SHORT TERM & SHORT DISTANCE DISPERSION MODELLING TO DETERMINE AND REDUCE ENVIRONMENTAL RISKS

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1. INTRODUCTION

Determination and reduction of environmental risks can be a major concern for industrial companies. Atmospheric dispersion models can help to better understand these risks, both in a qualitative and quantitative way. Once known, these risks can be integrated in the daily industrial processing and adaptations can be made to avoid or reduce these risks. In order to help these industrial companies, we developed a model, PC-puff, for the real time simulation of short distance advection and dispersion of pollutants emitted from different sources. Both continuous emissions and accidental releases can be considered. The model combines trajectory simulations based on a puff approach with the dispersion formulations as used for regulatory purposes. The resulting trajectories and concentrations can be visualised dynamically (e.g. minute by minute) at different heights and simulations can be carried out either in real-time or using data acquired in the past. The model can work in a reverse mode, i.e. starting from a receptor point and simulating the possible origin of a measured constituent (e.g. air pollution or odour).

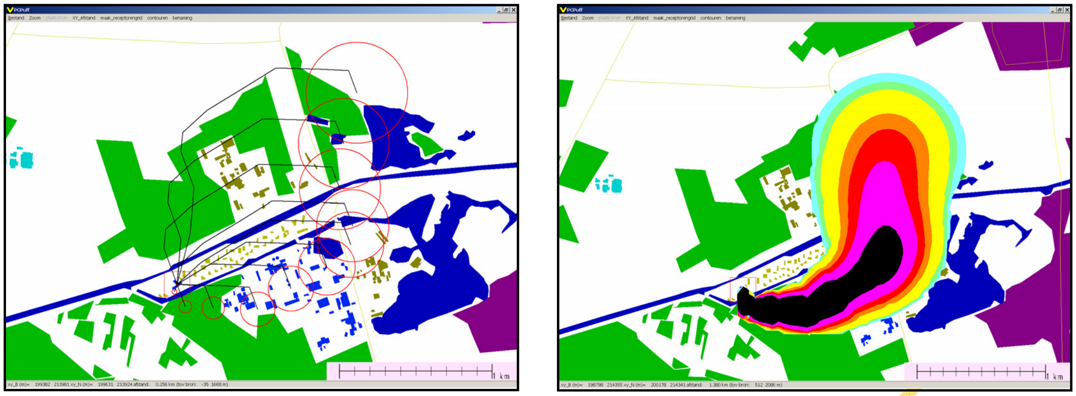
The model has been implemented for industrial companies to help them in assessing potential odour problems and as an early warning system for accidental releases. The software provides four different simulation approaches:

- identify a possible source of risk or pollution,
- evaluate the impact area of a release which occurred in the past,
- real-time impact simulations for actual releases,
- simulations for the near future (early warning).

We show the basic model concept and model characteristics in section 2. A very interesting feature is the question how to make the selection of stability classes as user friendly as possible in an operational mode, i.e. under real time emergency working conditions. This will be discussed in more detail. In section 3, the model application are illustrated by three different cases, in which the model has been implemented. A first application is the evaluation of the impact of accidental release after a fire occurring in the past. A second implementation had the objective to help a waste treatment company to reduce the impacts of odour. Finally an example is shown where PC-puff assists an industrial company in the determination of real-time potential accidental releases endangering valuable goods (i.e. a huge stock of new vehicles).

2. METHODOLOGY AND IMPLEMENTATION

PC-puff combines trajectory simulations based on a puff approach, e.g. described by Zanetti, P. (1990) with the dispersion formulations as used for regulatory purposes in Belgium (Cosemans G and Kretzschmar, J.G., 2000). It assumes a continuous or discontinuous emission source that is advected downwind in a non-steady mode by means of a puff. The puffs follow a trajectory (Figure 1a), that is obtained from direct (on-line) meteorological input.



a) b)

Figure 1: a) The simulation of the trajectories and distribution of puffs for a continuous release - b) Iso-concentration lines at ground level for simulations using dispersion coefficients as defined by Bultynck and Malet.

Wind speed, wind direction and atmospheric stability parameters are the required input parameters. A puff model allows a detailed assessment of the time and space variations in the advection process, particularly under low wind conditions.

When a series of puffs are dispersed downwind, their overlapping concentration distributions show up like a plume (Figure 1b). Due to the discrete and accurate evaluation of the wind vector, the shape of this plume may show a more meandering type of behaviour.

The dispersion characteristics are based on the stability classification scheme, known as the Bultynck-Malet classification (Bultynck, H. and Mallet, L. 1972). It is based on experimental observations using a 120 m. high meteorological tower located in Mol, Belgium. Atmospheric stability is defined as the ratio of the gradient of the potential temperature between 114 m. and 8 m. over the square of the wind speed at 69 m. This ratio is proportional to the Bulk Richardson number. The dispersion parameters $\sigma_y(x)$ and $\sigma_z(x)$ are functions of this Bulk Richardson number and determined from a statistical evaluation of 3D-wind fluctuation measurements at 69 m., according to Taylor's statistical theory.

For practical applications 7 stability classes (E1 .. E7) are defined ranging from very stable to very unstable. In cases or situations where the stability class can not be obtained from the 120 m. meteorological tower in Mol, it has to be approximated using information on the local weather situation. Table 1 shows the practical implementation of the Bultynck-Malet classification scheme in a user friendly operational mode used in PC-puff.

Through a user friendly interface, the user can select the atmospheric conditions, as well as the source characteristics (source height, source strength, ...). Wind speed and wind direction are obtained from a local or mobile meteorological tower or from other (off-line) sources like weather bulletins on the Internet. Data input can be arranged through an internet connection (FTP) via a PC-network, or via the parallel port directly from the data logger of the measuring tower (Adriaensen S. *et al.*, 2002). This input, in combination with a short model calculation time of the model, makes real-time simulations possible.

Table 1. Approximation of the Bultynck-Malet classification scheme in a practical PC-puff operation mode

Class (B&M)	Atmospheric condition	Typical weather conditions[1]
E1	Stable	Night: clear sky; low wind speeds
E2	Slightly stable	Night: covered; day: grey, calm weather
E3	Neutral	Windy; clouded or rain; begin/end of a sunny day
E4	Slightly unstable	Sunny weather; noon; no E5, E6 or E7
E5	Unstable	Daytime in October – April; sunny weather
E6	Very unstable	Daytime in May – September; very sunny; low wind
E7	$U_{69m} > 11.5$ m/s	Very high wind speeds

[1]Advected air masses can result in stable conditions during daytime or unstable conditions during night, when hot or cold air masses have travelled long distances over surfaces of different temperatures. This can only be detected by specific temperature measurements at two different heights.

3. APPLICATIONS

3.1 Evaluation of an accidental release after a fire occurring in the past.

On 10th December 2003 at 13h30 a fire started in an old cokes plant in Neder-over-Heembeek, in the north of Brussels. The fire lasted for 9 days and caused a black irritating smoke plume that travelled over Flanders and even stretched to Germany (Ruhr area, Aachen, Köln). From 14th December onwards, complaints of irritating smells were coming from different locations in Flanders, the south of the Netherlands and the west parts of Germany. Using PC-puff model, it could be confirmed that the fire in the cokes plant in Brussels was the origin of these complaints. Another major concern was the release of emissions of Poly-Aromatic Hydrocarbons (PAH). The PC-puff model was used to produce risk maps of PAH deposition, i.e. maps of areas where deposition of PAH had most likely occurred. Based on these maps, deposition samples were taken to complete the health risk assessment.

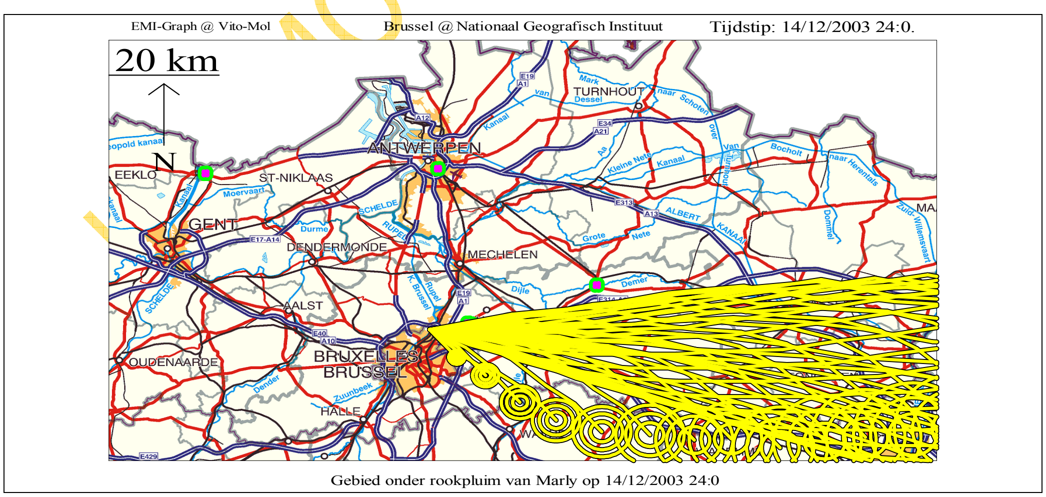


Figure 2: PC-puff trajectories and puffs originating from the burning cokes plant in Neder-over-Heembeek on 14th December 2003.

3.2 Reducing impacts of odour from waste treatments

Waste treatment, land fill and composting are processes that are associated with odour problems. One way of dealing with these odour problems is to optimize the process activities in function of the conditions that are more or less favourable for the dispersion of odour. PC-puff helps to map these conditions. When the conditions are unfavourable, e.g. when the odour plume will arrive at a residential zone at a critical moment, the plant manager can decide to postpone or alter some of the process conditions.

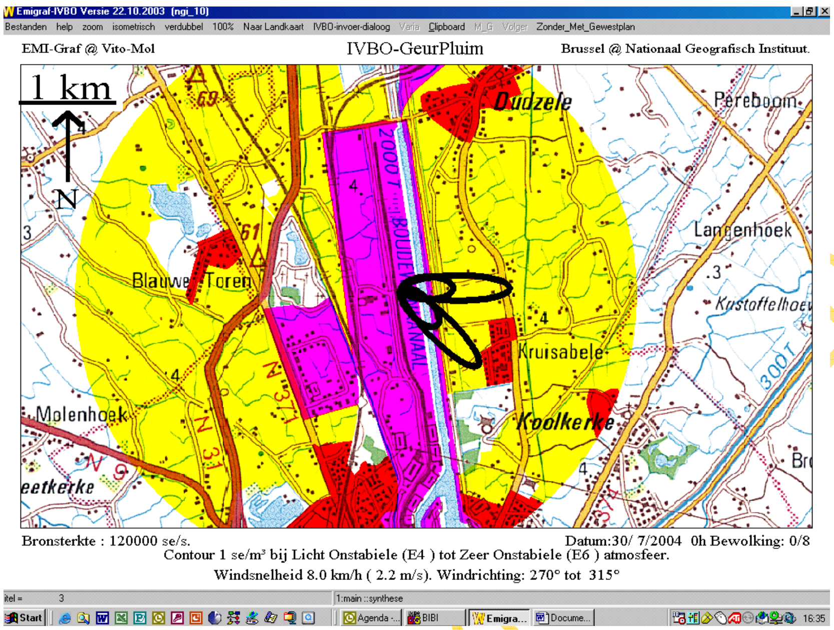


Figure 3: Potential odour risk calculated by PC-puff for the conditions provided by the user.

In order to provide a user friendly and fast screening tool for assessment of possible odour risks, PC-puff was configured in an easy to use off-line mode. In its operational mode, the meteorological input data are derived from a daily weather forecast bulletin found on the internet. Basically wind speed and wind direction for the region considered are required. The stability class is determined by the user by means of Table 1. Only one single data entry screen has to be completed. Three different source strengths (expressed in odour units per second) can be selected. As a result, Figure 3 gives the user an instantaneous picture of the potential risk zone for the conditions provided by the user. The black contour lines show the potential odour impact (≥ 1 odour unit per m^3) for atmospheric stability conditions ranging between E4 and E6 , a wind speed of 2.2 m/s and a wind direction varying between 270° and 315°. Colours are used to distinguish between different types of land use (industrial or waste treatment zone, indicated by the long dark area in the centre of Figure 3; residential zones indicated by the dark dotted areas in Figure 3). The light coloured circle shows the potential impact area (with a radius of +/- 3 km).

3.3 Determination of real-time potential accidental releases endangering valuable goods.
Another application of PC-puff is the assessment of the risks associated with real time potential accidental releases of paint spray from a nearby ship yard endangering valuable goods (25.000 new cars) on an industrial site of a transport company.

a) b)

Figure 4: a) Location of the site (storage of 25.000 new cars) for which risk assessment is made; b) Detail of the on-site light tower for measurement of wind speed and wind direction.

Figure 4a shows the location of the site. Meteorological equipment was installed in one of the 30 light towers installed on site (Figure 4b). Wind speed and wind direction were obtained at a height of 30 m. and these measurements were integrated in the general monitoring system operated by the transport company through their intranet. In this way PC-puff was made operational in an on-line real-time mode as an early warning system.

4. CONCLUSIONS

PC-puff has been developed as a model for calculating real time advection of puffs and displaying them in a clear and user-friendly way. The model has been implemented for industrial companies to help them to identify a possible source of risk or pollution, to evaluate the impact area of a release which occurred in the past, to assess real-time impacts of actual releases, or to simulate possible impacts in the near future (early warning).

A simple custom made user interface guarantees ease of use in a standard Windows PC-environment. Computer memory is managed efficiently and calculations are performed in a fast way, allowing almost real time assessments. Hardware requirements are inexpensive and can be dealt with in a very flexible way.

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