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CIVIL AND ENVIRONMENTAL ENGINEERING REPORTS

E-ISSN 2450-8594

CEER 2022; 32 (4): 0167-0183
DOI: 10.2478/ceer-2022-0051
Original Research Article

CHEMICAL COMPOSITION OF INDUSTRIAL WOOD WASTE AND THE POSSIBILITY OF ITS MANAGEMENT

Ryszard MALINOWSKI[1], Edward MELLER[1], Ireneusz OCHMIAN[2], Katarzyna MALINOWSKA[3], Monika FIGIEL-KROCZYŃSKA[2]
[1]Department of Environmental Management, West Pomeranian University of Technology in Szczecin, Szczecin, Poland
[2]Department of Horticulture, West Pomeranian University of Technology in Szczecin, Słowackiego, Szczecin, Poland
[3]Department of Bioengineering, West Pomeranian University of Technology in Szczecin, Szczecin, Poland

Abstract

Organic wood waste (sawdust, shavings, pieces of wood and bark), is widely used as a secondary raw material and, after composting, for soil fertilisation and substrate production in agriculture, horticulture, forestry, urban landscaping and rehabilitation of degraded land. However, problematic to process is wood waste that is very dirty with soil. They have limited calorific value and cannot be used in the R10 recovery process of land treatment benefiting agriculture or improving the environment. However, the morphological composition of these wastes indicates that they have good properties and can be used for agricultural use and for the reclamation of degraded land. The research involved wood waste with the code 03 01 99 (other unspecified waste from wood processing and the production of panels and furniture) generated during the preparation of deciduous tree logs for the veneer production process, and ashes from the burning of wood waste generated in the veneer production factory. The aim of the study was to assess the chemical composition of these wastes and the possibility of their agricultural use. In the samples of wood waste and ashes there was determined: pH; chlorines content;

[1] Corresponding author: Department of Environmental Management, West Pomeranian University of Technology in Szczecin, Słowackiego 17 Street, 71-434 Szczecin, Poland, ryszard.malinowski@zut.edu.pl, +48 91 449 63 89

conductivity; hydrolytic acidity; content of micro and macroelements and heavy metals. The morphological composition of the waste is dominated by sawdust, with a smaller share of shavings, bark and earth parts, and a small addition of pieces of wood of various sizes. It is rich in easily bioavailble as well as total macroelements and is not contaminated with heavy metals. Analyzed wood waste has deacidifying properties, high sorption and buffering capacity. Studies have shown that the wood waste produced at the veneer factory, can be used as an organic fertiliser, a component of other organic fertilisers, for soil mulching, horticultural substrate and soil and land reclamation.The ash obtained from burning wood is strongly alkaline and rich in alkaline cations, mainly Ca, Mg and K. It is not contaminated with heavy metals. The ash can be used for soil deacidification and fertilization, especially for soil reclamation. The waste from the heap can be used as an organic fertilizer, a component of other organic fertilizers, for mulching soils and as a gardening substrate. However, the possibilities for non-agricultural (e.g.: for the production of pallet, particle board) use are limited due to the high proportion of earthy parts.

Keywords: wood waste, biomass, ash, chemical composition, fertilizer value, agricultural use, soil reclamation

1. INTRODUCTION

The timber industry in Poland is well developed. The large area of forests, which in 2020 amounted to 9260 thousand hectares (including state forests of 7118 thousand hectares), is conducive to this. Timber resources were estimated at 2 656 094 thousand m^3. In the forests there are mainly: pine - 58.2%, oak - 8.0%, birch - 7.0%, beech - 6.2%, spruce - 5.4%, fir - 3.3% and other species [12].

In Poland there is a gradual increase in timber harvesting from forests: in 2010 it was - 35467 thousand m^3 and in 2020 - 39674 thousand m^3 [12]. The harvested wood was processed by the wood and paper industry. The wood industry generates significant amounts of wood waste, of which about 16-18.0 million m^3/year, (about 9.0 million tons) were generated annually [5, 22]. The market for industrial wood waste is sustainable, wood waste is almost entirely utilized by the wood and construction industry, in agriculture and horticulture, and for energy production [5, 37].

The largest amount of wood waste is generated by the sawmill industry - 63%, the furniture industry - 14%, and the wood panel industry - 13%. Among these wastes the largest percentage is of chunk waste - over 50%, sawdust and shavings - over 28%, and bark - 16% [37]. For industrial purposes, mainly chunk waste is used, while sawdust and shavings and bark are used for energy purposes [26, 11].

Approximately 49 million tonnes of wood waste is generated in the European Union from the wood industry, construction, municipal, and demolition waste [5]. On a European scale, wood waste is landfilled and incinerated at 37%, material recovery at 33%, and energy recovery at 30% [2, 26, 30].

Proper recycling of wood waste reduces its environmental impact and is cost-effective [23]. The use of wood waste for particleboard and energy purposes produces much less CO_2 than when produced from full-grade wood [17]. They are also used for other purposes such as: protecting soils from erosion [9] and as soil improvers [34].

The effective recycling process of wood waste depends on its homogeneity, and mechanical, physical and chemical properties [1]. The presence of concrete, bricks, earthy parts, glass, and plastic in wood waste limits its reuse including energy. Other contaminants like adhesives, paints, varnishes and other preservatives are also important [11]. Wastes contaminated with these compounds are not suitable for agricultural use. Producing energy from them yields ash contaminated with heavy metals, which must be properly stored [20].

The total amount of waste from the wood processing industry is dominated (more than 65%) by solid waste, the so-called "clean" waste [37]. Part of this waste is burned [5]. A much better way with more sustainable benefits for the natural environment is to use them in agriculture and horticulture, forestry, urban green areas and rehabilitation of degraded land [24, 44]. They are a valuable source of biomass rich in macro- and microelements [28,29]. Some countries like Germany, Switzerland, and Scandinavian countries have very good legal solutions to make optimal use of them [5].

In Poland, legal conditions of wood waste management, including the wood processing industry, do not allow them to fully utilize their raw material potential. For example, veneer production plants have problems with the so-called "clean" wood processing waste. This material is treated as production waste and cannot be sold and reused.

The aim of the study was to determine the chemical composition of wood waste produced at the veneer factory and ash waste obtained from the combustion of wood waste, and to evaluate the possibility of their agricultural management.

2. RESEARCH METHODOLOGY

Waste material obtained during the preparation of deciduous tree logs for the veneer manufacturing process was studied. Up to 4000 m^3 of wood is processed annually at the plant in Dobrzany (West Pomeranian Voivodeship, Poland). The preparation of wood for veneer production generates about 100-150 tons of wood waste per year, code 03 01 99 - (other unspecified waste from wood processing and board and furniture production), which is collected in the form of heaps (Fig. 1). Wood waste with code 03 01 99 is generated in the first stage of preparing deciduous tree logs for veneer production. The veneer plant also generates significant amounts of ash (waste code 10 01 03 - Fly ash from peat and wood not chemically treated) from the combustion of wood waste in the on-site heating plant.

Fig. 1. The process of creating wood waste in a veneer production plant

In order to evaluate the chemical properties of the wood waste, bulk samples were taken from the site of its production and storage (each bulk sample consisted of 20 primary samples):

1. 4 bulk samples were taken from the log pre-treatment station (mixed material consisted mainly of sawdust, bark and pieces of hardwood, earthy parts from tree washing);
2. Two types of waste were taken from the log cutting and storage station:
   a) wood waste (mixed material consisted mainly of sawdust, bark and pieces of hardwood) with a small amount of earthen parts - 3 bulk samples,
   b) wood waste (mixed material consisted mainly of sawdust, bark and pieces of hardwood) with a high proportion of earthy parts - 3 bulk samples.
3. 10 bulk samples were taken from the wood waste heap (mixed material consisted mainly of sawdust, bark and pieces of hardwood, earthy parts).

In addition, 3 bulk samples of ash from the combustion of wood waste in the heating plant of the veneer plant were taken for testing. A total of 23 bulk waste samples (20 wood waste samples and 3 ash samples) were collected for testing.

Laboratory tests were conducted in the laboratory of the Department of Soil Science, Meadow Science and Environmental Chemistry of the West Pomeranian University of Technology in Szczecin.

The wood waste samples were dried in a dryer at 105 ^{o}C and ground in a grinder.

Samples of wood waste were determined:

- organic matter content by the loss on ignition was determined by burning wood waste samples in a muffle furnace at the 550º C
- potentiometrically the pH value measured in distilled water and in 1M KCl at a ratio of 1:5;
- chlorines content by argentometry;
- conductivity by conductometry at a wood waste: water ratio of 1:5;
- total carbon, nitrogen and sulphur content by CNS elemental analyser (Costech Elementary Analyzer ECS 4010, Italy);
- hydrolytic acidity and by the Kappen method;
- the content of exchangeable cations: Ca, Mg, K and Na after extraction with 1 mol·dm^{-3} ammonium acetate by ASA method;
- bioavailable forms of K, Mg, Ca, Cu, Zn, Fe, Mn, Cd, and Ni after extraction in 0.5M HCl by ASA method, while P colourimetrically
- total content of P, K, Mg, Ca, Fe, Mn, Co, Cd, Pb, Ni, Cu and Zn after mineralisation in a mixture (1:1) of HNO_3 (V) and $HClO_4$ (VII) acid by ASA method with the flame atomic absorption spectroscopy using iCE 3000 Series, while P by colourimetry.

All determinations were performed in triplicate. All statistical analyses were performed with Statistica 12.5 (StatSoft Polska, Cracow, Poland). The data were subjected to one-factor ANOVA. Mean comparisons were performed using Tukey's least significant difference (LSD) test; the significance was set at $p < 0.05$.

3. RESULTS

3.1. Wood waste collected from the wood storage and cutting yard

a) Organic wood wastes: these are mainly sawdust, shavings, bark and pieces of hardwood. They were characterized by organic matter content of 63.24% on average (similar to organic matter content in sawmill waste), total carbon of 28.3% on average, alkaline reaction (pH_{KCl} - 7.69 on average), low salinity (254 μS·cm^{-1} on average) and chlorine content of 20.77 mg·100g^{-1} wood waste on average (Table 1). Moreover, the material had low hydrolytic acidity and very high base saturation (98.7% on average). The sorption complex was dominated by exchangeable Ca, and the other exchangeable cations Mg, K, Na had minor contributions (Table 1). There was also found a very high content of P soluble in

0.5 mol HCl and high contents of Mg and K (Table 1). Cu content soluble in 0.5 mol HCl was low and Zn content high (Table 2). Moreover, the total content of macronutrients and heavy metals (Table 1, 2) is important for the evaluation of the chemical properties of this waste. Among macroelements Ca had the highest content. It was several dozen times higher than other macroelements in total. Quantitatively, the remaining total elements in the studied wood waste can be ranked as follows: Fe > P > N > K > Mg > Mn. The detected heavy metal contents were at the level naturally occurring in soils.

Table 1. Basic waste properties

Parameter			**A***	**B**	**C**	**D**	**E**
Organic matter	%		39.29 c	63.24 d	15.10 a	30.23 b	11.60 a
pH	H_2O		8.00b	7.31a	7.61ab	7.62ab	11.68 c
	KCl		7.90b	7.69ab	7.41a	7.55a	11.2 c
Salinity	$\mu S \cdot cm^{-1}$		444b	254a	110a	236a	3020c
Cl	$mg \cdot 100g^{-1}$		31.4b	20.8a	16.9a	17.1a	57.7c
C	%		20.63c	28.30d	6.80a	14.22b	7.60a
N			0.43c	0.27b	0.25b	0.46c	0.05a
C:N			48.8b	105.3c	27.3a	30.8a	163.3d
H**	$cmol \cdot kg^{-1}$		1.02c	0.39b	2.23d	1.27c	0.00a
S			39.1c	28.6b	17.8a	33.0b	84.6d
T			40.2c	28.9b	20.1a	34.2b	84.6d
Exchangeable cations	Ca	$cmol \cdot kg^{-1}$	28.4c	22.8b	15.8a	28.5c	33.9d
	Mg		4.90c	3.64b	1.33a	3.01b	7.16d
	K		4.10b	1.71a	0.60a	1.13a	27.33c
	Na		1.71b	0.46ab	0.09a	0.30a	16.22c
V	%		97.5bc	98.7cd	89.0a	96.2b	100.0d
Biovailable cations	P	$g \cdot kg^{-1}$ d.m.	1.77ab	1.48a	1.84b	1.99b	1.88b
	Mg		1.61d	0.93b	0.40a	1.22c	0.72b
	K		2.44b	0.92a	0.27a	0.57a	17.53c
	Ca		133.6c	87.6ab	54.0a	125.7bc	355.5d
Total cations	P	$g \cdot kg^{-1}$ d.m.	4.5ab	4.7ab	4.2a	5.1b	7.9c
	S		0.4a	0.0a	0.1a	0.9b	0.0a
	Mg		2.61b	1.25a	1.11a	2.37b	1.71ab
	K		2.86b	1.12a	0.99a	1.82ab	21.01c
	Ca		401.4c	405.2c	91.5a	182.1b	696.6d

A* - Waste on the heap,
B - Wood waste collected from the wood storage and cutting yard (*Organic wood wastes)*,
C - Wood waste collected from the wood storage and cutting yard (*Earthy waste*),
D - Waste collected from the washing and tree preparation area for treatment,
E - Ash from the waste burning from the heap.

H** - Hydrolytic acidity, S – a sum of alkaline cations, T- capacity of the sorption complex, V - the degree of saturation of the sorption complex with alkaline cations.

Table 2. Content of heavy metals in waste

Parameter			A	B	C	D	E
Available heavy metals	Cu	$mg \cdot kg^{-1}$ d.m.	12.38c	5.80ab	3.85a	8.15b	67.60d
	Zn		59.8c	40.2b	12.4a	42.8b	79.8d
	Cd		0.79bc	0.95cd	0.58ab	1.10d	0.34a
	Ni		4.43b	2.32a	1.79a	2.68a	18.69c
	Fe		2465b	1407a	1254a	2093ab	3985c
	Mn		308b	195a	211a	171a	1173c
Total heavy metals	Co		38.5bc	58.1d	16.8a	46.3cd	28.3ab
	Pb		54.5bc	29.1a	31.8ab	63.9c	41.3abc
	Cu		16.60b	9.40ab	4.97a	11.70b	123.57c
	Zn		73.3c	49.1ab	26.3a	64.4bc	118.0d
	Cd		1.29a	1.90ab	1.42ab	2.32b	0.88a
	Ni		12.91b	5.77a	4.97a	7.88a	40.77c
	Fe		9666b	4874a	5203a	8109b	32463c
	Mn		332b	190a	241ab	185a	1742c

Slightly different chemical composition of the organic material studied from pure sawdust of deciduous trees was because it is a material enriched in bark and mineral (earthy) parts. Moreover, it stays for some time in the yard and undergoes partial mineralization which enriches it in macroelements, especially nitrogen.

b) *Earthy waste*: it consisted of mineral, earthy material enriched with humus and sawdust. The waste character was mineral-organic (average 15.10% organic matter), (Table 1). It was characterized by alkaline reaction (average pH_{KCl} - 7.41), low salinity (average 110 $\mu S \cdot cm^{-1}$) and low chlorines (average 16.87 $mg \cdot 100g^{-1}$ wood waste), (Table 1). It had a significantly higher hydrolytic acidity than the organic waste and a lower degree of saturation of the sorption complex with alkaline cations (Table 1). The sorption complex was dominated by Ca, while K, Mg, and Na contributed little (Table 1). This material is rich in bioavailable P but poor in bioavailable Mg and K (Table 1). What draws attention is a high share of Fe soluble in 0.5 mol HCl. Micronutrients (Cu and Zn) soluble in 0.5 mol HCl occurred in small amounts (according to the limit numbers for evaluating the content of macro and microelements in soils (Table 2). The total content of macronutrients quantitatively was as follows: Ca, Fe, P and N were the most abundant, and K, Mg had a significantly smaller share (Table 1). According to current recommendations, no contamination with heavy metals was found (Table 2).

3.2. Waste collected from the washing and tree preparation area for treatment

These wastes were earthy but with a high proportion of bark fragments, wood and sawdust. They were characterized by an average organic matter content of 30.23% and about half the proportion of total carbon, alkaline reaction (average pH_{KCl} - 7.55), low salt (average 236 $\mu S \cdot cm^{-1}$) and chlorines (average 17.13 $mg \cdot 100g^{-1}$ wood waste), (Table 1). They had a high sorption capacity (average 34.23 $cmol \cdot kg^{-1}$), with the sorption complex saturated mainly with exchangeable Ca, other cations constituted a small percentage (Table 1). Moreover, the material was rich in bioavailable P and Mg, and medium rich in bioavailable K (IUNG 1990), (Table 1). The content of bioavailable micronutrients (soluble in 0.5 mol HCl) was medium for Cu and high for Zn (Table 2). The total macronutrient content was dominated by Ca followed quantitatively by P and N, while Mg and K accounted for a small percentage (Table 2).

The waste from the tree washing and preparation area was significantly more abundant in macronutrients (N, P, K, and Mg) than the organic waste found in the tree storage and cutting area (Table 1, 2). At the same time, this material contained more heavy metals than the organic material found in the wood storage and cutting yard.

3.3. Waste on the heap

The mixture of the above-mentioned wastes was stored in a heap.The wastes taken from the heap were characterized by an average organic matter content of 39.29% and half the amount of total carbon, alkaline reaction (average pH_{KCl} - 7.90), low salinity (average 444 $\mu S \cdot cm^{-1}$) and low chlorines content (average 31.42 $mg \cdot 100g^{-1}$), (Table 1). A significant share of organic matter shaped high sorption capacity (average 40.15 $cmol \cdot kg^{-1}$), with sorption complex almost entirely saturated with exchangeable Ca, other basic and acid cations had a small share (Table 1). The material was also very rich in bioavailable P, K and Mg as well as in microelements Cu and Zn (Table 1, 2). The total content of macronutrients varied (Table 1). Ca dominated (on average 401.4 $g \cdot kg^{-1}$), in much smaller amounts occurred: Fe (average 9.67 $g \cdot kg^{-1}$), P (average 4.54 $g \cdot kg^{-1}$), N (average 4.30 $g \cdot kg^{-1}$), K (average 2.86 $g \cdot kg^{-1}$) and Mg (average 2.61 $g \cdot kg^{-1}$). The determined amounts of heavy metals (Co, Pb, Ni, Zn, Cu) were natural (Table 2).

3.4. Ash from the waste burning from the heap

The ashes resulting from the burning of wood waste from the heap were characterized by an alkaline reaction (pH_{KCl} - 11.2), a significant proportion of organic matter - 11.6% and an increased salt concentration (3020 $\mu S \cdot cm^{-1}$ on average), (Table 1). However, they did not have hydrolytic acidity, which is natural for their alkaline reaction. On the other hand, they had a high sorption capacity - 84.61 cmol·kg^{-1}. In the studied ashes, the content of exchangeable forms of cations can be presented according to the scheme: Ca > K > Na > Mg (Table 1). Moreover, it was rich in bioavailable phosphorus, potassium, zinc and copper and moderately rich in bioavailable magnesium (Table 1, 2). The total content of macroelements was dominated by Ca the other macroelements constituted a small percentage (Table 1). The content of heavy metals did not exceed the permissible amounts listed in the regulation (Journal of Laws 2008, no. 119, item 765), (Table 2).

From the tested wood wastes, the waste stored on the heap (A) had significantly better sorption properties (Tables 1, and 2). It contained exchangeable, bioavailable and total K, Mg and bioavailable Cu, Zn and Mn. In addition, this waste contained significant amounts of Na and Cl which influenced significantly higher salinity than in the other wastes.

Generally speaking, the worst chemical properties were in the wood waste with soil (C). It had significantly the lowest organic matter content, the lowest sorption capacity and contained the least exchangeable, bioavailable and total K, Mg and Ca. In contrast, the ash waste had different chemical characteristics from the wood waste (Tables 1, and 2).

4. DISCUSSION

The waste generated at the veneer factory is given the waste code 03 01 99 (wastes not specified from wood processing and the production of panels and furniture). These are classified as earth with sawdust. The addition of earthy parts in this wood waste means that it is not included in waste code 03 01 05 (Sawdust, shavings, cuttings, wood, particleboard and veneer). Wood processing waste with code 03 01 05 is used as a secondary raw material or can be used in the recovery process R10 of land treatment benefiting agriculture or improving the environment, while waste with code 03 01 99 is not. Wood processing waste with the code 03 01 99 cannot be used as a secondary raw material for procedural reasons, although it could be used for recovery through land treatment due to its research-proven beneficial properties. Farmers and gardeners are potentially interested in this waste. However, the generator of this waste is obliged to dispose of it in a landfill.

The veneer factory from which wood waste was collected for analysis processes several different deciduous tree species from a wide range of habitats. The chemical composition of sawdust/waste is closely related to soil properties and tree species [22]. In the veneer production process, wood waste is obtained from the washing and preparation of trees for processing and from the tree storage and cutting yard, which is then stored in a heap. There they undergo biological and chemical transformations in the composting process.

Wood waste produced at the veneer plant differs in chemical composition.

The waste deposited in the heap has the highest pH; salinity and Cl content; exchangeable, bioavailable, and total Mg and K; and some heavy metals: Cu, Zn, Ni, Fe, and Mn. The organic waste that ends up in the heap from the tree processing has properties typical of raw clean wood waste [15].

Heap waste has several times lower C:N ratios than wood waste (700:1), sawdust (200:1 to 750:1), hardwood and softwood chips (580 and 641:1, respectively), and sawmill waste (average 170:1) [15]. On the other hand, according to Czekała and Czekała [8], the C:N ratio in sawdust is 112:1; Kajda-Szcześniak [16] in spruce wood is 383:1; Kurowska [22] in pinewood is 202:1. The lower values of C: N ratio in compost waste were favourable and indicates a higher microbial activity of the tested material. The reduction in the C:N ratio of composted waste compared to raw waste confirms the composting processes that occur in the heap [25].

In the studied wastes, the contents of P, K, Mg and Ca were higher than in pure, raw sawdust of coniferous (pine) and deciduous (ash, maple, beech, oak) trees, [38], but similar to the abundance in biomass composts [41]. Sawdust is very poor in mineral nutrients, especially in nitrogen [13, 38]. The N content in the studied wastes was higher than generally found in shavings, sawdust and sawmill wastes [38]. According to the current legislation on fertilizers and fertilization (Dz.U. 2008 Nr 119 poz. 765), the tested wood wastes met the minimum requirements for solid organic fertilizers as to organic matter content: >30%; N: > 0.3%; P: > 0.2% P_2O_5 (>0.0873 P) and K: > 0.2% K_2O (>0.166 K). The contents of P, K and Mg, according to BN - 89/9103 - 09, are typical for class I compost, only the nitrogen content corresponds to class III. Moreover, the content of organic matter and the amounts of macroelements (P, K, Ca, Mg) were within the ranges found in composts from plant waste (grasses, leaves, tree branches and bark, etc.) only the nitrogen content was lower [41, 24].

The waste from the heap contained typical amounts of heavy metals found in clean, raw sawdust of deciduous trees (ash, maple, oak), [38]. They did not exceed permissible concentrations in organic and organic-mineral fertilizers: cadmium (Cd) - 5 mg, nickel (Ni) - 60 mg and lead (Pb) - 140 $mg \cdot kg^{-1}$ d.m. (Dz.U. 2008 Nr 119 poz. 765). However, they were much lower than in the standard BN-89 9103- 09 for compost from municipal waste class I and similar to the contents of metals in composts from organic waste [24, 41]. In addition, wood waste has low solubility of heavy metals and their availability to plants [44]. Wood waste may be introduced into soils only after fulfilling certain conditions in Dz.U. 2014, poz. 1293; Dz.U. 2016, poz. 1395; Dz.U. 2016, poz. 108; Dz.U. 2018, poz. 992; Dz. U. 2001 Nr 62 poz. 627; Dz.U. 2015, poz. 132. The regulation indicates, among other things, the need for prior composting of waste before it is introduced into soils. Composting is one of the methods of disposal of organic solid waste.

Composting of biomass from sawdust and smaller tree limbs should be done with the addition of calcium fertilizers (for coniferous tree waste), nitrogen fertilizers, and other biomass with small amounts of cellulose and lignins (with a narrow C:N ratio) or earthy parts. Application of such compost enriches the soil in organic matter, and plant nutrients, reduces soil acidity and improves soil sorption capacity and buffering capacity as well as water-air relations [13, 14, 28]. According to Szulc et al. [38], the best fertilizer value as a compostable product is characterized by deciduous tree waste. The resulting organic fertilizer can replace or supplement manure fertilization [42]. Siuta [35] indicates that the fertilizer value of organic wastes should be considered from the humus-forming perspective. The organic matter brought into the soil is more important for soil fertility than mineral nutrients.

Clean sawdust, shavings, and bark are commonly used as growing media in horticulture and for direct soil mulching in orchard cultures, with nitrogen fertilization then required. Mulching improves habitat conditions and benefits plant growth and yield [19, 29, 21].

The conducted research showed that the studied wastes do not pose a threat to the environment and meet the criteria of organic fertilizers. Mazur and Filipek-Mazur [24] believe that organic waste products and by-products, which meet the fertilizer criteria and do not pose a threat to the environment can be used in agriculture, horticulture, forestry, urban green areas and recultivation of degraded land. Another non-agricultural use of wood waste is burning it for energy. Burning biomass produces ash that may have fertilizer value due to its chemical properties [32].

The ash obtained from burning wood waste from the pile had an alkaline reaction, typical of wood ash, which was more abundant in Ca, K and poorer in P and Mg than wood ash studied by Siwek et al. [36] and Emilsson [10]. Biomass ashes contain almost all nutrients necessary for plant growth, except nitrogen, which is released in gaseous form during the combustion process [43]. Ashes from wood fuel combustion have high amounts of calcium, magnesium and potassium, while ashes from green fuels mainly have potassium [4, 39]. Kosior-Kazberuk and Lelusz [18] also indicate a significant proportion of magnesium in ashes from biomass combustion. Their deacidifying effect on soils is also well documented [3, 31,40]. Biomass ash fertilization is used for organic soils that are acidic and low in potassium [27]. Biomass ashes are much more abundant in potassium than coal and lignite ashes [7].

The possibility of agricultural use of ashes from wood waste is also determined by the content of heavy metals in them. It depends on the type and quality of wood and the place where it was harvested. The content of heavy metals

in the studied ash is lower except for nickel than those reported by Serafimova et al. [33] in wood ash. Compared to coal ash, the heavy metal content is significantly lower [6] and higher compared to green fuel ash [39].
In the examined ashes, as well as in the wood waste from which they were generated, the content of heavy metals does not exceed the permissible amounts specified in the Regulation of the Minister of Agriculture and Rural Development of 18 June 2008 on the implementation of certain provisions of the Act on Fertilizers and Fertilization (Dz.U. 2008 Nr 119 poz. 765).

5. CONCLUSION

Figures and tables should be included in the file with the main text. All figures
The study of the chemical composition of wood waste, which is produced in the veneer factory, and the ash obtained from the waste burning process showed that:

1. The composition of wood waste is dominated by sawdust, with a smaller part consisting of shavings, bark and earth parts and a small addition of pieces of wood of various sizes.
2. The waste is organic and meets the legal requirements for solid organic fertilizer.
3. They are rich in easily bioavailable as well as total macro- and microelements (N, P, Ca, K, Mg, Zn, Cu and Fe). The content of Cd, Co, Pb, Zn, Ni, Cu, and Fe is acceptable for solid organic fertilizers. Wood waste does not endanger the natural environment
4. They have deacidifying properties because of their alkaline reaction and high level of saturation with base cations (mainly calcium). They have high sorption and buffer capacity.
5. The tested wood waste, although it contains earthy parts, is similar to wood waste with code 03 01 05 and should be managed in a similar way.
6. The ash obtained as a result of thermal utilization of the product is strongly alkaline and rich in alkaline cations, mainly Ca, Mg and K. It is not contaminated with heavy metals, so it can be used for soil fertilization, especially for land reclamation.

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Editor received the manuscript: 05.09.2022