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QUANTIFYING UNCERTAINTIES IN AIR POLLUTANT EXPOSURE MODELLING FROM ACCIDENTAL POINT RELEASES

John G. Bartzis[1], Ioannis A. Sakellaris[1], Thalia Xenofontos[1] and Spyros Andronopoulos[2]

[1]Department of Mechanical Engineering, University of Western Macedonia (UOWM), Kozani, Greece
[2]Environmental Research Laboratory, INRASTES, National Center for Scientific Research (NCSR) Demokritos, Aghia Paraskevi, Athens, Greece

Abstract: The prerequisite for producing reliable input to emergency response, is to provide to the decision maker the relevant exposure related parameters(e.g. concentration, dose, contamination area, etc) not only in terms of their mean values but also in terms of the associated uncertainties to those values. When estimating such parameters several significant uncertainties beyond those related directly to the model itself, could be present such as: model input wind speed and direction time/space inherent variability, the source characteristics lack of knowledge(strength, position ,thermodynamics), imprecise description of the site/region characteristics etc. In the present work a relatively simple novel methodology is introduced and tested which considers the real probabilistic distributions (pdf) of the time varying wind and source, in combination with the mean values of the source to sensor concentration transfer functions to produce relevant exposure parameter statistics. The method is tested for the first time against the Mol radiological experiment (Drews et al, 2002) using a simple Laboratory Gaussian model able to estimate radiation doses. The first tests gave relatively good predictions not only on mean values but also on their variances, suggesting for further exploration of the present method. On the other hand the sensors fluence rate signals have been successfully exploited for source term identification indicating the present approach strength on solving such problems.

Key words: *Exposure uncertainties, Emergency response. Source term estimation***.**

INTRODUCTION

The prerequisite for providing reliable input to emergency response is to provide to the decision maker the relevant exposure related parameters not only in terms of the mean or likely values but also in terms of the associated uncertainties to those values. In addition, a sufficiently accurate uncertainty quantification can lead to (a) uncertainty reduction both in measurements and modelling, (b) concentration signal exploitations for source term identification (c) proper instrument selection and monitoring setup, (c) proper model selection and evaluation and (d) optimal experimental design for modelling purposes. The uncertainty quantification problem has been addressed in several studies that includes both flow and concentration parameterization. According to ASME V&V Standards (2009) the uncertainties in modelling, can be distinguished in three components, namely the input, numeric and model uncertainties. Concerning input related uncertainties not all relevant parameters have the same weight. In atmospheric, major concentration uncertainties come from the source(s) and the wind direction (Wellings et al. ,2018). The straightforward approach in quantifying uncertainties is to describe uncertain input parameters by a predefined probability density distribution (pdf) and perform an adequate number of simulations selecting appropriate input values from those pdf. Most of those methods (e.g., Monte Carlo) require a relatively high number of simulations often leading to prohibitive CPU costs (NEA, 2016).

METHODOLOGY

The present problem is twofold. **Problem 1**: Assume the source release rate as known and predict exposure related parameters and associated uncertainties at selected positions downstream **Problem 2**: Assume the source term unknown and predict the source release rate and its uncertainty from exposure related parameter signals at specific positions downstream.

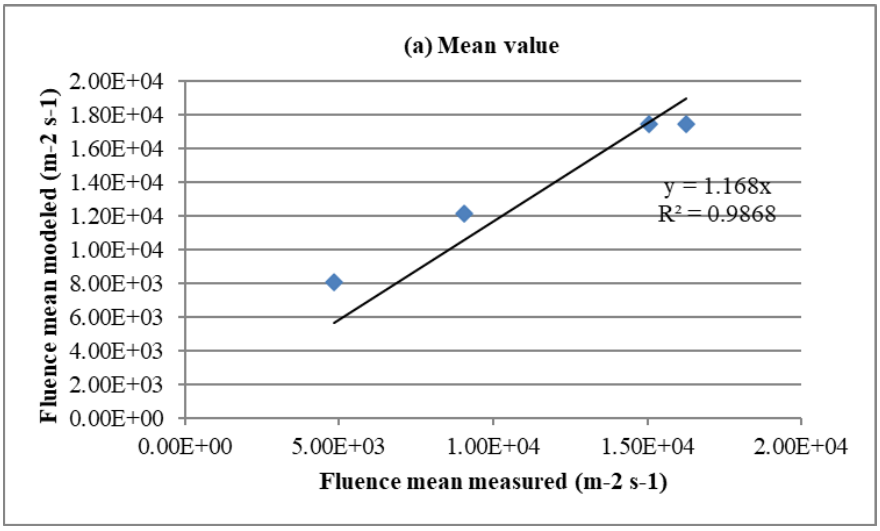
The ambition is, the whole methodology to be relatively simple with substantially low computational time even for complex problems with the aim to be manageable by the user even at operational level. It is based on (a) making direct use of wind speed and direction time series or their pdf. (b) restrict modeling to steady state reference wind speed and source term conditions (c) adopt to real conditions via proper scaling reflecting current expertise and (d) treat relevant parameters involvement via pdf creating a novel tool for this purpose.

APPLICATION AND RESULTS

The real-scale experiment consisting of routine releases of Ar-41 from the BR1 research reactor at the Belgium Nuclear Research Centre (SCK CEN, Mol – Drews et al., 2002, Rojas-Palma et al., 2004) has been used as a first application. Gamma radiation due to Ar-41 decay was measured near ground at downwind distances up to 1500m from the release point by sensors placed in arrays perpendicular to the main advection direction. The experiment was carried out during three consecutive days, namely the 3rd, 4th and 5th of October 2001. Radiation measurements were given mainly as fluence rates (photons m^{-2} s^{-1}). Measurements of meteorological variables (wind speed, wind direction and temperature at different heights above ground, atmospheric stability class) were taken from the SCK CEN weather mast. The study time interval 4 Oct, 10:18 – 16:00 has been selected reflecting a relatively good degree of wind flow stationarity. The Ar-41 release occurred from the reactor stack at 60m height at a constant rate of 4,27e+07 Bq s^{-1}. The wind speed and direction time series with 1-min time resolution given at 69 m have been taken as inflow modelling input. The exposure-related parameter is the fluence rate given in the form of 1 min resolution time series at four sensors downstream. A simple Gaussian model is used to model pollutant dispersion. In the model, the fluence rate is estimated following Andronopoulos and Bartzis (2010) and Gorshkov et al. (1995).

Concerning Problem 1 the predicted fluence rates in the four (4) sensors not only in terms of mean value but also in terms of standard deviation are shown in Figure 1. The comparisons with the experiment are excellent.

Concerning Problem 2, the sensors fluence rate signals real pdf have been derived and combined with the wind speed and wind direction associated pdf via the Gaussian model to produce the inverse source release pdf prediction shown in Figure 2. The derived pdf gives as the most probable value for the inverse release rate 2,27 e-08 s Bq^{-1}. This value is very close to the real value 2,34e-08 s Bq^{-1}. Figure 3 illustrates how the involvement of more sensors reduces the source term prediction uncertainty although the most probable value indicates the true value rather quickly.



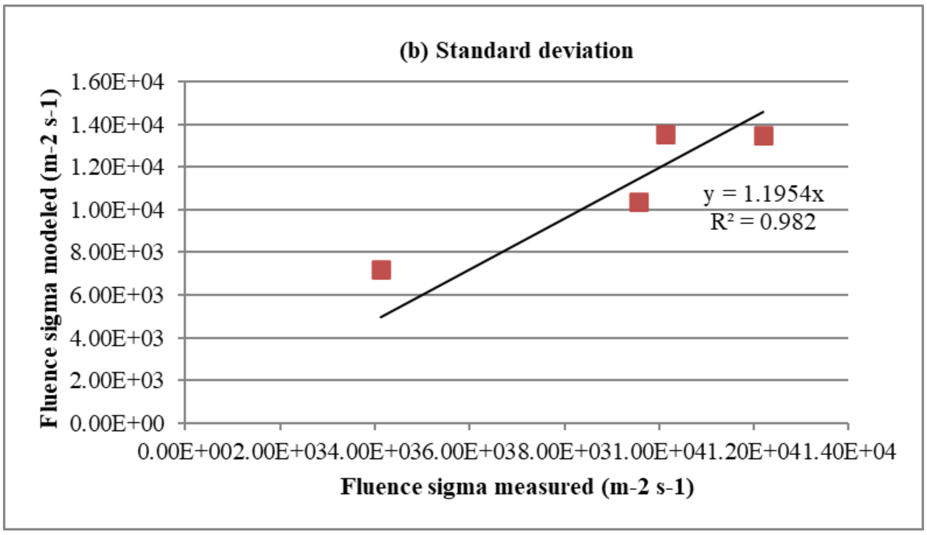


Figure 1. The Problem 1: The SCK CEN Mol Experiment fluence-rate Comparisons (a) the mean value (b) the standard deviation

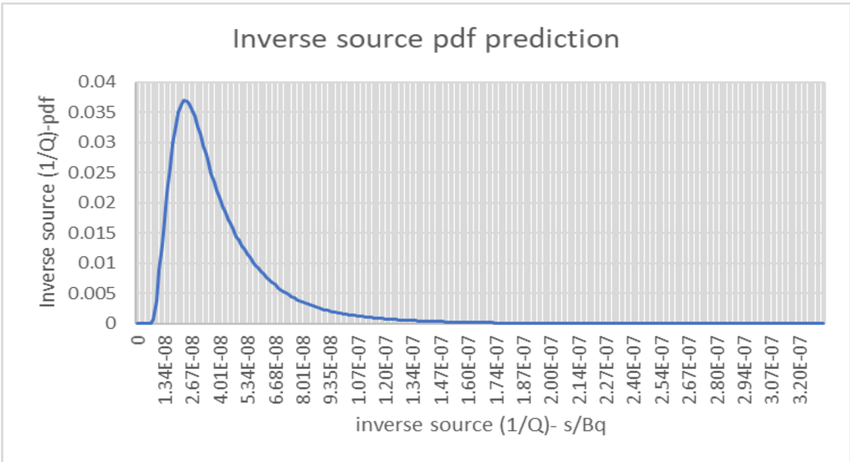


Figure 2. The Problem 2: The SCK CEN Mol Experiment Source Term prediction

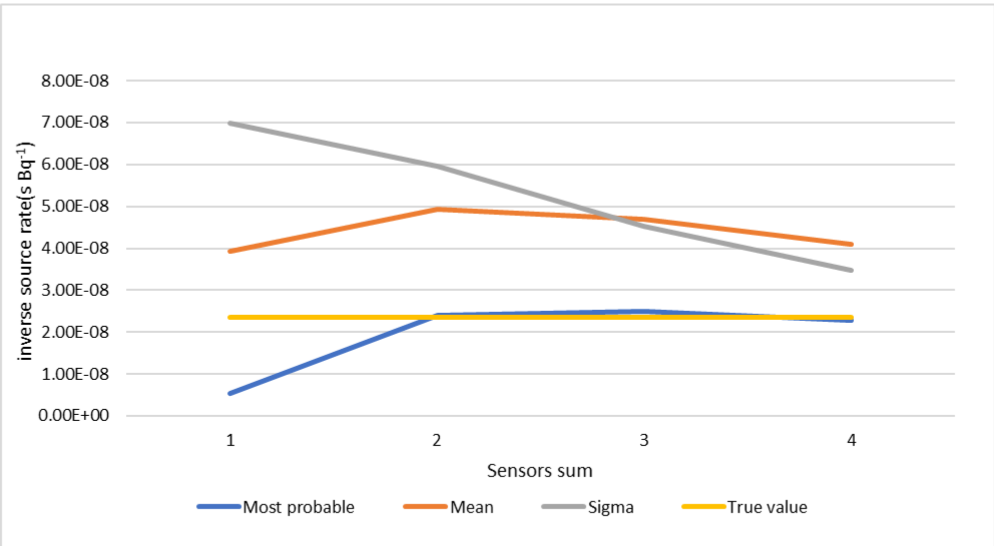


Figure 3. Inverse source term prediction vs number of sensors involved

CONCLUSIONS

Searching for more practical approaches, the exposure quantification in terms of expected value and its uncertainties has been put in a new basis. Applying this new concept in the SCK CEN Mol experiment – an experiment under real environmental conditions- the comparison results proved to be quite satisfactory. The new concept indicates its advantage as the method to predict the source term. The whole approach is under development and the present application is pressing to go forward.

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