



National Institute for Public Health
and the Environment (RIVM)
Ministry of Health, Welfare and Sport

Aggregate Exposure to Substances in Personal Care Products and Household Cleaning Products:

The Probabilistic Aggregate Consumer Exposure Model

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Aggregate exposure from consumer products



Consumer product exposure

Substances may be contained in multiple products ->

need to estimate total (or 'aggregate') exposure from combined product usage

- Aggregate exposure from consumer products not generally considered
- Appropriate methods or tools not publicly available



Low tier exposure estimation

(e.g. Cosmetics, SCCS guidance method)

- Assume all products are used together in high amount and frequency
- Assume all products contain the substance to the maximum concentration allowed

Table 4: Calculation of aggregate exposure for preservatives through cosmetic use.

Type of exposure	Product	g/d	mg/kg bw/d
Rinse-off skin & hair cleansing products	Shower gel	0.19	2.79
	Hand wash soap	0.20	3.33
	Shampoo	0.11	1.51
	Hair conditioner	0.04	0.67
Leave-on skin & hair care products	Body lotion	7.82	123.20
	Face cream	1.54	24.14
	Hand cream	2.16	32.70
	Deo non-spray	1.50	22.08
	Hair styling	0.40	5.74
Make-up products	Liquid foundation	0.51	7.90
	Make-up remover	0.50	8.33
	Eye make-up	0.02	0.33
	Mascara	0.025	0.42
	Lipstick	0.06	0.90
	Eyeliner	0.005	0.08
Oral care cosmetics	Toothpaste	0.14	2.16
	Mouthwash	2.16	32.54
TOTAL		± 17.4	269



Refining aggregate exposure assessment

Low tier aggregation methods:

- often lead to unrealistic exposure estimates
- useful for quickly excluding potential risks, but if it fails it provides no options for refinement

More realistic methods should account for:

- Actual product usage in population
 - Which products are used in combination
 - How often are products used
 - How much of the product is used per use
- Realistic product information:
 - Not all products contain the substance of interest
 - Not all products contain substance at maximum allowed concentration

Probabilistic Aggregate Consumer Exposure Model



PACEM (Probabilistic Aggregate Consumer Exposure Model):

- Information on product usage in population
 - Surveys on personal care and cleaning products
 - Cosmetics/PCP use (COLIPA 2007, Biesterbos et al. 2013)
 - Household products (EPHECT 2012)
 - Cosmetics & Cleaning products combined (Garcia-Hidalgo et al. 2017)
- Realistic information concentrations and occurrence of the substance in products
- Distribution (variability) of exposure in population

Probabilistic Aggregate Consumer Exposure Model (PACEM)



- Developed at RIVM in cooperation with ETH Zürich en RU Nijmegen (2013)
- Implemented in R programming language
 - Used only 'in house'
- Make available for public use
 - Develop into a freely accessible web application (2019/2020)
 - Prototype in R with a graphical user interface

This presentation:

- Method to calculate aggregate consumer exposure
- Examples of applications
- Demo of the PACEM proto type

Modelling procedure



Product usage (survey)

- Person information
- Body weight
 - Age
 - Sex

- Product usage
- Frequency
 - Amount used



Simulation

- Number of persons
- Number men/women
- Number of days

Simulated product use in population

Person information

- Copied from survey

Daily Product use

- Which products on each day
- How much product used

		Day 1	Day 2	Day 3	
Person 1					
Person 2					
Person 3					
Person 4					
Person 5					

Product concentration information

- Which product contain substance
- (distribution of) concentration



w_f

Exposure from each product use

- Exposure fraction (exposure per gram product)



E_f

Simulated exposure



$$A \times w_f \times E_f$$

Modelling procedure



Product usage (survey)

- Person information
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Product concentration information

- Which product contain substance
- (distribution of) concentration



Exposure from each product use

- Exposure fraction (exposure per gram product)



Simulated exposure



$$[A \times w_f \times E_f]_1 + [A \times w_f \times E_f]_2 + [A \times w_f \times E_f]_3$$

Modelling procedure



Product usage (survey)

- Person information
- Body weight
 - Age
 - Sex

- Product usage
- Frequency
 - Amount used



Simulation

- Number of persons
- Number men/women
- Number of days

Simulated product use in population

- Person information
- Copied from survey

- Daily Product use
- Which products on each day
 - How much product used

		Day 1	Day 2	Day 3	
Man	Bottle	Bottle		Bottle	
Woman	Spray			Spray	
Child	Tube	Tube	Tube	Tube	
Man	Bottle	Bottle	Bottle	Bottle	
Woman	Bottle	Bottle	Bottle	Bottle	

Product concentration information

- Which product contain substance
- (distribution of) concentration



Exposure from each product use

- Exposure fraction (exposure per gram product)



Simulated exposure

$$\text{Dose : } \frac{\sum A \times w_f \times E_f}{\text{body weight}}$$

$$\text{Dermal load : } \frac{\sum A \times w_f \times E_f}{\text{skin surface area}}$$

Modelling procedure



Product usage (survey)

Person information

- Body weight
- Age
- Sex

Product usage

- Frequency
- Amount used



Simulation

- Number of persons
- Number men/women
- Number of days

Simulated product use in population

Person information

- Copied from survey

Daily Product use

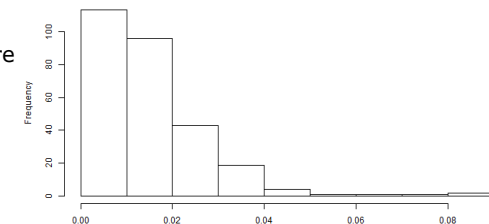
- Which products on each day
- How much product used

		Day 1	Day 2	Day 3	



Simulated exposure

- Average daily exposure
- (maximum) daily exposure
- Highest product contribution



Low tier screening methods

'there may be a problem with this substance contained in all these products'

Assessment with PACEM

- More realistic estimate of (distribution of) exposure
- Proportion of population actually exceeding some risk based level (TDI, RfD, AEL)
- Product's contribution to the exposure
- Evaluate policy options: what is the effect of limiting concentration in product(group)s?

Examples



I) parabens in personal care products

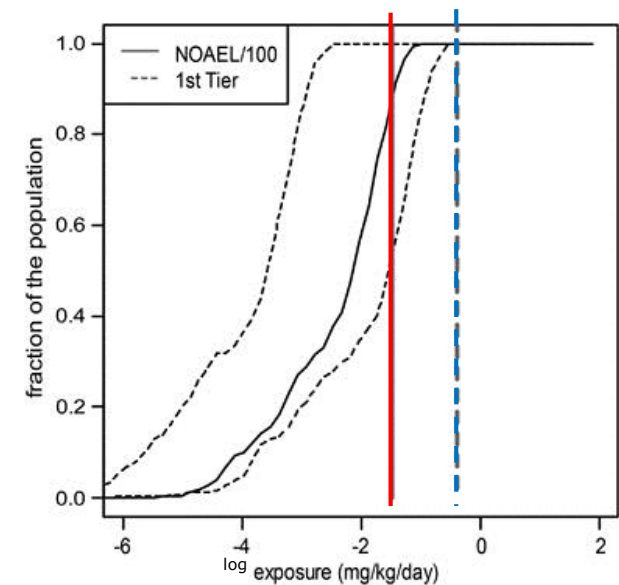


Exposure of children (0-3 years) to parabens from personal care products

Gosens et al., *J Expos Sci Environ Epidemiol* **24(2)**: 208-214

Compare PACEM to deterministic approach

- PACEM estimates 10-100 times lower
- Account for uncertainty and variability



Propylparaben exposure in young children

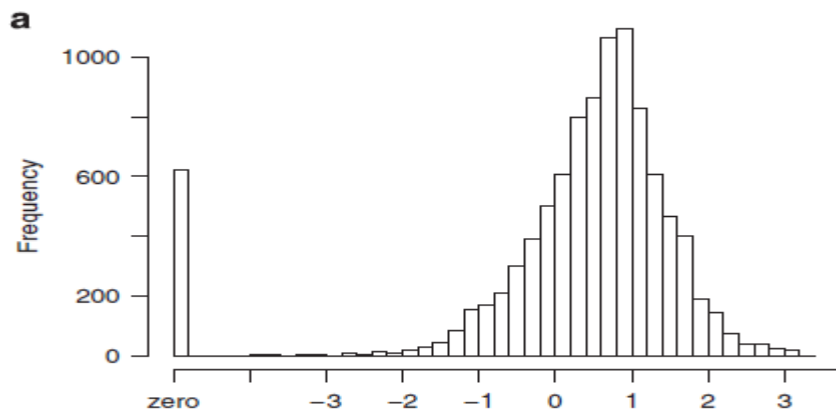
II) DEP in cosmetics and personal care products



Delmaar, C., B. Bokkers, W. ter Burg and G. Schuur (2014). "Validation of an aggregate exposure model for substances in consumer products: a case study of diethyl phthalate in personal care products." *Journal Of Exposure Science And Environmental Epidemiology* 25: 317.

Single day exposure distribution 10,000 persons, 1 day

Modelled versus measured dose



percentile	Modelled dose (ug/kg bw)	Exposure in biomonitoring study (ug/kg bw) (Koch et al. 2003)
50	4.1	2.3
95	67.8	22.1

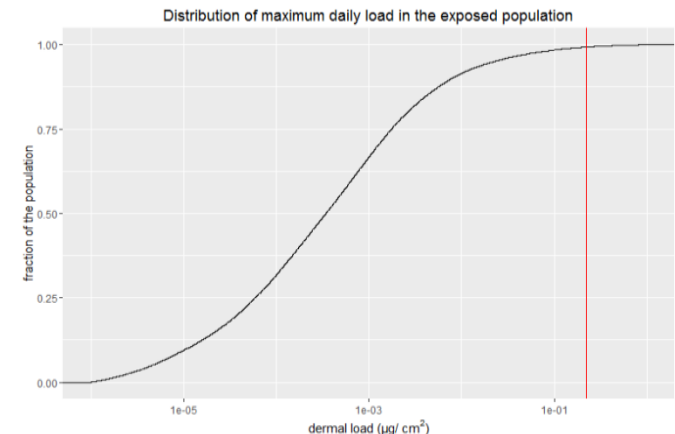
III) MI (conservative) in cleaning and personal care products

MI is a dermal sensitizer

Estimate proportion population at risk of being sensitized

Compare contribution via house hold products (HCP) and personal care products (PCPs)

Evaluate effect of limiting concentration in PCPs



HCPs give highest contribution, effect policy measure limited

J. Ezendam, et al. Food and Chemical Toxicology 112 (2018) 242–250

Scenario	Considering all products	Considering only HCPs	Considering only PCPs
Current situation	0.7%	0.5 %	0.2%
Restriction on allowed concentration in PCPs	0.5%	0.5%	0 %

Table: Risk characterization MI: proportion of the population exposed to MI that exceeds the AEL.

Making PACEM available



Prototype : using R Shiny package, interactive application in R code

- PACEM functionality and a graphical user interface
- Requires R (runs locally)

PACEM Shiny available for evaluation/testing

<https://doi.org/10.5281/zenodo.1475191>

**Assessment**

Survey and Endpoint

Concentration Data

Exposure Fractions

Simulation

Analysis

Results

Start new assessment

Please enter a name for a new assessment.

Continue with new assessment

Open existing project

Choose file

Browse...

OutputDEPexample.RData

Upload complete

Open & continue

Selection of survey & exposure metric



PACEM

✓ Assessment

✓ Survey and Endpoint

✓ Concentration Data

✓ Exposure Fractions

✓ Simulation

Analysis

Personal Care Products (PCPs) Survey

Dutch survey (Biesterbos 2013)

☐ Include household cleaning products

Please note: The Swiss survey includes information on both PCPs and HPs. For the Dutch and the mixed European surveys, another survey called EPHECT will be included to model exposure from HPs.

Exposure Metric

systemic exposure

Save as

Save & continue

Product composition



PACEM

- ✓ Assessment
- ✓ Survey and Endpoint
- ✓ Concentration Data
- ✓ Exposure Fractions
- ✓ Simulation

Analysis

Concentration data

Please enter product concentrations in ng/g

	Product name	Sample size	Distribution	Fraction without substance	Parameter 1	Parameter 2	Parameter 3	Parameter 4
1	Aftershave balsam	1000	trunc lognorm	0.2730	4.67	3.85	18.10	200.37
2	Aftershave spray		NA					
3	Aftersun cream	1000	trunc lognorm	0.5830	4.56	4.02	18.10	206.84
4	Bathingfoam	1000	uniform	0.9520	18.10	60.40		
5	Bathingoil	1000	uniform	0.9520	18.10	60.40		
6	Bodylotion milk	1000	uniform	0.7500	18.10	60.40		
7	Bronzing cream	1000	trunc lognorm	0.5830	4.56	4.02	18.10	206.84
8	Cleansing lotion	1000	trunc lognorm	0.8890	4.10	3.41	18.10	121.09
9	Conditioner	1000	uniform	0.8000	18.10	60.40		
10	Deo cream		NA					
11	Deo roller stick		NA					
12	Deo spray		NA					
13	Deo tissue		NA					
14	Shower gel	1000	uniform	0.9520	18.10	60.40		
15	Eyebrow pencil		NA					
16	Eyeliner pencil		NA					
17	Eye shadow		NA					



PACEM



✓ Assessment

✓ Survey and Endpoint

✓ Concentration Data

✓ Exposure Fractions

✓ Simulation

Analysis

Exposure fractions

	Product name	EF dermal	EF inhalation	EF oral
1	Aftershave balsam	1.0000		0.0000
2	Aftershave spray			
3	Aftersun cream	1.0000		0.0000
4	Bathingfoam	0.0050		0.0000
5	Bathingoil	0.0050		0.0000
6	Bodylotion milk	1.0000		0.0000
7	Bronzing cream	1.0000		0.0000
8	Cleansing lotion	0.0100		0.0000
9	Conditioner	0.0100		0.0000
10	Deo cream			
11	Deo roller stick			
12	Deo spray			

Simulation settings



PACEM



- ✓ Assessment
- ✓ Survey and Endpoint
- ✓ Concentration Data
- ✓ Exposure Fractions
- ✓ **Simulation**

Analysis

Number of exposure days

0



Number of women

5000

Number of men

5000

Save as

Save & simulate

☒ Save results to file? Please note: This could increase the file size significantly.

Analysis options



PACEM



- ✓ Assessment
- ✓ Survey and Endpoint
- ✓ Concentration Data
- ✓ Exposure Fractions
- ✓ Simulation

Analysis

Output analysis options

Your exposure simulation has finished.
Duration of model run: 1.54 min
for modeling exposure for 5000 women and 5000 men in 7 days.

Select exposure measure

acute

Select population

only exposed individuals

Select products

all products

Exposure routes

- ☒ dermal
- ☒ oral
- ☐ inhalation
- ☒ total

☒ Create MCRA output

Percentiles to display in table

0.01

0.05

0.10

0.25

0.50

0.75

Add more fields

Display results

Results (I)



PACEM

☰

✓ Assessment

✓ Survey and Endpoint

✓ Concentration Data

✓ Exposure Fractions

✓ Simulation

✓ Analysis

✓ Results

✓ MCRA - settings

SummaryPlotsSimulated data

Assessment results

Results for the exposed individuals. 70.72 % of the total population is exposed.

Table of percentiles

systemic exposure in ng/kg

route	0.01	0.05	0.10	0.25	0.50	0.75	0.90	0.95	0.99
dermal	0.00026	0.0011	0.010	0.19	0.6826	2.3234	8.595	14.768	36.271
oral	0.00000	0.0000	0.000	0.00	0.0015	0.0078	0.018	0.026	0.062
total	0.00225	0.0066	0.015	0.19	0.6859	2.3311	8.607	14.813	36.277

Result (II)

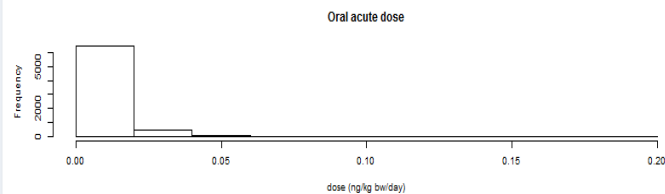
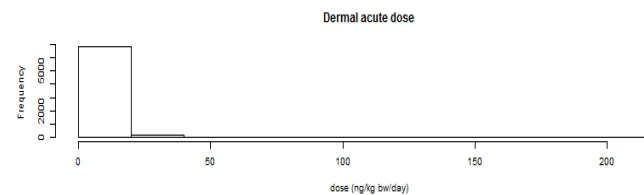
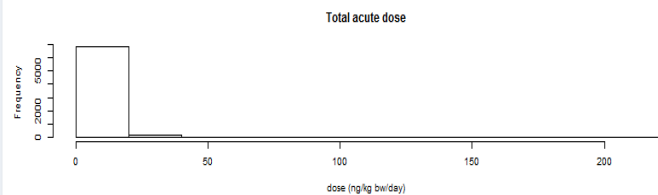


- ✓ Assessment
- ✓ Survey and Endpoint
- ✓ Concentration Data
- ✓ Exposure Fractions
- ✓ Simulation
- ✓ Analysis
- ✓ Results
- ✓ MCRA - settings

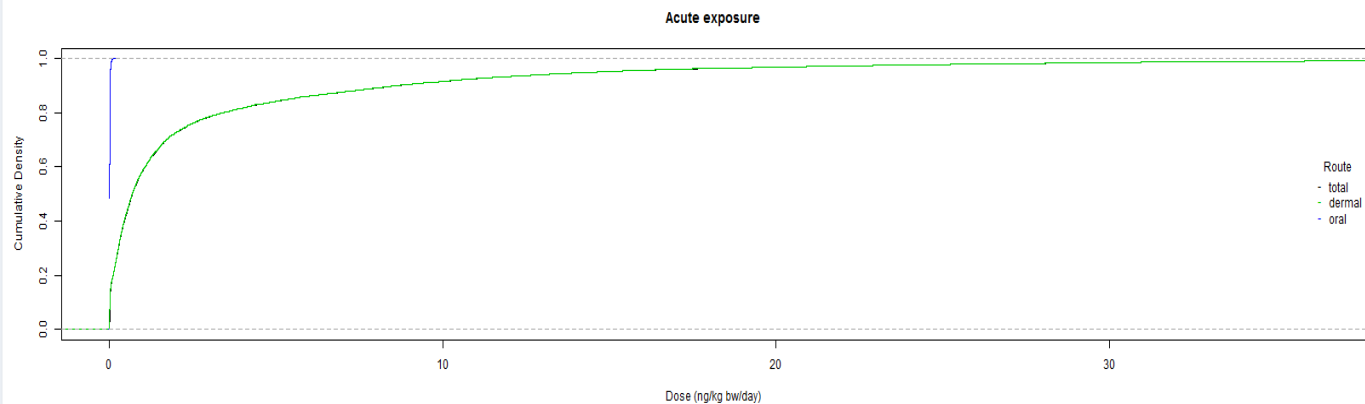
Summary Plots Simulated data

Histogram

Bins of histogram



Cumulative density function



Scale of x-axis

linear

Thank you



PACEM, shiny beta version (incl. documentation)
<https://doi.org/10.5281/zenodo.1475191>

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