TECHNICAL TRANSACTIONS | CZASOPISMO TECHNICZNE
CHEMISTRY | CHEMIA
1-Ch/2015

HALINA MACHOWSKA*

POWER INDUSTRY – COAL ECOLOGY

ENERGETYKA – WĘGIEL-EKOLOGIA

A b s t r a c t

In this work, the fuel structure of electric energy production is presented, and also the coal-based power industry influence on the environment, greenhouse effect, mercury emissions from coal burned by power stations. EU requirements regarding limits of mercury emissions, as well as methods and techniques enabling reduction of mercury emissions originating from coal burning processes.

Keywords: coal, mercury content in coal, mercury emissions, power industry, ecology

S t r e s z c z e n i e

W pracy przedstawiono: strukturę paliwową wytwarzania energii elektrycznej, wpływ energetyki, bazującej na węglu na środowisko naturalne, efekt cieplarniany, emisję rtęci z energetycznego spalania węgla, wymogi Unii Europejskiej w zakresie ograniczenia emisji rtęci, metody i technologie pozwalające na obniżenie emisji rtęci z procesów spalania węgla.

Słowa kluczowe: węgiel, rtęć w węglu, emisja rtęci, energetyka, ekologia

DOI: 10.4467/2353737XCT.15.106.4054

* Ph.D. Eng. Halina Machowska, Institute of Chemistry and Organic Technology, Faculty of Chemical Engineering Technology, Cracow University of Technology.

1. Introduction

For the second half of the XXI century, one should expect serious changes in the structure of natural fuels consumption, resulting from their availability. Fossil fuel, especially coal, will dominate as a result of a constantly growing world demand for electrical energy. Coal is the only raw material ensuring fulfillment of energetic demands for about 200 years, as crude oil resources will be exhausted after about 45 years and natural gas resources after about 60 years. Currently, many EU countries are obtaining electrical energy from coal because of its local availability. Exhausting of natural resources of hydrocarbons could be significantly accelerated, taking into consideration a serious increase in demand for natural energy carriers, mainly in Asian countries, e.g. China and India. This is the main reason for the return to using the most diffused energetic raw material in the world – coal [1].

2. Coal Merkury Emission

Hard coal and brown coal are the warranty of Polish energetic safety.

The structure of electrical energy production in Poland is as follows: hard coal – 56%, brown coal – 36.9%, gas – 2.9%, renewable energy sources – 4.2%.

The structure of coal consumption in Poland is as follows: power industry – 54%, coking plants – 14.2%, heating engineering – 13.5%, food processing industry – 8.2, households 10.1% [2].

The increase in demand for final energy in Poland, till the year 2030, will amount for about 45%, and for primary energy of about 35%.

In Poland, professional electric power engineering is responsible for the emission of: CO_2 of about 45%, SO_2 – 55%, NO_x – 30%, dust 10% [3].

The production of 1 kWh of electric energy is accompanied by the release to the atmosphere of about 1000 grams of CO_2, 8÷12 grams of SO_2, 3÷4 grams of NO_x.

The fuel structure of 15.8 GW of electric energy production in Polish Energy Group (PGE) for 2020 year is as follows: brown coal – 56%, hard coal – 18%, gas – 15%, renewable energy sources (RES) – 11%; for year 2035 with 21.3 GW of energy: brown coal – 33%, hard coal – 5%, gas – 11%, RES – 14%, nuclear energy – 37% [4].

The main source of mercury emitted to the atmosphere as a result of human activities is burning of fossil energetic raw materials, and especially coal, responsible for 45% of total mercury emissions, further 18% is connected to gold extraction from rocks and gold-dust. Two-thirds of total global mercury emissions come from Asia, mainly from China. In China and India, the main mercury sources are coal burning power stations, however, in South Africa mercury emission sources are gold mines.

The condition of coal share increase as energetic and chemical raw material is the introduction of clean coal technologies. It requires greater cost and solution of difficult technical problems – removing, storing and utilization of CO_2 from off-gases and processes.

Poland, after entering the EU, was obliged to transform the Polish power industry in order to meet guidelines given by the Commission Communication for the Council and European Parliament – Union Mercury Strategy – Brussels 28-01-2005. One of the main sources of mercury release is coal burning. Coal burning in power stations above 50 MW was defined in IPPC Directive (Integrated Pollution Prevention and Control), Council Directive 96/61/WE of 24-09-1996. IPPC Directive regarding integrated pollution prevention and control is the key instrument for mercury and other substances harmful to the environment.

Guidelines describing the best available technologies for individual industry branches contain so called *reference documents* (BREF – BAT – *Beat Available Technology*). For large burning sources, BREF defines that, taking into consideration the reduction of heavy metals share in flue gases from coal burning, the best control level can be achieved by the application of fabric filters (FF) and electrostatic precipitators (ESP) together with the processes of flue gases desulfurization (FGD). In order to reach further reduction in mercury emissions, it is recommended to practice mercury oxidation and adsorption on appropriate materials. An emissions level below 0.05 mg/m^3 is considered as one of the best for currently available technologies.

According to BAT, the reduction of the mercury emissions in the case of hard coal burning should amount to 70÷98%, and for brown coal 30÷70%. Lower admissible mercury emission reduction in the case of brown coal burning results from lower coal content in ashes formed during brown coal burning and higher mercury content in flue gases [5].

In Europe, mercury level in the air is below a value that influences human health, they are not in the Directive regulations regarding mercury.

Mercury is a natural coal component and occurs mainly with pyrite FeS_2, usually as a bivalent mercury forming complexes with humus substances or ferric sulfides [6]. Brown coal burning results in higher mercury emissions into the atmosphere than hard coal burning. During burning, the mineral substance undergoes profound physical and chemical transformations leading to slugs and fly-ashes. Mercury emitted to the atmosphere occurs as elementary mercury adsorbed on small dust particles and in a gaseous form. In the atmosphere, mercury can spread for very long distances (hundreds of kilometers).

The results of research works [6] show that mercury content in hard coals and brown coals exploited in Poland were in the range of several to several hundred ppb. Its average content in coal was: in Low Silesia deposits – 399 ppb, in Lublin deposits 105 ppb and in High Silesia deposits (the lowest mercury content) – 60 ppb.

Average mercury contents in brown coal were higher than mercury content in hard coal. Investigated brown coal deposits contained from a few dozen to over 1000 ppb, and its average content was 322 ppb and was several times higher than its content in hard coal. The highest average mercury content was found in brown coal from Bełchatów deposit – 416 ppb, and the lowest from Lubstów deposit – 199 ppb.

Mercury content in waste rocks, accompanying coal in deposits, was close to the mercury content in coal. The average mercury content in waste rocks found in investigated coal deposits was 129 ppb. Mercury content in waste rocks in brown coal deposits was lower than mercury content in coal samples. Average mercury content in investigated waste rocks accompanying brown coal deposits was 97 ppb – considerably lower than in coal, and also considerably lower than in waste rocks accompanying hard coal deposits.

Investigation of coals used in Polish power stations [7] showed that average mercury content in hard coal was in the range of 50 to 150 ppb, and in brown coal 120 to 370 ppb, which means that mercury quantity introduced with brown coal for burning in professional power stations is about three times greater than of that introduced with hard coal. During coal burning, mercury gathered mainly in fly-ashes, and some minor quantities in slug. When burning hard coal, the mercury amount in fly-ash was in the range of 130 to 1000 ppb, and in slug 2 to 30 ppb. When burning brown coal, the mercury amount in fly-ash was in the range of 130 to 1400 ppb, and in slug 15 to 90 ppb. These different levels of mercury emissions are caused by different amounts of mercury in different coals, and moreover, greater share of ash in coal causes greater mercury content. Also, different emissions level may depend on the type of furnace used: pulverized-fuel boiler, fluidized, stoker fired, and also of equipping boiler with dust extraction plants: electro-filters, bag filters and desulfurization plants incorporated into flue-gases stream [7].

Mercury emitted as a result of coal burning has a form of metallic mercury Hg^0, oxidized mercury Hg^{+2} and mercury bounded to Hg ash. Both mercury forms Hg^0 and Hg^{+2} have different physical and chemical properties and for this reason they react differently in flue-gases and in the atmosphere. Such a behavior imposes selective treating of each form. Metallic mercury Hg^0 is a durable form, volatile, of low solubility in water and easily spreadable in the atmosphere for long distances. Oxidized mercury Hg^{+2} is a form soluble in water and quickly undergoes wet or dry deposition.

In technical literature, there is relatively little data regarding Hg^{+2} compounds. Generally, it is assumed that $HgCl_2$ dominates, however, it also could be HgO, $HgSO_4$.

Coal enrichment before burning process, especially removing of pyrite, dust removing and gas cleaning can considerably lower harmful substances emission, generated in the burning process, including mercury.

Values of heavy metal emission into the air, determined in Poland for year 2010 show that comparing with year 2009 emissions, took place an increase in global Poland mercury emissions of about 4.4%. This slight increase in mercury emissions was caused, first of all, by a greater consumption of hard coal and brown coal in burning and industrial processes. So, the share of the greatest sectors of Polish economy in mercury emissions in 2010 year, together with Selected Nomenclature for Air Pollution (SNAP) codes, classification of pollutants emission sources is as follows [8]:

SNAP code 01, 59.1% – burning processes in the sector of energy production and transformation;
SNAP code 02, 12.0% – burning processes outside industry;
SNAP code 03, 23.4% – burning processes in industry;
SNAP code 04, 5.3% – production processes;
SNAP code 09, 0.2% – waste management.

Comparison of total emissions for 2010 and 2009 years is as follows:
Hg 104.43% (2010 y. 14.846 metric tons and 2009 y. 14.216 metric tons).
Total Hg emissions 2010/2009 slightly increased to 104.43%.

As an example, emission values for SO_2 and NO_x are also presented:
$SO_2$112.99% (2010 y. 973,586.864 metric tons and 2009 y. 861,682.310 metric tons);
NO_x 105.44% (2010 y. 866, 807.452 metric tons and 2009 y. 822,093.748 metric tons).

3. Climate and Energy package

On 23 January 2008, the European Commission presented a package of documents, so called the climate and energy package.

In Poland, problems with climate politics aroused in year 2008, when the European Commission started to push reduction goals, taking as a base the year 2005. Such an approach completely omits reductions introduced in Poland in the last decade of 20th century. Moreover EU forced tightening of climate politics in 2010 year, by introducing new emission accounting system in energy consuming industries, disadvantageous for coal, namely by rising emission prices on the permit market (so called *backloading*).

At present, the climate and energy package is also becoming problematic in other countries. Representatives of all energy-consuming industry branches (paper, glass, steel and chemical industries) think that climate politics is the main cause of high energy prices and a loss of competitiveness. In a time of depression, it is more and more important, but it seems that economic situation for changes could arise; for example, reduction of carbon dioxide emission in Germany was blocked, for new cars produced mainly in Germany [9].

Common European Union energy politics heads towards ensuring, for a long period, energetic safety and energy production abiding rules of sustainable development.

Basic trends of new energy politics are as follows:

– Up to year 2020, share of renewable energy should amount to 20% (average) and should be accompanied by a 20% decrease of carbon dioxide emission, as well as a 20% increase in average efficiency of electrical energy production in EU countries.
– Up to year 2030, production of electrical energy will be based on sources not generating carbon dioxide emissions, and power stations using coal will be forced to remove it and to sequestration.
– By 2050, only non-emitting power stations will be allowed to operate, using mainly hydrogen, renewable fuels and nuclear synthesis.

Eurostat (European Statistical Office) data show that, in 2011, carbon dioxide emissions in Germany *per capita* was higher than in Poland and amounted to 9.976 metric tons, in comparison with 8.573 metric tons in Poland. It was only slightly lower in Great Britain, and average value *per capita* in EU was 7.92 metric tons. In 2012, Germany emitted to the atmosphere 2% more carbon dioxide than in 2011, and in 2013, its emissions was still greater. In Poland, carbon dioxide emissions gradually decreasing.

In Poland, power engineering is based on coal and, for this reason Poland, is criticized, but on the other hand, coal consumption in Germany shows a rising tendency. Brown coal share in energy production in year 2012 rose in 2012 to over 25% in comparison with 22.7% two years earlier. Share of hard coal also rises and many new energy producing investments based on coal are underway. The greatest carbon dioxide emitters – China, United States of America and Russia, taking into account only their economic development, do not accept obligations regarding emissions reduction.

Imposed by EU reduction of carbon dioxide emissions, according to Polish Chamber of Commerce estimation could lead to the rise of electric energy prices in Poland by 35%, already in 2020 year, and to serious drop of Polish industry competitiveness [10].

4. Conclusions

The International Energy Agency claims that, in the oncoming decades, the world will not be able to satisfy its demand for energy without coal. Thanks to new technologies, coal will be more and more of an ecological energetic raw material.

EU climate and energy politics discriminate coal and have nothing against the use of crude oil, although, fuels produced from crude oil are responsible for nearly the same amount of carbon dioxide emissions (car off-gases constitute 65% of all the air pollutants in EU).

These fuels are burned in cars with very low effectiveness, because for the propulsion they use only 1% of energy contained in gasoline or diesel oil. In coal burning power stations, this index is at present between 35% and 45%, which is possible due to modernization of existing power units and the construction of new ones, and as a result of the introduction of new technologies, so called units of supercritical and extrasupercritical parameters.

The main task of recently introduced technologies called "clean coal technologies" and of new methods of energy production from coal is rising the effectiveness of coal power units and reduction of harmful to the environment carbon dioxide, dusts and gases emissions. These new methods and technologies include: pulverized fuel boilers, fluidized boilers, off-gases desulfurization and denitriding units, burning coal together with biomass, burning in an oxygen atmosphere or in the air with a higher oxygen content, coal gasification and underground coal gasification, nuclear-coal synergy, and finally, carbon dioxide capturing and storing with CCS (Carbon Capture and Storage) method. This method arises many doubts because it is unprofitable and markedly lowers energetic effectiveness of power units. Moreover, there is no certainty that carbon dioxide pumped under soil will not negatively influence the environment.

To the goals of climate-energy politics declared by European Commission till 2030 belong, among others, postulates of greenhouse gases emissions reduction by 40% and increase by 30% the use of Renewable Energy Sources – jointly, for all EU countries, and also an obligatory increase by 40% of the energetic effectiveness. Experts of the Polish Chamber of Commerce or Central Europe Energy Partners claim that the adoption of such rigorous goals of emissions reduction and increase of *green energy* share (this type of energy is at present three times more expensive than energy received from coal burning) will cause drastic increase of 1 MWh prices – even by 100%. Final result of such politics will be the relocation of plants to countries which did not adopt the emissions limits, like USA, where the price of gas is the basis for 60% of energy used in USA, it is five times lower [11]. The European Union is responsible for only 12% of global carbon dioxide emissions and the EU reduction plans, without similar decisions of other countries, will not contribute to climate improvement, and what's worse, it will cause the EU economy to be less competitive.

References

[1] Ściążko M., *Conditions of implementation of zero-emissions coal technologies in power engineering*, 2007, Zabrze, Ed. IChPW (Institute of Chemical Coal Processing).
[2] Szczepaniuk M., Dziennik Gazeta Prawna, 2013-07-29.
[3] Polityka Energetyczna Polski do 2013 r. (Polish Energy Politics till 2013).
[4] Szczepaniuk M., Dziennik Gazeta Prawna, 2013-05-09.
[5] Reference Document on BAT for the Large Combustion Plants, Seville-Spain, 2003.
[6] Bojakowska I., Sokołowska G., Bulletin of Polish Geological Institute, 2001, 394, 5–54.

[7] Wojnar K., Wisz J., Energetyka (Power Engineering), 2006, 4, 280–283.
[8] www.kobize.pl, Polish Centre of Emissions Balancing and Management, 2014.
[9] Szymański K., Rzeczpospolita (newspaper), 2013-07-16.
[10] Arendarski A., Rzeczpospolita (newspaper), 2013-11-19.
[11] Rzeczpospolita (newspaper), 2014-02-06.