Standards for human exposure assessment using probabilistic modelling - a contribution

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I. Goal and scope

Exposure assessment is a key element in every quantitative risk assessment (QRA). Information on exposure can be obtained from a variety of sources such as routine data, specific surveys and studies. In many situations, however, it is either not necessary or not possible to collect all information "from scratch". Therefore, the exposure assessment will often rely on existing human exposure data, accessible in printed or electronic format.

Recent trends in QRA point towards probabilistic modelling (Fig. 1). Probabilistic analysis requires distributional information on the model variables. From this background, the current project investigates how to derive default probability density functions for key exposure factors in a generic and efficient way.

II. Methods

Compilations of exposure factor distributions are available in the USA (AIHC, 1994; CalEPA, 2000; US EPA, 1997). However, the underlying data do not necessarily represent the situation in other countries sufficiently well. The German Exposure Assessment Standards document (AUH, 1995), on the other hand, provides only limited background information on the distribution of exposure factors.

Methods include a document analysis of exposure factor compendiums with regard to:

- Selection of exposure factors
- Quality criteria for the selection of key studies on exposure factors
- Specification of variability and uncertainty
- Guidance concerning the use of the exposure factors

Context: "Ecologic health promotion"

The analyses reported here originated in the broader context of ecologic health promotion (Fehr, 2001). Under this headline, efforts are taken to develop conceptual bridges between the separate traditions of environmental health / hygiene on one side and health promotion on the other. Key elements are an explicit structure model (extended DPSEEA) and the Public Health triad of assessment, policy development, and assurance.

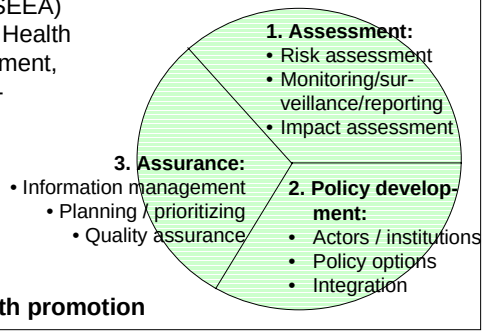
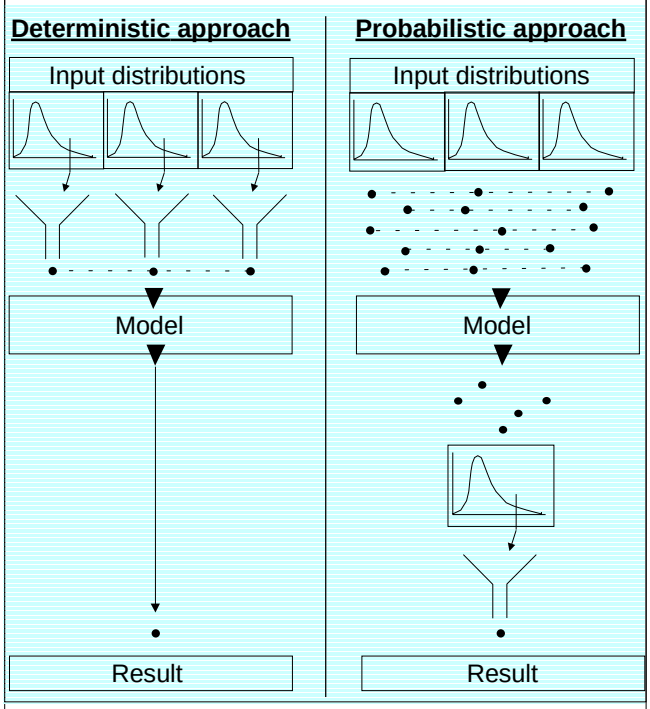


Fig. 1
Ecologic health promotion

Fig. 1: Comparison of deterministic and probabilistic approach in exposure modelling



III. Results and conclusions

A large variety of different exposure factors is covered by the compendiums under study. But for only 5 factors, information is given in all documents: drinking water intake rate, soil intake rate, body weight, skin surface area, and inhalation rate (Tab. 1). Food intake rates are covered in all documents too, but differ in aggregation level. The AIHC-document provides information on food consumption only at a high aggregation level, e.g. total food intake, whereas the AUH-document and the US-EPA-document provide information also on individual food products. The CalEPA document focuses on the intake of local produced food items and not on typical food consumption habits. Except for residence time, information on time use patterns is lacking in the CalEPA-document. Since a primary focus of the CalEPA-document is on the inhalation pathway, the time use and activity patterns are taken into account for the inhalation rate data.

In quantifying the variability of the exposure factors, all documents provide central values and 'high-end' estimates (upper percentiles) for use in deterministic exposure modelling (Tab. 2). Only for a small number of exposure factors, multiple percentiles and fitted probability functions are available. The leading US EPA exposure factors handbook contains only one fitted distribution (drinking water intake). CalEPA has derived distributions for 11 exposure factors, but not all of them are recommended for use in probabilistic modelling because the available data are problematic. In the AIHC-document, there is no discussion on the reliability of distributional information.

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EcoInforma 2001
Argonne Nat Lab
14-18 May 2001

Tab. 1 Coverage of exposure factors in compendiums

	AIHC 1994	AUH 1995	CalEPA 2000	US EPA 1997
Food intake				
Total dietary intake rate	+	+	-	-
Fruits and vegetables				
total intake rate	-	+	-	+
individual product intake rate	-	+	-	+
Meat and dairy products				
total intake rate	+[1]	+	-	+
individual product intake rate	-	+	-	+
Grains intake rate	-	-	-	+
Breast milk intake rate	-	-	+[2 3]	+
Fish intake rate	+[4]	-	+	+[5 6]
Home-produced food intake rates				
Fruits and vegetables	+	-	+[3 7]	+
Meat	+	-	+[3]	+
Dairy	-	-	+[3]	+
Eggs	-	-	+[3]	+
Drinking water intake rate	+	+	+[3]	+
Soil intake rate	+	+	+[3]	+
Soil adherence (dermal)	-	+	+	+
Physiological parameters				
Body weight	+	+	+	+
Body height	+	+	-	-
Skin surface area	+	+	+	+
Inhalation rate	+	+	+[3]	+
Life expectancy	-	-	+	+
Time use patterns				
Time indoors	+	+	-	+
Time outdoors	+	+	-	+
Time at home (weekly)	+	-	-	-
Time from home (weekly)	+	-	-	-
Time spent in vehicle	+	+	-	+
Showering/bathing time	+	-	-	+
Occupational tenure	+	-	-	+
Time at work (weekly)	+	-	-	-
Residence time	+	-	+	+
Building characteristics				
Residence volume	-	-	-	+
Residential air exchange	-	-	-	+

1 only meat
2 incl. duration, lipid concentration
3 adjusted for body weight
4 incl. shellfish
5 differentiated for general population, recreational marine/freshwater, and native americans
6 incl. serving size for fish
7 home-produced fruits and vegetables categorized by 'exposed', 'leafy', 'protected', 'root'

Tab. 2 Characterization of variability: average (av*), upper percentile (up), multiple percentiles (mp), (fitted) distribution (pdf)

	AIHC 1994	AUH 1995	CalEPA 2000	US EPA 1997
Food intake				
Total dietary intake rate	av, up	av, up	-	-
Fruits and vegetables				
total intake rate	-	av, up	-	av, up, mp
individual product intake rate	-	av, up	-	av
Meat and dairy products				
total intake rate	pdf	av, up	-	av, up, mp
individual product intake rate	-	av, up	-	av
Grains intake rate	-	-	-	av, up, mp
Breast milk intake rate	-	-	av, up, pdf	av, up
Fish intake rate	av, mp[1]	-	av, up, pdf	av, up[2]
Home-produced food intake rates				
Fruits and vegetables	pdf	-	av, up, pdf	av, up, mp
Meat	av, up	-	pdf	av, up, mp
Dairy	-	-	pdf	av, up, mp
Eggs	-	-	pdf	av, up, mp
Drinking water intake rate	mp, pdf	av, up	av, up, mp, pdf	av, up, mp, pdf
Soil intake rate	mp, pdf	av, up	av, up, pdf[3]	av
Soil adherence (dermal)	-	av, up	av, up, pdf[3]	av
Physiological parameters				
Body weight	av, mp[1], pdf	av, up, mp	av, up, pdf[3]	av, up, mp
Body height	av, pdf	av, up, mp	-	-
Skin surface area	av, mp[1], pdf	av, up	av, up	av, up, mp
Inhalation rate	av, pdf	av, up	av, up, pdf	av, up
Life expectancy	-	-	av	av
Time use patterns				
Time indoors	av	av	-	av
Time outdoors	av	av	-	av
Time at home (weekly)	av	-	-	-
Time from home (weekly)	av	-	-	-
Time spent in vehicle	av	av	-	av
Showering/bathing time	mp[1]	-	-	av, up, mp
Occupational tenure	av	-	-	av
Time at work (weekly)	mp[1]	-	-	-
Residence time	av, mp[1]	-	av, up, mp	av, up, mp
Building characteristics				
Residence volume	-	-	-	av
Residential air exchange	-	-	-	av

* expressed as mean, median or mode
1 multiple percentiles given and additionally expressed as a cumulative distribution
2 multiple percentiles for serving size fish
3 use of a distribution is not recommended

IV. Recommendations, outlook

Probabilistic techniques in exposure assessment hold the potential to provide more realistic exposure estimates for the population concerned since they make full use of the available information regarding variability and uncertainty of model variables. Making annotated probability density functions available is a promising contribution to promote good practice in exposure assessment. Together with appropriate guidance, it is expected to increase transparency and understanding of probabilistic exposure assessments and to promote use of these techniques in exposure assessment.

The proposed update of the German Exposure Assessment Standards document offers the opportunity to integrate probability density functions for selected exposure factors into this document. The data sets used in the AUH report are planned to be re-evaluated and re-analysed with respect to the requirements of probability distributions. Additional German data sets are available that until recently have not been used for purposes of determining exposure factors. An example is the "Environmental Health Survey" which provides data on activity patterns and time budgets of the German population. Special attention will be given to the goodness of fit as well as to the specification of probability density functions in terms of accuracy, computational requirements and remaining level of uncertainty.

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