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The mercury analysis in airborne particles emitted from coal-combustion processes

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Determination of trace elements in combusted materials has always been an interesting field of environmental studies. Particulate matter, in particular, is a serious problem which, can lead to air pollution especially by heavy metals emissions in urban and industrial areas. There is a considerable concern about the elevated level of mercury released during combustion and the proportion of anthropogenic mercury in the environment. Nowadays, small-scale installations have been identified as a significant source-pathway for mercury pollution, particularly those that use coal. A total amount of mercury was determined using Mercury Analyzer. The investigated material consists of bottom ash, fly ash, slag, soot or dust. The obtained results varied according to the type of the material and plant. The developed methodology was checked by carrying out the analysis of certificate material of Soil NCS ZC 73001 and the reference material of Soil-7.

Keywords: mercury, coal-combustion, mercury analyzer, ash.

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INTRODUCTION

The largest known single sources of mercury directly released into the atmosphere by smokers are coal-burning power plants, which possess threat to human health or environment. It is especially common in the case of plants with insufficient mercury removal systems. Unfortunately, air pollution controls are designed particularly for sulphur and other contaminants from utility stacks. Even some amount of this toxic element is emitted during combustion of wastes and the cleaning process of coal from impurities that affect combustion before burning at power plants. Additionally, each year a significant content of Hg is released into the atmosphere by being dumped into landfills or setting ponds or being involved in the production of road building material like cement or wallboard. Mercury is an extremely volatile metal, for that reason it can be transported over great distances after its penetration into the atmosphere, which makes it more toxic and hazardous. After Hg is spewed into the air it never disappears in the environment, causing long-term problems. So even a relatively tiny amount can be dangerous to humans, animals, plants and environment. The remaining amount of Hg is released in fly ash, bottom ash, boiler slag or scrubber waste.

Among the European countries Poland remains the country with the highest amount of Hg emitted from power plants. It is a problem which needs to be resolved and demands immediate actions, which have to be initiated. Generally, the quantity of mercury deposited directly downwind of the plant is affected by the height of stack, amount of rainfall and the form of Hg being released. EPA assessed, basing on the modeling data, that up to 15% of utility's Hg stack emissions can be deposited within 30 miles of the plant. In other studies authors estimated 50% fall within 600 miles[1 – 4].

The aim of this study was to determine the content of mercury in different ashes emitted by coal-fired power plants and other companies as well as to compare the results of mercury amount released from different pollution sources in order to collect the information about the quality of air pollution controls.

Using the recently collected samples from different sampling sites we estimated the influence of mercury emissions from power plants and other companies combusting materials and wastes. The samples were grouped by plant type and the combusted material.

MATERIAL AND METHODS

The samples were collected from different plants located in the Lodz region (power plants, incinerating room in hospitals, boiler room in hospitals), including furnaces in private houses. A detailed characteristic of the analyzed material is presented in Tab.1. The samples were grinded in the agate mortar before the analysis. The investigated material included the samples of fly ash, bottom ash, slag, soot, or dust (formed in the process of the desulfurization of combustion gas) and the particles formed as a result of the coal combustion process. The total Hg content was determined by Mercury Analyzer MERCURY SP-3D, Nippon Instrument Corporation. Each sample was determined three times. The accuracy of the applied method was verified by the analysis of certificate material of Soil NCS ZC 73001 and the reference material of Soil-7 and a good agreement was achieved (Tab.1.). In Tab.1. a statistical evaluation of CRM and RM is presented and expressed as mean ± RSD [ng g^{-1}].

Table 1. The results from the measurements of the certificate material of Soil NCS ZC 73001 and the reference material of Soil-7.[ng g^{-1}], (U-uncertainty)

Certificate Material	Certificate ± U	Experimental ± RSD	Recovery [%]
Soil NCS ZC 73001	33 ± 0,004	34,2 ± 0,5	103,6
Soil-7	40* (30 – 70)	42 ± 3	105,0

*95% confidence interval

Table 2. The average content of mercury in different combusted materials. [ng g^{-1}]

No	Sample	Source	Average content of mercury ± RSD [ng/g]
1	Dust from filters collected, formed in the process of desulfurization of combustion gas	Power plant, Kutno	2000 ± 85
2	Smoke-black from coal combustion	Power plant, Kutno	2200 ± 140
3	Slag	Power plant, Kutno	56 ± 5,2
4	Ash from filters collected	Hospital- boiler room, Kutno	650 ± 56
5	Slag	Hospital- boiler room, Kutno	130 ± 17
6	Ash from filters collected	Hospital- incinerating room (combustion of medical wastes, Kutno	10 007 ± 120
7	Ash from cyclone collected	Power plant, Kutno (coal delivered from Brzeszcze coal-mine)	470 ± 45
8	Ash from cyclone collected	Power plant, Kutno (coal delivered from Janina coal-mine)	470 ± 45
9	Ash before filter	Power plant, Gostynin	6680 ± 200
10	Slag	Power plant, Gostynin	50 ± 5,0
11	Ash from filters collected	Power plant, Gostynin	830,6 ± 60
12	Ash from filters collected	Power plant, Gostynin	1439 ± 45
13	Ash from cyclone collected	Power plant, Gostynin	115 ± 15
14	Bottom ash	Power plant, Lodz, EC-2	58 ± 2,8
15	Ash before electrofilter	Power plant, Lodz, EC-2	225 ± 24
16	Ash after electrofilter fraction > 10μm	Power plant, Lodz, EC-2	321 ± 32
17	Fly ash < 10μm	Power plant, Lodz, EC-2	440 ± 34
18	Ash before electrofilter	Power plant, Lodz, EC-4	119 ± 23
19	Fly ash < 10μm	Power plant, Lodz, EC-3	331 ± 32
20	Fly ash < 10μm	Power plant, Lodz, EC-4	398 ± 23
21	Coal-ash	Furnaces in private houses, Lodz	68 ± 3,9
22	Ash from combustion of domestic wastes	Furnaces in private houses, Lodz	107 ± 15
23	Smoke-black from coal combustion	Furnaces in private houses, Lodz	2264 ± 98
24	Breeze (coal-dust from stack)	Furnaces in private houses, Lodz	3918 ± 167
25	Smoke-black from combustion of domestic wastes	Furnaces in private houses, Lodz	727 ± 39

RESULTS AND DISCUSSION

Poland is a country where a lot of coal is burned in domestic ovens and small boiler houses. Such small-scale combustion is nearly accounted to 10% of the coal fired, which derives atmospheric Hg emissions. On a global scale the biggest sources of mercury emissions are connected with power plants and residential heating. That situation is observed despite significant reductions in emissions in recent decades. Generally it could be explained by improved control, but also partly due to large decreases in coal consumption. Communication from the Commission to the Council and the European Parliament on Community Strategy Concerning Mecury revealed that Poland still accounted for the largest proportion of Hg emissions[3].

During the combustion of solid substances such as coal or solid wastes some amount of the so-called ballast composed ash, slag, smoke-black and other materials are produced. Their chemical composition depends on the type of the mineral ingredients presented in the solid fuels and control devices used (e.g. filters, cyclones). The investigations reported in this paper were focused on the determination of the total Hg content in different substances after their combustion. The obtained results are gathered in Tab. 2. On the basis of the obtained results we can state that the highest Hg concentrations were noticed for the combustion products of medical wastes. It could suggest not the total combustion process resulting in lower levels of Hg released into the atmosphere. However, we could not exclude that medical wastes can contain more Hg than other investigated material in this work. It should be stressed as well that in the incinerating room only cyclones are used. Relatively low concentrations of Hg and, on the other hand, quite similar ones were found in slag and some samples of fly ashes. It could be attributed to the combustion process carried out at greater temperature causing Hg volatilization to a higher extent.

CONCLUSIONS

The obtained results suggest the necessity to perform the measurements focused on the determination of mercury in ambient air during the combustion process of various materials. The results indicated that the differences in the obtained mercury concentrations may be explained by the type of control devices applied, the material and the temperature of the combustion.

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