International Journal of Engineering & Technology, 7 (4.8) (2018) 415-419

International Journal of Engineering & Technology

Website:www.sciencepubco.com/index.php/IJET

Research paper

Carbon Redistribution During the Stages of Generation and Destruction of Municipal Solid Waste Organic Component

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Abstract

The estimation of carbon redistribution during generation and decomposition of organic component of municipal solid waste for different ways of treatment is presented in paper. The study of the transformation and distribution of carbon compounds during treatment options of organic component of municipal solid waste is implemented on the example of Odessa region and Odessa in particular. Such options as disposal and complex recovery of organic wastes are considered

Keywords: *municipal solid waste, organic component, treatment, greenhouse gases, emission, biogas, compost, recovery*.

1. Introduction

In modern conditions of agriculture, there is an intense loss of humus from soils: during the period from 1882 to 2010, the content of humus in soils of Ukraine decreased from 4.17 to 3.14% [1]. One of the main reasons is the extraordinarily low level of organic fertilizing: the application of organic fertilizers decreased from 9.4 t/ha (1985) to 0.5 t/ha (2014) while the minimum standard to ensure a deficit-free humus balance is from 10 t/ha and higher [2]. All of this determines the relevance of using bio-organic waste from economic and domestic activities of man as the source of soil replenishment by nutrients. If livestock waste are widely used as organic fertilizer, the organic component of municipal solid waste (MSW) is certainly not recovered and is disposed in dumps and landfills, so has become a source of environmental pollution. So, owing to anaerobic digestion of organic substances into the landfill body biogas is produced, whose main components are CH_4 and CO_2 – typical greenhouse gases (GHG). Dumps (landfills) of MSW are the third largest source of anthropogenic CH_4 emissions and provided 11-12% of the total mass, came from anthropogenic sources in 2010 [3, 4]. According to the National Inventory [5], the Waste sector is the only one that has a positive trend of GHG emissions, mainly due to MSW disposal (66.57% of GHG emissions by the sector, over the period 1990-2016 emissions increased by 26%). To minimize the impact of waste on the environment it is necessary to reduce the volume of disposing in dumps (landfills). It is possible if waste components are considered as resources and their use becomes more attractive than disposal.

Solid products of digestion process of MSW organic component, that form a potential source for the gumusoid substances, lose resource value due to mixing with other components at the disposal of the total MSW flow.

Thus, non-use theof the resource potential of MSW organic component leads to contamination of the environment by the products of waste destruction and impaired redistribution of nutrients in the environment.

The aim of the study is to assess the carbon redistribution in stages of generation and destruction of MSW organic component in different ways of treatment.

2. Main body

2.1 The basic theoretical part

It is necessary to single out the components containing biodegradable organic carbon (DOC) among the components of MSW (syn. biowaste, easily-decomposed organic waste). According to IPCC Guidelines for National Greenhouse Gas Inventories [6], these components include the following waste types: paper and cardboard, textiles, food waste, wood, garden and park waste, nappies (disposable diapers), rubber and leather. The content of these components in the total MSW mass is presented in table 1.

As we can see from table 1, more than 60% of the total MSW mass are the components containing different amount of DOC. The life cycle of such waste types is determined by anaerobic and aerobic decomposition processes depending on waste treatment procedures. The products of aerobic decomposition of organic matter (composting, for example) is H_2O and CO_2. During MSW disposal in landfills and dumps aerobic processes take place in surface layer of waste while in the mass – anaerobic processes, that are domanant in this case [7].

It is well known, that anaerobic digestion is aggregation of natural biochemical processes of organic matter decomposition with getting of stabilized products: gaseous compounds (CH_4 та CO_2) and solid product (digestate).

Table 1: The main characteristics of MSW components contain biodegradable organic carbon

MWS component	Carbon content in dry waste, %			Content in total MSW mass, %	
	total	biodegradable	calculated in [7]	national level (Ukraine)	regional lever (the Odessa region)
	by data of [6]				
Paper and cardboard	46	44	45,40	14,6	15,0
Textiles	50	30	46,20	4,0	3,0
Food waste	38	38	41,70	33,1	35,0
Wood	50	50	48,30	1,7	2,0
Garden and park waste	49	49	no data	3,8	10,0
Nappies (disposable diapers)	70	60	no data	1,1	–
Rubber and leather	67	47	59,80	1,7	2,0
Total				60,0	67,0

The carbon redistribution can be described by such a schematical equation:

$$C(waste) \rightarrow CH_4 + CO_2 + C(biomass) + C(leachate).$$

As it was shown in [8, 9], carbon transfers to leachate is 0.13% by 13 years or 3% by term of final environmental stabilization of waste mass (6,500 years).

The modern waste management and treatment practice in Ukraine does not envisage recycling or recovery of MSW components, that contain DOC (exception is paper and cardboard waste), but only their disposal in dumps and landfills. In such case the only way to use the "resource potential" of bioorganic waste is landfill gas collection and production, but it is expedient only in the large modern landfills. As marked above, such waste can be used for the production of organic fertilizers, but the necessary condition for this purpose is their separation from the general MSW stream at the moment of waste generation.

As an alternative to the European and the National waste management systems we suggest the use of the municipal solid waste treatment Concept based on ‘zero waste’ principle which has been developed at Odessa State Environmental University [10, 11]. The ultimate purpose of this Concept is to minimize environmental impact of municipal waste through a decrease in its disposal volume. Thus the main principle of the Concept is differentiation of the generated MSW into a number of streams. In accordance with the Concept the overall stream of wastes in a place where they are generated is separated into the following streams [10, 11]: 1) easily-decomposed organic waste; 2) potentially recyclable material resources, including inert mineral bulk waste; 3) hazardous waste.

Differentiation of MSW stream is implemented in the following way. At the beginning of a MSW “life cycle” easily-decomposed organic material is to be separated. The principally new solution in the area of MSW treatment is to implement separation of easily-decomposed waste components as a first-step measure. The separation of easily-decomposed waste components at the stage of generation makes it possible to obtain ‘pure’ resource for compost production. Moreover, elimination of this stream at the generation moment provides obtaining of other components (potentially recyclable material resources) in an uncontaminated form. It is very important because the recovery technologies for some kinds of waste (e.g. waste paper) yield appreciable results only in case of using of pure materials.

The stream of stabilized potentially recyclable material resources is distributed by components, and is then sent to special organizations for recovery. The stream of hazardous waste shall be separated through the organization of targeted collection of different types of waste.

For the stream of easily-decomposed organic waste separated at generation stage, the technique of complex recovery of organic waste was developed in this, which presupposes that such waste is exposed to the downstream bioconversion: anaerobic digestion with getting of biogas and digestate, which may be exposed to aerobic composting [12]. The technique scheme of organic waste complex recovery is presented at fig. 1.

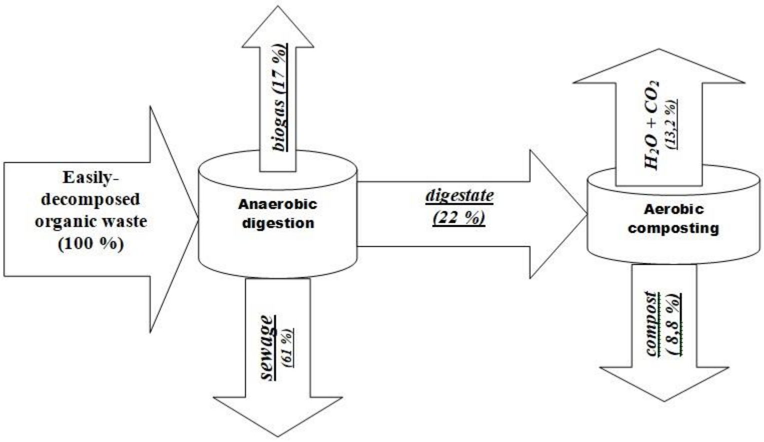


Fig. 1: The complex recovery scheme [12]

Industrial easily-decomposed organic waste, agricultural waste and sludge generated in aerobic treatment of wastewater at treatment plants (but only in the condition of its environmental safety) may be considered as an additional source of organic matter.

At the first stage we receive two useful products: digestate (organomineral fertilizer) and biogas. Under condition of lack of demand for digestate, they are exposed to the second stage of treatment – aerobic composting. As a result of this process the mass of digestate is reduced. We receive one useful product – compost.

2.2 Models and methods

The National multicomponent model, based on the fist order decay method of third detalization level (the National Model) was used in the present study to estimate methane emission as biogas component [5]. The improved parameters of National Model applied to regional condition (the Odesa region) were used by the results of previous researches [13, 14]. The mass balance method and some results of [7] were used to estimate carbon redistribution in the complex recovery process.

2.3 The results and discussion

2.3.1. Input data

The research of carbon transformation and distribution in treatment process of MWS organic component is implemented in the Odesa region condition and Odesa in particular. About 5.6 million m^3 of MSW is generated in the Odessa region per year; it is 9% from the total MSW volume in Ukraine. Almost MWS mass is disposed into landfills and dumps, the total amount of them being608 in 2016, the total area – 1274.9 ha. “Dalnitsky Kar’yery” – is the largest landfill of the Odessa region, total area is 96 ha. It has been accepting waste from the Odesa metropolitan area since 1968 and is in the top seven hazardous landfills of Ukraine. In 2016 922,000 ton of MSW was generated in the Odesa region, 544,600 ton out of which was disposed in “Dalnitsky Kar’yery” [15].

2.3.2. Carbon distribution during MSW disposal in landfill

The methane mass generated from disposal of annual MSW mass is calculated by the National Model for the landfilling conditions of “Dalnitsky Kar’yery”. Using CH_4 /CO_2 mass ratio in landfill gas generated in landfills [7], we have estimated the carbon transfer to these compounds (see table 2) during the decomposition of organic waste containing DOC.

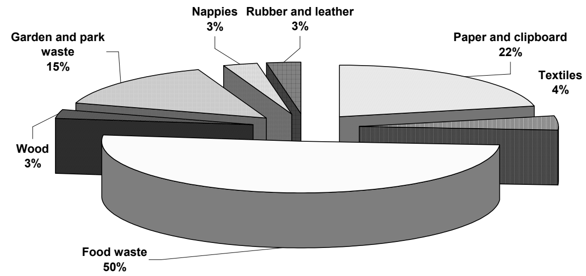
Table 2: Carbon distribution during the decomposition of MSW in “Dalnitsky Kar’yery”

Term, year	Carbon mass in…, ton		Part of carbon transferred into gaseous compounds, %
	CO_2	CH_4	
1	729,6	933,6	1,9
13	5973,5	7634,7	15,5
50	10411,9	13307,6	27,1

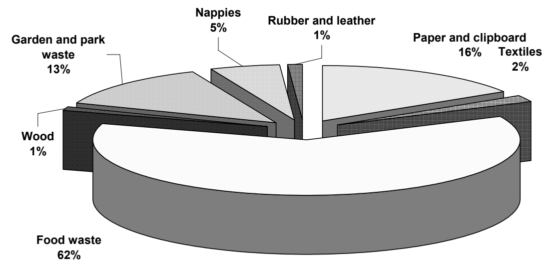
It was calculated that carbon mass is 87495.44 ton in the total mass of 375229.4 ton of wet organic waste types (see table 1) (or 16% of the mixed MSW mass).

Thus, 2% of carbon from waste will enter into the atmosphere in a year after waste disposal into the landfill, the rest part will stay into a landfill body and transfer to leachate.

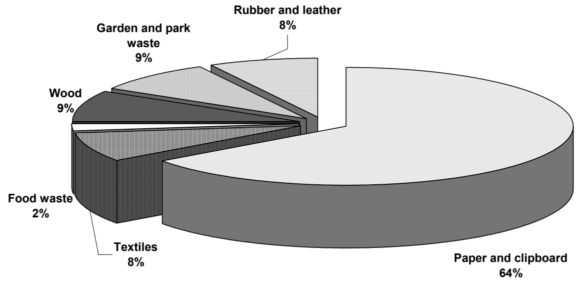
The main factors determining CH_4 generation into landfill body (by the National Model) are: waste composition, DOC content (see table 1) and the rate of waste decomposition. Figure 2 shows the distributions of CH_4 emission depending on MSW components containing DOC.



Waste composition



Methane emission after a year



Methane emission after 50 years

Fig. 2: The CH_4 emission from decomposition of waste types, containing DOC

As we can see, in a year after waste disposal the most of CH_4 (62%) is produced from food waste, which are predominant by mass, but 50 years after its part was deceased to 2%. The second largest component is paper and cardboard waste, which, in 50 years after disposing, will produce 65% of CH_4 from the total mass produced by the decomposition of all components.

2.3.3. Carbon distribution during the complex recovery of organic waste

The option of feedstock separation from the total flow of MSW for the complex recovery is considered by scheme at fig. 1. The feedstock is 100% of food waste, garden and park waste, wood and nonstandard waste paper (15% of total waste type mass). Accounting the content of such components in the total mass of MSW, we calculated 268215 ton of feedstock, supposing, that other waste types containing DOC (see table 1) are recycled, with the exception of nappies, rubber and leather disposed into the “Dalnitsky Kar’yery” landfill. The mass balance of such option of easily-decomposed organic waste treatment is shown at figure 3.

During compilation of National Inventory [5], it is only CH_4 that is accounted in “Waste disposal” section, other substances, by 2006 IPCC Guidelines [6], are not included in national totals in the section, especially CO_2, that has a biogenic origin.

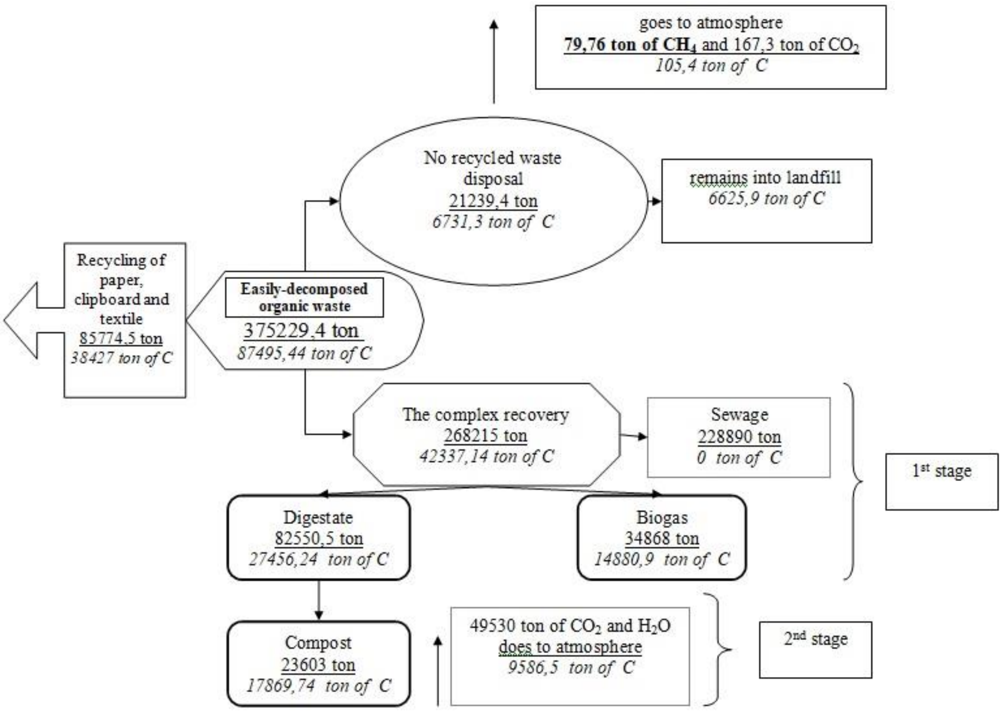


Fig. 3: The mass balance during the complex recovery of organic waste part of MSW

It can be assumed, that carbon transition to sewage during the anaerobic digestion process is zero, as it is temporal, and carbon compounds from sewage are consumed by anaerobes, so transferred to digestate (solid products).
It is noted, that if we don't realize the second stage of the complex recovery of organic waste (see fig. 3) for reducing mass of digestate, we can actually obtain "zero emission" of GHG – CO_2 and H_2O (with the exception of biogas process losses above 5%).
After a year, 98 % of carbon will stay into the landfill body, 2% will transfer to GHG (see fig. 3). In fact, 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 (so, it will engages in natural cycle) after 50 years.
Unlike waste disposal, the complex recovery significantly reduces the time of organic waste decomposition and enables to receive useful products: biogas, to which 35% of carbon passes, and digestate (fertilizer) in which, 65% of carbon is concentrated. Using of these products will make it possible to return carbon from the waste to the environment and include it in the natural cycle. During the realization of the 2nd stage of the complex recovery, 65% of carbon transfers from digestate to compost, and 35% goes to the atmosphere with CO_2.

2.3.4. Carbon admission by organomineral fertilizer

Using the data of waste and chemical composition [7, 15] and agrochemical characteristics of MSW [16], the carbon flows during anaerobic digestion of some waste components are estimated (see table 3).

3. Conclusions

Based on the research, can the following conclusions be drawa:
– The main part of the total MSW flow (more than 60%) is easily-decomposed organic waste. Due to the fact, that the main method of MSW treatment is to dispose them into dumps and landfills, the resource potential of this part of MSW is not used now. But they can be used as a feedstock for biogas and organomineral fertilizers production.
– Through the general MSW collection, the easily-decomposed organic waste is mixing with other MSW components, including hazardous, which it impossible to reuse them. Therefore, it is necessary to organize the separation of easily-decomposed organic waste from the MSW at the time of its generation.
– The rstudyof carbon distribution during degradation in the landfill body showed that there is a long-term releasing of carbon has with landfill gas, which will enhance to the greenhouse effect. At the same time, a large share of the carbon remains is localized in the landfill body.
– Unlike waste disposal, the complex recovery significantly accelerates the processes of carbon transfer from waste to the environment with carbon dioxide (due to methane combustion by the use of biogas including) and with organomineral fertilizers, a significant part of carbon (65%) passes to which. In the condition of the significant shortage of organic matter for reproduction of humus, the flow of carbon from organomineral fertilizers to soils is particularly relevant.

Table 3: Characteristics of carbon flow under anaerobic digestion of some organic waste types of Odessa (2016)

MWS component	Waste mass		The moisture, %	Dry mass, th. of tones	Carbon content in dry mass, %	Carbon, that isn't transfer to CH_4, %	Carbon content in organo-mineral fertilizers	
	%	th. of tones					%	th. of tones
Food waste	35	190,6	72,0	53,4	44,96	50,0	22,46	12,0
Paper and cardboard	15	81,7	10,24	73,3	43,39	56,0	24,3	17,8
Textile	3	16,3	10,0	14,67	54,76	70,0	38,3	5,6
Wood	12	65,4	20,0	52,32	50,58	51,0	26,3	13,8
Total								49,2

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