Environmental burden by burning waste in small heat sources

Nikola Čajová Kantová[1*], *Robert* Cibula[1], *Michal* Holubčík[2] and *Jozef* Jandačka[2]

[1]Research Centre, University of Žilina, Univerzitna 1, 010 26 Žilina, Slovakia
[2]Department of Power Engineering, Faculty of Mechanical Engineering, University of Žilina, Univerzitna 1, 010 26 Žilina, Slovakia

Abstract. Deteriorated air quality is often related to the use of alternative fuels in heat sources, often in the form of waste. This article deals with the chemical composition of four types of alternative fuels: solid non-separable waste, solid non-separable waste with more plastic content, linden leaves and maize husks. The measurements were realized on a CHN628 analyzer and an energy-dispersive X-ray fluorescence spectrometer. The chemical composition of the fuel is connected with the composition of emissions during their combustion. Results showed an increased chlorine content in each sample, then sulfur content (except maize husks) and also nitrogen content in the case of two samples (solid non-separable waste and maize husks). In the case of the content of toxic elements, no relevant concentration was detected in investigated samples. Therefore, it is not suitable to burn waste in conventional solid fuel heat sources. Heat source users should only use permitted fuels that are recommended by the heat source manufacturer.

1 Introduction

Deteriorated air quality is often related to the use of alternative fuels in heat sources, often in the form of waste [1]. The largest producer of particulate matter in Central Europe is the combustion of solid fuels in households according to Karagulian et al. [2]. Particulate matter, ozone, and other air pollutants cause a range of adverse health effects, such as respiratory and cardiovascular diseases, also cancer [3].

However, the emission production can be enormous with the connection of incorrect operation of heat sources with imperfect combustion. Šyc et al. measured the highest emission factors of nonchlorinated pollutants for the old-style boilers with over-fire and under-fire designs, manual stoking, and natural draft. The type of appliance had the most significant impact on the amount of nonchlorinated pollutants released; the type of fuel had the less significant impact. Emissions of chlorinated pollutants were proportional mainly to the chlorine content in fuel [4].

The chemical composition of the fuel (mainly carbon, hydrogen, oxygen, nitrogen, sulphur and chlorine) affects the mechanism of particle formation. Sulphur and chlorine can produce particulate sulphate and chlorinated salts, following a similar mechanism as for potassium

* Corresponding author: nikola.cajovakantova@uniza.sk

[5]. The chemical composition of the fuel is connected with the composition of emissions during their combustion. Therefore, it is inappropriate to burn waste in conventional heat sources.

This article deals with the chemical composition of four types of alternative fuels: solid non-separable waste, solid non-separable waste with more plastic content, linden leaves and maize husks. The obtained results are compared to spruce wood. Health risks of tested waste are further discussed in the case of their combustion.

2 Material and method

2.1 Used material

The following waste materials were used: solid non-separable waste, solid non-separable waste with more plastic content, linden leaves and maize husks. These materials were dried and crushed. Thus prepared samples shown in Figure 1 were used for other tests for the determination of their chemical composition.

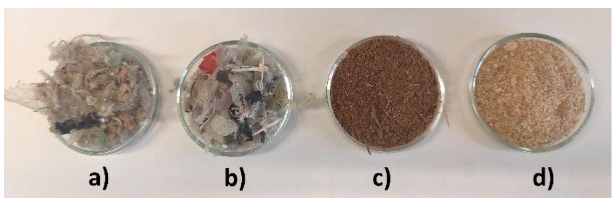

Fig. 1. The individual waste samples: a) solid non-separable waste, b) solid non-separable waste with more plastic content, c) linden leaves, d) maize husks.

2.2 Chemical composition

The content of carbon, hydrogen and nitrogen was detected by CHN628 analyzer with a working temperature of about 950°C. The individual samples were combusted in the absence of atmospheric gases. The content of inorganic elements was measured by ARL™ QUANT'X EDXRF spectrometer. The individual samples were analyzed by energy-dispersive X-ray fluorescence spectrometry in a vacuum atmosphere. The content of oxygen was calculated based on the difference between the measured values and 100%.

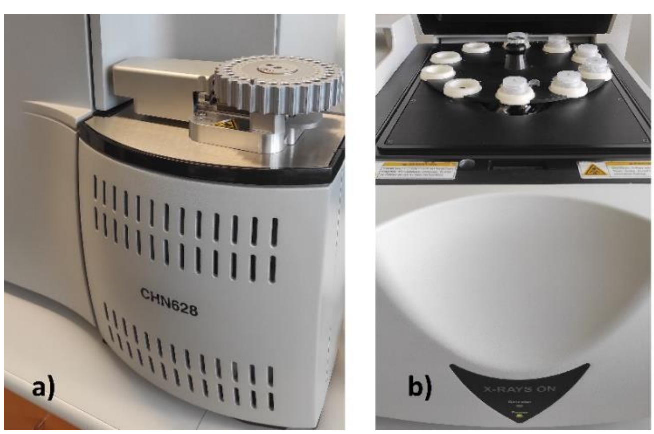

Fig. 2. Used devices: a) CHN628 analyzer, b) ARL™ QUANT'X EDXRF spectrometer.

3 Results and discussion

Results of chemical composition of tested samples are shown in Figure 3 (for solid non-separable waste and solid non-separable waste with more plastic content) and Figure 4 (for linden leaves and maize husks). The highest carbon content was measured in solid non-separable waste with more plastic. Solid non-separable waste had the highest content of nitrogen. The highest hydrogen content was detected in solid non-separable waste with more plastic. Maize husks had the highest oxygen content. The highest content of inorganic elements was measured in linden leaves. Detailed results of inorganic elements of tested samples are stated in Table 1.

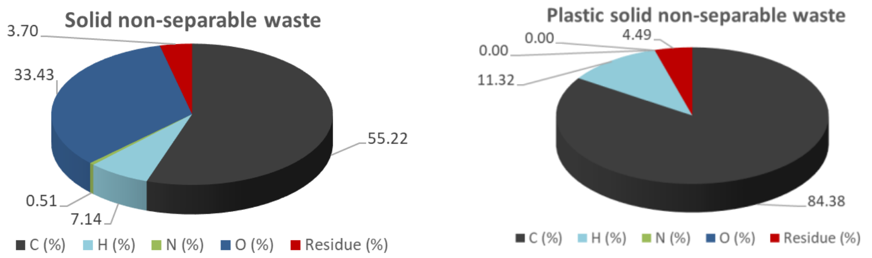

Fig. 3. Results of chemical composition: solid non-separable waste and solid non-separable waste with more plastic content.

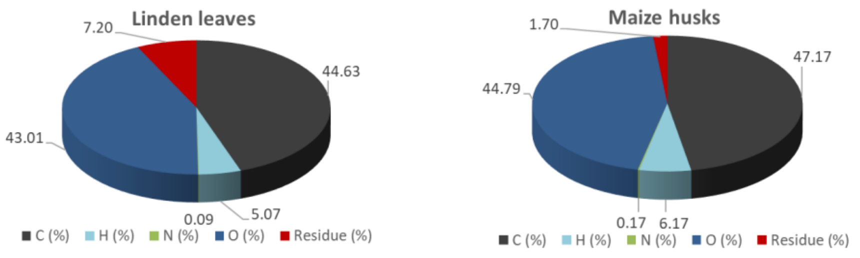

Fig. 4. Results of chemical composition: linden leaves and maize husks.

Compared to spruce wood investigated in the work of Mikeska et al., solid non-separable waste and also plastic non-separable waste had higher carbon content. Contrary, linden leaves and maize husks had lower carbon content. Linden leaves and maize husks had similar hydrogen content and linden leaves also similar nitrogen content. Mikeska et al. stated the following contents: 47.46% for carbon, 5.65% for hydrogen, 0.09% for nitrogen and 39.12% for oxygen [6].

Slovak legislation (Law no. 137/2010 on air protection and Decree of the Ministry of the Environment of the Slovak Republic no. 411/2012 as amended) determines the list of substances that are defined as indicators of air pollution and must be monitored. Raw material requirements are directly derived from these requirements, which would be used for combustion so that it does not contain, respectively it contained a minimal amount of substances that could produce air pollution in the burning process. Except for carbon compounds (oxo-compounds, cyclic and aromatic hydrocarbons, halogenated hydrocarbons, etc.), mainly the following elements are concerned: S, N, Cl, F, and toxic elements (Pb, Cd, As, Hg, Ni). Sulfur oxides can be formed from S. Nitrogen oxides or ammonia can be formed from N. Gaseous compounds of chlorine can be formed from Cl, expressed as hydrogen chloride or halogen hydrocarbons. Gaseous compounds of fluorine can be formed from F, expressed as hydrogen fluoride. Toxic elements can be in the air either as part of particulate matter or in the form of gaseous vapours.

Table 1. Results of inorganic elements of tested samples.

Element	**Solid non-separable waste**	**Plastic solid non-separable waste**	**Linden leaves**	**Maize husks**
Ca (%)	1.760	1.380	3.110	0.042
Si (%)	0.454	0.888	1.380	0.306
K (%)	0.185	0.116	0.949	0.891
Al (%)	0.264	0.657	0.494	0.000
Mg (%)	0.069	0.311	0.342	0.050
Cl (%)	0.321	0.435	0.251	0.245
S (%)	0.247	0.230	0.236	0.040
P (%)	0.080	0.102	0.175	0.105
Fe (%)	0.171	0.130	0.164	0.016
Mn (%)	0.011	0.004	0.048	0.000
Ti (%)	0.111	0.212	0.017	0.000
Sr (%)	0.003	0.000	0.010	0.000
Ba (%)	0.003	0.000	0.006	0.000
Zn (%)	0.013	0.013	0.005	0.000
Cr (%)	0.002	0.007	0.000	0.002
Br (%)	0.000	0.003	0.000	0.000
Cu (%)	0.003	0.003	0.000	0.000
Sn (%)	0.000	0.000	0.000	0.000
Pb (%)	0.001	0.000	0.000	0.000
Zr (%)	0.000	0.000	0.002	0.000
$\sum$	**3.698**	**4.491**	**7.190**	**1.696**

The measured S contents were in the range of 0.23 to 0.25 for both non-separable wastes and linden leaves. Maize husks had only 0.04% of S. The highest N content was measured in solid non-separable waste with a value of 0.51%. Plastic solid non-separable waste had the highest Cl content (0.435%) and maize husks had the lowest Cl content (0.245%). F and heavy metals were not detected, except for a very small Pb content (0.001%) in solid non-separable waste. The analytical technique that would measure F concentration was not available. For this reason, F content was not measured in investigated samples.

4 Conclusion

Small heat sources are among the biggest air polluters. Therefore, it is necessary to address this issue. The article focused on the chemical composition of four types of waste: solid non-separable waste, solid non-separable waste with more plastic content, linden leaves and maize husks. Each tested waste sample contained at least one element classified as an air pollution indicator by comparing the results from chemical composition measurements with the legislative requirements for air protection. This was mainly in an increased chlorine content in each sample, then sulfur content (except maize husks) and also nitrogen content in the case of two samples (solid non-separable waste and maize husks). In the case of the content of toxic elements, no relevant concentration was detected in investigated samples. Based on the results, it can be summarized that waste fuels differ from wood fuels in their chemical composition, which is also connected with the composition of emissions during their combustion. Therefore, it is not suitable to burn waste in conventional solid fuel heat sources. Heat source users should only use permitted fuels that are recommended by the heat source manufacturer.

Funding

This publication has been produced with the support of the Integrated Infrastructure Operational Program for the project: Creation of a Digital Biobank to support the systemic public research infrastructure, ITMS: 313011AFG4, co-financed by the European Regional Development Fund, APVV-21-0452 Impact of using small electrostatic precipitators to reduce particulate pollutants in domestic fuel combustion, VEGA 1/0150/22: Energy utilization of produced waste in connection with the COVID-19 pandemic through pellets as an alternative fuel and KEGA 032ŽU-4/2022 Implementation of knowledge about modern ways of reducing environmental burden in the energy use of solid fuels and waste into the pedagogical process.

References

1. Taušová, M., Mihalik, E., Čulková, K., Stehlíková, B., Tauš, P., Kudelas, D., Štrba, Ľ., Domaracká, L. Sustainability, **12** (14), 5818 (2020).
2. Karagulian, F., Belis, C., Dora, C. F., Prüss-Ustün, A. M. Bonjour, S., Adair-Rohani, H., Amann, M. Atmospheric Environment, **120**, 475-483 (2015).
3. Kim, K. H., Kabir, E., Kabir. S. Environment International, **74**, 136–143 (2015).
4. Šyc, M., Horák, J., Hopan, F., Krpec, K., Tomšej, T., Ocelka, T., Pekárek, V. Environ. Sci. Technol. **45**, 9427–9434 (2011).
5. Demirbas, A. Prog. Energy Combust. Sci., **30** (2), 219-230 (2004).
6. Mikeska M., Najser J., Peer V., Frantík J., Kielar J. Energy Explor. Exploit., **38** (2), 406-416 (2020).