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GEO-REFERENCED PROBABILISTIC ECOLOGICAL RISK ASSESSMENT

GEOGRAFISCH GEREFEREERDE PROBABILISTISCHE ECOLOGISCHE RISICOANALYSE

door

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Summary

Environmental pollution of toxic substances has led governments to develop new laws and regulation that puts constraints on these chemical emissions. These are based on environmental quality standards and environmental/ecological risk assessment. The key question to be answered is: “What is the likelihood (i.e. probability) of adverse effects occurring to exposed ecological systems due to exceedance of a toxicity level by an environmental concentration?”. The goal of ecological risk assessment is to estimate this likelihood. It is based on the comparison of a predicted or measured exposure/environmental concentration with a ‘no effect concentration’ based on a set of (acute or chronic) toxicity test results (i.e. testing species sensitivity).

This PhD dissertation studied and developed a range of statistical techniques needed to answer the key question with a risk probability and an uncertainty or confidence interval rather than with the current black white “yes, there is potential risk / no risk” answer which the conventional risk assessments provide. Such answers may mislead stakeholders to think that ecological risks are simple black and white issues.

After all, in a Probabilistic Ecological Risk Assessment (PERA), the exposure concentration and species sensitivity are treated as random variables taken from probability distributions (respectively Exposure Concentration Distribution (ECD) and Species Sensitivity Distribution (SSD)) which are combined to give a risk probability. In this way, the inherent variability and uncertainty of the environmental concentration and the species sensitivity is accounted for. Variability represents inherent heterogeneity or diversity in a well-characterised population. Uncertainty represents partial ignorance or lack of perfect information about poorly characterised phenomena or models (e.g. sampling or measurement error). PERA therefore delivers a more transparent, realistic and non-conservative approach to estimate risks. It is recognised in literature that probabilistic methods would improve the environmental evaluation of chemicals, if appropriate action is taken to address their potential weaknesses.

Some of these current (mainly statistical) weaknesses in probabilistic ecological risk assessment are addressed in this PhD dissertation. Most of them deal with misuse of existing techniques (e.g. Monte Carlo analysis, bootstrap), reliability of statistical techniques at small sample size, the lack of consensus on which method or model or what sample size to use, misinterpretation of probability distributions (e.g. output of Monte Carlo analysis), inappropriately or insufficiently dealing with uncertainty or variability (e.g. one- versus two-dimensional Monte Carlo analysis), discussions on how to calculate probabilistic risk…

It was shown that interpretation of all probability distributions in a PERA framework should be made carefully. In Monte Carlo simulations, separation of uncertainty and variability and the correct application of Monte Carlo analysis simplify the interpretation of a model's output distribution of interest. A case study showed that the exposure concentration of total ammonia nitrogen in a Flemish river will be larger than 10 mg/l for 40% of the time. This is a quite different result than being 40% certain that the exposure concentration will be larger than 10 mg/l.

A probabilistic risk should be interpreted as the probability that a random selected exposure or environmental concentration will exceed a species sensitivity. Examples were developed that show that the same risk probability can represent different environmental conditions (e.g. depending on whether the ECD represents spatial or temporal variability). Therefore, it is suggested to always include as much information as possible in the answer to the key question described above: indicate what type of variability the ECD or the SSD represents (geo- or time-referenced), what endpoint was used …

Throughout this dissertation, parametric and nonparametric methods were often compared. The results appear to be very sensitive to the chosen method. The proper use of distribution selection methods was stressed as well. Statistical tests, graphical exploration and expert knowledge can help in identifying the appropriate distribution. To calculate a lower percentile (e.g. the 5^{th} percentile), it was found that preference should be given to parametric methods when the sample size is below 10 while preference should be given to nonparametric methods when the sample size is large (e.g. 50). For the intermediate sample sizes, either parametric or nonparametric techniques can be used or maybe a combination of the two could be used.

Several examples and case studies have proven that the probabilistic risk characterisation considers the quantitative information of the full range of the ECD and SSD (including lower SS than its 5^{th} percentile and higher ECs than the 90^{th} percentile) instead of only considering the upper tail of the ECD and the lower tail of the SSD as in traditional risk assessment. Consequently, several issues on calculating tail percentiles can be omitted because they are no longer needed in the risk characterisation.

Finally, attention was focused on the fact that the probability distributions in probabilistic risk assessment can be wide due to large spatial (and temporal) variability. Instead of lumping all the sources of variability into one probability distribution, spatial and/or temporal differences and dependencies between EC and SS can be explicitly accounted for in a respectively geo- and/or time-referenced analysis (or spatial-temporal analysis). In this way, the risk assessment becomes more realistic as more information is taken into account. This was confirmed by several case studies.