UNCERTAINTIES OF ENVIRONMENTAL IMPACT ASSESSMENT DUE TO INPUT MODELLING DATA VARIABILITY

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INTRODUCTION

This paper demonstrates the importance of accounting for the uncertainties associated with input data when using air dispersion models in environmental impact assessment (EIA) studies. EIA studies are developed at the project stage, prior to the construction and operation of the particular facility under assessment. As such, dispersion models are applied with expected and typical or average-like input data. This fact is particularly important as far as emission data is concerned but is also significant for the meteorological input. In fact, in many circunstances, only data measured in a distant meteorological station is available at the moment of the development of the study.

On the contrary, in this paper a very detailed database was used. This database consists of three years of hourly measured emission data, and coincident six air quality and meteorological observations associated to a power plant located in Central Portugal. Ground level concentrations of several pollutants were estimated with the ISCST3 model developed by the US Environmental Protection Agency. Application of the model followed a methodology developed for environmental impact assessment and results were analysed considering the philosophy of the EU framework directive (96/62/EC) recently transposed to the Portuguese law. A large number of simulations, with different but equally valid input data set, were performed in order to compare the results with a typical EIA simulation.

METHODOLOGY

The Model

The Gaussian model Industrial Source Complex – Short Term (ISCST3) (U. S. EPA (1995)), was used to simulate the basic gaussian dispersion from a point source and to calculate the steady-state ground-level concentration at a particular time. Input data to ISCST3 model includes: source and receptor data, meteorological parameters, and terrain data. The meteorological data includes: wind velocity and direction, ambient temperature, mixing height and stability class. The meteorological parameters were obtained from meteorological stations near the Power Plant. In this particular study ISCST3 was applied aiming to simulate the dispersion of NO_2 (considered as non-reactive for this local study). The input parameters that were used are listed in Table 1.

Table 1. Source Parameters.

Parameter Name	Value
Stack height	225 m
Stack diameter	5,1 m
Stack gas temperature	409 K
Emission rate	340 g NO_2.s^{-1}
Stack gas velocity	18,3 m.s^{-1}

Modelling domain

The study was perfomed over a domain covering the six stations, with a grid of 26 x 27 km^2, with a horizontal grid spacing of 1 x 1 km^2. Figure 1 presents the simulation domain with the terrain data, the six air quality stations (MA, MG, MM, MF, MO and MP), the six meteorological stations (MC, MG, MM, MF, MO and MP) and the location of the power plant. Ground level concentrations were estimated for 702 receptors, according to the chosen grid simulation domain.

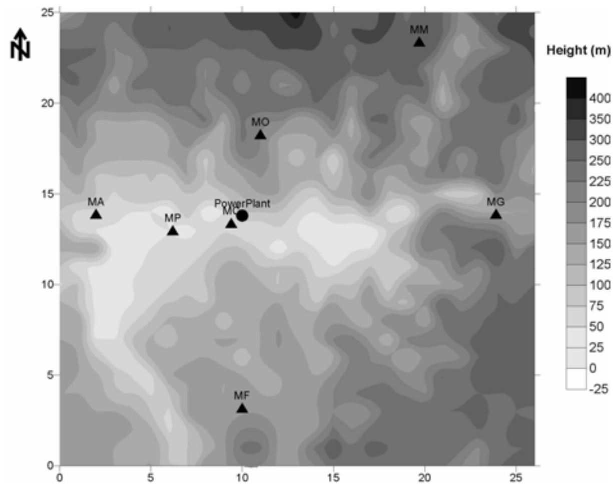

Figure 1. Modelling Domain.

Sensitivity Test

The following items are some of the tests that have been conducted to investigate the sensitivity of ISCS3 to changes in emissions and meteorological data:

Set 1 – Using an annual average of NO_2 emissions from the power plant and the six meteorological stations (MC, MG, MM, MF, MO and MP) with 3 years of data (1999, 2000 and 2001), in a total of 18 scenarios;

Set 2 – Using the nearest station to the power plant (MC), and two type of emission: and annual average emission and hourly variable emissions measured by the continuous monitoring system from 1999 to 2001, in a total of 6 scenarios.

Z-score

Z-score is a special application of the transformation rules. The Z-score for an item indicates how far and in what direction, that item deviates from its distribution’s mean. The mathematics of Z- score tranformation is such that if every item in a distribution is converted to its Z-score, the transformed scores will necessary have a mean of zero and a standard deviation of one. The Z- score transformation is specially useful when seeking to compare the relative standings of items from distributions with different means and/or different standard deviations. The Z-score (see Eq. 1) is useful for quantifying how different a value is from normal.

$$Z = \frac{VR - VS}{U} \tag{1}$$

with
Z = Z-Score
VR = Reference value
VS = Simulated value
U = deviation unit admissible

$$U = \sqrt{\left(\left(\frac{Sh}{\sqrt{n}}\right)^2 + U^2 ISCST3\right)} \qquad (2)$$

with
Sh = standard deviation
n = number of simulated values
U_{ISCST3} = uncertainty of the ISCST3 model, considered to be equal to 2.

The Z-score limits are defined within an acceptable performance when $| Z | \leq 2$, a questionable performance when $2< |Z| \leq 3$ and an unacceptable performance when $| Z | > 3$.

MODEL RESULTS AND DISCUSSION

Tables 2 and 3 show some of the predicted ground level NO_2 concentrations for Set 1 and 2, respectively.

Table 2. Simulated values and comparison with Portuguese limit values for the Set 1 simulations.

	Maximum Simulated value																		Limit
	MC			MG			MM			MF			MO			MP			
	99	00	01	99	00	01	99	00	01	99	00	01	99	00	01	99	00	01	
P98 hourly values	38	43	38	40	42	44	45	51	44	45	49	39	36	41	37	43	47	108	200 µg.m^{-3} NO_2 (Portaria nº 286/93 de 12 de Março)
Number of exceedances	28	23	12	6	9	6	17	11	15	4	2	6	13	10	10	18	22	24	200 µg.m^{-3} NO_2 (value that can't be exceeded more than 18 times in a year) (Decreto-Lei nº 111/2002 de 16 de Abril)
Annual limit for Human protection	2	2	2	2	2	3	3	3	2	3	3	2	2	2	2	3	3	4	40 µg.m^{-3} NO_2

For the purpose of this comparative study, careful examination of Table 2 reveals that differences between all the scenarios are relatively small for the percentile 98 of the hourly concentrations (P98). Only in the MP01 scenario, the P98 concentration is relatively high in comparison with the other scenarios.It can also be seen that the number of exceedances provides larger differences between the scenarios. This parameter will replace P98 on January 2010 and belongs to recently transposed EU Air Quality Directive (96/62/EC).

Analysing the two parameters it can be seen that the input data variability has more influence in the number of exceedances than in the P98. This can be a problem when regulatory decisions are based on this parameter. In fact, in this case, environmental assessmente decision are clearly dependent of the input data used in the simulation.

Table 3. Simulated values and comparison with Portuguese limit values for the Set 2 simulations.

	Maximum Simulated value for MC						Limit
	Annual emission average			Hourly emission average			
	1999	2000	2001	1999	2000	2001	
Percentile 98 (P98) hourly values	38	43	38	71	45	35	200 µg.m^{-3} NO_2
umber of exceedances	28	23	12	43	23	8	200 µg.m^{-3} NO_2 (value that can't be exceeded more than 18 times in a year)
Annual limit for Human protection	2	2	2	5	2	2	40 µg.m^{-3} NO_2

In what the Set 2 simulations are concerned, it can be seen that P98 of 1999 for the hourly emission average is substantially different from the others runs. The use of the hourly variable emissions, measured by the continuous monitoring system, exercise a strong influence in the results. Once again it is in the number of exceedances that the differences are higher.

A probabilistic estimate accounting for the variance in the input helps to make better-informed decisions (Anand Yegnan (2002)). The use of the Z-score application for the P98 and the number of exceedances, are represented in Figures 2 and 3. Z-score was calculated for each simulation using as reference value the average concentration from all the model runs.

Figure 2 shows that in 21 tests that were perfomed, fourteen have an acceptable performance with a $| Z | \leq 2$, five a questionable performance ($2< |Z| \leq 3$) and only two have an unacceptable performance with $| Z | > 3$.

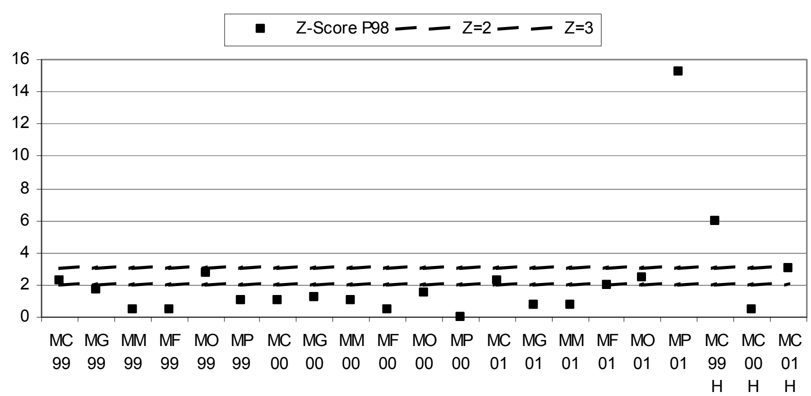

Figure 2. Z Score for 98th percentile of the hourly concentrations.

The Z-score for the number of exceedances can be observed in Figure 3 and shows that only nine tests have an acceptable performance. There are eight tests with a questionable perfomance and finally, with unacceptable perfomance there are 4 tests.

The Z scores of the output concentration plotted in Figures 2 and 3 shows that the number of exceedances is more sensitive than P98 to changes on the meteorological and emission input data.

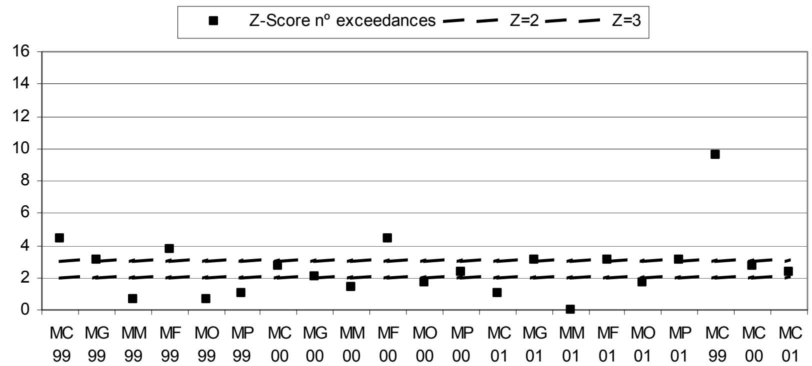

Figure 3. Z-Score for the number of exceedances.

CONCLUSIONS

Uncertainity associated to the variability of the input parameters is typically not considered on EIA decisions and might lead to inappropriate conclusions. Meteorological data used in EIA studies significantly influence the transport and chemistry in dispersion modelling and hence this input data should be more real and complete. Use of real emission data which incorporates real emission variability can also play an important role on the analysis of modelling results.

Results of this paper evidentiate a larger uncertainty when EIA decisions are based in the exceedance criterium than when the percentile 98th is used.

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