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Estimated mercury emissions from coal combustion in the households sector in Poland

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A B S T R A C T

Coal consumption secures more than 50% of needs of Polish economy for primary energy carriers and the consumption of hard coal alone amounts 70–80 million Mg annually. Almost 14% of hard coal consumption – up to 11 million Mg per year – fall to households in Poland. Coal combustion in domestic furnaces and boilers is regarded as the main source of emissions into the atmosphere, referred to as the low-stack emission. The matter of the paper is the assessment of the emission of mercury from the households sector as the result of coal combustion. The results of the assessment were collated with GUS data on mercury emission from this sector. A change in the annual emission of mercury from the household sector has been proposed and justified, assuming that the whole low-stack emission of mercury is the result of coal combustion only.

1. Introduction

Low-stack emission poses a problem as various contaminants, usually in large amounts, are released in to the atmosphere in a scattered manner. A large amount of the contaminants released in the process of furnace and boiler usage in households are a result of: the type of fuels used (mainly hard coal), the low efficiency of conversion in these furnaces and boilers and a lack of equipment for reducing the impacts of combustion on the environment. Emissions from the household sector are evaluated through indirect methods due to the huge number and variety of emitters and the resulting measurement difficulties.

Low-stack emission occurs, first of all, as a result of coal utilisation in fuel combustion processes away from industrial processes – mainly in households. Therefore, actions are being taken to eliminate coal as a source of fuel, especially in households (Atmoterm, 2010). Low-stack emission is not only an effect of coal combustion in boilers without protective equipment, but it also results from the market availability of different fuels, including those with bad quality parameters.

Much less is known about the real emission of mercury from furnaces and boilers used in households (Hławiczka, 2008; Hławiczka, Kubica, & Zielonka, 2003; Hlawiczka & Fudala, 2008) than about emissions of other contaminants, e.g. dust, sulphur oxides and others (Kubica, 2010; Sobolewski & Matuszek, 2014), and emissions of mercury from large coal combustion installations, including the knowledge on the methods of mercury emissions reduction (Pavlish et al., 2003; Swaine, 2000; UNEP, 2010; Yudovich & Ketris, 2005). Until recently this resulted in part from a lack of representative data concerning the contents of mercury in combusted coals and in part from the number of emitters and the lack of possibilities to evaluate the work of all the installations or even their groups. Additionally, a lack of legal regulations made the issue of mercury in coal and mercury emissions more cognitive (scientific) than practical, despite the awareness of threats to the environment and human health resulting from the presence of anthropogenic mercury in the environment (Hławiczka, 2008). The issue of mercury emissions became an important topic, especially in Poland, only when actions to develop legal regulations aimed at reducing mercury emissions were taken, such as:

- the European Commission's ongoing work concerning mercury, which resulted in a proposal of standards for mercury emissions from large combustion plants (European Commission, 2013),
- the introduction of mercury emission standards in a number of countries (Canada, USA, China) (Sloss, 2008, 2012),
- work performed for a few years within the framework of the United Nations Environmental Programme (UNEP), resulting in an agreement on the Minamata Convention, which is a global

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convention and while it does not define any standards or other detailed regulations on mercury emission alone, work is being carrying out on executive documents (Minamata Convention, 2013).

Coal combustion is considered to be one of the main anthropogenic sources of mercury emissions on a global scale (UNEP, 2008; UNEP, 2013). In Poland coal consumption makes up an exceptionally high level of economy energy security. In 2013 coal (hard and brown) accounted for approximately 54% of the primary energy carriers' consumption and almost 90% of electricity was produced using coal (Central Statistical Office, 2014a). In the same year approximately 11 million Mg of hard coal was used in households (Central Statistical Office, 2014b).

In the authors' opinion, methods for evaluating mercury emissions into the atmosphere based on available indexes do not show the real values of emissions. Most probably the "available" indexes are still based on insufficient data concerning both emission measurements and mercury contents in coals, especially the coals used in the household sector. These are most frequently specific sorts (coal size grades) of coal, incomparable with those used mainly in combustion processes in the energy production and transformation sector, which is the area where there is currently the largest amount of data concerning mercury content. Furthermore, data concerning mercury content in coal used in households in Poland (ranging from 140 μg/kg to 1780 μg/kg) are disseminated internationally in the context of health risks (WHO IAQ Guidelines, 2014). This article delivers quite different values originated from the authors' own studies covering all hard steam coal size grades produced in Poland.

The aim of the analysis in this article was to assess the emission of mercury resulting from coal combustion in the household sector. Due to the lack of statistical data on the structure (in terms of coal size grades and quality) of the coal combusted in households, the element of the assessment was the variant evaluation of this structure. The basis for the assessment was the results of the determination of mercury content in all coal size grades produced in Poland ("Hg Base" Project). The assessment results were compared with data provided by the Central Statistical Office (GUS) and developed by the National Centre for Emission Balance and Management (KOBiZE). A change in the annual value of mercury emissions from households was proposed and justified, based on the assumption that low-stack mercury emission is the result of coal combustion only.

Due to quality requirements imposed by commercial coal recipients, raw coals are usually cleaned and subjected to fractionation according to the size of grains (coal size grades). The list of currently produced coal size grades is quite lengthy [PN-82/G-97001, 1982]. Examples of limit values of coal grain size in the most popular coal size grades on the market are presented in Table 1. It can be seen that the size distribution of the coal offered on the market is quite broad, but the selection of fuel for a particular household depends on the construction of the boiler (furnace) used. Traditionally, the types of coal dedicated for small furnaces and boilers in households mainly include so-called 'coarse' coal size grades (especially nut coals and cobbles) and medium coal size grades (pea coal). Recently, small boilers which allow the relatively effective combustion of smalls and the finest grades of coal have been constructed (Kubica, 2010; Sobolewski & Matuszek, 2014). The production of so-called "qualified fuels" for recipients from the household sector has also begun (Korzeniowski, Kurczabiński, & Łój, 2012).

Table 1
Limit values of the size of coal grains in selected coal size grades according to PN-G-97001.

Name of coal size grade	Upper size of grain, mm	Lower size of grain, mm
Cobbles	200	63
Nut coal	80	25
Pea coal	31.5	8
Smalls I	31.5	0
Smalls II	20–10	0
The finest coal	1	0

Apart from coal fuel grains size, a key issue in the coal trade are its quality parameters, the most important of which include:

- calorific value [kJ/kg],
- ash content [%],
- moisture content [%],
- sulphur content [%],

Other parameters, such as: volatile matter, content of chlorine, mercury etc., which are equally important from the point of view of coal combustion and its environmental effects, are usually not of interest to recipients from the household sector. Coal quality parameters can be improved in coal cleaning processes. There is a wide choice of processes, and their application depends on the size of the cleaned grains of raw coal. Coal cleaning is performed in preparation plants, which are located on the premises of each hard coal mine in Poland. Improving the quality of coal fuel is understood to consist of the removal of contaminants from raw coal which after its combustion turn into ash as well as other contaminants that are harmful from the point of view of coal combustion processes and its environmental effects. When contaminants (which are usually incombustible) are removed from raw coal, the cleaned coal is characterized by a higher calorific value, i.e. a higher concentration of energy in a unit of coal fuel mass than raw coal. The quality of raw coal (calorific value, ash content, sulphur content) is very changeable in practice. The quality of cleaned products, when analysed in particular collieries, is practically stable. However, due to the different characteristics of coal in particular mining areas, there are differences between same size coal grades produced by different collieries.

All raw coal with a grain size over 20 mm, from which coarse and medium coal size grades can be obtained, are fully cleaned. Smalls, accounting for more than 60% of raw of mine coal mass, are only partially cleaned, and in many mines they are sold "as raw coals". This means that the possibility of improving raw coal quality through cleaning is not fully utilised. A clear and repeatable tendency for each mine to change the quality of coal between size grades is observable. The highest quality, i.e. the lowest content of ash and the highest calorific value, is observed in the case of coarse and medium size coal grades. Smalls have worse quality and the finest coal the worst (also smalls and the finest coals fully cleaned). Data illustrating this tendency for the average production of coal companies can be found in literature (Łój & Kurczabiński, 2011; Paprotny, Wróbel, & Sitko, 2011).

Price is an important factor which influences the recipients of coal. The price of cleaned coarse and medium coal size grades (cobbles, nut coals, pea coals) can be as much as twice as high as that of smalls and nearly three times higher than of the finest coal (Katowicki Holding Węglowy S.A., 2015; Kompania Węglowa, 2015; Tauron Wydobycie, 2015). An important issue is the fact that after recalculating the price of particular size grades per unit of energy, e.g. 1 GJ (1 GJ), different prices for 1 GJ of energy for particular coal size grades are obtained. The highest price of 1 GJ is obtained for the highest quality coals (coarse and medium coal size grades) and the lowest for the worst quality smalls and the finest coal. This means that the higher the "concentration" of energy in a unit of