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Odour Load from Passenger Ships

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The study describes the investigation of the odour sources in the vicinity of a new planned residential area nearby Helsinki city centre. A field investigation was performed in order to define the role of the largest VOC-emitter in the neighbourhood, a ship yard where ships under construction were painted in the open-air. However, the results of the investigation showed a passenger harbour nearby to be more considerable odour source. The odour load of the exhaust gases from passenger ships docked in the harbour as well as the ship departures were found to be significant. In ongoing cargo Harbour project Vuosaari all cargo activities from Ports of Helsinki are moved to Vuosaari Harbour. As result there are old harbour areas which will be utilised in city planning for residential areas. Therefore, the ships were further investigated by odour emission measurements and dispersion calculations. The odour emissions of the ship exhaust were measured by olfactometer.

Odour dispersion model of Finnish Meteorological Institute (ODO-FMI) was applied to study the exhaust gas odour emissions and odour dispersion from the passenger ships. The odour calculations were done in order to estimate the situation in year 2030 when the new planned residential area will be ready. ODO-FMI differs from other dispersion models by its capability to represent the short-term peak values of the concentrations of odorous compounds, which may vary with the time scales less than one minute.

Dispersion calculations included the exhaust gas emissions from the passenger ships docked in harbour, ship manoeuvres in the inner harbour area and in the beginning of boat route. Future scenario for the passenger ship traffic and respective odour load was estimated for the year 2030. According to the dispersion calculation results the passenger ship traffic in the study area may cause odour nuisance around the harbour in about 500 meters radius.

This paper describes and compares the results of two different assessment methods for ambient odour caused by passenger ship traffic close to harbour area: field investigation and dispersion calculations. These two methods used support each other and are suitable for studying the odour dispersion and occurrence. Field investigation, however, cannot be used to predict the odour dispersion in future scenario study cases.

1. Introduction

New residential areas are planned to be built near industrial areas due to the demand of a compact community structure in Helsinki. Environmental issues, such as odour load, have to be investigated before the planning is completed in order to avoid annoyance of future residents. In Finland no odour guidelines exist but according to Finnish Environmental Protection Act odour may not cause annoyance to residents (Finnish Parliament, 2000).

Figure 1: Aerial photograph of current West Harbour, Port of Helsinki.

Figure 2: Design view of West Harbour, Port of Helsinki in year 2030

In this case study, a new future residential area was planned nearby Helsinki city centre. In the neighbourhood there was a ship yard where ships under construction were painted in the open-air. The odour load of the area was decided to be investigated because of odorous VOC-emissions. This area is called West Harbour and is nowadays used for passenger and cargo traffic harbour (Fig.1). In ongoing cargo harbour project all the cargo activities from Ports of Helsinki are going to be moved to new Vuosaari Harbour but the passenger harbour continues operating close by planned new residential area (Fig.2).

2. Odour Determination Methods

Odour determination methods used in this study are field investigation, olfactometric measurements and dispersion calculations.

The field investigation was performed according to VDI 3940 (VDI 3940, 1993) with 104 single measurements using combination of grid and plume methods during spring and summer term in 2001 in various meteorological conditions. Olfactometric measurements were made according to the standard EN13725 (EN13725, 2003).

2.1 Odour Dispersion Model ODO-FMI

The main feature in the ODO-FMI is to assess the concentration fluctuations caused by atmospheric turbulent diffusion (Rantakrans et al, 1995; Savunen et al, 1998). Model comprises two computational methods: the so-called meandering plume method for point sources and the internal fluctuation method (probability density function modelling) for area and volume sources (Hanna, 1986).

The model is based on the assumption that the concentration time series due to the meandering of the plume can represented by half-minute periods in one-hour sample. Each of the half-minute concentration values is assumed to correspond to the position of the axis of the plume with reference to the average airstream in both horizontal and vertical direction at each of the points around the source (Beaman, 1988).

Before calculating the instantaneous (30 s average) and the mean (1 hr average) concentrations needed in the model, the corresponding dispersion parameters and the dispersion of the plume axis have to be determined. Högström's method (Högström, 1972) is used to calculate the instantaneous (30 s average) dispersion parameters and for the dispersion of the plume axis. Determination of the dispersion parameters required in the calculation of average concentrations is based on research on boundary layer meteorology (Karppinen, 2001; Businger, 1971; Caughney, 1971; Hanna, 1985; Holtslag, 1984; Wratt, 1987).

Peak concentration caused by the effect of several sources together can be estimated in the odour dispersion model by so-called background method or by the Monte-Carlo method. In the background method it is assumed that the hourly mean concentration caused by each source makes up the background concentration due to the other sources. In the Monte-Carlo method it is assumed that each source produces, during the one hour sampling period, instantaneous concentrations (30 s average), which are independent of the other sources, following, however, a certain probability distribution. From these random concentrations caused by each source the portion at each receptor point is calculated, and these are then combined; from this time series of concentrations the maximum concentration is then chosen. Step by step the ODO-FMI calculates the hourly mean and peak concentrations using the corresponding meteorological and emission situation until the whole meteorological period (usually at least one year) has been employed. The time series is used to calculate the relative duration of odour as the number of times a specific threshold concentration has been exceeded. The odour dispersion model estimates odour frequencies as a percentage during one year (normally) and the GIS tools are employed to produce the areal distribution of these frequencies. The schematic picture of the ODO-FMI is presented in the Figure 3.

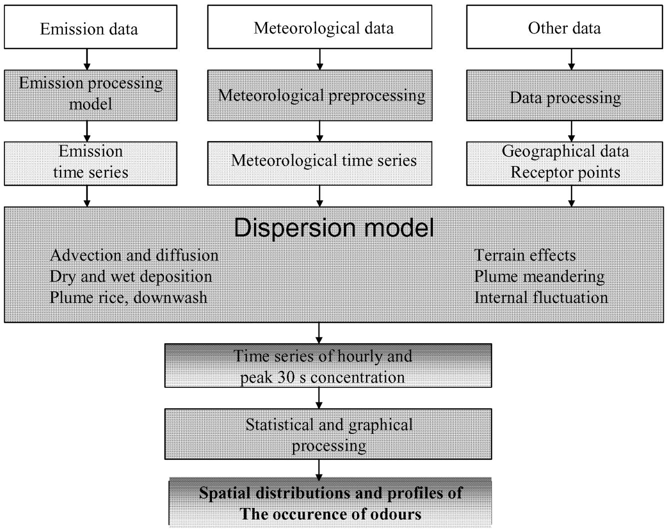

Figure 3: Schematic picture of the odour dispersion model ODO-FMI.

The odour emission information required by the ODO-FMI is the amount of odour emissions per time unit. The odour emission can be estimated either by the olfactometric or by the standard emission measurements. The emission can be described in the model either by odour units (ou_E/m^3, ou_E/s) or by mass units (g/m^3, g/s).

3. Odour Load Determination

3.1 Results of the Field Investigation

Because of dispersed VOC-emissions of open-air painting in the ship yard a field investigation was carried out in order to define the role of the largest VOC-emitter in the neighbourhood. Unexpectedly, already during the first measurement observations in the area the role of passenger ships was perceived. Consequently, later on Helsinki City Planning Department required also the determination of odour load from passenger ship traffic.

The results of field investigation showed that odour load of the exhaust gases emitted by passenger ships was significant compared to ship yard, which role was rather unimportant, Figure 4. According to the results the odour frequencies were the highest nearby the dock areas, 4 to 5 % of yearly hours.

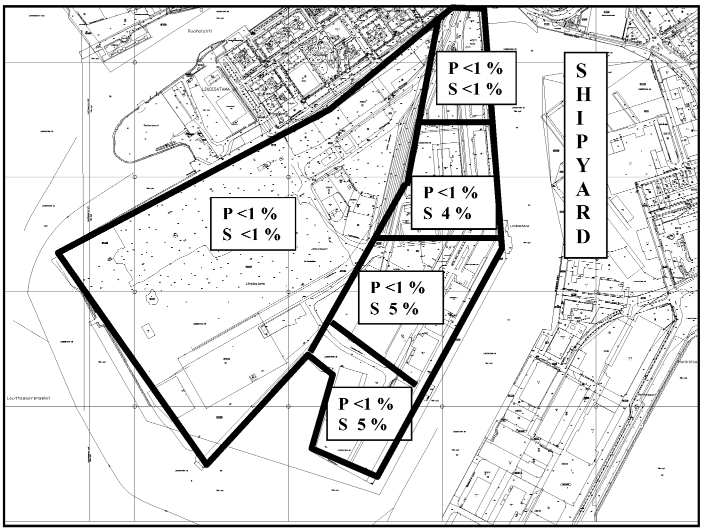

Figure 4. Results of field investigation, odour frequences (percentages of yearly hours) from open-air painting of ship yard (P) and from ship traffic (S) in study area.

3.2 Odour Emission Measurements

In ongoing cargo Harbour project Vuosaari all the cargo activities from Ports of Helsinki are going to be moved to new Vuosaari Harbour. In case of West Harbour a new residential areas are planned to be built on the old cargo harbour area and the passenger harbour continues operating.

Thus, the passenger ships were further investigated by odour emission measurements and dispersion calculations in 2006. Passenger ship traffic was estimated for the year 2030 and the odour emissions of the three most representative, various type of passenger ships were determined. These three ships included one fairly small and fast passenger ship and two more sizeable ones. Two of these ships used both heavy and light fuel oil and one used only light fuel oil. Variation of sulphur concentration in fuel oil varied from 0.2 % to 1.48 %. The ship exhaust odours were measured by olfactometer and flow rates were calculated from the total engine energy consumption.

Sampling for odour concentration determination was challenging because of extremely hot exhaust gases (520 K to 740 K). Gas was pre-diluted during sampling with nitrogen to prevent the condensation and also to decrease the temperature before the sample bag. Odour emission measurements were carried out in three stages; while the ships were docked in harbour, moving in inner harbour (speed 0 to 8 knots) and speeding up in the beginning of boat route (speed 4 to 15 knots). These measurements were done to estimate the emission factors of different type of ships at different moving phases, speeds and engine powers. The results of odour emission measurements are shown in Table 1.

Table 1. Odour emissions (ou_E/s) and total engine power (kW) from the three sample ships.

	Ship 1 31 000 kW	Ship 2 15 300 kW	Ship 3 24 000 kW
Docked	86 000 ou_E/s	19 000 ou_E/s	4 600 ou_E/s
Departure	640 000 ou_E/s	120 000 ou_E/s	170 000 ou_E/s
Beginning of a boat route	1 000 000 ou_E/s	140 000 ou_E/s	410 000 ou_E/s

3.3 The Ship Emission Application of ODO-FMI

The ODO-FMI model was applied to study the dispersion of odours emitted by passenger ship traffic in West Harbour, Port of Helsinki, (Puputti, 2007). Calculations were made for the future scenario in year 2030 when the residential area around the harbour will be built-up. In future scenario the land use of West Harbour area has changed from cargo and passenger harbour to residential area after the cargo activities have been moved to new Vuosaari Harbour. Volume of the passenger traffic has been estimated to increase considerably in West Harbour and the type of operating ships to change towards more sizeable and powerful ships.

Port of Helsinki provided the estimation of the future passenger traffic frequencies and the type of ships used in year 2030. The hourly emission time series for individual emission sources were produced based on the emission measurement data and the technical information of the ships. The emission height and other relevant technical parameters of the emission sources were considered in the calculation. Ships docked in harbour were examined as point sources and the ship movements as lines of several point sources.

According to the dispersion calculation results the odour frequencies were the highest between two major docks in the harbour area (Fig.5). In closest residential area (around 500m radius from the docks) the short-term odour occurrence frequency of clearly noticeable odour (3 ou_E/m^3) was between 3 to 6 % of yearly hours.

Calculation results also indicated the odour impacts from passanger ship traffic to be more significant during summer months compared to winter months due to the seasonal nature of the cruiser traffic and the seasonal meteorological differences.

Modelling calculations were also carried out for the vertical direction of the building frontages closest the docks. Some of the buildings locate in 50m radius from docked ships. The height of the ship stack can be up to 45m, thus it is likely to people living in higher floors close to the docks to experience the smell of exhaust gases from the ships.

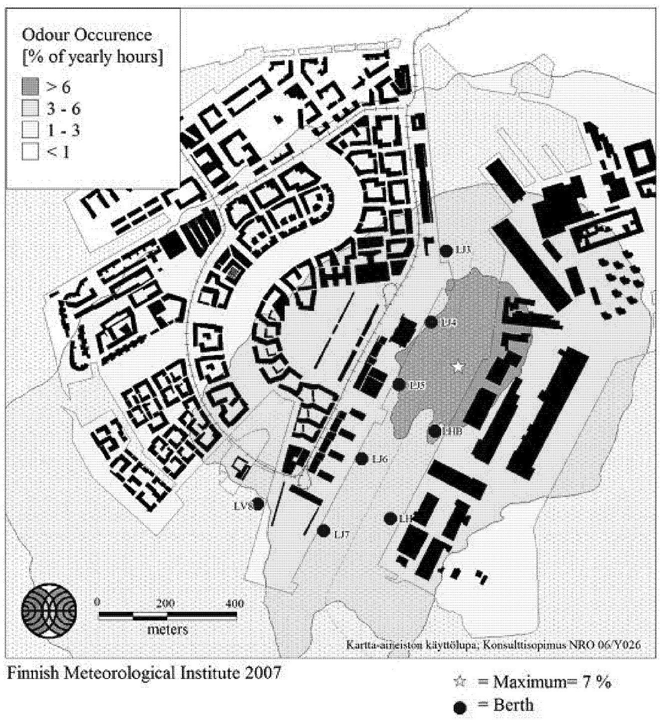

Figure 5: Dispersion modelling result of the short-term (30s) odour occurrence frequencies (percentages of yearly hours) of clearly noticeable odour (3 ou_E/m^3).

4. Conculsions

The odour load of the exhaust gases from passenger ships docked in the harbour as well as the ship departures were significant according to both field investigation and dispersion calculations. According to field investigation studies in 2001 the odour occurence frequencies in 500 m radius around the docks in West Harbour was determined to be 4-5 % of yearly hours. The modelling results for year 2030 respectively estimated 3-6 % odour occurence frequences to approximately the same area.

Therefore these two methods used support each other and are suitable for studying the odour dispersion and occurrence. Field investigation, however, cannot be used to predict the odour dispersion in future scenario study cases.

Generally, the odour emissions from traffic are not considered to be annoying. Nevertheless, in the case of West Harbour there have been complaints about the ship exhaust gas odours from the people living close by the harbour. Thus, the importance to consider the ship odour emissions in city planning cannot be neglected.

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