

The Influence of Boiler Type, Hg and As Content in Coal on the Content of these Elements in Chimney Soot as a Source of Air Pollution

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Introduction & background

Apart from the main elements (C, H, O, N), coal contains a number of toxic elements including mercury and arsenic. Mercury is a highly toxic heavy metal for which the human body does not demonstrate physiological demand. Hg and As are classified by the US Environmental Protection Agency (US EPA) as hazardous air pollutants. They are also elements with a very high bioaccumulation factor. Moreover, according to the data from the International Agency for Research on Cancer, As has a proven carcinogenic effect. One of the main users of hard coal, apart from the electricity and heat generation sector, is the households sector. Households in Poland burn an average of 10 million Mg of hard coal annually, which is related to a significant emission of toxic elements to the atmosphere estimated at the level of 1.1 Mg / year and 16.9 Mg / year, respectively for mercury and arsenic. The average content of Hg and As in Polish subbituminous coals ranges from 25 to 300 $\mu\text{g}\cdot\text{kg}^{-1}$ and 0 ÷ 40 $\text{mg}\cdot\text{kg}^{-1}$, respectively. International activities aimed at reducing of their emissions to the environment prompted the initiation of research focused on: the determination of their content in the combusted fuels, their behavior in the combustion process and monitoring of their emissions. In the case of home heating boilers, one of the possibilities to reduce mercury and arsenic emission is the use of coals with a low content of these toxic elements and the use of chimney electrostatic precipitators that allow to remove a significant amount of fly ash and soot particles from the exhaust gases and thus Hg and As adsorbed on their surface.

The aim of this work was to determine the influence of the home heating boiler type and the content of mercury and arsenic in the combusted fuel on the content of these elements in the chimney soot, which emitted into the atmosphere constitute a serious source of air pollution forming smog in residential areas.

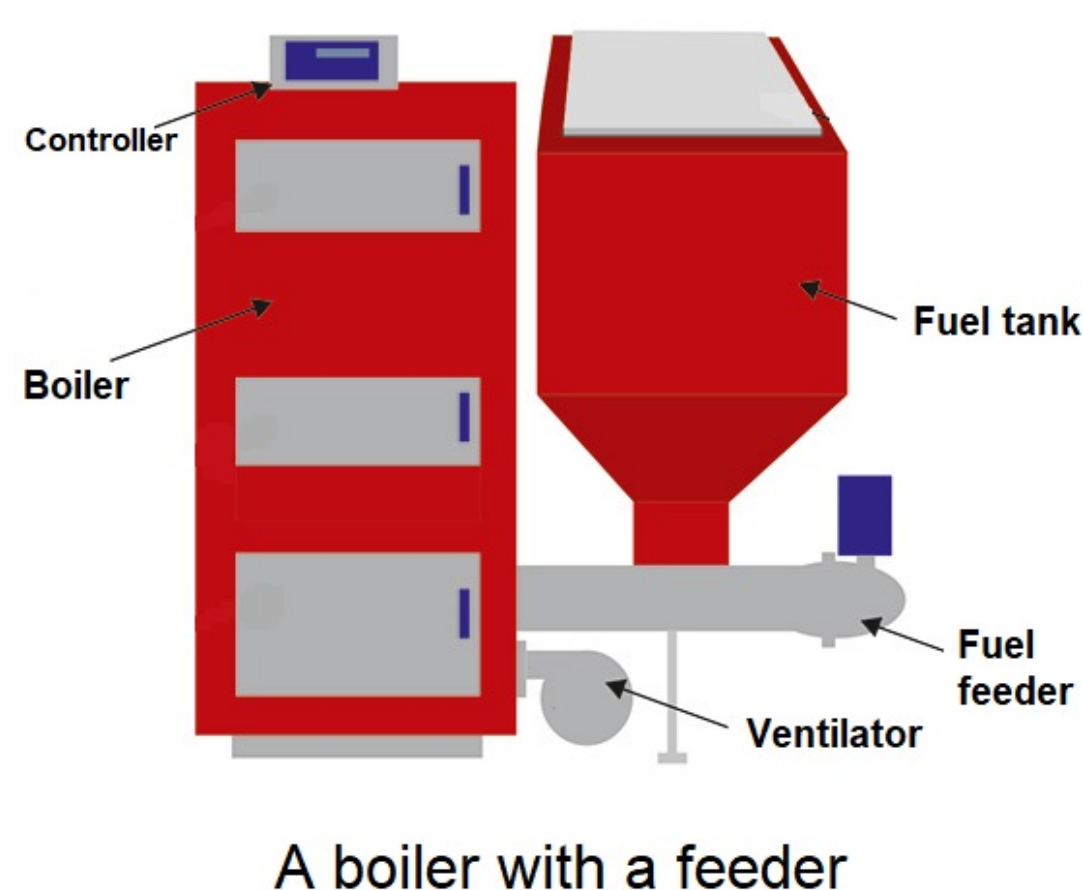


Fig.1. Scheme of a central heating boiler with a feeder

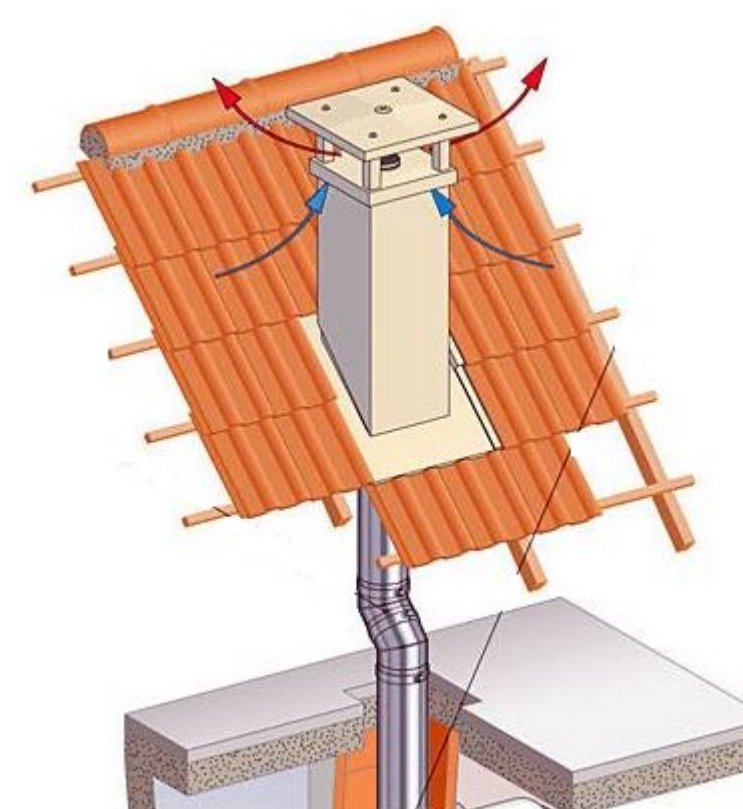
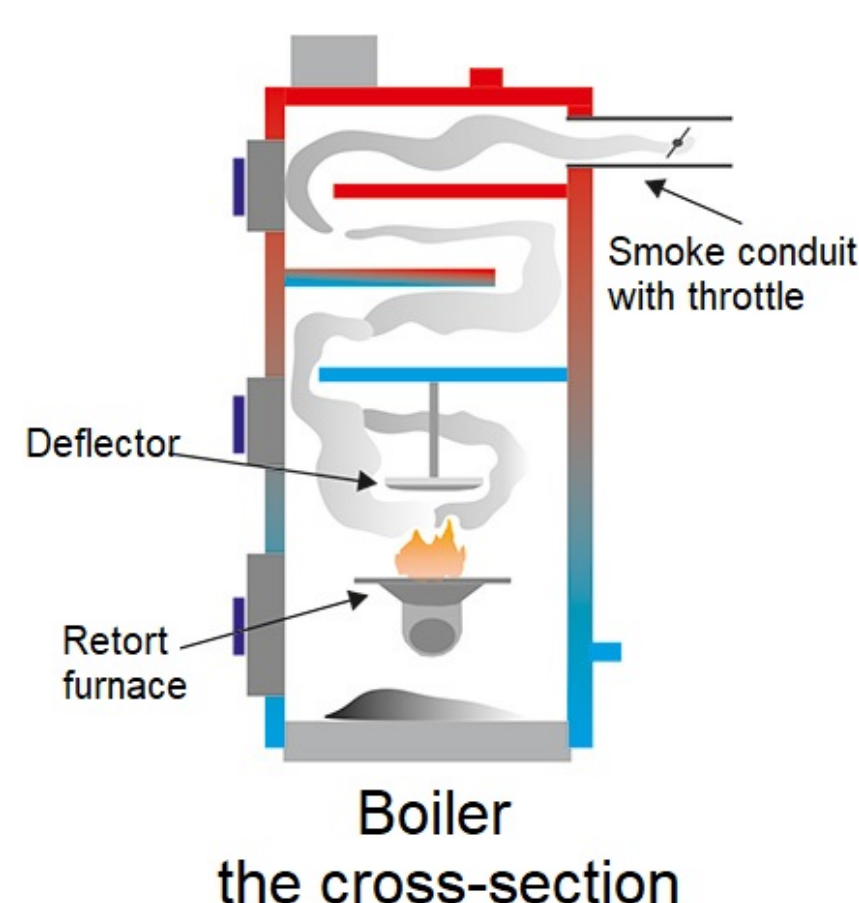


Fig.2. Place of sampling - chimney

Methodology

Samples for testing were obtained from home boilers of various classes, fueled with subbituminous coal (3 boilers) and biomass pellet (1 boiler). Determination of mercury and arsenic content in raw fuels as well as in chimney soot were performed using the DMA-80 analyzer for Hg and Atomic Absorption Spectrometry technique for As. The scope of samples measurements included the proximate and ultimate analysis in accordance with the ISO standard (ISO 17246:2010, ISO 17247:2013).

The high mercury content in chimney soot (Fig. 4) could be explained by both the very good adsorptive properties of soot and the long contact time of soot with the mercury contained in flue gas, even up to a few months. By settling on the chimney walls, soot formed an effective layer of an adsorbent. Furthermore, it was found that As was also adsorbed in large quantities on the surface of chimney soot as well (Fig. 6). On the one hand, adsorbing ecotoxic elements by chimney soot is advantageous, because it reduces emissions into the atmosphere, but on the other hand, this results in its harmful properties to health. Different Hg and As contents in combusted fuels affected the content of these elements in chimney soot (Fig. 3 and 5).

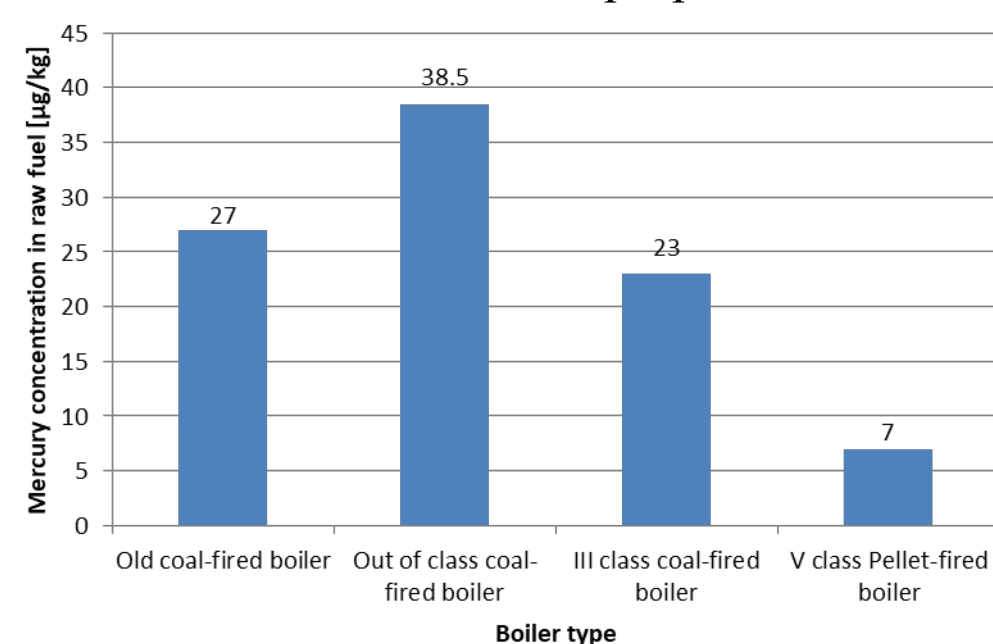


Fig. 3. Mercury concentration in fuel

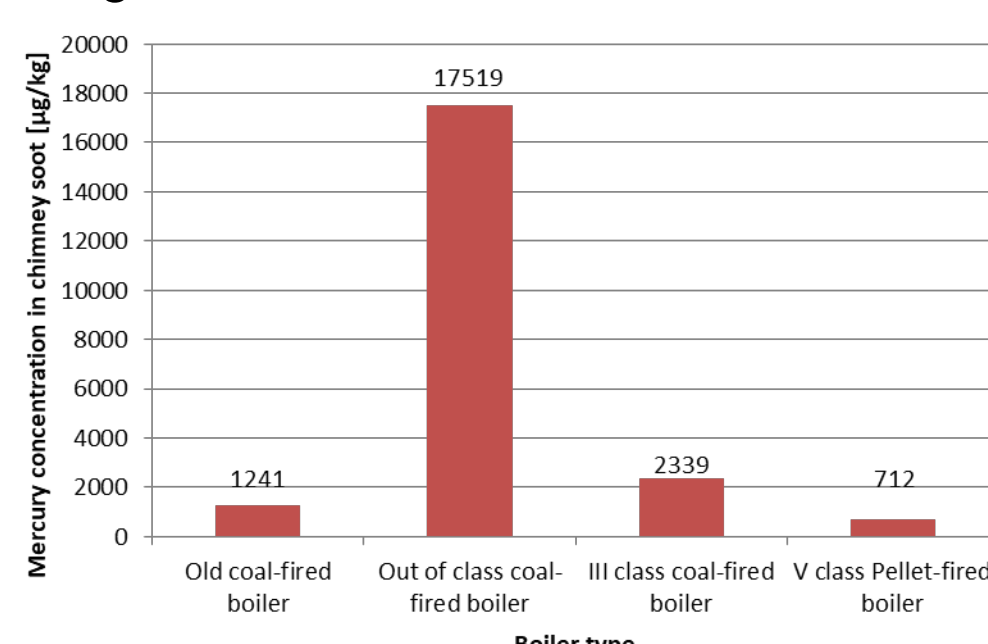


Fig. 4. Mercury concentration in chimney soot

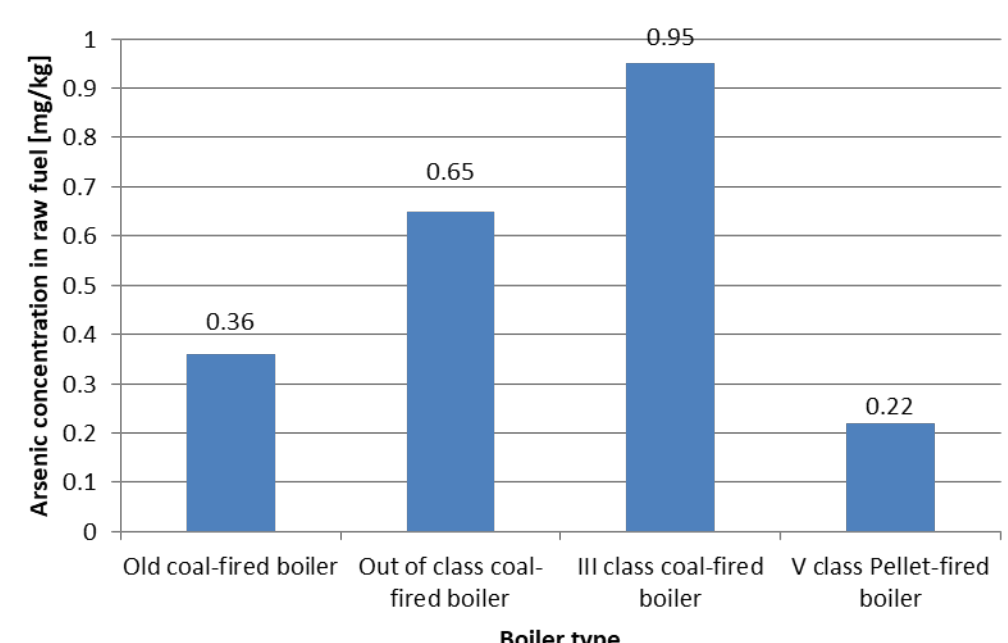


Fig. 5. Arsenic concentration in fuel

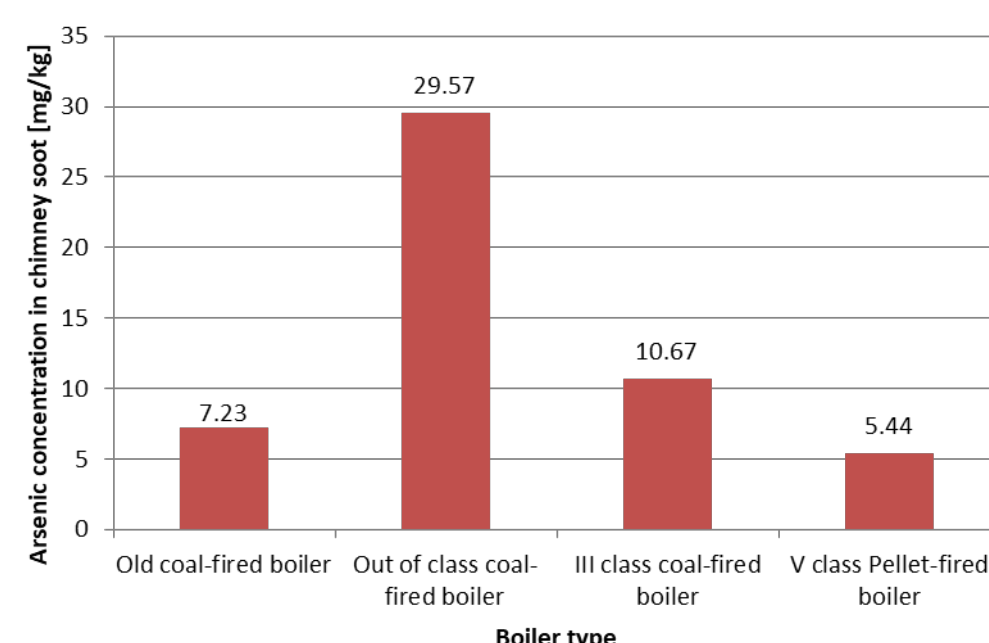


Fig. 6. Arsenic concentration in chimney soot

Tab. 1. Characteristic of fuels combusted in investigated boilers and of obtained chimney soots

Parameter	Old coal-fired boiler (bad condition)		Out of class coal-fired boiler (good condition)		III class coal-fired boiler		V class Pellet-fired boiler	
	Coal	Soot	Coal	Soot	Coal	Soot	Coal	Soot
Amount of combusted fuel [kg]	2000	-	5000	-	3000	-	4000	-
Soot yield [kg]	-	1.3	-	6.0	-	1.8	-	0.6
M^{ar} [%]	4.7	3.9	14.0	5.3	9.6	6.7	7.1	56.4
A^{ad} [%]	3.7	60.1	5.3	55.3	4.2	51.4	0.6	48.0
C^{ad} [%]	76.8	23.3	74.8	30.0	71.3	35.2	48.8	25.7
H^{ad} [%]	4.29	1.10	3.46	1.43	3.57	1.56	5.93	1.50
S_{O}^{ad} [%]	0.61	2.74	0.96	2.43	0.99	3.31	0.03	3.55

Conclusion

- The investigated chimney soot were characterized by a high content of mercury as well as arsenic. This should be explained by the relatively low temperature prevailing in the chimney, which enables the adsorption process on the surface of the soot particles.
- The amounts of Hg and As in the chimney soot were affected by both the amount of combusted fuel, Hg and As content in fuel as well as by yield of chimney soot.
- It was shown that 2.99 %, 45.5 %, 6.10 %, 1.53 % of the mercury contained in fuel is adsorbed by chimney soot derived from old coal-fired boiler, out of class coal-fired boiler, III class coal-fired boiler and V class pellet-fired boiler, respectively.
- It was shown that 1.31 %, 0.97 %, 0.67 %, 0.37 % of the arsenic contained in fuel is adsorbed by chimney soot derived from old coal-fired boiler, out of class coal-fired boiler, III class coal-fired boiler and V class pellet-fired boiler, respectively.
- No significant influence of home heating boiler type on Hg content in the chimney soot was observed. In the case of arsenic, it was noted that the more modern the boiler design, the lower amount of arsenic is passing into the chimney soot.