Spatial Modelling of Emissions from Residential Wood Combustion

Morten Tranekjær Jensen and Henning Sten Hansen

Department of Policy Analysis, National Environmental Research Institute (NERI),
University of Aarhus
PO Box 358, DK-4000 Roskilde, Denmark
mtj@dmu.dk
hsh@dmu.dk

Abstract. As part of the integrated research project (WOODUSE), NERI is dealing with the environment and health effects of residential wood combustion. For this purpose a method for high resolution geographical emission mapping has been developed. The method has been applied to a case-study area covering four municipalities in the urban fringe of Copenhagen. The output map showing the annual emissions of specific air pollutants on a grid serves as input to local air quality models used for human exposure calculations. This paper describes the fundamental principles and basic data applied in the mapping exercise.

1 Introduction

The present work contributes to development of a method for residential emission mapping in the WOODUSE project and deals with the environment and health effects of residential wood combustion. One of the main tasks is to gain knowledge on local air quality in residential areas to serve as input to human exposure calculations [1]. This paper will address the issue of combining geo-referenced data for modelling emissions of particulate matter. The mapping was applied to four municipalities (Værløse, Ballerup, Herlev and Stenløse) in the urban fringe of Copenhagen (see Figure 1). In principle, the present method should be extended to cover the whole of Denmark, but for the time being this is not an option due to lack of data and discrepancies in data quality.

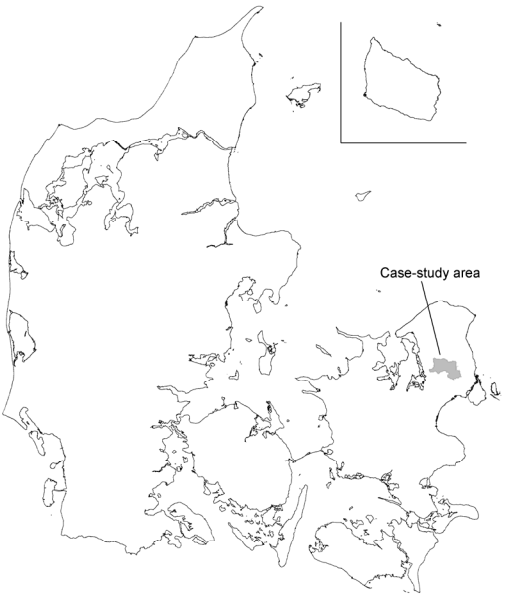

Fig. 1. Localization of the case-study area near Copenhagen.

2 Basic data

Several geo-referenced basic datasets have been applied in the present work. The most intensively used data are from the central Building and Dwelling Register (Danish abbreviation – BBR) and extracted data from chimney sweeps. The following section deals briefly with the content and structure of these data.

2.1 Data from the chimney sweep registers

The chimney sweep registers contain accurate information on the number and type of facilities used for wood combustion in every single household. The register enumerates every boiler, stove or fireplace, which are connected to the chimney(s) on the property. Besides information on the residential combustion plants it also contains information on heights of chimneys, but only for chimneys higher than 10m. Information on heights of the emission sources is important for atmospheric modelling. The register does not include specific information from which it is possible to quantify the usage of the combustion plant, which might be interesting in

an environmental context. In rare cases the chimney sweep makes a comment concerning the amount and type of soot deposited in the chimney, but normally the comments concern more technical issues, e.g. condition on chimney and special instructions for inspection [2].

At first sight, the address information provided with the register was insufficient for geo-coding as standardized addresses are not used. The data containing number and type of wood stoves and boilers was however geo-coded with some manual address-matching in the Danish official standard address register (OSAK), necessary due to the disparate street name spellings.

The data are not publicly accessible and are sparsely documented. Moreover, data quality shows great variation across districts and regions, and geographical coverage of the country is not complete.

2.2 Data from the central Dwelling and Building Register (BBR)

The BBR is a countrywide register with data on every building and residence. The register was established in 1977 with the aim of improving planning and administration. The register has a hierarchical setup with 3 interrelated levels. The 3 levels contain data associated with the property, the buildings and the residence unit, respectively. Data in this project relate mainly to the building level, which includes information on heating type, housing area, building usage and other characteristics. All information from the BBR can accurately be positioned at address level by coordinates, because the combination of municipality number, street-code and street-number constitutes a unique and common reference to the coordinates [3].

3 Methodological aspects of mapping air emissions

The major challenge in the present work was first to combine and link geo-referenced data from different hierarchical levels and second to calculate estimates on fuel (wood) consumption for each household as a basis for the final emission calculation.

Besides the difficulties with geo-coding data from the chimney sweep registers, some adaptation has been carried out to link chimney sweep registrations on a property level with data from BBR on a building level. A typical property constitutes more than one building, e.g. a house plus a garage. Due to registration level it is not clear whether the wood stove or boiler is placed in the house or in the garage, but placing is more likely to be in the house itself. In the current work, we attached the chimney sweep registrations to the building with the lowest building number in the BBR, because this in general represents the building within the property used as residence.

Based on the geo-referenced information on wood-burning facility, primary heating type, housing area and building usage we estimated a potential wood consumption for each household in the case-study area. The estimates for wood consumption are based on well-known relationships between dwelling area and total energy consumption for heating in different sizes and types of residences (single-

family house, housing estates, block of flats and holiday houses). In practice, wood consumption per household was estimated from the parameters in a linear regression describing the relationship between housing area and energy consumption for heating in different dwelling types [4]. By looking at the primary heat source for each household, a specific contribution from wood burning to total energy consumption (per household) was estimated – households without access to public heating supply (district heating or natural gas) are more likely to use wood stoves or boilers for heating as this represents an often economically favorable alternative. Furthermore, the wood consumption estimates take the efficiency of wood combustion for heating into consideration. The estimates on wood consumption were calculated on the basis of the following function:

$$WC_{household} = (a_i \times area_i + b_i) \times (3{,}6 \times 10^{-3}) \times c_j \times 1{,}43$$

Where:

$WC_{household}$ = Total wood consumption per household in Giga Joule (GJ)

a_i = Increase in energy consumption (kWh) per m^2 housing area for the given type of residence

$area_i$ = Housing area in m^2 for the given type of residence

b_i = Constant (kWh) for the given type of residence

$3{,}6 \times 10^{-3}$ = Factor for conversion of kWh to GJ

c_j = Proportion of total heat requirement covered by wood burning for a residence with primarily heating type j

$1{,}43$ = Factor for correction of fuel efficiency

The last step in the mapping procedure was to apply emission factors and then to aggregate the point-based air pollutant emissions at address level in a grid with a resolution of 100m x 100m (see Figure 2).

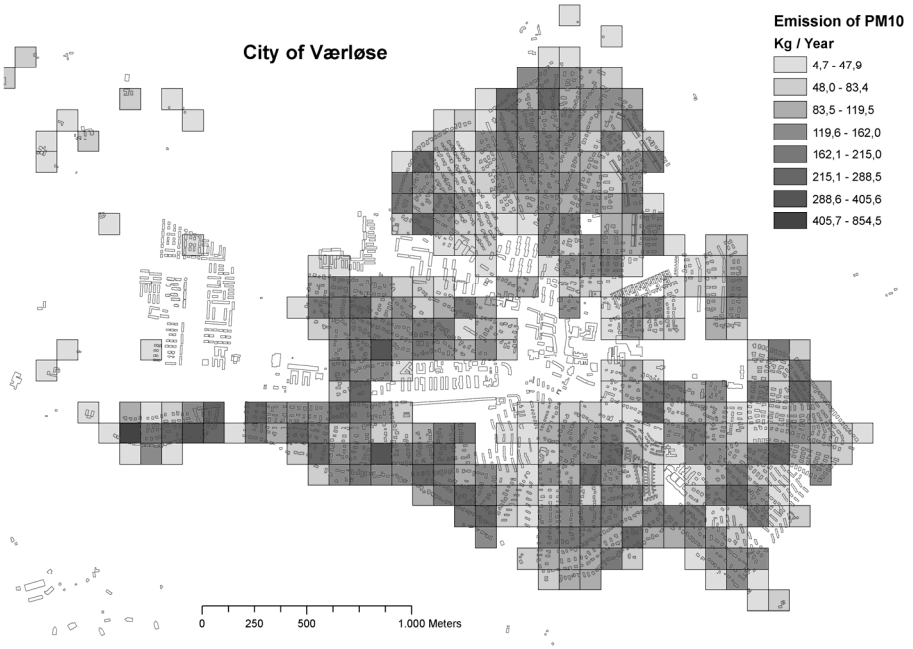

Fig. 2. Estimated annual emission of particulate matter (particle size < 10μm) in Værløse city.

The estimates for fuel consumption and also the final emission calculations have been set up as macros in a personal geo-data base (based on MS Access), which stores basic data as well as the populated geo-referenced data.

4 Concluding remarks and future work

The present work is an example of multiple combination and advantageous use of different sources of geo-referenced data for purposes which reach far beyond the original scope of the data. The authors see a wide perspective for this type of mapping if extended countrywide as it can serve as input to local air quality modelling and analysis of the impacts on the environment and people. Furthermore, it can be used as decision support for targeting environmental policy and regulation through scenario calculations, highlighting the consequences of different regulatory initiatives.

The WOODUSE project is ongoing, and the forthcoming work includes some improvement and validation of the estimated annual air emissions. This will be based on concrete measurements of concentrations of air pollutants as well as data from a questionnaire survey carried out in the case-study area.

References

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