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ASSESSMENT OF MERCURY CONTENT IN DIFFERENT FUEL TYPES

Ana Marinković[1a], Jovana Buha Marković[1b], Jasmina Savić[1c], Milica Mladenović[1d], Milić Erić[1e], Zoran Marković[1f], Biljana Vučićević[1g]

[1] Vinča Institute of Nuclear Sciences – National Institute of the Republic of Serbia, University of Belgrade, Serbia
[1a] aradojevic@vinca.rs, 0000-0002-3206-1102
[1b] jbuha@vinca.rs, 0000-0002-5820-6541
[1c] jasnas@vinca.rs, 0000-0003-1094-7292
[1d] mica@vinca.rs, 0000-0003-1924-0437
[1e] milic@vinca.rs, 0000-0001-6850-3112
[1f] zoda_mark@vinca.rs, 0000-0003-0553-3263
[1g] bee@vinca.rs, 0000-0002-5817-0171

Abstract

Mercury is a highly toxic trace element that poses a serious global environmental threat due to its mutagenic properties, persistence in ecosystems, and its capacity for bioaccumulation. Combustion of fossil fuels, particularly coal, is one of the primary sources of atmospheric mercury emissions, prompting many countries to implement stringent regulatory limits. In response, this study aims to investigate and compare the mercury content in various types of coal and biomass fuels (wood chips and pellets) to evaluate their environmental suitability for energy production. The results demonstrate a clear and substantial difference in mercury concentrations between the two fuel groups. All analyzed coal samples contain significantly higher levels of mercury compared to biomass fuels. This variation is strongly influenced by sulfur content and other key fuel quality parameters, including calorific value, ash content, and elemental composition. These findings are essential for understanding how intrinsic fuel properties affect mercury emissions during combustion. Ultimately, the study aims to inform cleaner energy production practices by guiding fuel selection and optimizing combustion technologies to minimize environmental mercury release.

Keywords: *coal, wood biomass, mercury, direct mercury analyzer, environmental protection*

1. INTRODUCTION

Mercury, a globally recognized toxic pollutant, exists in several chemical forms, including elemental (Hg^0), oxidized (Hg^{2+}), particulate-bound (Hg^p), and organic (MeHg), which differ in mobility, reactivity, and toxicity, resulting in complex environmental behavior [1]. Among the specified mercury forms, methylmercury (MeHg) is the most hazardous due to its neurotoxic effects and ability to bioaccumulate. Mercury has been identified as a harmful air pollutant, and its regulation in the United States was formalized by the Clean Air Act Amendments in 1990. A significant milestone came in 2012 when the US EPA implemented the Mercury and Air Toxics Standards (MATS) to limit power plant emissions [2]. These regulations have been highly effective, significantly reducing mercury emissions and preventing thousands of premature lives annually.

Mercury appears in the atmosphere both from natural and anthropogenic sources. Coal-fired power plants and combustion facilities that burn different biomass fuels represent a significant anthropogenic contributor. Mercury emissions are not solely a function of the utilized combustion technology or operating conditions; they also depend on fuel type and characteristics such as ash and volatile yield, carbon and sulfur content [3, 4]. Generally, higher mercury content in coals is associated with elevated carbon content (organic matrix), particularly in higher-rank fuels such as bituminous and anthracite coals. Furthermore, sulfur (particularly pyritic sulfur) contained in coals usually results in elevated mercury levels, owing to mercury's affinity for sulfide minerals and its relationship with pyrite. This underscores the need to consider mercury content as a fundamental fuel characteristic when assessing environmental impact.

The prior literature analyzes the mercury concentration of coal and biomass [5, 6]. Given the variety of factors that impact the composition and characteristics of these fuels, it is critical to quantify and compare the mercury content of various fuel samples available in this climate. This study aims to assess, compare, and correlate the mercury content among different fuel types with their properties.

2. EXPERIMENTAL

Brown coal, anthracite, lignite, wood pellet and wood chips were analysed in this study. The proximate and ultimate analyses were done by LECO TGA 70 and LECO CHN 628 Series with a Sulfur add-on module, respectively. The heating value was determined using an IKA C200 calorimeter. Mercury content in samples was determined on Direct Mercury Analyzer- DMA1 evo. Standard methods were applied for all analyses [7, 8]. All samples are anlaysed in triplicate. The data obtained from tests at the same conditions were averaged to get the final results.

3. RESULTS AND DISCUSSION

The quality of feed fuels used for energy production (coal and biomass samples) is evaluated by proximate and ultimate analysis. The results of these analyses are presented in Table 1. As can be seen, there are significant differences among the investigated coals. Anthracite has much lower ash and volatile content, much higher heating value, and carbon content than lignite and brown coal, which is expected. Furthermore, samples of wood pellets and chips compared with all investigated coal samples have much higher volatile and oxygen content (Table 1). This is in accordance with the literature [5, 6], where the volatile yield in biomass samples includes light hydrocarbons, CO, CO_2, H_2, moisture and tars, and its content is usually much higher than in coal samples [9]. Additionally, wood pellets and chips have considerably lower ash content than lignite, while their carbon content and calorific value are slightly higher.

Table 1. Proximate and ultimate analysis of different coal and biomass types

		Anthracite	**Brown Coal**	**Lignite**	**Wood pellet**	**Wood chips**
Proximate analysis (%)	Inherent Moisture*	3.48	2.96	3.39	4.38	5.47
	Ash	4.64	6.16	33.73	0.51	1.28
	Total Sulfur	0.75	0.78	1.52	0.04	0.02
	C-fix	88.05	44.96	25.97	15.50	17.49
	Volatile	7.30	45.92	40.31	83.99	81.23
Heating value (MJ/kg)	High	32.86	27.63	17.80	22.40	19.68
	Low	32.46	26.58	16.90	21.10	18.45
Ultimate analysis (%)	Carbon	87.08	67.63	44.33	50.96	49.56
	Hydrogen	1.93	5.11	3.90	6.31	5.97
	Com. Sulfur	0.64	0.30	0.80	/	/
	Nitrogen	1.09	1.39	0.75	0.08	0.29
	Oxygen	4.62	19.22	16.50	42.14	42.90

*as determined; all other data are given on a dry basis

Figure 1 shows the mercury and sulfur content of analyzed coal and biomass samples. Wood chips and wood pellets have significantly lower sulfur content compared to the coal samples. It is in accordance with literature data, which indicates that the sulfur content in biomass typically ranges from 0.01% to 2.30%, except in bark and straw, which usually have higher sulfur content than wood samples [10]. Among all investigated samples, lignite has the highest sulfur content.

As can be seen, mercury content varies in coals from 0.053 ppm (brown coal) to 0.874 ppm (lignite), while in biomass samples, concentrations are much lower, ranging from 0.003 ppm (wood chips) to 0.007 ppm (wood pellets).

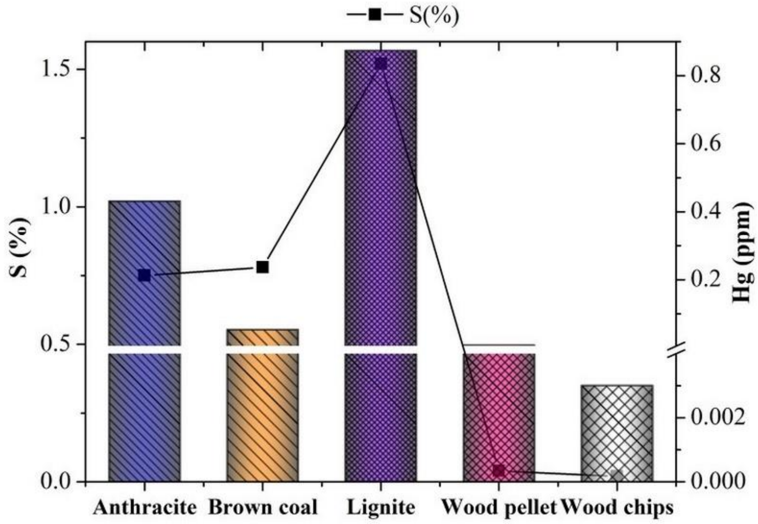

Figure 1. Mercury and sulfur content in different types of coal (anthracite, brown coal and lignite) and biomass (wood pellet and wood chips)

Although biomass samples generally contain very low Hg concentrations, this trace element exhibits high volatility during combustion. Studies have shown that mercury released during biomass combustion can be deposited through both dry and wet pathways, thereby contributing to the formation of toxic methylmercury species that bioaccumulate in living tissues [11]. Within biomass matrices, mercury may be bound to both organic components, such as thiol groups, and inorganic components, such as pyrite [5]. Global studies on coal indicate that mercury is primarily associated with pyrite in higher-rank coals, whereas lower-rank coals tend to have a higher proportion of organically bound mercury [12].

In this study, a notable correlation was observed between sulfur and mercury content. Fuels characterized by low sulfur content, such as wood pellets and chips, exhibited significantly reduced mercury concentrations, aligning with observations reported in the literature [5]. Additionally, biomass samples displayed substantially higher volatile matter yields compared to coal samples (Table 1) despite their markedly lower mercury concentrations. This finding is consistent with existing studies that report a negative correlation between volatile matter and mercury contents [6].

4. CONCLUSION

In this study, proximate, ultimate and mercury analyses were conducted on coal and biomass samples to explore their interrelationships. Among investigated samples, wood pellets and wood chips were characterized by significantly lower ash and sulfur contents. Still, they exhibited higher volatile matter yields, whereas anthracite showed the highest heating value, as anticipated. Investigated low-sulfur and high volatile biomass fuels show significantly lower mercury content. These correlations are consistent with previous literature and highlight the crucial role of fuel composition in mitigating mercury emissions during biomass combustion.

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