 1987). In the case of a wooden floor 0.2 should be used.

CN_p: 0.02 (-) (Porosity of the concrete) (ECETOC, 1990)

CN_a: 0.01 (-) (Air content of the concrete) (ECETOC, 1990)

L_c: 0.75 (m) (mean length of contaminant diffusive path) concrete or open floor

3.2 Fixed Bath Parameters

K_g: 29.88 (m/h) (gas phase mass transfer coefficient) (ECETOC, 1990)

K_l: 0.2 (m/h) (liquid phase mass transfer coefficient) (ECETOC, 1990)

T_{sh}: 313 (K) (water temperature during showering)

radius: 0.5 (mm) (radius of the droplet, to calculate A_d and V_d)
In calculation $1.0 * 10^{-3}$ (m) is used.

t_f: 1.0 (s) (falling time of the droplet) (ECETOC, 1990)

t_s: 0.5 (h/shower) (duration of showering) (ECETOC, 1990)

N_s: 7 (showers/w) (number showers per week) (ECETOC, 1990)
In calculation 7 / 7 (showers/d) is used.

t_b: 0.5 (h/bath) (duration of bathing) (ECETOC, 1990)

N_b: 7 (baths/w) (number baths per week) (ECETOC, 1990)

In calculation 7 / 7 (baths/d) is used.

V_b: 15 (m^3) (Volume of the bathroom) (v.d. Berg, 1991)

V_w: 0.15 (m^3) (Volume of water used) (ECETOC, 1990)
In calculation $0.15 * 10^3$ (l) is used.

f_{exp}: 0.4 (-) (fraction of skin exposed) (v.d. Berg, 1991)

3.3 Fixed Cattle Parameters

W_c: 550 (kg) (weight of a cow)

VA_c: 130 (m^3/d) (volume of air breathed by a cow) (ECETOC, 1990)

Y_c: 0.8 (m) (breathing height of a cow)

AID_c: 0.72 (kg/d) (amount of soil ingested by a cow) (ECETOC, 1990)

t_s1_o: 24 (h) (time spent outside in summer per day)

d_s2_o: 7 (d) (time spent outside in summer per week)

t_w1_o: 12 (h) (time spent outside in winter per day)

d_w2_o: 7 (d) (time spent outside in winter per week)

t_c: 1825 (d) (age of the cow)

f_{fme}: 0.25 (-) (fraction of fat in meat)

f_{fmi}: 0.03 (-) (fraction of fat in milk)

f_{rc}: 0.75 (-) (fraction retained in the lung)

f_{gc}: 0.5 (-) (fraction ground water in drinking water)

f_{sc}: 0.5 (-) (fraction of surface water in drinking water)

Q_{pc}: 16.5 (kg/d) (plant (grass) consumption)
In calculation 16.5 * 5 (kg/d) based on fresh weight is used.

Q_{wc}: 55 (l/d) (water consumption)

Q_{mi}: 30 (l/d) (milk production)

SG_{mi}: 1 (kg/dm^3) (bulk density of milk)

3.4 Fixed Climate Parameters

f_x: 6 (months/year) (fraction summer in the year)
In calculation 6/12 (-) is used.

TSP_o: 70 (ug/m^3) (total suspended particulates in air) (v.d. Berg, 1991). In calculation $70 * 10^{-9}$ (kg/m^3) is used.

T_{soil}: 283 (K) (average temperature of the soil) (ECETOC, 1990)

X_a:	0.005	(m)	(thickness of the sublayer) (v.d. Berg, 1991)
E_v:	0.0001	(m/d)	(flux of evaporating water) (v.d. Berg, 1991)
V_h:	18000	(m/h)	(wind velocity at height h) (ECETOC, 1990)
h:	10	(m)	(height (wind velocity)) (ECETOC, 1990)
$f_{rs,i}$:	0.8	(-)	(fraction of re-suspended soil in dust, indoors) (v.d. Berg, 1991)
$f_{rs,o}$:	0.5	(-)	(fraction of re-suspended soil in dust, outdoors) (ECETOC, 1990)

3.5 Fixed Crop Parameters

(ECETOC, 1990)

CROP	Y_v (kg/m^2)	t_e (d)	$f_{l/r}$ (-)
MIXED	0.280	180	0.5
fruit	0.062	100	1.0
grass	0.200	30	1.0
leafy vegetables	0.380	100	1.0
lettuce	0.440	60	1.0
non-leafy veg.	0.114	180	0.0

Y_v yield (dry weight); t_e growth period; $f_{l/r}$ fraction of leafy product.

f_{in}:	0.40	(-)	(fraction intercepted)
f_{Ei}:	0.033	(1/d)	(weathering constant)
DR_o:	60	($mg/m^2.d$)	(deposition rate)

In calculation $60 * 10^{-6}$ ($kg/m^2.d$) is used.
Based on a deposition rate of 1cm/s and 70 $\mu g/m^3$ (ECETOC, 1990).

3.6 Fixed Fish Parameters

fish	C (-)	D (-)	Adult Q_{fi} (kg/d)	Adult f_{fi} (-)	Child Q_{fi} (kg/d)	Child f_{fi} (-)
MIXED	0.76	0.23	0.007	0.1	0.002	0.1
mussel	0.858	0.808	0.007	0.1	0.002	0.1

Q_{fi} fish consumption; f_{fi} fraction caught in the vicinity of the location.

3.7 Fixed Recipient Parameters

		Adult	Child
Age	(y)	30	10
Weight	(kg)	70	15
AID	(mg/d)	142	354
DAR_{org}	(1/h)	0.005	0.01
DAR_{inorg}	(1/h)	0	0
DAE_i	(kg/m^2)	0.00056	0.00056
DAE_o	(kg/m^2)	0.0375	0.0051
A_{tot}	(m^2)	1.8	0.95
A_{fh}	(m^2)	0.17	-
A_{ah}	(m^2)	0.34	0.10
A_{lf}	(m^2)	-	0.18
A_h	(m^2)	0.09	0.03
VA	(m^3/d)	20	7.6
Y	(m)	1.5	1.0
fm	(-)	0.15	0.15
fr	(-)	0.75	0.75
Q_{fv}	(kg/d)	0.56	0.3
f_{fv}	(-)	0.1	0.1
		Adult	Child
Q_{mp}	(kg/d)	0.14	0.07
f_{mp}	(-)	0.1	0.1
Q_{md}	(kg/d)	0.3	0.5
f_{md}	(-)	0.1	0.1
Q_{fa}	(kg/d)	-	-

		Adult	Child
f_{fa}	(-)	-	-
Q_w	(l/d)	2.0	1.0

AID amount of soil ingested, in calculation 160 * 10^{-6} and 370 * 10^{-6} are used. DAR dermal absorption rate; DAE amount of soil or dust on the skin; A surface area of the skin, f foot, h hand, a arm; VA volume of air breathed; Y breathing height; Q_{fv} amount of product consumed; f_{fv} fraction of product from the location, fv fruit and vegetables, mp meat and poultry, md milk and dairy product; Q_w water consumption.

3.8 Fixed/User Soil Type Parameters

soil type	f_{oc} (-)	SG kg/dm^3	SN_w (-)	SN_a (-)	K (m/d)
MIXED	0.05	1.8	0.15	0.4	5
sand	0.06	1.9	0.16	0.4	0.6
standard soil	0.02	1.5	0.2	0.2	1

f_{oc} organic carbon content; SG bulk density; SN_w water content; SN_a air content; K hydraulic conductivity.

3.9 Fixed/User Soil Usage Parameters

Agriculture }
Industrial } see annex II for values
Urban }
Recreational }

A user **Soil Usage** can also be defined.

3.10 Fixed Water Parameters

f_g:	0	(-)	(Fraction ground water used for drinking water)
q_{re}:	1	(mm/d)	(recharge of ground water through rainfall)

		In calculation 1 * 10^{-3} (m/d) is used.
d:	2	(m) (thickness of the mixing zone in the aquifer)
SL:	2	(mm/y) (soil loss)
		In calculation 2 * 10^{-3} / (365 * 24) (m/h) is used.
d_t:	24	(h/d) (Duration of the permeation)
		In calculation 24 / 24 (-) is used.
Q_w:	500	(l/d) (Amount of water used in one day)
		In calculation 500/1000 (m^3/d) is used.

3.11 Chemical Parameters

Chemicals:

- TCDD
- Toluene
- Benzene
- Zinc
- Nickel
- Lead

User **Chemicals** can also be defined.

3.12 Run parameters

These parameters are normally user defined. In the CSOIL calculations with HESP II, the following set of parameters is used.

Scenario:	Netherlands 1.00
Soil type:	Standard soil
usage:	urban
Site length:	100 (m)
width:	100 (m)
Crop:	MIXED (for cattle grass is standard)
Fish:	MIXED

Chemical:	as appropriate	
External dust source	No	
C(t) = C(m) = C(d)	as appropriate	
Adult/Child:	SHOWER	
basement:	OPEN	
basement length:	10	(m)
width:	5	(m)
height:	0.5	(m)
d_c:	0.1	(m)
service pipe:	HDPE	
r:	9.8	(mm) (Calculation $9.8 * 10^{-3}$ (m))
d_e:	2.7	(mm) (Calculation $2.7 * 10^{-3}$ (m))
I (hydraulic gradient)	0.001	(m/m)
Q_{ev}	0	(m^3/h)
Q_{sw} (init)	200	(m^3/h)

4. BIBLIOGRAPHY

Baes, C.F. (1982). Environmental transport and monitoring; Prediction of radionuclide K_d values from soil-plant concentration ratios. Trans. Amer. Nucl. Soc. 41, 53.

Cataldo, D.A., Garland, T.R. and Wildung, R.E. (1981). Cadmium distribution and chemical fate in soybean plants, Plant Physiol. 68, 835.

Dijkshoorn, W., Lampe, J.E.M. and Broekhoven van, L.W. (1981). Influence of soil pH on heavy metals in ryegrass from sludge-amended soil. Plant and Soil 61, 277.

Dijkshoorn, W., Lampe, J.E.M. and Broekhoven van, L.W. (1983a). Effect of soil pH and ammonium and nitrate treatments on heavy metals in ryegrass from sludge-amended soil. Neth. J. Agric. Sci. 31, 181 - 188.

Dijkshoorn, W., Lampe, J.E.M., Broekhoven van, L.W. (1983b). The effect of soil pH and chemical form of nitrogen fertilizer on heavy-metal contents in rye-grass. Fertilizer Research 4, 63.

ECETOC (1990). Hazard Assessment of Chemical Contaminants in Soil. Technical Report No. 40.

Fast, T., Kliest, J. and van de Wiel, H. (1987). De bijdrage van bodemverontreiniging aan de verontreiniging van de lucht in woningen. Rapport nr. 6 in de publikatiereeks Milieubeheer, VROM (Ministery of Housing, Physical, Planning and the Environment) Leidschendam.

Gerritse, R.G., Driel van, W., Smilde, K.W. and Luit van, B. (1983). Uptake of heavy metals by crops in relation to their concentration in the soil solution, Plant and Soil 75, 393.

Gerritse, R.G. and Driel van, W. (1984). The relationship between adsorption of trace metals, organic matter, and pH in temperate soils. J. Environ. Qual. 13, 197.

Jarvis, S.C., Jones, L.H.P. and Hopper, M.J. (1976). Cadmium uptake from solution by plants and its transport from roots to shoots. Plant and Soil 44, 179.

Kenaga, E.E. (1980). Correlation of bioconcentration factors of chemicals in aquatic and terrestrial organisms with their physical and chemical properties. Environ. Sci. Technol. 14, 553.

Lyman, W.J., Reehl, W.F. and Rosenblatt, D.H. (1982). Handbook of chemical properties estimation methods; Environmental behaviour of organic compounds. McGraw-Hill.

Reades, D.W. and Gorber, D.M. (1986). A site specific approach for the development of soil clean-up criteria for trace organics; Shell's Oakville Refinery, Golder Associates/SENES Consultants Ltd, May 1986.

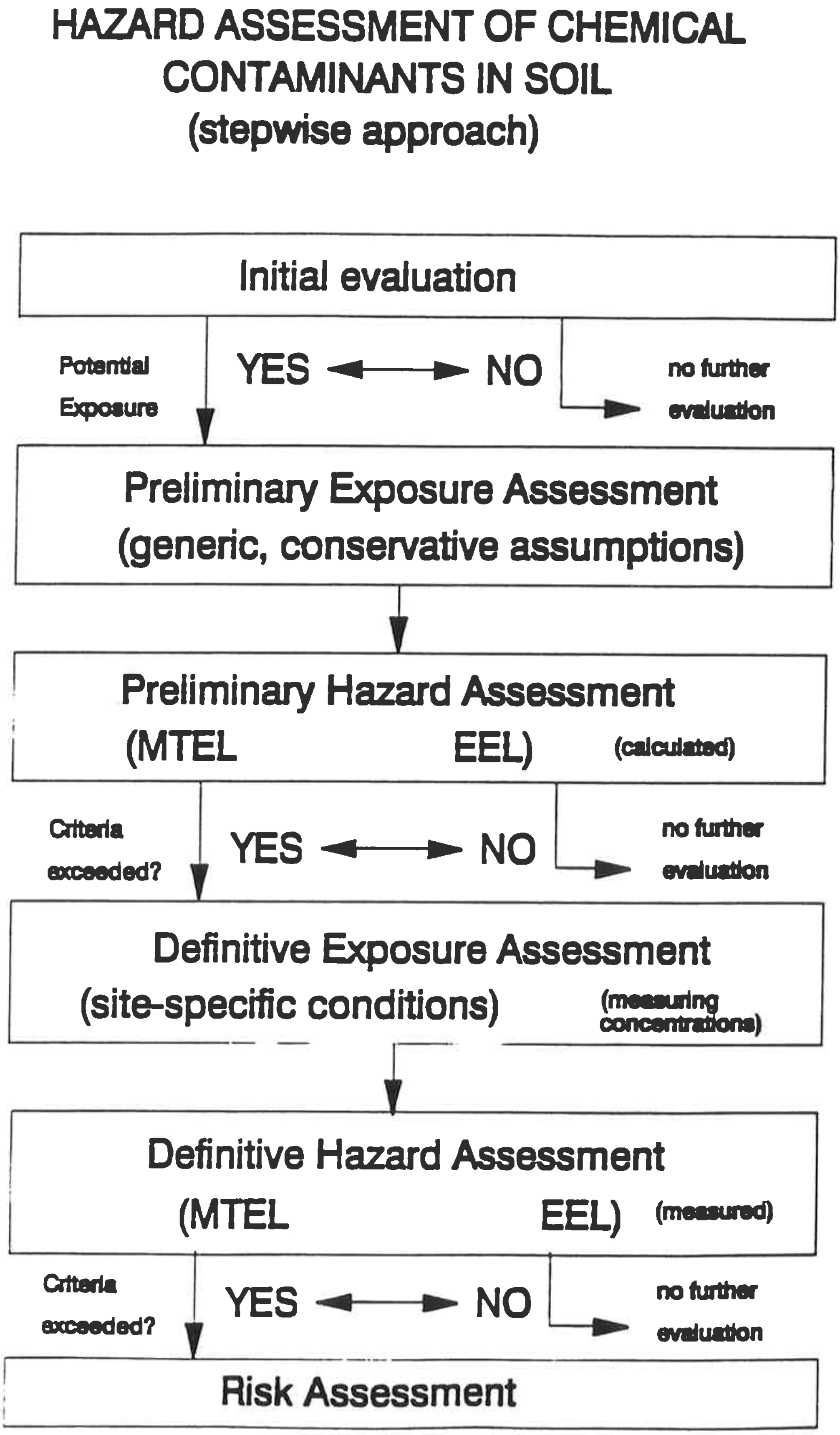
Ryan, J.A., Bell, R.M., Davidson, J.M. and O'Connor, G.A. (1988). Plant uptake of non-ionic organic chemicals from soils. Chemosphere 17, 2299.

Travis, C.C. and Arms, A.D. (1988). Bioconcentration of organics in beef, milk, and vegetation. Environ. Sci Technol. 22, 271.

van den Berg, R. (1991). Blootstelling van de mens aan bodemverontreiniging. Report 725201006 National Institute of Public Health and Environmental Protection, Bilthoven, April 1991.

Veerkamp, W. and Laffoon, B.W. (1992). HESP User Guide Version 1.3. Shell Internationale Petroleum Maatschappij BV, The Hague.

FIGURE 1


HAZARD ASSESSMENT OF CHEMICAL CONTAMINANTS IN SOIL
(stepwise approach)
Initial evaluation
Potential Exposure
YES
NO
no further evaluation
Preliminary Exposure Assessment
(generic, conservative assumptions)
Preliminary Hazard Assessment
(MTEL
EEL)
(calculated)
Criteria exceeded?
YES
NO
no further evaluation
Definitive Exposure Assessment
(site-specific conditions)
(measuring concentrations)
Definitive Hazard Assessment
(MTEL
EEL)
(measured)
Criteria exceeded?
YES
NO
no further evaluation
Risk Assessment

ANNEX I

Parameter	Description	Unit
A_{ah}	- surface area of arms and hands	m^2
A_d	- surface area of the droplet	m^2
ADI	- Acceptable Daily Intake	mg/kg.d
A_{exp}	- surface of the skin exposed to contaminant	m^2
A_{fh}	- surface area of forearms and hands	m^2
A_h	- surface area of hands	m^2
A_{lf}	- surface area of legs and feet	m^2
A_t	- surface area of basement walls and floor	m^2
A_{tot}	- total surface area of the skin	m^2
AID	- amount of soil ingested daily (yearly average) by man	mg/d
AID_c	- amount of soil ingested daily (yearly average) by cattle	mg/d
BCF	- bioconcentration factor for plants	-
BCF	- bioconcentration factor for aquatic organisms	-
C	- constant K_{ow} - BCF_m relationship	-
C^o	- initial air concentration	mg/m^3
c	- index indicating cattle	-
C_{ba}	- concentration in basement-air	g/m^3
C_d	- concentration in the soil layer > 1.5m	mg/kg-dm
C_{dep}	- concentration in plant due to deposition of dust	mg/kg-dm
C_{dust}	- concentration in dust (external source)	mg/kg-dm
C_{dw}	- concentration in the drinking water	mg/l
C_{gw}	- concentration in the ground water	mg/l
C_{la}	- concentration in living room air	g/m^3
C_m	- concentration in the soil layer 0.25 - 1.5 m	mg/kg-dm
C_{me}	- concentration in the meat (cattle)	mg/kg
C_{mi}	- concentration in the milk (cattle)	mg/l
C_{oa}	- concentration in the outdoor air	g/m^3
C_{pl}	- concentration in part of the plant	mg/kg-dm
C_{pt}	- average concentration in garden produce	mg/kg-dm
C_{pw}	- concentration in porous water	mg/l
C_{root}	- concentration in root parts of the plant	mg/kg-dm
C_s	- total average soil concentration	mg/kg-dm
$C_{s,o}$	- average soil concentration outdoor	mg/kg-dm
$C_{s,bo}$	- average soil concentration used in the calculation for the basement air concentration (open)	
$C_{s,bc}$	- average soil concentration used in the calculation for the basement air concentration (concrete).	
C_{sa}	- concentration in soil-air	g/m^3
$C_{s,max}$	- maximum concentration in soil which corresponds with the water solubility	mg/kg-dm
C_{stem}	- concentration in upper parts of the plant	mg/kg-dm
C_{sw}	- concentration in surface water	mg/l
C_t	- concentration in the soil top layer 0 - 0.25 m	mg/kg-dm
C_{wp}	- concentration of the contaminant in the service pipe after 24 hours of stagnancy	mg/l
CN_a	- air content of concrete	m^3/m^3

CN_p	- porosity of concrete	m^3/m^3
CN_s	- solid phase of concrete	m^3/m^3
CN_w	- water content of concrete	m^3/m^3
Co	- correction factor for roughness length	-
D	- constant K_{ow} - BCF_m relationship	-
d	- thickness of the mixing zone in the aquifer	m
D_a	- diffusion coefficient through air	m^2/h
d_c	- thickness of the concrete	m
d_e	- thickness of the service pipe wall	mm
D_{ef}	- diffusion coefficient in soil	m^2/h
D_{me}	- permeation coefficient (metal-pipe)	m^2/d
D_{pe}	- permeation coefficient (LDPE-pipe)	m^2/d
D_{pvc}	- permeation coefficient (PVC-pipe)	m^2/d
D_{sa}	- diffusion coefficient in the gasphase in soil	m^2/h
D_{sac}	- diffusion coefficient in the gasphase in concrete	m^2/h
D_{sw}	- diffusion coefficient in the waterphase in soil	m^2/h
d_t	- number of hours that the water is stagnant	h/d
D_w	- diffusion coefficient in free water	m^2/h
DA	- total dermal absorption	mg/kg-bw.d
$DA_{x,n}$	- dermal absorption equivalent for soil or dust per day in a season	kg soil/d
DA_w	- dermal absorption through water contact	mg/kg-bw.d
DA_{sw}	- dermal absorption during swimming	mg/kg-bw.d
DAE_y	- amount of soil on the skin, indoors (i) or outdoors (o)	kg/m^2
DAR	- dermal absorption rate for soil or dust	1/h
DAR_w	- dermal absorption rate for exposure in water	m/h
DU	- total direct ingestion	mg/kg-bw.d
DU_c	- total direct ingestion for cattle	mg/kg-bw.d
DU_{wc}	- direct ingestion through water consumption for cattle	mg/kg-bw.d
$DU_{n,x}$	- direct ingestion of soil or dust per unit body weight per season	mg-soil/d
DU_w	- direct ingestion through drinking water	mg/kg-bw.d
DR_o	- deposition rate of dust (outdoors)	$mg/m^2.d$
dx_y	- time spent in days per week in season	d/w
E_v	- evaporation flux of water	m/d
f_{bi}	- fraction of basement air contributing to indoor air	-
$f_{a,ing}$	- fraction uptake/intake for ingestion	-
$f_{a,inh}$	- fraction uptake/intake for inhalation	-
$f_{ac,ing}$	- fraction uptake/intake for ingestion for cattle	-
$f_{ac,inh}$	- fraction uptake/intake for inhalation for cattle	-
f_c	- fraction of area covered by housing or growth	-
f_{gc}	- fraction of ground water used by cattle	-
f_{sc}	- fraction of surface water used by cattle	-
f_{ex}	- fraction of metal uptake excreted by cattle	-
f_{exp}	- fraction of the skin exposed	-
f_{fme}	- fraction of fat in meat	-
f_{fmi}	- fraction of fat in milk	-
f_g	- fraction of ground water used for consumption	-
f_h	- fraction of soil covered by housing or pavement	-
f_{hv}	- fraction of consumption of home grown produce	-

f_{in}	- fraction initially intercepted	-
$f_{l/r}$	- fraction of leafy products in the garden produce	-
f_m	- matrix factor	-
f_{oc}	- fraction of organic carbon in soil	-
f_{om}	- fraction organic matter in soil	-
f_r	- fraction retained in the lung	-
f_{rc}	- fraction retained in the lung for cattle	-
$f_{rs,y}$	- fraction of soil in dust, indoors (i) or outdoors (o)	-
f_x	- fraction of the season	months/y
f_z	- fraction of food products from the vicinity of the location (fish, dairy, milk or meat)	-
f_{Ei}	- weathering constant	1/d
H_s	- Henry's Law Constant at T_{soil} (K)	$Pa.m^3/mol$
H(T)	- Henry's Law Constant at T (K)	$Pa.m^3/mol$
h	- height (wind velocity)	m
he	- the hight of the basement	m
I	- hydraulic gradient	m/m
IP	- inhaled chemical via dust	mg/kg-bw.d
IP_c	- inhaled chemical via dust by cattle	mg/kg-bw.d
$IP_{y,x}$	- inhaled particulate matter per season as soil	mg soil/d
IV	- total inhaled vapour	mg/kg-bw.d
IV_c	- total inhaled vapour by cattle	mg/kg-bw.d
IV_w	- inhaled vapour during showering	mg/kg-bw.d
$IV_{y,x}$	- inhaled vapour in a season	mg/d
J	- total flux	$g/m^2.h$
J1	- concrete flux	$g/m^2.h$
J2	- boundary layer flux	$g/m^2.h$
J3	- water evaporation flux	$g/m^2.h$
J4	- diffusion flux water-soil	$g/m^2.h$
J_{oa}	- total flux outdoor air	$g/m^2.h$
J_{ba}	- total flux basement air	$g/m^2.h$
K	- hydraulic conductivity of the aquifer	m/d
k	- Karman constant	-
K_d	- partition coefficient soil/water	dm^3/kg
kG	- gas mass transfer coefficient	m/h
K_g	- the gas phase mass transfer coefficient	m/h
kL	- liquid mass transfer coefficient	m/h
K_l	- liquid phase exchange rate (CO_2)	m/h
K_{me}	- partition coefficient meat/diet	(mg/kg)/(mg/d)
K_{mi}	- partition coefficient milk/diet	(mg/kg)/(mg/d)
K_{fa}	- partition coefficient fat/diet	(mg/kg)/(mg/d)
K_{oc}	- organic carbon partition coefficient	dm^3/kg
K_{ow}	- octanol/water partition coefficient	g/g
k_{wa}	- extent of evaporation	-
l	- the length of the basement	m
L	- the length of contaminated area	m
L_c	- length of the diffusive path in the soil	m
L_w	- width of the location	m
L_{ws}	- width of the soil loss zone	m
M	- molecular weight	g/mol
m	- index indicating aquatic organisms	-
MI	- equivalent uptake through meat, milk and dairy products	mg/kg-bw.d

MTEL	- Maximum Tolerable Environmental Level	
n	- index indicating dust or soil	-
N_b	- times per week bathing occurs	bath/w
N_{exp}	- exposure while bathing or showering	-
N_s	- times per week showering occurs	shower/w
N_{sw}	- fraction of day bathing per year	-
$N_{x,y}$	- fraction of time spent, indoors (i), outdoors (o), sleeping (sleep) or absent in season	-
N_y	- fraction of time spent annually, indoors (i), outdoors (o), sleeping (sleep) or absent from the location	-
N_{yc}	- fraction of days for cattle spent indoors (i) or outdoors (o)	-
P	- vapour pressure at T_{soil} (K)	Pa
P(T)	- vapour pressure at T (K)	Pa
P_a	- mass fraction in soil gas phase	-
P_{erm}	- dermal absorption rate	m/h
Ps	- mass fraction in soil solid phase	-
Pw	- mass fraction in soil liquid phase	-
pH	- acidity	-
Q_{di}	- amount of water discharged from the aquifer to surface water	m^3/d
Q_{dw}	- total amount of water used per household per day	l/d
Q_{ev}	- amount of water evaporated from surface water	m^3/d
Q_{fi}	- consumption of fish	kg/d
Q_{fv}	- consumption of fruit and vegetables	kg/d
q_{inf}	- infiltration rate	m/d
Q_{mi}	- amount of milk produced per day	l/d
Q_{pc}	- consumption of plants by cattle (dry weight)	kg/d
q_{re}	- recharge rate	mm/d
Q_{sw}	- mass flow of surface water	m^3/h
Q°_{sw}	- initial mass flow of surface water	m^3/h
Q_w	- water consumption of recipient	dm^3/d
Q_{wc}	- amount of water consumed by cattle	l/d
Q_z	- consumption of meat, fat or dairy products	kg/d
r	- internal radius of the service pipe	mm
R	- universal gas constant	$Pa.m^3/mol$
R_a	- ventilation rate in the basement	1/h
R_o	- run-off of soil	mm/y
S	- water solubility at T_{soil} (K)	mol/l
S_w	- water solubility at T_{soil} (K)	mg/l
S(T)	- water solubility at T (K)	mol/l
S_w(T)	- water solubility at T (K)	mg/l
SG	- bulk density of dust or soil	kg/dm^3
SG_{mi}	- bulk density of milk	kg/dm^3
SL	- soil loss	mm/y
SN_a	- air content of soil	m^3/m^3
SN_s	- volume phase of solid phase	m^3/m^3
SN_w	- water content of soil	m^3/m^3
sr	- surface roughness	m
Sz	- Pasquill dispersion coefficient in vertical direction, weather stability class D	m
T_{sh}	- temperature of bathing water	K

T_{soil}	- temperature of the soil surface	K
t_b	- duration of bathing	h
t_c	- time the cattle spent on contaminated land	d
t_e	- crop growth period	d
t_f	- falling time of the droplet	s
t_s	- duration of showering	h
TI_c	- total intake of contaminants by cattle	mg/d
TSP_y	- total suspended particulates in the air, indoors (i) or outdoors (o)	$\mu g/m^3$
T_{soil}	- average soil temperature	K
T_x	- average ambient air temperature	K
$tx1_y$	- time spent in hours per day in season	h/d
$tx2_y$	- time spent in days per week in season	d/wk
txo_c	- time spent outside per day by cattle	hr/d
V^*	- the friction velocity	m/h
V_h	- the wind velocity at a height of h m	m/h
V_Y	- the wind velocity at a height of Y m	m/h
Vb	- volume of the basement	m^3
V_{bath}	- volume of the bathroom	m^3
V_d	- volume of the droplet	m^3
V_w	- volume of water used during a shower	m^3/shower
VA	- volume of air breathed	m^3/d
VA_c	- volume of air breathed by cattle	m^3/d
Vf	- dilution velocity	m/h
Vg	- mean wind velocity	m/h
VI	- uptake via fruit and vegetables	mg/kg-bw.d
VI_c	- uptake via grass consumption by cattle	mg/kg-bw.d
W	- receptor's weight	kg
W_c	- cattle weight	kg
w	- the width of the basement	m
x	- index indicating summer or winter	-
X_a	- thickness of the boundary layer	m
y	- index indicating indoor, outdoor, sleeping or absent	-
Y	- breathing height	m
Y_c	- breathing height of cattle	m
Y_v	- vegetative productivity	kg/m^2
z	- index indicating meat, fat, dairy products, or fish (me, f, mi, fi)	-
Z_a	- fugacity capacity constant air	$mol/m^3.Pa$
Z_s	- fugacity capacity constant soil	$mol/m^3.Pa$
Z_w	- fugacity capacity constant water	$mol/m^3.Pa$

ANNEX II

Netherlands 1.00: Soil Usages.

II A. Urban (As described in the CSOIL model calculations (59))

Fixed/User Soil Usage Parameters

Scenario : Netherlands
Version : 1.00

Soil Usage : Urban
sr : 1.00 m
fh : 0.60

	Adult Sumr	Adult Wintr	Child Sumr	Child Wintr	
d,act	2	2	5	5	days/week
t,sleep	8	8	12	12	hours/day
t,away,act	0	0	0	0	hours/day
t,out,act	8	0	8	0	hours/day
t,away,pass	8	8	0	0	hours/day
t,out,pass	0	0	0	0	hours/day
t,swim	0	0	0	0	hours/day

Intake route	
Inhalation	
vapour	Yes
dust	Yes
shower	Yes
Ingestion	
soil/dust	Yes
crop	Yes
water	Yes
meat/dairy	No
fish	No
Dermal	
soil/dust	Yes
water	Yes

F2=NEW F3=SAVE F4=DEL F7=NEXT F8=NEXT ESC=EXIT S-F1=USRSOIL

II B. Agriculture

Fixed/User Soil Usage Parameters

Scenario : Netherlands
Version : 1.00

Soil Usage : Agriculture
sr : 0.10 m
fh : 0.10

	Adult Sumr	Adult Wintr	Child Sumr	Child Wintr	
d,act	6	6	5	5	days/week
t,sleep	8	8	12	12	hours/day
t,away,act	0	0	0	0	hours/day
t,out,act	12	6	8	0	hours/day
t,away,pass	0	0	0	0	hours/day
t,out,pass	0	0	0	0	hours/day
t,swim	0	0	0	0	hours/day

Intake route	
Inhalation	
vapour	Yes
dust	Yes
shower	Yes
Ingestion	
soil/dust	Yes
crop	Yes
water	Yes
meat/dairy	Yes
fish	Yes
Dermal	
soil/dust	Yes
water	Yes

F2=NEW F3=SAVE F4=DEL F7=NEXT F8=NEXT ESC=EXIT S-F1=USRSOIL

Netherlands 1.00: Soil Usages.

II C. Industrial

Fixed/User Soil Usage Parameters

Scenario : Netherlands
Version : 1.00

Soil Usage : Industrial
sr : 3.00 m
fh : 0.60

	Adult Sumr	Adult Wintr	Child Sumr	Child Wintr	
d,act	5	5	0	0	days/week
t,sleep	0	0	0	0	hours/day
t,away,act	15	15	24	24	hours/day
t,out,act	4	4	0	0	hours/day
t,away,pass	24	24	24	24	hours/day
t,out,pass	0	0	0	0	hours/day
t,swim	0	0	0	0	hours/day

Intake route	
Inhalation	
vapour	Yes
dust	Yes
shower	Yes
Ingestion	
soil/dust	Yes
crop	No
water	Yes
meat/dairy	No
fish	No
Dermal	
soil/dust	Yes
water	Yes

F2=NEW F3=SAVE F4=DEL F7=NEXT F8=NEXT ESC=EXIT S-F1=USRSOIL

II D. Recreational

Fixed/User Soil Usage Parameters

Scenario : Netherlands
Version : 1.00

Soil Usage : Recreational
sr : 0.30 m
fh : 0.10

	Adult Sumr	Adult Wintr	Child Sumr	Child Wintr	
d,act	5	4	5	4	days/week
t,sleep	0	0	0	0	hours/day
t,away,act	16	22	16	22	hours/day
t,out,act	8	2	8	2	hours/day
t,away,pass	24	24	24	24	hours/day
t,out,pass	0	0	0	0	hours/day
t,swim	2	0	2	0	hours/day

Intake route	
Inhalation	
vapour	Yes
dust	Yes
shower	No
Ingestion	
soil/dust	Yes
crop	No
water	Yes
meat/dairy	No
fish	Yes
Dermal	
soil/dust	Yes
water	Yes

F2=NEW F3=SAVE F4=DEL F7=NEXT F8=NEXT ESC=EXIT S-F1=USRSOIL

ANNEX III

RELATED LITERATURE (not cited in the text)

Andelman, J.B. (1985). Inhalation exposure in the home to volatile organic contaminants of drinking water. Science Total Environ. 47, 443.

Anonymous (1980). Landbouw Economisch Instituut/CBS, Landbouwcijfers, Den Haag.

Anonymous (1986). Advies Bodemkwaliteit, VTCB A86/02-I and II, Leidschendam, June 1986.

Anonymous (1988). Leidraad Bodemsanering. Staatsuitgeverij, s'Gravenhage 1983 (updated Nov. 1988). ISBN 90 12044030.

Baker, J.L., Laflen, J.M. and Johnson, H.P. (1978). Effect of tillage systems on runoff losses of pesticides, a rainfall simulation study. Trans. Amer. Soc. Agricul. Eng. 20, 886.

Binder, S., Sokal, D. and Maugham, D. (1986). Estimating Soil Ingestion: The use of trace elements in estimating the amount of soil ingested by young children. Arch. Environ. health 41, 341.

Bysshe, S.E. (1982). Bioconcentration factor in aquatic organisms. In: "Handbook of chemical properties estimation methods", 5-1 (34).

Canadian Council of Resource and Environment Ministers (CCREM) (1988). Contaminated soil clean-up in Canada, Vol. 1, Methods and strategies currently used to develop cleanup criteria for contaminated sites. Prepared for the Decommissioning steering Committee.

Canadian Council of Resource and Environment Ministers (CCREM) (1988). Contaminated soil clean-up in Canada", Vol. 2, Interim report on the "Demonstration" version of the AERIS model (an Aid for Evaluating the Redevelopment of Industrial Sites). Prepared for the Decommissioning steering Committee.

Canadian Standards Association (CSA) (1986). Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities CSA Standard. CAN3-N288.1. (Draft).

Donigian, A.S. Jr. and Carsel, R.F. (1987). Modelling the impact of conservation tillage practices on pesticide concentrations in ground and surface waters. Environ. Toxicol. Chem. 6, 241.

Dutkiewics, T. and Tyras, H. (1968). Skin absorption of toluene, styrene and xylene by man. British J. Industrial Medicine 25, 243.

Environ Corporation (1986). In: "Site selection process. Phase 4A: Selection of a preferred site(s) - generic risk assessment, Vol. 2, Technical appendices". Prepared for the Ontario Waste Management coorporation.

Geyer, H., Sheehan, P., Kolzias, D., Freitag, D. and Korte, F. (1982). Prediction of ecotoxicological behaviour of chemicals: Relationship between physico-chemical properties and bioaccumulation of organic chemicals on the mussel Mytilus Edulis, Chemosphere 11, 1121.

Haith, D.H. (1987). Extreme event analysis of pesticide loads to surface waters. J. Water Pollution Control Fed. 59, 284.

Haith, D.H. (1980). A mathematical model for estimating pesticide losses in runoff", J. Environ. Qual. 9, 428.

Hawley, J.K. (1985). Assessment of health risk from exposure to contaminated soil. Risk Analysis, Vol. 5, 4, 289.

Hetrick, D.M. and McDowell-Boyer, L.M. (1984). Users manual for TOX-SCREEN, EPA Report 560/5-83-024.

Hushon, J.M., Klein, A.W., Strachan, W.J.M. and Schmidt-Bleek, F. (1983). Use of OECD premarket data in environmental exposure analysis for new chemicals. Chemosphere 12, 887.

Hwang, S.T. (1985). Estimation of multi exposure related to hazardous waste facilities., U.S. EPA Exposure assessment Group.

International Commission on Radiological Protection (ICRP) (1975). Publication 23, Report on the task group on reference man. Pergamon Press.

Karickhoff, S.W. (1981). Semi-empirical estimation of sorption of hydrophobic pollutants on natural sediments and soils. Chemosphere 10, 833.

LaGoy, P.K. (1987). Estimated soil ingestion rates for use in risk assessment, Risk Analysis, 7, 355.

Lepow, M.L., Bruckman, L., Rubino, R.A., Markowitz, S., Gilette, M. and Kapish, J. (1975). Investigations into sources of lead in the environment of urban children. Environ. Res. 10, 415.

McKone, T.E. and Layton, D.W. (1986). Screening the potential risks of toxic substances using a multimedia compartment model: Estimation of human exposure, Regulatory Toxicol. Pharmacol. 6, 359.

McKone, T.E. and Layton, D.W. (1986). Exposure and risk assessment of toxic waste in a multimedia context, Proc. 79th Annual Mtg Air Pollution Control Association, June 22-27, 1986.

Nijs de, A.C.M., Knoop, J.M. and Vermeire T.G. (1988). Risk assessment of new chemical substances. Report 718703001 National Institute of Public Health and Environmental Protection, Oct. 1988, Bilthoven.

Nutrition Canada (1977). Food consumption patterns report, Department of national health and welfare.

Olie, K., van de Berg, M. and Hutzinger, O. (1983). Formation and fate of PCDD and PCDF from combustion processes, Chemosphere 12, 627.

Paustenbach, D.J. Shu, H.P. and Murray, F.J. (1986). A critical examination of assumptions used in risk assessments of dioxin contaminated soil, Regulatory Toxicol. Pharmacol. 6, 284.

Poels, C.L.M., Gruntz U, Isnard P, Riley. D., Spiteller. M, ten Berge. W., Veerkamp. W. and Bontinck, W.J. (1991). Hazard Assessment of Chemical Contaminants in Soil, Chemosphere 23, 3.

Poiger, H. and Schlatter, Ch. (1980). Influence of solvents and absorbents on dermal and intestinal absorption of TCDD, Food Cosmetics Toxicol. 18, 477.

Productschap voor groente en fruit (mondeling), opgave betreft 1986.

Roberts, T.M., Gizyn, W. and Hutchinson, T.C. (1974). Lead contamination of air, soil, vegetation and people in the vicinity of secondary lead smelters, Conf. Trace Subst. Environ. Health 8, 155.

Roels, H.A., Buchet, J.P. and Lauwerys, R.R. (1980). Exposure to lead by the oral and pulmonary routes of children living in the vicinity of a primary lead smelter, Environ. Res. 22, 81.

Rosenblatt, D.H., Small, M.J. and Kainz, R.J. (1983). Application of the preliminary pollutant limit value (PPLV) environmental risk assessment approach to selected land uses. In: "Fate of chemicals in the environment", eds. R.L. Swann and A. Eschenroeder, ACS Symp. Ser. 255, 263.

Rosenblatt, D.H., Dacre, J.C. and Cogley, D.R. (1982). An environmental fate model leading to preliminary pollutant limit values for human health effects. In: "Environmental Risk Analysis for Chemicals", ed. R.A. Conway, 474.

Sauerbeck, D. (1988). Der Transfer von Schwermetallen in die Pflanze. In: "Beurteilung von Schwermetallkontaminationen im Boden", DECHEMA, Frankfurt am Main, 281.

Schaum, J. (1983). Risk Analysis of TCDD contaminated soil, EPA.

Soil Conservation Service USDA (1971). SCS National Engineering Handbook, Section 4, Hydrology, US Govt. Printing Off. Washington DC.

Ten Berge, W. (1985). Soil contamination with volatile organic chemicals and the estimation of impact on human health. In: J.W. Assink and W.J. van den Brink (eds.), "Contaminated Soil", Nijhoff Publishers.

US Food and Drug Administration (FDA), Radiological health Handbook: Bureau of Radiological Health (1970).

Veerkamp, W., Koch, V., Marsmann. M. and Wittlinger. R. (1991). Abschätzung der Gefährlichkeit von Chemischen Schadstoffen in Boden an Beispiel von 2,3,7,8-TCDD. Proceedings, Dioxin Informations-veranstaltung, Augsburg, November 1991, Universität Bayreuth, Bayerisches Institut fuer Abfallforschung.

Vonk, M.W. (1985). Permeation of organic compounds through pipes for drinking water supply", H_2O, 18, 529.

Wauchope, R.D. (1987). Tilted-bed simulation of erosion and chemical runoff from agricultural fields: I. Runoff of sediment and sediment-associated copper and zinc, J. Environ. Qual. 16, 206.

Wijnen, J.H. van (1987). Een modelmatige benadering van het Gezondheidsrisico bij bodemverontreiniging; Onderzoek in de Steendijkpolder te Maassluis, T. Soc Gezondheidsz. 65, 383.

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No.12 Joint Assessment of Commodity Chemicals, (HFA-124) 1-Chloro-1,2,2,2-Tetrafluoroethane
No.13 Joint Assessment of Commodity Chemicals, (HFA-123) 1,1-Dichloro-2,2,2-Trifluoroethane
No.14 Joint Assessment of Commodity Chemicals, (HFA-133a) 1-Chloro-2,2,2-Trifluoromethane
No.15 Joint Assessment of Commodity Chemicals, (HFA-141B) 1-Fluoro 1,1-Dichloroethane
No.16 Joint Assessment of Commodity Chemicals, (HCFC-21) Dichlorofluoromethane
No.17 Joint Assessment of Commodity Chemicals, (HFA-142b) 1-Chloro-1,1,Difluoroethane
No.18 Joint Assessment of Commodity Chemicals, Vinylacetate
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No.4 Hepatocarcinogenesis in Laboratory Rodents : Relevance for Man
No.5 Identification and Assessment of the Effects of Chemicals on Reproduction and Development (Reproductive Toxicology)
No.6 Acute Toxicity Tests, LD_{50}(LC_{50}) Determinations and Alternatives
No.7 Recommendations for the Harmonisation of International Guidelines for Toxicity Studies
No.8 Structure-Activity Relationships in Toxicology and Ecotoxicology: An Assessment
No.9 Assessment of Mutagenicity of Industrial and Plant Protection Chemicals
No.10 Identification of Immunotoxic Effects of Chemicals and Assessment of their Relevance to Man
No.11 Eye Irritation Testing
No.12 Alternative Approaches for the Assessment of Reproductive Toxicity (with emphasis on embryotoxicity/ teratogenicity)
No.13 DNA and Protein Adducts: Evaluation of their Use in exposure Monitoring and Risk Assessment
No.14 Skin Sensitisation Testing
No.15 Skin Irritation
No.16 Mutation Research, Special Issue: Early Indicators of Non-Genotoxic Carcinogenesis

TECHNICAL REPORTS

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No.1 Assessment of Data on the Effects of Formaldehyde on Humans
No.2 The Mutagenic and Carcinogenic Potential of Formaldehyde
No.3 Assessment of Test Methods for Photodegradation of Chemicals in the Environment
No.4 The Toxicology of Ethylene Glycol Monoalkyl Ethers and its Relevance to Man
No.5 Toxicity of Ethylene Oxide and its Relevance to Man
No.6 Formaldehyde Toxicology : an Up-Dating of the ECETOC Technical reports 1 and 2
No.7 Experimental Assessment of the Phototransformation of Chemicals in the Atmosphere
No.8 Biodegradation Testing: An Assessment of the Present Status
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No.19 An Assessment of Occurrence and Effects of Dialkyl-o-Phthalates in the Environment
No.20 Biodegradation Tests for Poorly-Soluble Compounds
No.21 Guide to the Classification of Carcinogens, Mutagens and Teratogens Under the 6th Amendment
No.22 Classification of Dangerous Substances and Pesticides in the EEC Directives. A Proposed Revision of Criteria for Inhalational Toxicity
No.23 Evaluation of the Toxicity of Substances to be Assessed for Biodegradability
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