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Implementation of probability table for qualitative reconstruction of pollutants plume using biological assay data

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Indirect assessment of pollutant plumes recently gains considerable interest due to its cheap, quick and non-invasive properties. One of these indirect methods, among others, is based on biological assays (bioassays). While considerable efforts have been devoted to the biological effects of pollutants on organisms, the use of bioassays to investigate the level of pollutants is much less common. It could however potentially lead to significant benefits, particularly for detecting on site contaminations at preliminary stages, either on qualitative or semi-quantitative bases. Working along these lines, preliminary studies including sampling design, measurements campaigns and laboratory testing relating effects on organisms to pollutants contamination levels have been done using standard protocols.

The present study will focus on bioassays using fish embryos from the Danio rerio (DarT) species, along with the luminescent bacteria Vibrio fischeri. Based on a statistical methodology, the aim is to estimate the pollutant concentration levels from these bioassays realized with groundwater samples under static conditions from a BTEX polluted site in Zeitz, Germany, where benzene is the main source of contamination. Our approach consists in building first a joint probability table between pollutants concentration and fish embryos mortality rates, expressed as percentage. Mortality rates were equally split in three classes, namely low (0-33.3 %), medium (33.3-66.6 %) and high (66.6-100 %) mortality rates, while concentration levels were similarly split into three classes as well. Crossing these two set of classes yields a bivariate table of probabilities that can be rebuilt at best from the available information using a maximum entropy principle. Conditional probability tables of pollutant concentration levels given the observed mortality rates can then be obtained afterwards and continuous conditional probability distribution functions (pdf's) can be estimated from them using a constrained radial basis function smoothing procedure, where the conditional probabilities of the concentration classes are incorporated as constraints.

Using the aforementioned methodology, it is thus possible to obtain a conditional pdf of the concentration level given the observed mortality rate at each spatial location where groundwater samples were taken and used in the bioassay procedure. Thanks to a Bayesian data fusion procedure, these conditional pdf's can then be integrated in a spatial mapping framework, possibly along with the few direct measurements of concentrations that were obtained using standard methods, thus yielding a final map of the estimated pollutant concentration levels. Similarly, the same procedure was used to obtain conditional pdf's of pollutant concentration given the effects on luminescent bacteria and to draw afterwards the corresponding map of estimated pollutant concentrations. A comparison of these two maps reveals that both exhibit identical global patterns, with some discrepancies for few parts of the study area. Using a naïve Bayes data fusion procedure, a single pollutant map can be obtained at the end.

In order to validate our approach, this fused map was compared to the "true" pollutant map, as drawn from direct groundwater samples only. Our map is visually in close agreement with respect to plume extension in the northeast-southwest direction, while leading at the same time to overestimations of the pollutant concentrations. It can be concluded that bioassays can be considered as a valuable source of information for the qualitative characterization of a contaminant plume. Nevertheless, the interpretation of the results on a quantitative basis needs additional information, especially in the case of mixture toxicity.

As a conclusion, our study shows that bioassays is a valuable indirect assessment method for qualitatively assessing the extension of a contaminant plume and to draw some conclusions about the quantitative concentration levels, thanks to an elaborate statistical methodology which allowed us to relate both kind of measurements. Other

indirect measurement methods could possibly be combined as well using this methodology. An attempt to apply it to tree cores sampling and geophysical measurements in order to improve the spatial delineation of a contaminant plume is currently under study.