Six-year study of biofuel ash to assess its ecological risk in Lithuania

LITHUANIAN RESEARCH CENTRE FOR AGRICULTURE AND FORESTRY

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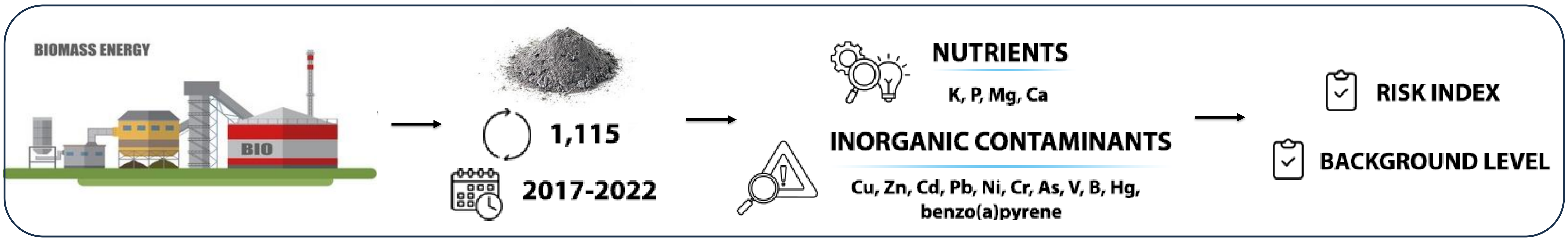
INTRODUCTION

The growing concern over global warming, primarily driven by fossil fuel combustion, has significantly increased interest in bioenergy as a sustainable alternative. The use of biofuels is attributed as more environmentally friendly than fossil fuels and neutral to greenhouse gas emissions (Saidur et al., 2011). However, biofuels generate a large amount of ash every year (Vassilev et al., 2013). The literature analysis demonstrated that around 18.5 million tons of wood ash are produced annually (2.42 million tons in Europe) (Zhai et al., 2021). It is important to note that the physicochemical properties of different types of ash can vary significantly (Abdalla et al., 2024) and mainly depend on feedstocks and combustion conditions (Mäkelä et al., 2016). The main objective of this study was i) to determine the agronomic value and ii) to continuously determine the pollution levels of biofuel ash for six years.

METHODOLOGY



RESULTS

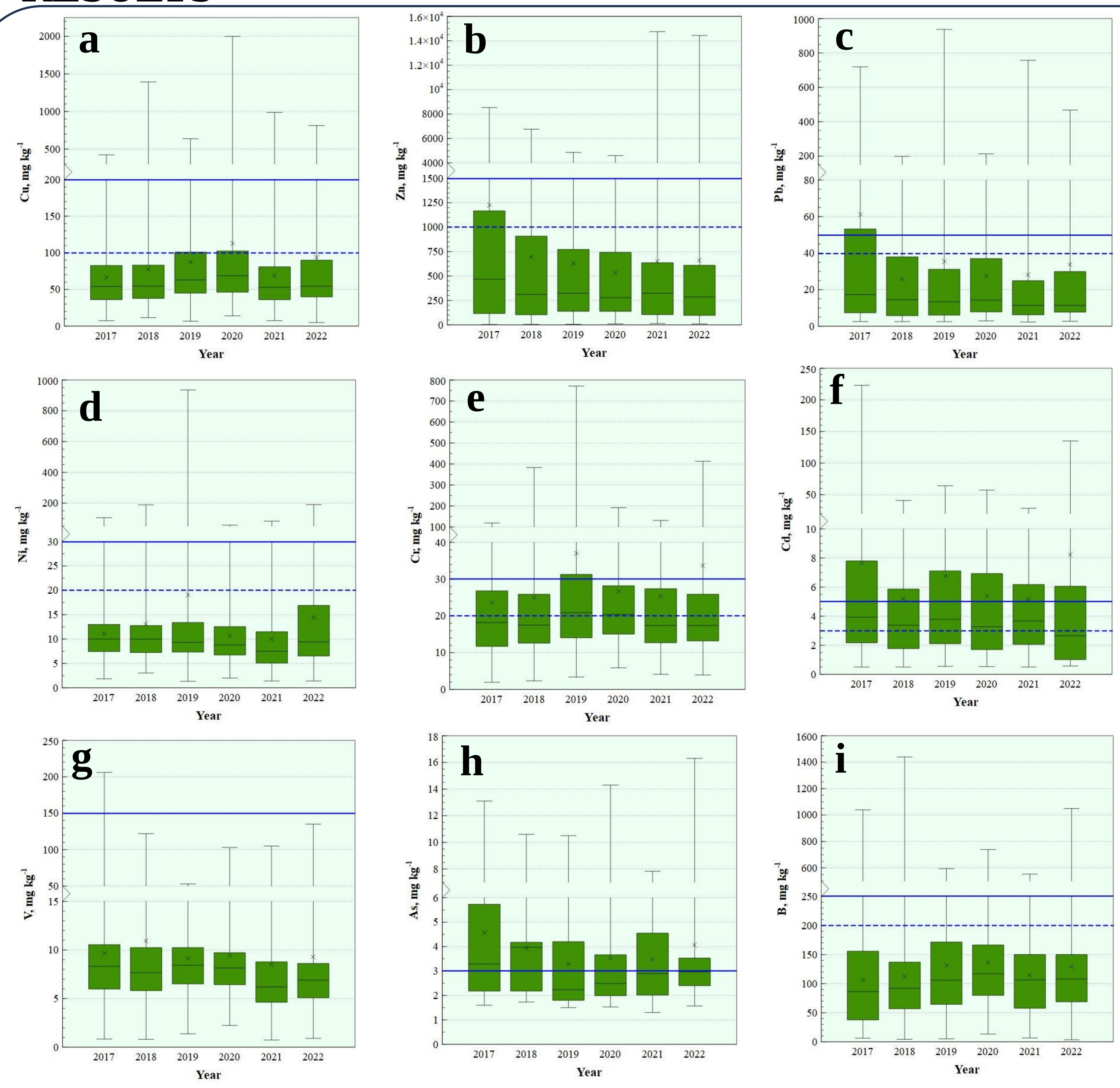


Figure 1. Cu (a), Zn (b), Pb (c), Ni (d), Cr (e), Cd (f), V (g), As (h) and B (i) amount in biofuel ash during six-year. *Note:* (x) average, (−) median, (|) min and max value, ([]) 25% 75%. The dashed blue line indicates the maximum allowed limit in forestry and the straight line – in agriculture (Lietuvos respublikos aplinkos ministerija, 2011)

Table 1. Multi-annual risk assessment of individual heavy metals (E_r) and cumulative heavy metals potential ecological risk of environmental (RI) in biofuel ash. *Note:* Green color − low risk; blue color – moderate risk; red color – high/very high risk)

Metals	Grade of ecological risk of single metal (E_r)					
	2017	2018	2019	2020	2021	2022
As	15.0	12.9	10.8	12.5	11.5	13.3
Cd	1313.1	893.1	1158.9	977.1	884.6	1410.9
Cr	1.3	1.4	2.0	1.5	1.4	1.8
Cu	34.8	40.6	45.7	63.9	36.1	49.2
Hg	67.2	59.4	46.2	22.9	18.3	18.3
Ni	3.7	4.4	6.3	3.6	3.3	4.8
Pb	20.5	8.6	11.8	9.4	9.4	11.3
Zn	39.8	22.4	20.3	17.8	21.0	21.3
Grade of potential ecological risk of environmental (RI)	1495.4	1042.8	1301.9	1108.7	985.6	1530.9

Table 2. Estimated annual maximum inputs of inorganic contaminants (g ha^{-1} year^{-1}) and time (in years) needed to double inorganic contaminants' background concentration in soil by continuous application of biofuel ash following phosphorous annual allowable rate

Inorganic Contaminant		2017	2018	2019	2020	2021	2022	Average
As	Max input	19.24	17.32	13.81	17.08	15.82	18.29	16.93
	Time	412	458	574	464	501	434	**474**
B	Max input	450.53	495.43	553.26	625.17	512.36	581.57	536.39
	Time	173	157	141	125	152	134	**147**
Cd	Max input	32.25	22.90	28.46	25.62	23.19	36.99	28.24
	Time	15	20	16	18	20	13	**17**
Cr	Max input	99.79	109.89	155.79	123.60	113.71	151.46	125.71
	Time	964	875	618	778	846	635	**786**
Cu	Max input	279.58	340.66	367.16	548.31	310.11	422.02	377.97
	Time	89	73	68	45	80	59	**69**
Hg	Max input	0.62	0.57	0.43	0.22	0.18	0.18	0.37
	Time	336	364	489	926	1157	1157	**738**
Ni	Max input	46.74	57.54	80.13	48.99	44.94	65.17	57.25
	Time	834	678	487	796	868	598	**710**
Pb	Max input	258.53	113.80	149.52	127.19	126.74	151.91	154.61
	Time	151	343	261	307	308	257	**271**
V	Max input	40.84	48.04	38.48	44.49	38.38	41.80	42.01
	Time	2578	2192	2736	2367	2743	2519	**2523**
Zn	Max input	5200.00	3054.51	2653.47	2484.49	2921.35	2970.79	3214.10
	Time	16	26	30	32	28	27	**27**

CONCLUSIONS

This study analyzed 1,155 biofuel ash samples and the results represent the six-year chemical composition and environmental risk assessment of biofuel ash generated in Lithuania. The amount of inorganic contaminants in biofuel ash varied significantly in different years. When assessing the potential use for biofuel ash in agriculture and forestry, it was found that about 30% of biofuel ash samples had Cd concentrations exceeding the maximum allowable limits for use in agriculture, and more than 50% – in forestry. The total cumulative potential ecological risk of heavy metals for biofuel ash samples was estimated to be very high which is determined by the high Cd amount. Also, it was determined that after the annual biofuel ash application, the background level for Cd and Zn would increase twice after 17 and 27 years respectively. Other investigated elements have not demonstrated a significant risk. A completed environmental risk assessment can help manage the amount of biofuel ash and control its quality in Lithuania. Considering that the determined concentrations of inorganic contaminants in biofuel ash often exceeded the maximum allowable limits set previously, it is acceptable to conclude that the Government of Lithuania can rely on the research results and regulate these limits.