

An evaluation of software for probabilistic risk assessment

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Introduction

Probabilistic risk assessment (PRA) has been used extensively in the US to estimate exposure risks from contaminated land. Until recently the acceptance for PRA in Europe has been rather limited, but we now see a surge in interest. The Swedish EPA has funded a study to investigate the requirements for a wider application of PRA to adopt site specific remediation goals and a literature review was recently completed [1]. The next phase in this project is to evaluate software, develop a guidance document and organize dissemination of information through seminars and courses in environmental risk analysis. The software evaluation has now been completed and the results are reported here.

Methods

Three commercial software were chosen for this evaluation:

- **Crystal Ball®** (Decisioneering), v2000.5
- **Analytica®** (Lumina Decision Systems), v3.1
- **Risc Calc™** (Applied Biomathematics), v4.0

Many other specialized commercial and research software are available, and general mathematical software such as Matlab® and Mathematica® may also be used for PRA. However, the selected software represents three substantially different approaches, which make this comparison of interest for the subsequent development of a guideline document.

The software were evaluated by application to a previously reported case study of a closed steel mill in southern Sweden [2], Figure 1.

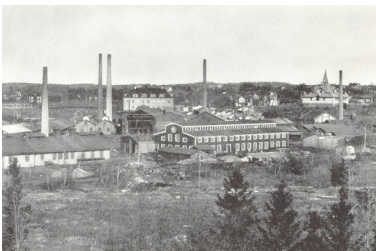


Figure 1: The metal works in Kallinge, Sweden, 1854-1991. Picture taken in 1923.

In this study, the Swedish multimedia exposure model for contaminated land was used, Figure 2. Human exposure for six elements and benzo(a)pyrene was estimated, but without two minor exposure routes (inhalation and surface water).

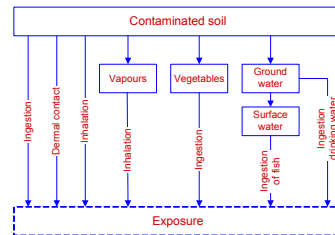


Figure 2: Transport and exposure pathways considered in the Swedish multimedia model

The criteria for our evaluation of the software were; *functionality and usability*.

All three software run on a standard PC with the Microsoft® Windows® operating system. Our evaluation was run on a PC with an Intel®M 1.86 GHz CPU and 504 MB RAM. The operating system was Windows® XP Pro version 2002 SP2.

Results

We start our comparison with a very brief description of the three software, with regard to functionality and usability, and then we proceed to an actual comparison of calculation and results from the case study.

Crystal Ball® is a Microsoft Excel® add-on, extending Excel's functionality with capability for Monte Carlo- and Latin Hyper Cube simulations (LHS). Variability and uncertainty can be separated with two-dimensional simulations. Calculations and model definitions are easy to implement and follow in a small model, but larger models often suffer from a limited transparency in the spreadsheet format. A thoughtful design by the user may however circumvent many of these problems. The software is easy to learn, especially since most users are familiar with Microsoft Excel®. List price for the standard edition is USD 835.

Analytica® is a stand-alone software with capability for Monte Carlo simulations and LHS. Two dimensional simulations are possible, but require substantial user intervention to implement. Large models are easy to build and communicate, due to the graphical style with influence diagrams, Figure 3. This software is also relatively easy to learn, and the manual is straightforward with many application examples. List price for the standard edition is USD 1,235.

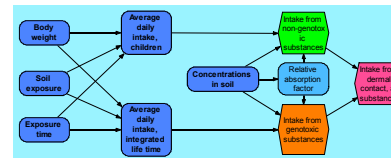


Figure 3: The dermal exposure pathway as an influence diagram in Analytica®.

Risc Calc® is a stand-alone software for probability bounds analysis (PBA). Computations can be executed in a command window and viewed in graph windows, but the models are conveniently implemented as scripts where all computations are run in sequence. Risc Calc® can thus be seen as a fourth generation language (4GL) for probability analyses. The software is flexible and the code is transparent, but this software is somewhat more difficult to master than the previous two. List price for this software is USD 160.

Case study comparison

The multimedia exposure model had 60 variables and constants, and most of these were characterized with probability distributions. A comparison of calculation results, on the intake of cadmium, is reported as cumulative probability distributions (CDF) in Figure 4. Crystal Ball® and Analytica® give the same result, while Risk Calc® show a high and low estimate due only to rounding errors for the constants. The uncertainty due to rounding errors can be extended further by assigning probability boxes instead of specific distributions. The consequence of acknowledging this uncertainty is also shown in the figure, and it spans an interval between 2-3 orders of magnitude.

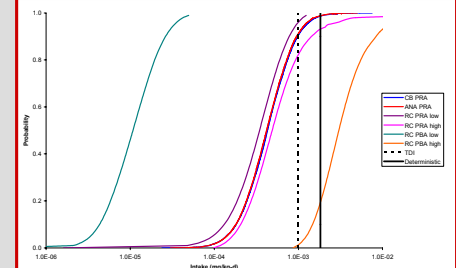


Figure 4: CDFs for the intake of cadmium from PRA calculations with Crystal Ball®, Analytica® and Risk Calc®, together with PBA estimates.

In this comparison all input variables were assumed to be independent. The bounds between the high and low estimates will increase further if this assumption is left out.

Conclusions

A general conclusion is that all three software are suitable for conducting a PRA in the environmental arena. They were selected with the purpose to compare different approaches and it is thus difficult to choose one as better than the other. Crystal Ball® and Analytica® have similar functionality. Crystal Ball® is easier to use, but Analytica® has greater transparency in the presentation of the model structure. Risc Calc®, finally, offer the most comprehensive and flexible set of methods.

It is important that future guidelines to the implementation of PRA give an adequate consideration to the methodological differences, without imposing unnecessary constraints to choose the most suitable PRA approach for each specific situation.

References

1. Öberg, T.; Bergbäck, B. (2005) *J Soils & Sediments* 5, 213-224.
2. Sander, P.; Öberg, T. *J Soils & Sediments*, in press.

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