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ISSUES OF BIODEGRADABLE COMPONENTS IN MUNICIPAL SOLID WASTE: SHORT OVERVIEW OF THE PROBLEM AND ITS POSSIBLE SOLUTION IN UKRAINE

Veronika PRYKHODKO [a]*, Tamerlan SAFRANOV [b], Tatyana SHANINA [a]

[a] PhD, Associate Prof.; Faculty of Nature Protection, Department of Environmental Science and Environmental Protection, Odessa State Environmental University, 15 Lvivska Street, Odessa, Ukraine
*Corresponding author. E-mail address: *vks26@ua.fm*

[b] DSc, Prof.; Head of the Dep., Faculty of Nature Protection, Department of Environmental Science and Environmental Protection, Odessa State Environmental University, 15 Lvivska Street, Odessa, Ukraine

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Abstract

The paper focuses on the problem of biodegradable waste in municipal solid waste in Ukraine. More then 60% of the total municipal solid waste mass in Ukraine is biodegradable waste. At present, this waste group is almost completely dumped on waste disposal sites and landfills that lead to "resource value" loss and to environmental problems. The work presents a classification of the group of biodegradable waste in municipal solid waste as well as quantitative characteristics of the group and the results of data variability analysis. Methane emission and disruption of the natural cycles of nutrients, in particular carbon, are considered as the environmental problems, related to such waste disposal on the waste dumps. Based on the biodegradable waste classification, the main possible ways of the problem solution that will help to achieve a "zero waste" goal for this group are presented. Efficient use of such waste as recyclable material resources is possible in case of easily-decomposed organic waste separation at the waste generation moment.

Keywords: **Biodegradable Waste; Disposal; Greenhouse Gases; Management and Treatment.**

1. INTRODUCTION

Above all, the term "biodegradable waste" is to be defined. According to the Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste [1], this term means any waste that is capable of undergoing anaerobic or aerobic decomposition. Thus, the biodegradable characteristic of this waste group means biodegradable organic carbon (DOC) content as a source of food for microorganisms. According to The Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories [2], the components containing DOC among municipal solid waste (MSW) components include the following waste types: paper and cardboard, textiles, food waste, wood, park and garden waste, personal hygienic items (nappies). According to Ukraine's Greenhouse Gas Inventory [3] rubber and leather are considered as biodegradable waste (category VII) and are taken into account in calculations of the methane emissions from waste disposal sites. The attribution of rubber waste (as well as leather waste) to biodegradable waste is a rather controversial issue, as we assume that it is mainly synthetic leather and rubber. Moreover, the [2] contain a note indicating that "rubber and leather contain also certain amounts of non-fossil carbon, but this is hardly degradable". A more detailed study of leather and rubber waste composition in the MSW of Ukraine is an important practical task necessary for an informed answer to the question. In this research, we will conditionally consider the rubber and leather waste as biodegradable, as it is needed to comply with the national classification of biodegradable waste [3].

Biodegradable waste constitutes the larger part of MSW (above 60%) and therefore it is important to describe this part of MSW for the aim of efficient waste management and treatment. For Ukraine, it is a very topical issue due to the fact that the basic method of the MSW problem solution is disposal of such waste into dumps and landfills (94% of MSW), which is the highest rate in Europe [4]. Almost 100% of waste types containing DOC are not recovered, but are disposed. Thus, these components lose their resource value and become a source of environmental pollution due to bio-destruction processes in the landfills. One of the environmental pollution effects from landfill is generation and emission of greenhouse gases (GHG). According to [3], the share of "Waste sector" in national GHG emissions is too small (1.4–3.9%) and having a sustainable trend in Ukraine: from 1990 to 2019 the total GHG emission was decreased by 0.96%; but in particular, methane emission from landfills was increased by 21%. Nowadays, Ukraine is at the beginning of the way of significant changes in the MSW management area. For example, the Waste Management Law of Ukraine is in the developmental stage; the National Waste Management Strategy 2030 was adopted at the end of 2017. However, the first effort to change the current crisis situation in MSW area was an amendment to The Law of Ukraine on Waste (1998) [5] according to which disposal of untreated MSW was forbidden from 1 January, 2018.

Unfortunately, the amendment to the Law [5] was not brought into effect in real life. All attempts to select and recycle relate to "classic" recyclable waste types (plastic and glass bottles, paper), but not to biodegradable waste. An agreement between the European Union and Ukraine signed in 2014 provides implementation of the European legislation and experience of the developed countries in the MSW area management in Ukraine. Among other things, Article 5 of Directive [1] stipulates that the EU member states should implement the reduction of biodegradable waste going to landfills within specified time limits. Consequently, the analysis and research of biodegradable waste group as a basis of effective MSW management system is an actual scientific and practical task. We expect a proper use of biodegradable waste will entail a reduction of human pressure on the environment created by waste as well as allow more efficient processing of the whole MSW stream. So we can formulate specific objectives of the research: 1) to describe the biodegradable waste group in MSW of Ukraine; 2) to make assessment of environmental effects in terms of current state of the MSW problem; 3) to develop general recommendations for creating the conditions to start the 3Rs (reuse, recycling and recovery) of the biodegradable waste group based on the obtained results.

2. MATERIALS AND METHODS

The results of waste composition studies for various cities and towns of Ukraine were used as the input data for research, in particular the database for 15 Ukrainian cities obtained by Biodynamic experimental private enterprise "Sashik" and Skrypnik [6, 7], single field observations and studies [8–11], the complex waste management programs for some regions of Ukraine (Poltava, Zakarpattya, Odessa). The most complete information about the biodegradable wastes in MSW appears in the Ukraine's Greenhouse Gas Inventory Reports (for example, the last version is Inventory Report (2021) [3]). The studies of the Science and Technology Center "Biomass" and the National Center for Greenhouse Gas Emissions Accounting (Matveev, Pukhnyuk, Shmarin and others) were used to compose Inventory Reports, so the original results were taken for studies, specifically those from the paper [12]. This paper is also based on the results of our earlier researches dedicated to issues of GHG emission from landfills [13–14] and carbon redistribution during different waste treatment methods [15].

The National multicomponent model, based on the first order decay method of third detalization level (the National Model) and other models from Inventory Report (2021) [3] were used by us to estimate GHG emission from waste disposal and incineration.

We present the National Model equation from Inventory Report (2021) [3] in form adapted for estimation of the annual methane emission $Q(t)$ from MSW mass generated per year (annual MSW generation):

$$Q(t) = \sum_{j=1}^{m}\sum_{i=1}^{n} A \cdot k_j \cdot MWS_i \cdot MWS_{i,j} \cdot L_{0i,j} \cdot e^{-k_j \cdot (t-x)}, \quad (1)$$

A – the normalizing factor correcting the sum, determined by (2)

$$A = (1 - e^{-k_j}) / k_j, \quad (2)$$

k_j – the constant rate of methane production (reaction constant) for waste type *j*, year^{-1}

MWS_i – the total amount of MSW landfilled in year *i*, t ·year^{-1}

$MWS_{j,i}$ – content of waste type j of MSW in year *i*

t – calculation year

x –start year (disposing year)

$L_{0j.i}$ – CH_4 generation potential, *t* of CH_4 per *t* of MSW, defined by the formula:

$$L_{0i,j} = DOC_j \cdot DOC_F \cdot F \cdot 16/12 \cdot MCF_i \ , \qquad (3)$$

DOC_j – the total amount of DOC for type of waste j

DOC_F – fraction of DOC that can decompose ($DOC_F = 0.5$)

F – fraction of CH_4 in generated landfill gas ($F = 0.5$)

16/12 – molecular weight ratio CH_4/C

MCF_i – methane correction factor depending on waste disposal practices.

The equation for estimating CO_2 emission (Q_{CO_2}) from incineration is [3]:

$$Q_{CO_2} = MSW_{inc} \sum_{j=1}^{m} WF_j \cdot dm_j \cdot CF_j \cdot FCF_j \cdot OF_j \cdot 44/12 \qquad (4)$$

MSW_{inc} – total amount of MSW as wet weight incinerated *t/year*

WF_j – fraction of waste type j in the incinerated MSW

dm_j – dry matter content in the waste type j of MSW

CF_j – carbon fraction of dry matter of waste type *j*

FCF_j – fraction of fossil carbon in the total carbon of waste type *j*

OF_j – oxidation factor

44/12 – the conversion factor from C to CO_2.

The calculations of CH_4 and N_2O emissions are based on the amount of waste incinerated/open-burned and on the related emission factors (see eq. (5, 6):

$$Q_{CH_4} = MSW_{inc} \cdot EF_{CH_4} \cdot 10^{-6} \ , \qquad (5)$$

$$Q_{N_2O} = MSW_{inc} \cdot EF_{N_2O} \cdot 10^{-6} \ , \qquad (6)$$

EF_{CH_4} and EF_{N_2O} – aggregate emission factors for CH_4 and N_2O.

For Ukraine, the EF_{CH_4} for all types of waste is 118.5 g of CH_4 kt^{-1}; EF_{N_2O} is 55.100 g of N_2O kt^{-1} [3].

3. RESULTS AND DISCUSSION

3.1 Characteristics of biodegradable waste group in MSW in Ukraine. As previously mentioned, the group of biodegradable waste in MSW stream consists of seven waste types containing DOC: paper and cardboard, textiles, food waste, wood, park and garden waste, personal hygienic items (nappies), rubber and leather. Consequently, we can make a short classification within the group by common properties as an indicator of further treatment (See Table 1). From 2020, another biodegradable component can be identified – bio-based plastic. Today, its content in the total mass of MSW is very small, but due to changes in legislation from 2023, a gradual increase to 1–2% is expected. The municipal solid waste Treatment Concept was chosen as a basis for this classification. The municipal solid waste treatment Concept was developed at Odessa State Environmental University including the authors of this paper [16–18]. In accordance with the Concept the overall MSW stream is separated into the following streams: 1) easily-decomposed organic waste; 2) potentially recyclable material resources, including inert mineral bulk waste; 3) hazardous waste. The essential condition of the Concept realization is MSW stream differentiation at the beginning of its “life cycle”.

At first, the time trends in some waste types content level were considered by us (Fig. 1).

Table 1.
Classification of biodegradable waste types in MSW

easily-decomposed organic waste (moisture-laden)		**potentially recyclable material resources**				**hazardous waste**
food waste	park and garden waste	paper and cardboard	textiles	wood	rubber and leather	personal care products (nappies)

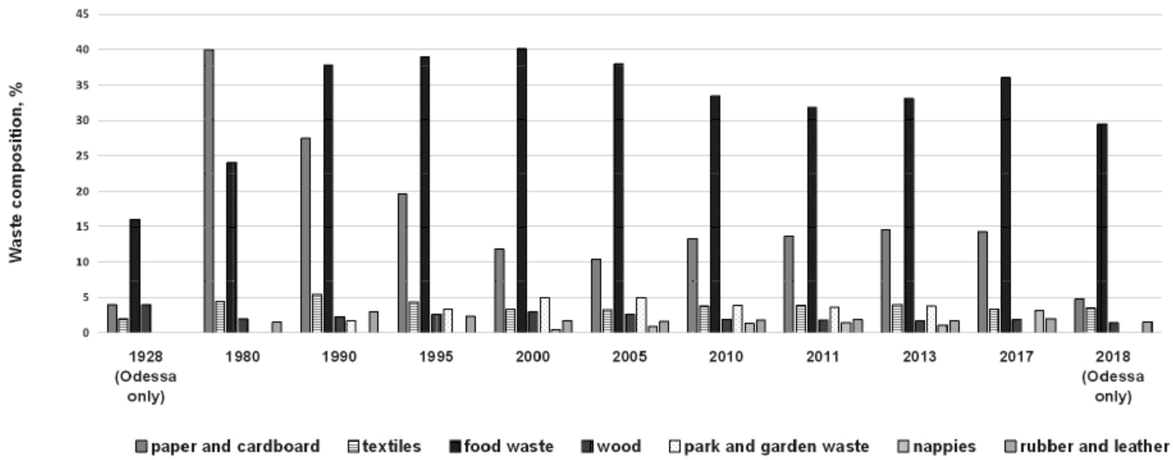

Figure 1.
The share of waste types in total MSW mass in Ukraine (performed by the authors using data: 1928, 1980 from [19]; 1990–2011 – from [3]; 2013 – from[12]; 2017 – http://www.uabio.org/activity/uabio-analytics; https://www.globalmethane.org/; 2018 – from The Project of Odessa Regional Waste Management Plan)

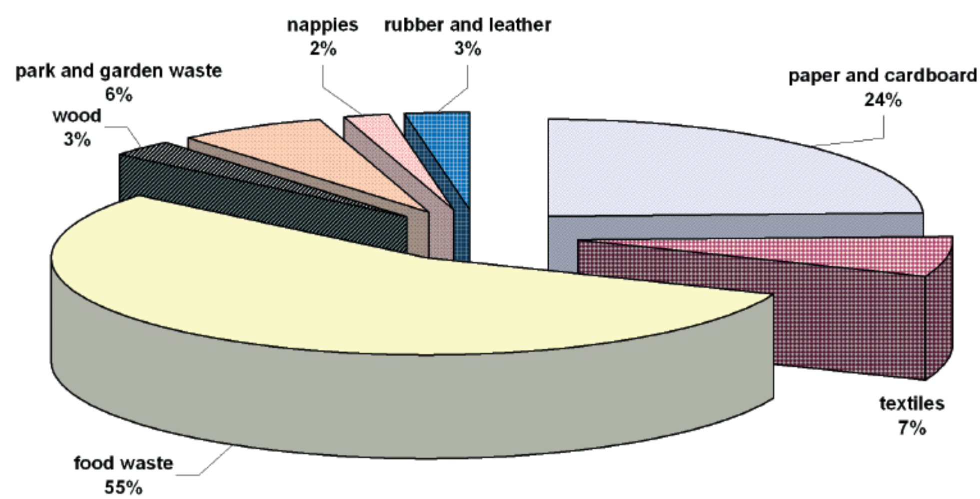

Figure 2.
Composition of biodegradable waste group (based on data from [12])

As we can see, during the period of 1980–2017 there was a significant decrease (2.8 times) of paper and cardboard content in MSW. In 1980 the segment of this waste was 10 times more in comparison with 1928. The share of food waste increased 1.3–1.6 times from 1980. Also, the share of garden and park waste also increased almost 5.6 times from 1990 to 2013. During the period from 1980 to 2017 the portion of wood, leather and rubber was slightly changed. Beginning from 2000, the new component in MSW – personal care products – is taken into account. Now their mass is 1.3% of the total MSW and its content increased 7.6 times from 2000 to 2017. It must be noted, there was a lack of data in regard to garden and park waste during 1928-1990. We also note that since 2011, the MSW composition in this data source [3] has not changed, so further we will use the data obtained by Shmarin et al. [12] as a full set of components including garden and park waste.

Fig. 2 shows the mass ratio between waste types within biodegradable waste group based on data from [12]. As we can see, the largest segment is food waste (55%), the next is paper and cardboard (24%) and garden and park waste (6%). 15% of total mass of the group are formed by the rest components. Waste types are differed in DOC content [2, 20].

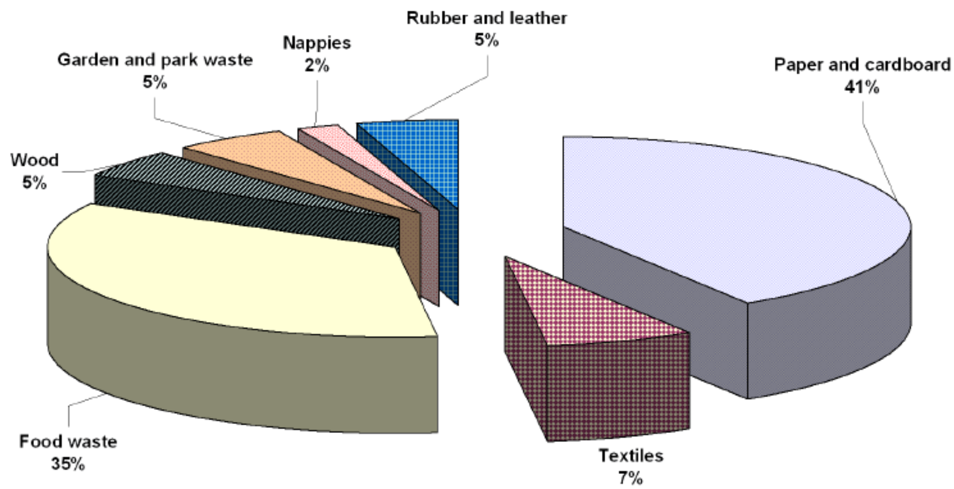

Figure 3.
The DOC mass redistribution in the biodegradable waste group (Ukraine)

Fig. 3 shows the distribution of DOC mass between different waste types.

To compare the diagrams (Fig. 2, 3), we can see that despite the largest share of food waste (55% by mass), they contain only 35% of total DOC mass. Another situation is for paper and cardboard waste. As we can see from eq. (3), DOC is one of parameters to determine the methane emission from landfills.

It is necessary to consider the territorial differences in the quantity of biodegradable waste types. Each city has its own waste composition, which can considerably vary from national and regional averaged data. Due to the lack of data sufficient amount, we couldn't make the reliable generalization by regions in Ukraine. Pavliuk [11] presents some results of analysis the MSW composition by cities of Ukraine, depending on the level of income. The results presented by Pavliuk also support the fact that biodegradable waste is the large part of MSW.

The results obtained by Skrypnik [6, 20], Korinevskaya [21] show that composition of waste in cities with population 10,000 to 1 mln. people differs from composition of waste in the cities with population more than 1 mln. and from rural settlements. For the research of differences in the qauntity of biodegradable waste types depending on the place of its generation, we have formed a data base for the group of cities with a population 10,000 to 1 mln. people. As an assessment criterion the variability of the waste type part in the MSW, we choose the coefficient of variation – a standardized measure of data dispersion.

We used data of waste composition for 21 Ukrainian cities with population 10,000 to 1 mln. people received from different data sources: see "Materials and methods". Table 2 shows the estimation result of data variability for some biodegradable waste types of MSW.

As we can see from Table 2, the most variable is the share of rubber, leather and wood in total mass; the most stable is the share of food waste. It can also be noted, the larger is the share of some waste type in solid waste total mass, the more stable is its value relative to the mean of average content level. Unfortunately, there is a lack of data about park and garden waste and nappies.

It has to be said about significant differences between real and average data, data from different sources. So, it may be concluded, that it is better to use real data of MSW composition, than average data for the purpose of waste management system development for a particular city or region of Ukraine. Real waste composition data is the basis for the development of clear and realistic Waste Management System [22]. Unfortunately, there is a great lack of data about waste composition, especially biodegradable components.

3.2. Environmental effects assessment

The main method of saluting the MSW problem in Ukraine is disposing in dumps and landfills. This is especially applied for biodegradable waste group of MSW. The two main environmental problems connected with MSW landfilling can be defined. The

Table 2.
The variability of biodegradable waste type content level (in MSW of Ukrainian cities with 10,000 to 1 mln. people) and averaged data from different sources of information

	Waste type				
	Paper and cardboard	Food waste	Wood	Textile	Rubber and leather
Average content,%	8.62	33.78	1.91	3.08	1.63
Coefficient of variation, %	38.80	31.25	85.49	49.74	82.47
Source of data	**Average data about content level (% by mass) of biodegradable waste types by different data sources**				
[6]	6.37	40.02 (with park and garden waste)	1.19	2.33	1.07
[21]	8.81	31.49 (with park and garden waste)	2.72	2.95	2.24
[12]	14.6	33.1	1.7	4.0	1.7
[3]	13.7	31.8	1.8	3.9	1.9

Note: [1]for cities with population 10,000 to 1 mln. people

Table 3.
GHG emission from the main MSW treatment methods in Ukraine (composed by the authors on the basis of data from [3, 23]

Treatment method	GHG	Trend 1990–2019
Waste disposal into landfills and dumps	$\underline{CH_4}$, CO_2, N_2O, NMOC	increased by 30.25%
Incineration	$\underline{CO_2}$, $\underline{N_2O}$, $\underline{CH_4}$, C_mH_n	decreased by 81.6%
Biological treatment (including livestock waste and others)	CO_2, $\underline{N_2O}$, $\underline{CH_4}$, H_2O, C_mH_n	decreased by 76.2 %

Note: underlined substances whose emission is calculated in the Inventory Reports

first problem is GHG emission, produced by anaerobic digestion of organic substances from waste into the landfill body. Obviously, GHG is also generated in other waste treatment methods – biological treatment and incineration (see Table 3).

But the main sources of GHG for Waste Sector in Ukraine continue to be landfills and dumps (99.5%). GHG generation from incineration and biological treatment is rather negligible due to the low prevalence of these MSW treatment methods.

For the purpose of illustrating GHG generation from seven biodegradable waste types, we used the National Model and input data from Inventory Report (2021) [3] recommended for Ukraine: methane correction factor 0.697 and others parameters from eq. (1–3). Annual MSW generation in 2019 – 10417.58 kt. However, similar calculations for regional conditions within a country should be performed by using the specified to regional conditions parameters. For example, in our previous research [13] we specified the parameters of k_j and MCF_i for the Odessa region. As a result, the calculated annual methane emission using specified parameters was decreased by 21.7% (from 2.12 to 1.66 kt of methane).

In 2020 the total CH_4 generation from the annual mass of biodegradable waste in MSW disposing was 21.14 kt or 443.94 kt CO_2-eq. That is 6.2% of total CH_4 generation from landfill and dumps in Ukraine (340.47 kt CO_2-eq. calculated in Inventory Report (2021) [3] with account for MSW disposal in previous years).

Fig. 4 shows CH_4 generation distribution between waste types next year (Fig. 4a) and next 50 years (Fig. 4b) after waste disposal.

Therefore, a year after waste disposal the most of CH_4 (54%) is produced from food waste destruction, that is predominant by mass, but in 50 years' time its part will be decreased to 5%. The second largest component is paper and cardboard waste that will produce 61% of total CH_4 mass within 50 years after disposing. But a year after disposing its part forms only 30% in total CH_4 generation.

The important conclusion follows from the results (Fig. 2–4) – non-admittance of paper and cardboard waste disposal in landfills and dumps is as important as non-admittance of food waste disposal for the purpose of GHG emission reduction.

GHG emission from waste disposal sites is a long-term process, taking more than 50 years. As it was shown in the previous research [15], a year after MSW disposal, 98% of carbon stays into the landfill body, 2% transfer to the atmosphere with GHG.

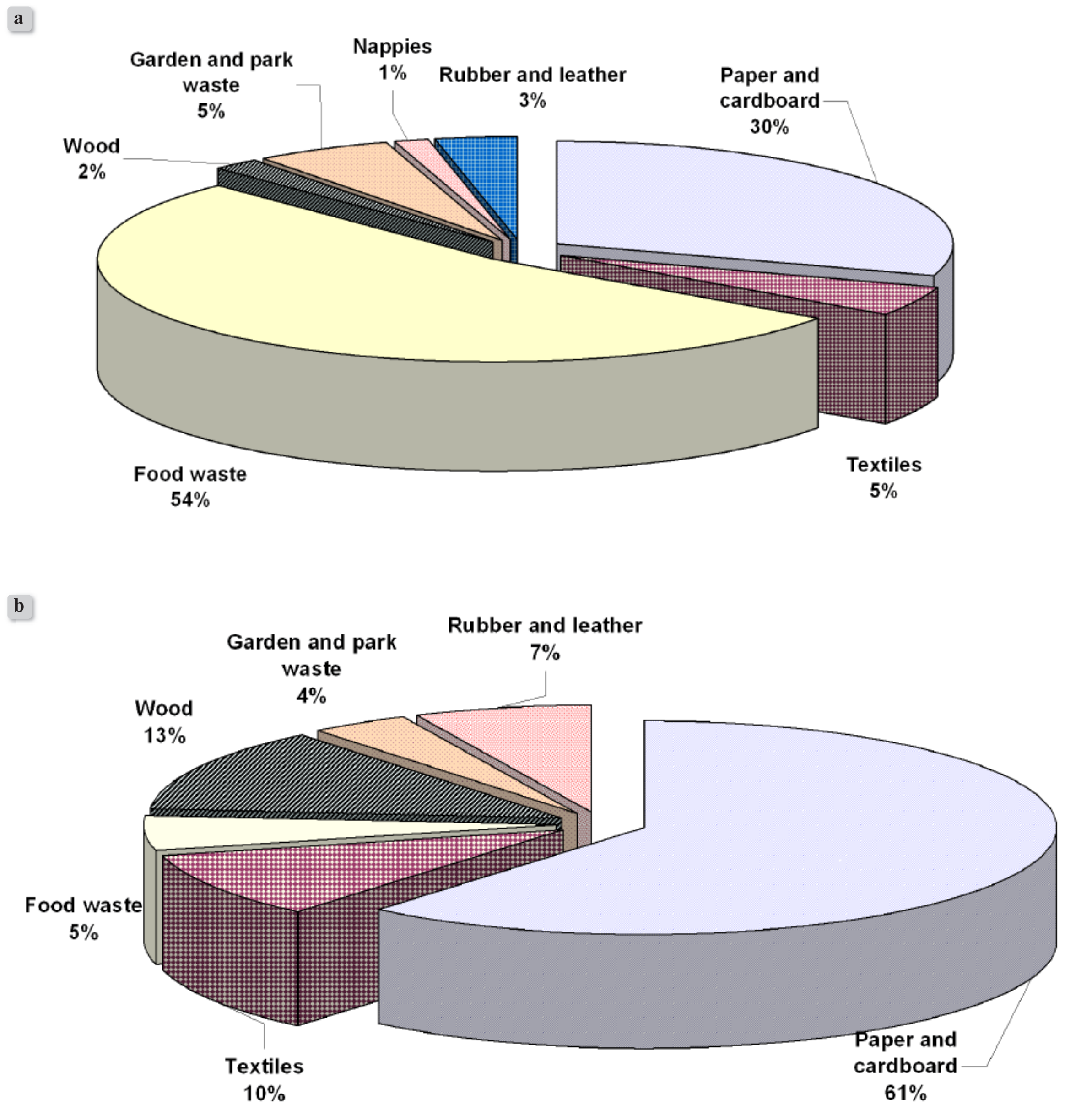

Figure 4.
The CH_4 generation from decomposition of biodegradable waste annual mass (2019) in landfills and dumps in Ukraine: a – a year after disposal (2020); b – 50 years after disposal (2069)

So *the second environmental problem* connected with MSW landfilling is disturbance of natural cycles, especially of nutrients. In particular, the natural cycle of carbon is disturbed because of the main part of its mass is localized in the MSW disposal sites for a long time – only 27% of carbon will come to the atmosphere and involve in natural carbon cycle within 50 years [15]. We can assume, that almost all the mass of phosphorus and nitrogen remain localized into the landfill body. The main way to involve nitrogen e.g. is N_2O emission in atmosphere and transfer of nitrogen compounds to the leachate. According to the National Regulations on landfilling, it should not enter the environment but be localized in the landfill territory.

To minimize the MSW impact on environment it is necessary to reduce the disposing volume in landfills and dumps. It is possible in case MSW components to be considered as potential resources and their use to become more attractive than disposal. It is a very acute issue for biodegradable waste group as the largest in mass, and its failure to use up leads to contamination by waste destruction products and to disturbance of nutrients redistribution in environment. In case of disposing the only way to use the “resources” in waste disposal sites is methane recovery. According to Inventory Report (2021) [3], 25.30 kt of methane from landfills was recovered in 2019 by 19 landfill gas extraction systems. It was only 7.43% oftotal methane emission volume from waste disposal sites.

3.3. Recommendations to start the recovery of biodegradable waste from MSW in Ukraine.

On the basis of the obtained results, we have worked out basic recommendations for the use of resource potential of biodegradable waste group in MSW.

The Waste Hierarchy [24] can be used as an effective biodegradable waste management base. The Waste Hierarchy includes 5 steps: prevention, reuse, recycling, recovery, disposal.

Prevention is the first «product» (non-waste) stage. The general rule to prevent biodegradable waste generation is shopping planning: don’t buy more than you need, save money and don’t generate extra waste. It is successful principle to prevent waste generation that works in Ukraine.

The next four steps of Hierarchy form the waste stage. Now we deal with waste. It is necessary to realize the Concept [16–18] and separate MSW stream into the following streams (see Table 1) for the purpose of realizing 3R (reuse, recycling and recovery) for different waste types. The paper has discussed the key principles of the Concept concerning biodegradable waste.

Separation of MSW into streams is implemented in the following way -people separate easily-decomposed organic waste at the moment of generation using specially designed storage containers, and the rest of MSW components is collected into separate container (or different containers) and sent then to a waste sorting plant for sorting and further recycling and recovery. The entirely new approach proposed by us to MSW problem solution is to implement separation of easily-decomposed waste stream as a first-step measure. Unlike The Guidelines of organization separate MSW collection, developed by the Ministry of Housing and Utilities of Ukraine in 2008 [25], the realization of the Concept implies to use of only two types of waste containers – for easily-decomposed organic waste and residuary waste. We think, it is more practical than separate waste collection, e.g. into five containers as it is recommended by Guidelines [25]). Thus, only one component (easily-decomposed organic materials) of MSW is to be separated instead of two or more in case of separate collection.

We present the MSW flows distribution in the diagram form (Fig. 5) for better illustration the differences in the regulatory (Guidelines [25]) and our proposed approach to separate MSW collection in the Ukrainian cities.

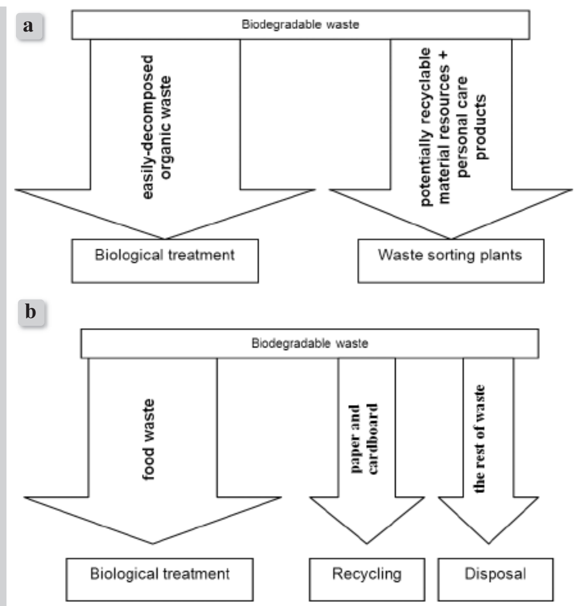

Figure 5.
The differences between our (a) and regulatory (b) approaches to MSW stream differentiation for biodegradable waste

The second advantage of the Concept realization is possibility to obtain “pure” resource for biological treatment with biogas and compost production. Moreover, elimination of this stream at the beginning of MSW “life cycle” provides obtaining the potentially recyclable material resources in the uncontaminated form and thereby increasing the 3R effectiveness.

There is a big problem with a hazardous waste stream in Ukraine. In accordance with the Concept, hazardous waste is to be separated through organization of targeted collection for different types of waste, but it can not be accomplished in actual practice. But in case of easily-decomposed organic waste separation, hazardous waste will be detached with the other part

Table 4.
The biodegradable waste management and treatment system

easily-decomposed organic waste (containing moisture)		potentially recyclable material resources				hazardous waste
food waste	park and garden waste	paper and cardboard	textiles	wood	rubber and leather	personal care products (nappies)
Biological treatment, for example, the complex recovery[1]		reuse		recycling and recovery	incineration or disposal	
		recycling				
		← Non-standard part →				

Note: [1]by Shanina et al. [22]

Table 5.
The estimation of GHG emission from the biodegradable waste management and treatment system

easily-decomposed organic waste(containing moisture)		potentially recyclable material resources				hazardous waste
food waste	park and garden waste	paper and cardboard	textiles	wood	rubber and leather	personal care products (nappies)
The first stage (anaerobic digestion) of complex recovery1		reuse recycling recovery			incineration or disposal	
GHG emissions						
0 kt CO_2-eq., excluding biogas process losses above 5%[2]		Depends on recycling and recovery technologies, reported in others Sectors of Inventory Report. Reuse is characterized by zero GHG emission			7389.57 kt CO_2-eq. or 601.11 kt CO_2-eq. (during 50 years after disposal)	

Note: [1]by Shanina et al. [22]
[2] by Prykhodko et al. [15]

of MSW, and we hope, it will be set apart from the stream of potentially recyclable material resources at a waste sorting plant. In this case the required condition for further use of "resource value" from potentially recyclable material is availability of waste sorting plants or lines.

Table 4 shows the main directions of biodegradable waste treatment that can be realized according to the Concept principles.

It has to be said a few words about the technique of organic waste complex recovery developed by our group (co-authored by O. Gubanova). According to the complex recovery scheme, organic waste is exposed to the downstream bioconversion: anaerobic digestion with getting of biogas and digestate, which may be exposed to aerobic composting. As it was shown in the publications [14, 15], unlike waste disposal, the complex recovery allows us to obtain "zero emission" of GHG (anaerobic digestion only) and significantly accelerates the processes of carbon transfer from waste to the environment with carbon dioxide (due to methane combustion by use of biogas) and with organomineral fertilizers (65% of carbon passes to them).

It is considered that park and garden waste can't be used for compost production, because of heavy metal content (as we can see in the result obtained by Samchuk and Vovk [26]; Tkachenko and Aslonyants [27]; Vorob'ev [28]). So, to make a right decision about treatment of park and garden waste with food waste, we must keep in mind the ration between these types of waste, actual data of heavy metal content in waste, further use of fertilizers (only for urban soils, for example).

Due to significant differentiation within the group and insignificant volume of generation, the rubber and leather waste group should be incinerated or disposed (more practical).

As a result of introduction of the biodegradable waste management and treatment system (Table 4), GHG emissions were calculated (Table 5). Thus, we can obtain significant decreasing of GHG emission by implementation of the Concept principles and following treatment of biodegradable waste types by scheme in Table 4.

4. CONCLUSIONS

As it is seen, biodegradable waste is the largest group in MSW that forms more than 60% of total MSW mass in Ukraine. The main components of such group are food waste (55%) and paper and cardboard waste (24%), altogether they contain 75% of DOC from total MSW mass.

There is a significant variability of waste composition due to the place of generation. So, for the purpose of biodegradable waste "resource value" estimation the real data of waste composition should be used. Nowadays, most of biodegradable waste in MSW is being disposed into landfills and dumps in Ukraine, so they lose their resource value. It is the landfill gas collection and recovery system that is the only way to "use" disposed waste. But Ukraine is at the beginning of this way. Such approach to MSW problem decision leads to secondary environmental pollution by waste destruction products. The main environmental problems due to biodegradable waste landfilling are GHG emission and impaired redistribution of nutrients, carbon in particular. GHG emission from landfill and dumps is a long-term process, and for significant reduction of GHG generation the treatment technologies of food, park and garden waste and paper & cardboard are required. The degree of biodegradable waste treatment depends on the approach to the MSW separate collection. Approach to separation of easily-decomposed organic waste at the beginning of the "life cycle" proposed by our group, will allow for the most efficient selection of biodegradable components and further treatment of them.

The further biodegradable waste treatment is determined by available capabilities in Ukraine and may include biological treatment for easily-decomposed organic waste, different 3R technologies for potentially recyclable material resources and disposal for non-use types of waste.

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