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DETERMINATION OF THE ROLE OF MODELING IN THE SELECTED ODOUR EMISSIONS SOURCES IMPACT ASSESSEMENT

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Abstract: Odour dispersion mathematical modeling is a very important tool in odour nuisance survey. It allows to estimate the odour plume extent and distribution of particular odours concentrations in the area of an industrial object causing odour nuisance. This paper presents results of field studies in the plume, geostatistical analysis using ordinary kriging method and odour dispersion calculations using CALPUFF model. The analysis prove that the use of mathematical model with a meteorological module provides fast and efficient air quality assessment around the odour emission source.

Key words: *odours, field inspections, dispersion modelling, GIS.*

INTRODUCTION

Odours are emitted from agriculture, municipal and industrial sources (National Research Council Committee on Odours, 1979),(Nicell J., 2009), (Aatamila et all., 2011) and can significantly reduce life comfort of people living on areas located in the neighbourhood of a chosen odour emission source. Prolonged exposure to odours not only reduces the quality of life but can also cause headaches, nausea and vomiting as well as anxiety or depression in extreme cases. Therefore, methodology applicability assessment of measurements at the source, odour emission impact and odour nuisance level on areas located in the neighbourhood of a chosen odour emission source, seems to be very important. Measurements at the source are based on measurement of odour concentration in the emitter. Concentration and gas flow rate allow to calculate odour emission value and to perform the odour dispersion model calculations. Another way to determine odour emission source impact are field studies, including odour intensity field measurements and surveys. Surveys allow to determine if an odour nuisance occurs on a given area and whether it is related to the activity of a given object (VDI 3883 Part 1, 1997). Field measurements can be carried out through research in the grid and in the plume. Research in the grid are based on measurements in constant, predetermined computational grid and they give occurrence frequency of an odour at the chosen point in the given area (VDI 3940 Part 1, 2006). Field measurements in the plume give a quantitative characteristic of odour occurrence in the selected area, taking into account meteorological situation (VDI 3940 Part 2, 2006).

This paper proves that using only one method to assess odour impact may not be sufficient (Ribeiro et all., 2010), (Sironi et all., 2010). Two objects being odour emitters were examined: swine farm (agricultural facility) and distillery (industrial plant). In the first case, field measurements in the plume were made, supplemented by geostatistical calculations. In the case of an industrial plant, both field measurements in the plume supplemented by geostatistical calculations and mathematical odour dispersion model were performed.

MATERIALS AND METHODS

Measurements were taken in the area of two objects in Poland: agricultural and industrial. An industrial plant (distillery) is located on the outskirts of a city with a population exceeding 500 thousand, in the industrial-service area. Nearest residential buildings are located approximately 1500 metres south from the plant. The distillery produces ethanol and gluten for industrial purposes. Processes causing the odour emission are: gluten drying, fodder drying and alcohol fermentation. The second object is a swine farm in a rural area. Nearest residential buildings are located approximately 2500 metres away from the farm. On the site of a farm, there are 9 pigsties, an outbuilding and two manure lagoons. Odours emitted from the object are typical for this type of activity and deriving from pigsties and lagoons.

Field measurements in the plume were conducted both in the area around and inside selected objects, in accordance to methodology included in German guidelines VDI 3940 part 1 (VDI 3940 Part 2, 2006). The objective of measurement was to determine the intensity of odours deriving from studied objects and the extent of their impact. Distillery field inspections were conducted on June 25 - 29, 4 measurement series were received. Swine farm field inspections were conducted on July 3 - 7, 2012, 5 measurement series were received. An area where field measurements in the plume were conducted was set at the very beginnig of the study, depending on current wind direction and topography. The measurement was attended by 9 properly qualified field inspectors, selected and tested according to EN 13725 and 2 operators. Before the measurement, field inspectors were acquainted to different types and intensity of odours emitted from the plant. An evaluator, standing at the designated point, senses the surrounding air and every 10 seconds for 10 minutes, writes down the intensity of sensed odour and its type on a specially prepared protocol. Each odour was marked with a letter symbol. Table 1 presents characters of sensed odours and their symbols, as well as odours characteristic for tested objects (in bold), respectively for the distillery (table 1A) and swine farm (table 1B). Operators' task was to indicate the area of research and measurement points, determine their locations (using GPS) and measure meteorological data at each point: air temperature, relative humidity and wind direction and speed. Field inspectors determined the intensity of odour on a scale of 0 to 6, where 0 meant no odour and 6 - extremely strong odour. For each type of odour, intensity scale is individual. After the research, on the basis of collected measurement protocols, a database of test results and information on measuring points have been built. As each measurement lasted for 10 minutes and results were recorded every 10 seconds, the maximum value of each odour intensity at each measuring point was determined.

Table 1. Odour characters and symbols: A) distillery, B) swine farm.

A)

Odour symbol	Odour character
A	no odour
B	agricultural odour
C	agricultural odour: manure
D	agricultural odour: pig breed
E	agricultural odour: cattle breed
F	agricultural odour: horse breed
G	agricultural odour: hay, grain
H	car exhaust odour
I	smell of burned coal
J	grass smell
K	other: specify
L	**smell of baked bread**
M	**gluten (pasta)**
N	**alcohol (yeast)**
O	sewage sludge

B)

Odour symbol	Odour character
A	no odour
B	agricultural odour
C	**agricultural odour: pig breed**
D	agricultural odour: cattle breed
E	agricultural odour: horse breed
F	agricultural odour: hay, grain
G	car exhaust odour
H	smell of burned coal
I	grass smell
J	other: specify
L	**manure lagoons**
P	**carrion, rotten meat**
R	utilization 1
S	utilization 2

In addition to field measurements conducted in the distillery area, odour dispersion calculations using CALPUFF model were performed. For this purpose, it was necessary to calculate odour emissions (E, ou^E/s), which were based on the knowledge of odour concentration (C, ou_E/m^3) and gas flow ($\dot{V}$, m^3/s). The odour concentration in test samples was determined using the method of dynamic olfactometry, according to EN-13725 (CEN, 2003).

CALPUFF is a non-steady-state Lagrangian Gaussian puff model (Scire et all., 2000). This model assumes, that the load of emitted pollutants is divided into partial loads (clouds), introduced into the air at certain time intervals. The loads move independently of one another, according to local meteorological conditions. The model takes into account terrain (topography and land use) as well as temporal and spatial variability of meteorological conditions in three dimensions. To determine the concentration of pollutants at the receptor point, concentrations of all generated clouds are summed. Therefore, it is an appropriate model for studies related to odour nuisance assessment. CALPUFF model consists of three preprocessors: CALMET - meteorological preprocessor, which sets meteorological parameters at each point of computational grid, CALPUFF - proper dispersion model, modeling propagation of pollutants, and CALPOST which allows to visualize calculations results. CALMET requires a number of inputs for each grid point on terrain parameters (eg terrain heights or terrain roughness factor (z_0)) and meteorological data from the nearest meteorological stations - ground and aerological. Meteorological data from ground stations are given once per hour, while data from aerological stations are given once every 12 hours. CALPUFF requires i.a. modeling start date and duration in hours as well as emittors and emission parameters. As written above, 3 characteristic odours are emitted from studied distillery area. Due to different chemical compositions of mixtures of these odours, they were treated as separate pollutants and propagation calculations were performed separately for each odour. (VDI 3788 Part 1, 2000). Calculations were performed according to parameters current on June 25 - 29, 2012.

RESULTS

Field measurements results were visualised using a Geographic Information System (GIS) in ArcGIS 10.0 ESRI. Identified odours (table 1) have been presented separately on the maps. It should be noted that all of odours listed above were sensed during each measurement. Examplary field measurement results are shown on figure 1A (distillery, 1st measurement series) and 1B (swine farm, 4th measurement series).

A) B)

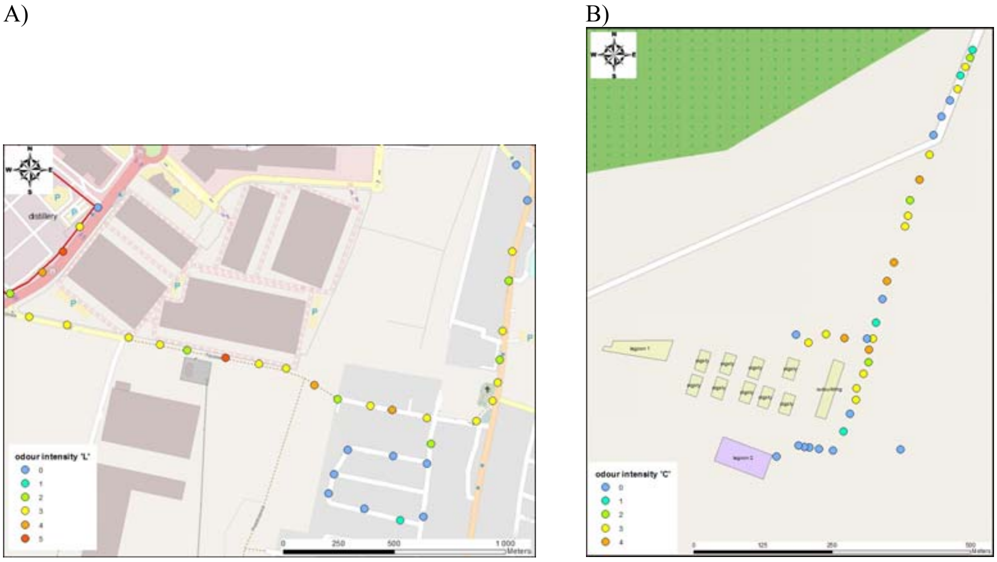

Figure 1. Maximum odour intensity value: A) baked bread smell ('L') from a distillery B) pig breed odour ('C') from a swine farm (Basemap source: OpenStreetMap in ArcGIS 10.0).

Figure 1 presents measurements results in the form of points where odour intensity values were measured. During such measurements, primarily due to procedures as well as time limits and the need to involve a team of inspectors, measurement can not be performed at any point. To measure odour intensity spatial distribution across tested area, a geostatistical interpolation can be performed. Kriging method is considered best in terms of accuracy but also most complicated. Odour intensity interpolation results, using Ordinary Kriging method are shown on figure 2A (distillery) and 2B (swine farm).

A) B)

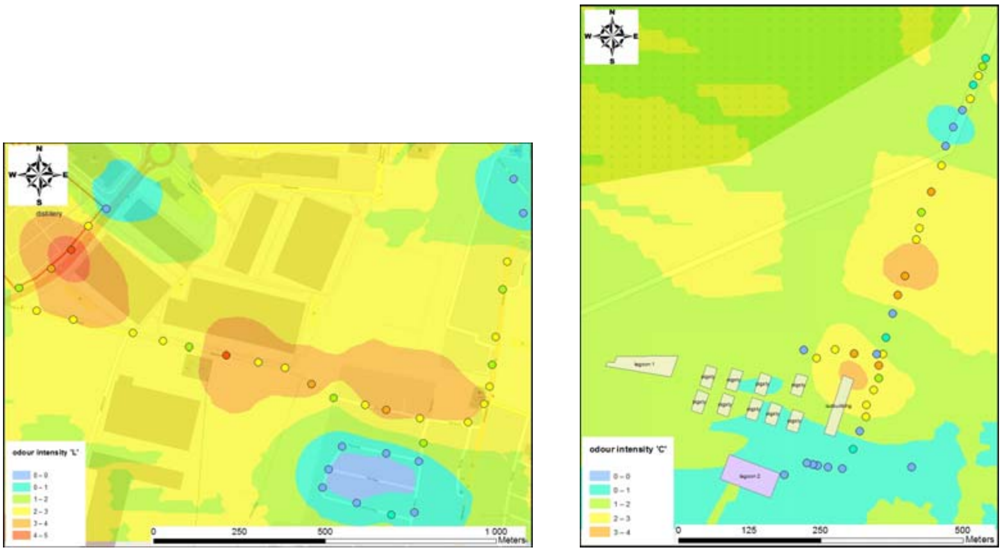

Figure 2. Odour intensity spatial distribution obtained by geostatistical interpolation, using Ordinary Kriging method A) for a measurement shown on figure 1A (distillery), B) for a measurement shown on figure 1B (swine farm).

The use of geostatistical interpolation allowed to estimate intensity values at points where measurements could not be made but in the range of performed field measurements. Using geostatistical methods, areas beyond measurement area cannot be analyzed (by extrapolation) due to high error values but it is possible using odour dispersion model.
Figure 3 presents odour concentration calculations results, using CALPUFF model, related to 'L' odour emission (baked bread), points measured in 4th measurement series were also marked. Model calculations were performed until finishing measurements, so intensity and concentration calculations are given at the same time.

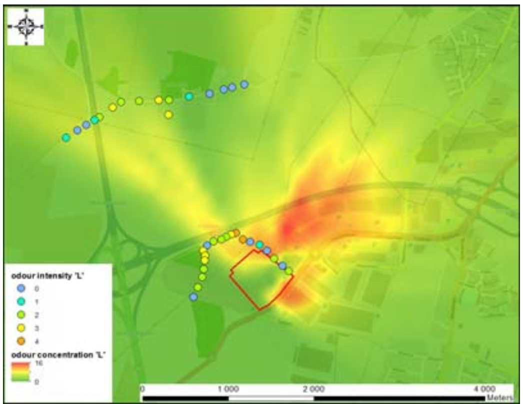

Figure 3. Odour concentrations spatial distribution (ou_E/m^3) obtained by calculations using CALPUFF model, during 4th series of field measurements.

Geostatistical interpolation applied to this measurement series indicated that the extent of the odour plume ends at the site of measurement (about 1500 m from the plant's border), while model tests indicate that odour impact may have much bigger range – even exceeding 3000 m.

Field measurements in the plume are a very good method to measure temporary odour intensity values on the selected area. One of their advantages is an opportunity to record all types of odours deriving from selected facility, affecting the air quality in the area of research (Sówka et al., 2012). However, they're not sufficient enough to fully assess air quality in the area of analyzed object. A number of measurement series would have to be conducted, in different weather conditions (especially different wind directions), in different times of year, including extreme temperatures. That would be time – consuming and require involving qualified staff for a long time. Therefore, proper odour dispersion model application is a best solution. A proper model must process meteorological parameters properly, such as CALPUFF model does. Using the right model allows to estimate pollutants concentrations distribution in the studied area quickly and at any time. It is important especially in winter – in Poland, temperature in winter may drop to -20°C during the day. It would be extremely difficult to carry out field measurements in such conditions. Additionally, model calculations results are obtained in concentration units, which allows to calculate required emission reduction (if the reference value is exceeded) and to propose solution to reduce odour emission from studied object.

In odour impact studies related to particular facility, air pollutants dispersion model use is recommended as it's easier to perform and the analysis rate allow to simulate the shape and odour plume propagation under different emission conditions and meteorological scenarios. In order to verify calculations results using the model, performing additional field measurements emphasizes the reliability of results obtained using mathematical model.

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'Development of a dynamic-statistical model of odour nuisance propagation in urban and industrial agglomerations', National Science Centre, Poland, 0188/B/P01/2011/40

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