



The Initial Results of the “Baza Hg” Project Concerning Mercury in Commercial Products of Polish Hard Coal Mines

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Summary

The consortium of 4 institutions obtained the grant for project entitled: “The elaboration of a data base on mercury content in domestic coal, technological guidelines of the further mercury reduction, including the defining of benchmarks for domestic indices of mercury emission” – acronym “Baza Hg”, within the scope of the 2nd call of Applied Research Programme of the Polish National Centre for Research and Development. In the article the genesis of the project is described as well as its objectives and the research tasks which will be realised to achieve the objectives. The results, originating from the first year of the project realization, and their description are presented. The discussed results focus on the mercury content in chosen groups of commercial products: sized coal of steam coals. Thus the discussion involves the impact of the degree of coal cleaning.

Keywords: mercury, steam hard coal, commercial products, “Baza Hg” project

Introduction

Awareness of the possibility of introducing regulations on mercury emissions in Poland has been existing for many years now. The European Commission regularly came back to this subject [10, 11], and the introduction of the limiting regulations on mercury emissions in Canada [3, 17] with some issues in the USA [4, 17], only confirmed the quick introduction of such regulations in the European Union and in the country. The draft of the new European reference document on Large Combustion Plants (LCP) already contains the proposal of the limits on the mercury emissions from the coal burning objects [2]. In the meantime the Minamata Convention was passed. The convention is a world scale treaty on mercury [7, 8], for which the executive acts are currently being prepared, most probably based on the Best Available Technologies (BAT)/ Best Environmental Practices (BEP) [18]. In Poland the mercury emission issues are mainly related to coal utilization (hard coal and lignite) [6,12]. Nonetheless, until quite recently the representative information on the actual scale of the coal contamination with mercury was lacking. The annual emissions in Poland [5,6] provided before recalculation gave rise to concerns increased by the proposal to define the large mercury emitter postulated in the frames of the Minamata Convention. In the end, the proposal above did not enter the negotiated version

of the Convention. A country counted among the large emitters would have to introduce special reparatory programs in order to reduce the mercury emissions. In this atmosphere of intensive preparation of legal regulations on mercury in 2013 the consortium of four institutions obtained funding for the project: The elaboration of a data base on mercury content in domestic coal, technological guidelines of the further mercury reduction, including the defining of benchmarks for domestic indices of mercury emission” – acronym “Baza Hg”, within the scope of the 2nd call of Applied Research Programme of the Polish National Centre for Research and Development

The main objective of the Project is to elaborate a database on the mercury content in commercial coals and the possibility to reduce the mercury charge during the production process. In the meantime, both the consortium partners, as well as other institutions developed own databases on the mercury contamination in coal [1,9,19,20,21]. Nonetheless, the data-bases are fragmentary and limited most often to steam smalls burned in large power plants and CHP plants [19,20]. This does not decrease the importance of the Baza Hg, since the project is realized from the point of view of coal producers and will provide complex information on the mercury contamination of various commercial products and their selected components. The project concerns both hard coal as well

as lignite. The project duration is between December 2013 – August 2016.

Within the main objective of the project (obtaining of the records – determination of mercury content in coal – for the database) the same sampling scheme repeated twice in 2014 and 2015 for all the coal producers in Poland has been assumed. Up till now the results of the first sampling cycle have been closed and elaborated. This paper presents the results of the analysis of the mercury content in the commercial products of hard coal mines obtained in 2014. Due to the division of tasks in the project, the presented data is limited to the mines mainly producing hard steam coal, i.e. excluding the coals produced in the Jastrzębska Spółka Węglowa S.A. (JSW S.A.).

The objectives and tasks of the Baza Hg Project – methodology of hard coal commercial product sampling

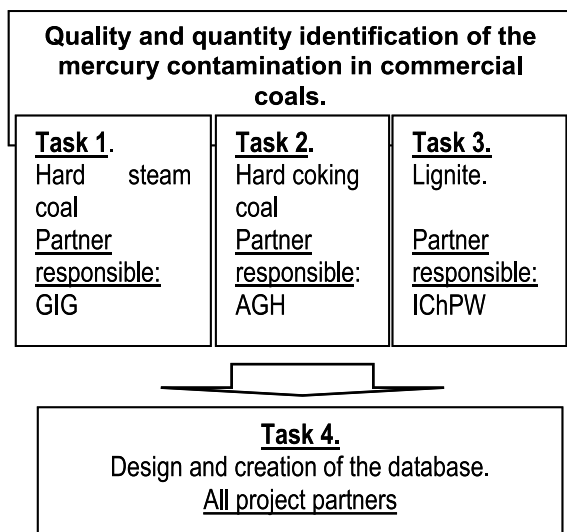
The objectives and tasks of the Baza Hg project

The project consortium comprises of:

- Główny Instytut Górnictwa – Central Mining Institute (GIG) – consortium leader,
- Akademia Górniczo – Hutnicza – AGH University of Technology – Fuel Technology Department (AGH),
- Institute for Chemical Processing of Coal (IChPW),
- Częstochowa University of Technology – Energy Engineering Department (PCz).

Figure 1 presents the objectives which will be realized in the course of the project. The figure also illustrates the relations between the planned

Objective 1. Designing and creation of the database supporting the management of mercury content in coal products as well as data collection



Objective 2. Elaboration of guidelines for the technology of reduction of mercury in commercial coals (in particular the smallest particle size fractions) as well as in waste products.

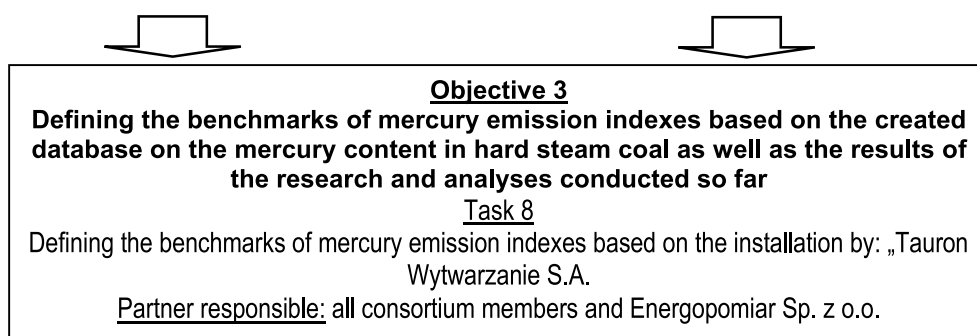
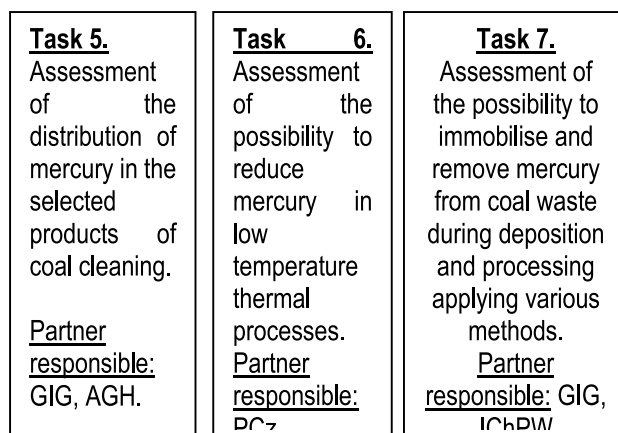


Fig 1. The generic scheme of the project

Rys.1. Schemat realizacji projektu

research tasks and the project objectives. The works in the Baza Hg project were divided into 8 research tasks. Moreover on Figure 1 the distribution of the competences of the respective consortium members within the project is shown through their participation in the respective tasks.

For the achievement of Objective 1.: Designing and creation of the database supporting the management of mercury content in coal products as well as data collection, four re-search tasks are realized. Three of them consist in data collection – records of the database, separately for:

- hard steam coal; this task is realized by GIG and, in practice, concerns all the hard coal mines in Poland with the exception of those belonging to JSW S.A.
- coking hard coal; this task is realized by AGH and, in practice, concerns exclusively the mines belonging to JSW S.A.,
- lignite, this task is realized by IChPW, one of the tasks is also related to programming the software for the basis as an IT tool.

For the purpose of achievement of the Objective 2.: Elaboration of guidelines for the technology of reduction of mercury in commercial coals (in particular the smallest particle size fractions) as well as in waste products, realized are three tasks in the framework of which industrial and laboratory research is conducted on the assessment of the possibility to reduce the mercury content in the respective unit processes (cleaning processes) as well as in the result of low-temperature coal pyrolysis. A separate task, resulting from the need to identify the threats created by the waste from the cleaning processes and the possibility of their reduction, is the research on the possibility to immobilize mercury in the waste together with the waste processing methods.

The achievement of objective 3.: Defining the benchmarks of mercury emission indexes based on the created database on the mercury content in hard steam coal as well as the results of the research and analyses conducted so far, should give the results of the project an even more utilitarian character. Here, the analytical tasks, combining the obtained complex and systematized information on the contamination of the Polish coals with mercury with the knowledge on the possibility to reduce mercury emissions in the power plants and CHP plants brought in by the Energopomiaru Sp z o.o. experts is conducted. Based on the results of works performed for Tauron Wytwarzanie S.A. on the assessment of mercury emissions, new benchmarks of the mercury emission indexes will be

proposed to enable the recalculation of the mercury emissions in Poland.

The methodology of sampling the steam hard coal commercial products

The results presented and discussed in this article concern the task No. 1 – steam hard coal performed by GIG. A sampling method has been selected which comprises of composing the sample for tests of increments taken over the period of one up to two weeks. Commercial product samples were taken and, in the case of the complex process of production of the commercial products, in particular the commercial smalls, components of the commercial products were sampled. From the increments laboratory test samples were prepared in accordance with the PN-G-04502:2014-11 standard [14]. The results of the mercury determination performed according to GIG procedure [16] and the determination of the ash which was done in compliance with the PN-ISO1171:2002 standard [15] were provided for the analytical state of the fuel. The results of mercury content are given in $\mu\text{g}/\text{kg}$ (ppb).

Initial results of mercury content in the commercial products of steam hard coal mines and discussion

The results of the determination of the mercury content in the commercial products of steam hard coal mines were provided in four basic product groups. The groups are distinguished by the various degree of coal cleaning and their sales directions. These are in particular:

- coars (coarse sized coals) – coal fully cleaned applying the accessible and currently profitable technologies,
- middles (medium sized coals) – coal fully cleaned applying the accessible and currently profitable technologies,
- smalls – coal mainly raw, or only partially cleaned. In the case of steam coal, as a rule, it cannot be said that the coal in the smalls was cleaned in the full particle size range. In some of the mines of Kompania Węglowa coking coal is produced which was included in the work despite the limitation imposed by the task's name. These are smalls fully cleaned.
- the finest coal with various cleaning degree.

In table 1 data on the structure of hard coal production in Poland is presented. The coars and middles which are sold mainly as heating sources in the municipal sector can be equated to the “other recipients in the country” – and comprise

around 16% of the production of hard coal mines. The smalls are primarily sold to commercial and industrial power industry but also to other recipients – they comprise around 50% of the production of hard coal mines. The remaining product groups, mentioned above, are not fully identifiable with the coal sales targets provided in table 1. The fines enter the market as the fuel addresses to the municipal sector and the sampled parts of coking fuel cannot be identified with the total production of coking coals which is the basic product of JSW S.A (beside the analysis described into this article).

Identification of the hard coal production in Poland, the scope of cleaning, as well as the main sales directions, are of significance from the point of view of estimation of the mercury emissions and assessment of the threats related to these emissions. In practice, there lack regulations on the mercury emissions and the mercury emission reduction methods in Poland dedicated for installations of very small capacity (households and small municipal objects). For large coal combustion plants the mercury emission reduction was identified as the effect accompanying the reduction of emissions of other pollutants: dust, sulphur dioxide, nitrogen oxide. Techniques for reducing mercury emissions dedicated to this pollutant only are already known and applied. The emission is also regulated [17,18].

In the first stage of realisation of the project 183 samples of commercial products of hard coal or its components were obtained from 31 mines including:

- 44 samples of coars (larges, cobbles, nuts),
- 31 samples of middles (peas),
- 72 samples of smalls and their components (excluding fines), including coking coal,
- 30 samples of the finest coal fines, in many cases the components of smalls,
- 6 samples of other components of commercial products coals, mainly the middlings from coal cleaning.

Figures 2, 4, 6, 8 present the distribution of mercury content determined in samples of various sized coals and their components. All the empirical distributions of mercury content describe the distribution of the relative frequencies expressed in %. Figures 3, 5, 7, 9 present the distribution of ash content in samples of various sized coals and their components as the parameter characterizing the quality of coal. Additionally table 2 presents the selected numerical values which characterize the distribution of mercury and ash in the respective assortments. The above, allow to conduct analyses of the distribution of mercury content in relation with the analysis of the quality of coal.

The distribution presented on figures 2-9 shows similarities and differences in the comparison. In the case of the coars and middles population we are dealing with narrower variability intervals of ash and mercury content than in the case of the other analysed populations.

Mean average of the mercury content in the population of coars equals 74 µg/kg and 50% of the results fits into the interval (1st and 3rd quartile): 47- 92 µg/kg. Over 80% of the results do

Tab. 1. The sales structure of hard coal produced in Poland in 2012 and 2013 [13].

Tab. 1. Struktura sprzedaży węgla kamiennego produkowanego w Polsce w latach 2012-2013 [13].

Specification		Coal sales in 2012.		Coal sales in 2013.	
		million tons	%	million tons	%
Total sales		71,17	100,0	75,74	100,0
Domestic sales		63,79	89,6	65,28	86,3
of which:	to commercial power industry	35,36	49,7	35,65	47,1
	to industrial power plants	1,48	2,1	1,76	2,3
	to industrial and municipal heating plants	5,56	7,8	4,44	5,9
	to other industrial recipients	0,43	0,6	0,57	0,8
	to coking plants	9,77	13,7	10,36	13,7
	to other domestic recipients	11,19	15,7	12,49	16,5
Export		7,38	10,4	10,46	13,7

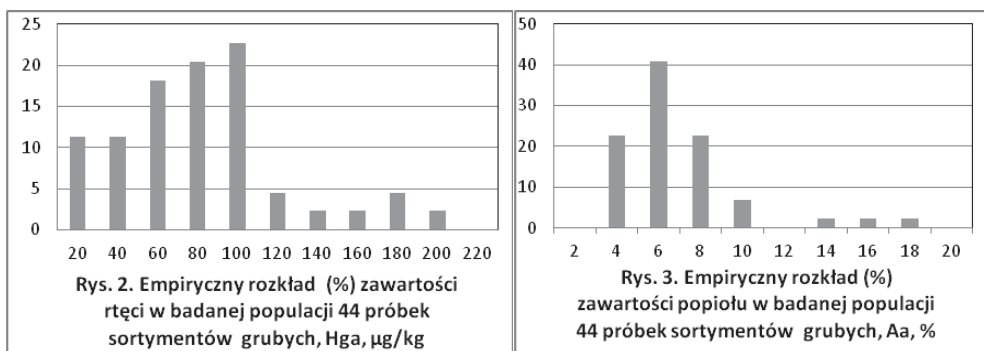


Fig 2. Empirical distribution (%) of the mercury content in the analysed population of 44 samples of large-size assortments, Hga, µg/kg.

Fig 3. Empirical distribution (%) of the ash content in the analysed population of 44 samples of large-size assortments, Aa, %

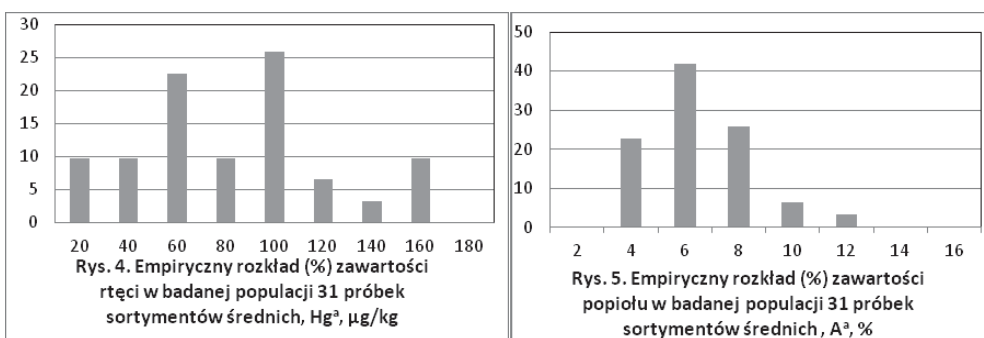


Fig.4. Empirical distribution (%) of the mercury content in the analysed population of 31 samples of medium-size assortments Hga, µg/kg.

Fig.5. Empirical distribution (%) of the ash content in the analysed population of 31 samples of large-size assortments, Aa, %.

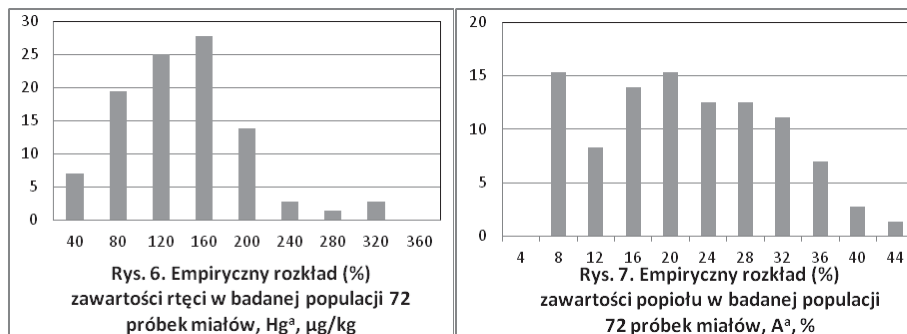


Fig. 6 Empirical distribution (%) of the mercury content in the analysed population of 72 samples of smalls, Hga, µg/kg.

Fig. 7. Empirical distribution (%) of the ash content in the analysed population of 72 samples of smalls, Aa, %.

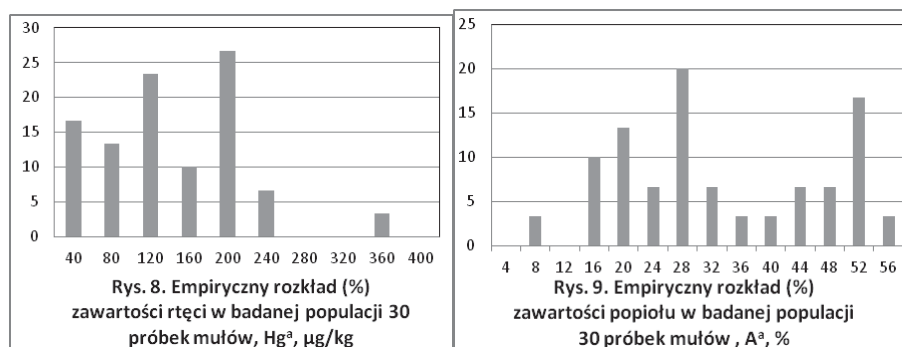


Fig 8. Empirical distribution (%) of the mercury content in the analysed population of 72 samples of fines, Hga, µg/kg.

Fig 9. Empirical distribution (%) of the ash content in the analysed population of 72 samples of fines, Aa, %.

Tab. 2. Selected numerical values which characterise the distribution of mercury and ash in the respective assortments

Tab. 2. Wybrane wartości liczbowe, charakteryzujące rozkłady zawartości rtęci i popiołu w poszczególnych sortymentach

Sized coals	No. of samples	Mean value		1st and 3rd quartile	
		Aa, %	Hg, µg/kg	Aa, %	Hg, µg/kg
coars	44	< 6	74	4,1 – 6,8	47 - 92
middles	31	< 6	79	4,2 – 6,7	46 - 98
smalls	72	20	121	13 - 27	80 - 157
The finest coal	30	31	129	20 - 44	75 - 181

not exceed 100 µg/kg. In the case of the population of the samples of the middles the mean average equals around 79 µg/kg, and 50 % of the results lies in the interval (1st and 3rd quartile): 46 – 98 µg/kg. Almost 80% of the results does not exceed 100 µg/kg.

Mean average of the mercury content in the population of smalls equals around 121 µg/kg and 50% of the results fits the interval (1st and 3rd quartile): 80-157 µg/kg. The range of the values of the mercury content is significantly broader here. In some of the smalls' samples values up to above 300 µg/kg were determined. Only around 40% of the results do not exceed the value of 100 µg/kg. In case of the population of fines, the mean average of mercury content equals 129 µg/kg and 50% of the results fits the interval (1st and 3rd quartile): 75-181 µg/kg. Only 40% of the results do not exceed the value of 100 µg/kg. The mercury content of above 360 µg/kg in one of the samples was determined.

The indicated difference in the mercury content and its distribution chiefly result from the degree of cleaning of the coals represented by the analysed sample populations. The coars and middles are the cleaned coals and thus the variability of characteristics of these coals is narrower, including the mercury content. This is confirmed by the results of analyses of the ash content in the samples of these sized coals and the analysis of the distribution of the population of the ash content results. Mean ash content in the coars and middles amounts to below 6%, and the maximal value does not exceed 17%. 50% of the results falls into the interval (1st and 3rd quartile): 4.1 – 6.8% - coars and 4.5 – 6.7% - middles. The range of the determination results of the ash content equals around 14 percent points in the case of the coars and only around 8 percent points in the case of medium sized assortments.

Smalls and fines are the cleaned coals, raw coals and their blends. Thus the mean ash content in the smalls equals around 20%, and the maximal value exceeds 40%. The range of the determination results is also very large and equals around 31 percent points. For the fines the mean ash content equals 31% and the maximal value reaches 50%. The range of the de-termination results equals around 50 percent points.

Conclusions

1. The current results of the Baza Hg Project indicate that the cleaning has significant impact on the mercury content in Polish commercial steam hard coals. The coars and middles which are fully cleaned are characterised with smaller mercury content than the other analysed sized coals with high participation of the raw coal.

2. Mercury content in the cleaned sized coals concentrate around mean values which equal 74 µg/kg in the case of large-size assortments and 80 µg/kg in the case of the medium size assortments. In over 80% of the cleaned assortment samples the mercury content was smaller than 100 µg/kg.

3. The small mercury content in the coars and middles are very beneficial from the point of view of mercury emissions to the atmosphere. Those coals are combusted in boilers of small and very small power (i.e. heating of individual buildings), where it is difficult to expect implementation of mercury emission reducing installations.

4. The remaining products, in particular the smalls are characterised by slightly higher mercury content. Mean mercury content in smalls equals 121 µg/kg, and in fines 129 µg/kg. They are most often combusted in large industrial installations, equipped with diversified "protective" installations. These installations are required due to the emission limits for other pollutants such

as: dust, sulphur dioxide, nitrogen oxides etc. In practice those installations also limit the mercury emissions – the so called “accompanying effect”.

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The elaboration of a data base on mercury content in domestic coal, technological guidelines of the further mercury reduction, including the defining of benchmarks for domestic indices of mercury emission” – acronym “Baza Hg”, (PBS2/A2/14/2013). The authors would like to thank the staff of the coal quality assessment departments of the respective mines for their cooperation in obtaining the samples.

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Literatura - References

1. Białecka B., Michalska A., 2012, Mercury content in coal and the mining waste. *Prace Naukowe GIG, Górnictwo i Geoinżynieria* 3, p. 73–87 (in Polish).
2. Best Available Techniques (BAT) Reference Document for the Large Combustion Plants. Draft 1 (June 2013), http://eippcb.jrc.ec.europa.eu/reference/BREF/LCP_D1_June_online.pdf
3. Canadian Council of Ministers of the Environment. Canada-Wide Standards for Mercury Emissions http://www.ccme.ca/files/Resources/air/mercury/hg_epg_cws_w_annex.pdf
4. Carter L.D., 2014, Regulatory and other challenges to coal use in the USA. United States Carbon Sequestration Council, IEA Clean Coal Centre, April 23.
5. Central Statistical Office of Poland. Protection of the Environment 2012, Warszawa 2012 (in Polish).
6. Central Statistical Office of Poland. Protection of the Environment 2013, Warszawa 2013 (in Polish).
7. <http://www.mercuryconvention.org/Convention/tabid/3426/Default.aspx>
8. http://www.mos.gov.pl/artykul/7_archiwum/23417_polska_podpisala_konwencje_w_sprawie_rtoci.html
9. Kłojzy-Kaczmarczyk B., Mazurek J., 2013, Studies of Mercury content in selected coal seams of Upper Silesian Coal Basin. *Gospodarka Surowcami Mineralnymi, Volume 29, Periodical 4*, p. 95–106 (in Polish).
10. Communication from the Commission to the European Parliament and the Council on the review of the Community Strategy Concerning Mercury. Brussels, 7.12.2010, COM(2010) 723 (final).

11. *Communication from the Commission to the European Parliament and the Council on Community Strategy Concerning Mercury. Brussels, 28.01.2005, COM(2005) 20 (final).*
12. *Paczosa A., 2014, Mercury emissions to air. Conference "The mercury issues in Poland in view of the new global regulatory solutions.". Polish Ministry of the Environment, Warszawa 20 October 2014 (in Polish).*
13. *Paszczka H., Pitura K., 2014, Hard coal mining in Poland in 2013. Wiadomości Górnicze 6, p. 314–324 (in Polish).*
14. *PN-G-04502:2014-11 Hard coal and lignite – Sampling and preparation of the samples for laboratory tests (in Polish).*
15. *PN-ISO 1171:2002 Solid fuels – Determination of ash. (in Polish)*
16. *Procedure SC-1.PB.23 (edition 4 dated 27.02.2012) accredited method for determining the mercury content Hg applying the cold-vapor atomic absorption spectrometry (CVAAS) (in Polish).*
17. *Sloss L. L., 2012, Legislation, standards and methods for mercury emissions control. CCC/195. London, UK, IEA Clean Coal Centre.*
18. *Sloss L. L., 2015, The emerging market for mercury control. CCC/245. London, UK, IEA Clean Coal Centre.*
19. *Werner G., Głowacki E., 2014, Actual level of mercury emissions from energy combustion of fuels in Poland between 2010 – 2014. Conference „Issues related to mercury in Poland in view of New global regulatory solutions: Polish Ministry of the Environment, Warszawa 20 October 2014 (in Polish).*
20. *Wichliński M., Kobyłecki R., Bis Z., 2013, The investigation of mercury content in Polish coal samples. Archives of Environmental Protection. Vol. 39 no. 2, p. 141–150*
21. *Wojnar K., Wisz J., 2006. Mercury in Polish Energy Sektor. Energetyka, 4, p. 280–283 (in Polish).*

Wstępne wyniki projektu „BazaHg” w zakresie zawartości rtęci w produktach handlowych kopalń węgla kamiennego

Konsorcjum 4 podmiotów uzyskało finansowanie i realizuje projekt „Opracowanie bazy danych zawartości rtęci w krajowych węglach, wytycznych technologicznych jej dalszej redukcji wraz ze zdefiniowaniem benchmarków dla krajowych wskaźników emisji rtęci” – akronim „Baza Hg”, w ramach II konkursu Programu Badań Stosowanych Narodowego Centrum Badań i Rozwoju. W artykule opisano genezę powstania projektu, cele realizacji projektu oraz zadania badawcze, zaplanowane dla ich osiągnięcia. Przedstawiono i omówiono wyniki pochodzące z pierwszego roku realizacji projektu, dotyczące zawartości rtęci w wybranych grupach sortymentów węgla handlowych do celów energetycznych w powiązaniu ze stopniem ich wzbogacenia.

Słowa kluczowe: rtęć, węgiel kamienny do celów energetycznych, produkty handlowe, projekt Baza Hg