4th International Workshop
on Uncertainty in Atmospheric Emissions
7-9 October 2015, Krakow, Poland

PROCEEDINGS

IBS PAN

IIASA

KRAKÓW
krakow.pl

4th International Workshop on Uncertainty in Atmospheric Emissions

7–9 October 2015, Kraków, Poland

PROCEEDINGS

Warszawa 2015

4th International Workshop on Uncertainty in Atmospheric Emissions
7- 9 October 2015, Cracow, Poland

Printed from the material submitted by the authors.

ISBN 83-894-7557-X
EAN 9788389475572

About the Workshop

The assessment of greenhouse gases and air pollutants (indirect GHGs) emitted to and removed from the atmosphere is high on the political and scientific agendas. Building on the UN climate process, the international community strives to address the long-term challenge of climate change collectively and comprehensively, and to take concrete and timely action that proves sustainable and robust in the future. Under the umbrella of the UN Framework Convention on Climate Change, mainly developed country parties to the Convention have, since the mid-1990s, published annual or periodic inventories of emissions and removals, and continued to do so after the Kyoto Protocol to the Convention ceased in 2012. Policymakers use these inventories to develop strategies and policies for emission reductions and to track the progress of those strategies and policies. Where formal commitments to limit emissions exist, regulatory agencies and corporations rely on emission inventories to establish compliance records.

However, as increasing international concern and cooperation aim at policy-oriented solutions to the climate change problem, a number of issues circulating around uncertainty have come to the fore, which were undervalued or left unmentioned at the time of the Kyoto Protocol but require adequate recognition under a workable and legislated successor agreement. Accounting and verification of emissions in space and time, compliance with emission reduction commitments, risk of exceeding future temperature targets, evaluating effects of mitigation versus adaptation versus intensity of induced impacts at home and elsewhere, and accounting of traded emission permits are to name but a few.

The *4th International Workshop on Uncertainty in Atmospheric Emissions* is jointly organized by the *Systems Research Institute of the Polish Academy of Sciences*, the Austrian-based *International Institute for Applied Systems Analysis*, and the *Lviv Polytechnic National University*. The 4th Uncertainty Workshop follows up and expands on the scope of the earlier Uncertainty Workshops – the *1st Workshop* in 2004 in Warsaw, Poland; the *2nd Workshop* in 2007 in Laxenburg, Austria; and the *3rd Workshop* in 2010 in Lviv, Ukraine.

Steering Committee

Rostyslav BUN (Lviv Polytechnic National University, UA)
Matthias JONAS (International Institute for Applied Systems Analysis, AT)
Zbigniew NAHORSKI (Polish Academy of Sciences, PL) – Chair

Scientific Committee

Evgueni GORDOV (Siberian Center for Environmental Research & Training, RU)
Piotr HOLNICKI-SZULC (Polish Academy of Sciences, PL)
Joanna HORABIK-PYZEL (Polish Academy of Sciences, PL)
Olgierd HRYNIEWICZ (Polish Academy of Sciences, PL)
Katarzyna JUDA-REZLER (Warsaw University of Technology, PL)
Petro LAKYDA (National University of Life and Environmental Sciences of Ukraine, UA)
Myroslava LESIV (Lviv Polytechnic National University, UA)
Gregg MARLAND (Appalachian State University, USA)
Sten NILSSON (Forest Sector Insights AB, SE)
Tom ODA (Univ. Space Research Association, NASA Goddard Space Flight Center, USA)
Stefan PICKL (Universität der Bundeswehr München, Germany)
Elena ROVENSKAYA (International Institute for Applied Systems Analysis, AT)
Kazimierz RÓŻAŃSKI (AGH University of Science and Technology in Cracow, PL)
Dmitry SCHEPASCHENKO (International Institute for Applied Systems Analysis, AT)
Anatoly SHVIDENKO (International Institute for Applied Systems Analysis, AT)
Jacek SKOŚKIEWICZ (National Centre for Emissions Management, PL)
Philippe THUNIS (EC Joint Research Centre Ispra, EU)
Marialuisa VOLTA (University of Brescia, IT)

Local Organizing Committee

Joanna HORABIK-PYZEL
Jolanta JARNICKA - Chair
Weronika RADZISZEWSKA
Jörg VERSTRAETE

Inventories of domestic heating sources and their emissions in urban areas – methods, results and uncertainty

Marek Rosicki[1], Magdalena Załupka[2]

ATMOTERM S.A.
Opole, Poland
[1]*rosicki@atmoterm.pl*
[2]*zalupka@atmoterm.pl*

Abstract

Results of recent projects on domestic heating emission inventories in Poland are presented in the paper. Wider context information concerning the impact of domestic heating emissions on air quality in urban areas is provided based on the authors' experiences at the field of Air Quality Action Plans (AQAP). Past and current methods used for emission inventories are discussed including GIS analysis, questionnaires, interviews and calculations. The influence of Low Carbon Economy Plans (LCEP) on the domestic heating emission inventories is presented as well. Case studies for Kraków (AQAP) and Gdańsk (AQAP/LCEP) cities are described together with general conclusions on the role of precise inventories in the urban environmental and development programmes.

Keywords: air quality, emission inventory, domestic heating sources

1. Introduction

Past and recent investigations have demonstrated that urban air quality in many Polish cities depends on the emissions from domestic heating systems. PM10 and B(a)P parameters measured in the heating season are elevated comparing to the summer period (see Figure 1).

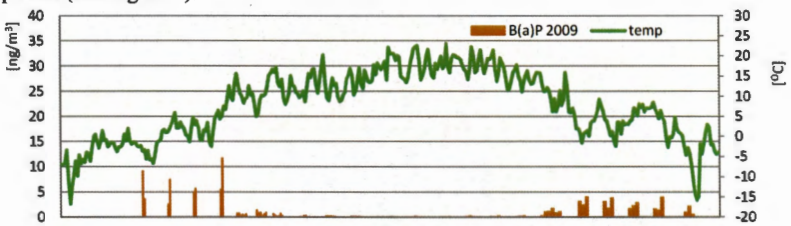

Figure 1. 2009 time series of B(a)P concentration in Poznan (Załupka et al., 2012).

During the JRC project (Junninen et al., 2009) the high contribution of coal fired domestic sources in air pollution in Krakow was proved by the chemical mass balance method.

Air quality modelling results (Lochno et al., 2013) also show that domestic heating sources are one of the main group of emission sources that influence the air quality in Krakow and other cities. An example of source apportionment modelling results is presented in Table 1.

Solid fuel fired domestic heating sources (SFFDH sources) has been indicated as a high priority issue in majority of Air Quality Action Plans (AQAP) prepared in Poland since 2005. Local and regional decision makers are facing the problem of SFFDH sources identification to set up the appropriate strategy of emissions reduction. In many cases heat energy balance calculation method is applied to provide information for

decision makers on the overall number of SFFDH sources. However some of city administrations decided to start deep investigation and launched bottom-up inventory projects.

Table 1. Contribution of different emission sources to PM10 and B(a)P annual concentration in Kraków for the areas where EU limit/target values are exceeded (Lochno et al., 2013)

	Local domestic heating	*Local transport*	*Local industry*	*Background and other sources*
PM10	42,3%	17,0%	21,0%	19,7%
B(a)P	48,7%	9,4%	3,5%	38,4%

2. Kraków case study

In May 2014 Kraków City administration began a new air quality project titled 'MONIT-AIR: An integrated spatial data monitoring system for better air quality in Kraków'. As a part of this project a precise bottom-up inventory of existing SFFDH sources was started. The main reason to undertake this task was necessity to understand were the remaining SFFDH sources are located, are they concentrated or dispersed and what is the real scale of the solid fuels problem within the city. The city of Kraków was divided into seven areas for which inventory sub-projects were set up (Figure 3).

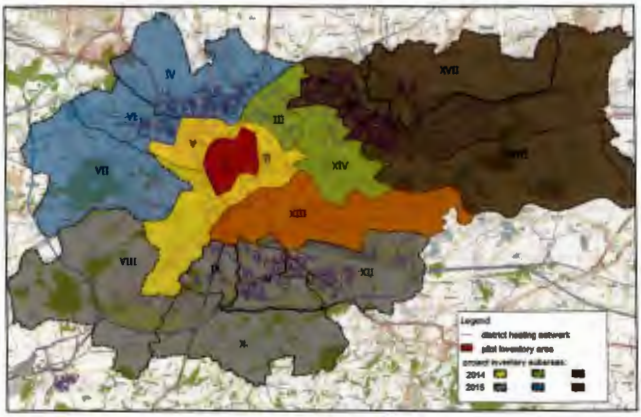

Figure 2. The areas of SFFDH inventory in Kraków.

After several months of field work the inventory is still in preparation. Before publishing the final results it is already possible to share some experiences on methodology and uncertainty issues.

The inventory sub-project starts from the analysis of existing data on non-solid-fuel based heating systems and networks within the selected area (district heating, gas and electricity networks). Basing on such analysis the set of buildings likely to contain SFFDH sources is being prepared. Then a questionnaire interview begins. Each

interviewer has assigned a subset of buildings where he asks questions on the type of heating, fuels used for heating and the number of heating sources. In the cases where the residents of building are absent or refuse to answer the questions there is a special procedure of filling in the questionnaire basing on interviewer observations. All information collected using the questionnaires has to be recorded in the database using an on-line IT application.

The interviewers are trained before starting the field work on every relevant aspects of their work. Although a special attention is paid during the trainings to the possible errors there are a lot of uncertainty sources that can be met in the inventory process. The most important are specified in Table 2.

Table 2. Factors influencing uncertainty of questionnaire-interview based inventory of SFFDH sources.

Factor	***Description***
Place of interview	The interviewers have no rights and obligation to go inside the building/apartment. There can be situations where the interview is carried out at the front of the building. The street noise and traffic can adversely affect the results of interview.
Attitude and knowledge of interviewees	Some interviewees can have negative attitude to the project and interview itself. In some cases the persons asked have not sufficient knowledge to answer the questions.
Skills of the interviewers	Although all the interviewers are trained before starting their project activities they cannot avoid some errors during the interviews and during entering data into the web IT application.
Time scale of the project	During the project run (18 months) changes in the heating systems can happen.

The final results of the inventory will be available through the urban GIS. This will provide decision makers and general public with precise information on the location of SFFDH sources and allow to develop detailed financial plan of solid fuel elimination. Further steps will include a transformation of the inventory into an IT system which will support city administration to monitor continuously domestic heating technology improvement and emissions changes. The main outcome of the inventory will be the numbers of SFFDH sources in the subareas. Using the specific emission factors it will be possible to convert the data into emission inventory and then use localised emission data for air quality modelling tasks. For PM10 emissions application of NFOŚiGW emission factor (380 g/GJ) is considered.

The SFFDH inventory project report in Kraków will include an uncertainty analysis of the received numbers of SFFDH sources. So far two uncertainty models have been considered: GUM based model and a counting model (W. Bich and F. Pennecchi, 2012). For the GUM based model a symmetric rectangular distribution is assumed for every measurement process (each interviewer). The limit uncertainty Δ_{gi} is assessed individually for each interviewer 'i' and a standard uncertainty can be calculated as:

$$u_i = \frac{\Delta_{gi}}{\sqrt{3}}$$

Then a combined uncertainty can be determined using the GUM equation for uncorrelated input quantities. As a second method of uncertainty estimation a model proposed by Bich and Pennecchi (2012) for counting processes has been considered. A preliminary uncertainty estimation gives results below 10% for the number of SFFDH sources in each investigated subarea. The counting model gives generally the lower uncertainty results then GUM based model.

3. Gdańsk case study

First time an inventory of domestic heating sources was made for the purposes of the Air Quality Action Plan (AQAP 2013). Calculated emissions for 2010 were prepared to use for air quality modelling. Calculations were based on heat demand analysis for the city buildings pertaining to the number of city residents and the contributions of different heating methods. This procedure requires to accept several assumptions. The first is heat demand per capita. Perfectly, such information comes from a heat supply plan. This plan for Gdańsk related then to the 2003 year. For that reason it was necessary to analyse changes from 2003 to 2010. It was done using statistical data, which are published by the Central Statistic Office of Poland every year. During the first inventory the following data presented by the Central Statistic Office were used:

- the number of residents in Gdańsk,
- the number and useable floor area of dwellings,
- the number of dwellings heated with natural gas,
- the sale of district network heat to residential buildings.

Because of the target – air quality modelling – an identification of emissions locations was very important. This is why a GIS analysis of heating and gas networks arrangement was necessary. After collating buildings layer and district heating network layer an emission-free areas were obtained. These are multi-family housing development built in the second half of the twentieth century. For the remaining areas emission density was differentiated depending on the type of buildings (scattered single-family or dense multi-family) and heating method. Emissions were calculated using EMEP/EEA factors proposed in the 2009 guidebook.

A next inventory of emissions from residential buildings in Gdańsk has been made for the purposes of Low Carbon Economy Plan (LCEP 2015, ongoing). In that case the carbon dioxide emissions were in the foreground. However at the same time emissions of air pollutants were also inventoried, i.e.: particulate matter (PM10 and PM2.5), benzo(a)pyrene, sulphur dioxide, nitrogen oxides. There are a few basic differences in LCEP inventory method comparing to the AQAP inventory:

- taking into account additional fuels - propane-butane and firewood,
- carrying out a field questionnaire-based survey on SFFDH sources in selected areas to verify the calculated number of heating sources fired by solid fuels.

Other elements which have an impact on the emissions in LCEP inventory include:

- a different base year – 2013,
- availability of an updated heat supply plan for 2012,
- an attempt of getting the actual data from district heat suppliers and fuel suppliers,

– a change of the EMEP/EEA emission factors in the new 2013 guidebook - they were reduced substantially, especially for gas and oil heating (see Figures 3 and 4).

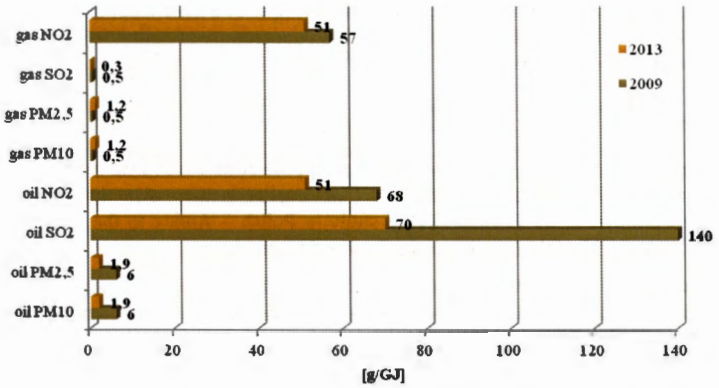

Figure 3. A comparison of EMEP/EEA emission factors for PM, SO_2 and NO_2.

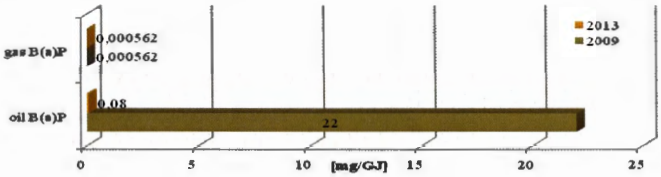

Figure 4. A comparison of EMEP/EEA emission factors for benzo(a)pyrene.

A comparison of the results for both inventories shows that the second one, more detailed, gave lower emissions. Experiences gained during both projects allow to indicate the following sources of uncertainty:

a) Availability of data on fuel consumption is partly insufficient. Heat suppliers can provide data on heat consumption. Natural gas supplier can provide data on gas consumption. However the consumption of other fuels like coal, propane-butane, oil and firewood must be estimated.
b) There is no accurate information on the age of the residential buildings and their thermal insulation which affects the estimation of heat demand.
c) Applied EMEP/EEA emission factors may be not suited for the local conditions.
d) In the course of the inventory projects human mistakes can happen (e.g. when data on the heat/gas consumption are collected).

4. Conclusions

Depending on the applied methodology approach and type of input data different results of emission inventory from domestic heating sources can be obtained. Factors

influencing uncertainty of such inventory include human mistakes, lack of raw data and emission factors errors. To achieve precise data for air quality modelling and management a critical data set concerns a number and location of solid-fuel-fired emissions sources. The project of bottom-up inventory of SFFDH sources in Kraków should demonstrate a lower uncertainty comparing with a traditional calculation based inventory. Further investigation and analysis on uncertainty of domestic heating sources inventories is necessary.

References

[1] Załupka M., et al. (2012). Program ochrony powietrza w zakresie benzo-alfa-pirenu dla strefy aglomeracja poznańska (Air quality action plan in the range of benzo(a)pyrene for Poznan city), a study in Polish – Annex to the Resolution No. XXIX/566/12 of the Wielkopolska Regional Council.

[2] Junninen H. et al. (2009). Quantifying the impact of residential heating on the urban air quality in a typical European coal combustion region. Environmental Science and Technology 43(20), pp. 7964-70.

[3] Lochno A., et al. (2013). Program ochrony powietrza dla województwa małopolskiego (Air quality action plan for Małopolska region), a study in Polish – Annex No. 1 to the Resolution No. XLII/662/13 of the Małopolska Regional Council.

[4] Evaluation of measurement data – Guide to the expression of uncertainty in measurement – JCGM 100:2008 (GUM 1995 with minor corrections). Bureau International des Poids et Mesures 2008.

[5] W. Bich and F. Pennecchi (2012). Uncertainty in measurements by counting. Metrologia 49 (2012), pp. 15-19.

[6] Program ochrony powietrza dla strefy aglomeracji trójmiejskiej (Air quality action plan for Gdańsk-Gdynia-Sopot agglomeration), a study in Polish – Annex No. 1 to the Resolution No. 754/XXXV/13 of the Pomorskie Regional Council, 2013.

[7] EMEP/EEA air pollutant emission inventory guidebook, 2009.

[8] EMEP/EEA air pollutant emission inventory guidebook, 2013.