RESEARCH ARTICLE | DECEMBER 07 2023

Municipal solid waste composting as a factor of sustainable development of the modern city

Natalia Grynchyshyn; Tetiana Datsko; Oksana Mazurak; Natalia Kachmar

AIP Conf. Proc. 2490, 060018 (2023)
https://doi.org/10.1063/5.0122780

Municipal Solid Waste Composting as a Factor of Sustainable Development of the Modern City

Natalia Grynchyshyn[1, a)], Tetiana Datsko[2, b)], Oksana Mazurak[2, c)] and Natalia Kachmar[2, d)]

[1]*Department of Environmental Safety, Lviv State University of Life Safety 35, Kleparivska St., Lviv, 79007, Ukraine*
[2]*Department of Ecology, Lviv National Agrarian University 1, V. Velykyy St., Dubliany, Lviv region, 80381, Ukraine*

[a)] Corresponding author: *nata_gryn123@ukr.net*
[b)] *datsko_tetyana@ukr.net*
[c)] *oksana_mazurak@ukr.net*
[d)] *kachmarnatali@ukr.net*

Abstract. Proper municipal solid waste management is relevant in the context of sustainable development of modern cities. It is especially essential for developing countries. The organic fraction of municipal solid waste is significant and biodegradable. Extraction of organic matter and its composting is classified as the most preferable approaches of the strategy of sustainable management of municipal solid waste. Composting technology is characterized by its economic efficiency compared to other alternatives and is most commonly used worldwide. In Ukraine, there is no practice of municipal solid waste composting. For the first time, the pilot project on the practice of composting the organic component of municipal solid waste was introduced in Ukraine in the Lviv city. The paper presents the results of research of physical and chemical properties, agrochemical parameters and heavy metals content of the formed compost in accordance with the Ukrainian Standard of fertilizers. Due to received data, the city's municipal solid waste compost can be used as fertilizer in agriculture.

INTRODUCTION

Municipal solid waste (MSW) is one of the most important by-products of the urban lifestyle. Around the world, it generation rates are rising even faster than the rate of urbanization. According to the World Bank, in 2025 urban residents will produce an average of 1,42 kg / person of solid waste per day compared to the current 0,74 kg [1].

Compared to those in developed nations, residents in developing countries are more severely impacted by unsustainably managed waste. In low-income countries, over 90 % of waste is often disposed in unregulated dumps or openly burned. These practices create serious health, safety, and environmental consequences. Poorly managed waste serves as a breeding ground for disease vectors, contributes to global climate change through methane generation [1].

Managing waste properly is essential for building sustainable and livable cities, but it remains a challenge for many developing countries and cities [1]. MSW management is the biggest challenge for both small and large cities in developing countries [2].

Since the organic fraction of MSW is significant and biodegradable, it can be removed, processed and used as a potential source of plant nutrients, rather than lost due to improper disposal/treatment [3, 4]. Extraction of organic matter from MSW for reuse and recycling is classified as the most preferable approaches in integrated solid waste management systems in a framework of a circular economy [5].

Today composting is the most widely used worldwide technology for the disposal of sorted organic waste and which can be practically implemented at any scale [5].

Composting technology is characterized by its economic efficiency compared to other alternatives [6].

5th International Scientific and Practical Conference "Innovative Technology in Architecture and Design" (ITAD-2021)
AIP Conf. Proc. 2490, 060018-1–060018-6; https://doi.org/10.1063/5.0122780
Published by AIP Publishing. 978-0-7354-4686-1/$30.00

The composting process is the conversion of organic matter into stable, sanitary and high-quality final product «compost» through biochemical / biological actions.

The recycling of organic waste through composting is viewed as a sustainable approach for waste management as it provides a valuable source of organic matter for enhancing soil organic matter content that is being deteriorated due to various anthropogenic activities, and it is recognized as a reliable approach for improving different soil properties [5].

Compost is characterized by a high content of organic matter as well as a much of microelements and macronutrients.

The application of compost improves soil structure, prevents erosion. It is useful in bioremediation of contaminated soil and plant disease control. Composting also increases soil biodiversity [7].

Importantly, compost can replace inorganic fertilizers, which are used in large quantities in agricultural activities. Therefore, compost application is being promoted as an alternative to heavy chemical fertilization to enhance agricultural sustainability [8].

Composting has a lot of benefits like: reduce landfill space, decrease surface and groundwater contamination, reduce methane emissions, and also lower air pollution from burning waste.

The quality of compost can be different and depends on the quality of organic waste. The main problem is the high content of heavy metals.

It was investigated that the content of heavy metals is higher by 43-194 % in compost prepared from organic wastes of large cities in comparison with small towns. Composts prepared from separated biogenic wastes contained higher organic matter (by 57 %), total N (by 77 %) and total P (by 78 %), but lower concentrations of heavy metals (63-84 %) as compared to those prepared from mixed wastes [9].

The quality of compost as an organic fertilizer must comply with certain requirements.

To limit the usage of compost as a fertilizer, as well as the potential for soil and food chain contamination, standards for compost prepared from organic matter (OFMSW) have been set in some countries.

Due to variations in compost quality, it is not always possible for compost to be beneficially used on soil. In such cases, compost may be used as alternative daily cover in landfills [10].

The problem of solid wastes is one of the urgent environmental problems of Ukraine. Despite the fact that over the last 20 years the population of Ukraine has been constantly declining, the volume of MSW is increasing. The main method of MSW management is their removal and disposal in landfills and dumps, most of which do not keep environmental safety requirements.

The signing of the Association Agreement between Ukraine and the European Union in 2014 and the approval of the National Waste Management Strategy in Ukraine until 2030 require local authorities to take immediate and decisive actions to implement European standards into MSW management.

According to the National Waste Management Strategy in Ukraine until 2030 it is planned to recycle 15 % of MSW in 2023, and in 2030 – 50 % of MSW from the total volume of their generation.

Due to the fact that 70 % of the population of Ukraine lives in the cities, the removal of the organic component of biodegradable MSW can significantly reduce the load on urban landfills and dumps.

The pilot project on the practice of composting the organic component of municipal solid waste was first introduced in Ukraine in the Lviv city in 2020. As of January 2021, population of Lviv was 721 510. The city's residents generate about 150 tons of solid waste daily.

In this work, we investigated the quality of prepared MSW compost in accordance with the Ukrainian Standard of fertilizers formed from organic fraction of municipal solid waste [11]. The purpose of the research was to establish the intended use of the finish compost.

MATERIAL AND METHODS

Compost Production

The technology of processing organic fraction of MSW at the Composting Station in Lviv city has preparatory and main stages.

At the preparatory stage, the organic matter of solid waste is manually sorted by householders and loaded into special containers. The types of wastes that can be disposed into containers are food wastes, tea infusions and coffee grounds, mown grass, withered flowers, dry leaves.

Containers with organic matter are taken to the City Station for composting process. The composting site is located so that the liquid formed during the composting process falls on the sewage treatment facilities of the city.

The composting process has three stages – Start, Peak and Finish. At each stage, professional equipment and appropriate biological products are used. Humidity and temperature are controlled throughout the all composting period.

At the first stage organic waste materials are loaded into a special container for disinfection. Sterilization of wastes takes place within 72 hours at a temperature of up to 72-80 degrees and ensures the destruction of bacteria and removal of various odors.

At the second stage the organic matter is stacked in the large piles which are aerated, moistened and added microbiological preparations (start and finish) using a special aerator. The waste is being up to two months in the piles depending on the time of year and air temperature.

At the third stage the formed compost is sieved through a special equipment to separate the large fraction which can be used as a natural bacterial preparation to enrich other piles.

Sample Selection and Methods

Sample selection for research was carried out from different batches of formed compost. Subsamples were collected from different parts of one batch manually using a scoop. The weight of a single sample was not less than 0,3 kg. The number of subsamples aggregated into one sample for further experiments was not less than 30. To obtain an average sample, the combined one was thoroughly mixed on polyethylene coverage, distributed in a layer of equal thickness and reduced to a weight of at least 1 kg by the method of quartering. The obtained sample was placed in a double plastic bag, tied and labeled. It was transferred to the laboratory and stored in a cold room at a temperature of 4ºC for further analysis.

The quality of compost was evaluated as an organic fertilizer according to the Ukrainian Standard [11]. Since the compost can be applied in agriculture, forestry, green building and land reclamation, it is necessary to analyze its basic physical and chemical properties, agrochemical and toxicological parameters before use. By the Standard, quality indexes for compost were measured(the content of large fractions (> 50 mm), the content of organic matter, humidity, pH value, total nitrogen, phosphorus, potassium, the content of Cd, Co, Cu, Ni, Mn, Pb, Sr, Cr, Zn, Hg, Fe).

The content of large fractions in compost was determined by selection of particles larger than 50 mm manually. Treatments were replicated three times.

Determination of moisture content was carried out according to the State Standard 26713-85. This method is based on measuring the weight loss of the compost sample during drying to constant weight.pH value was measured in a sample of compost with the original moisture by potentiometric method with a glass membrane electrode(based on the State Standard 27979-88).Organic matter content was determined by the thermogravimetric method according to the State Standard 8454:2015. The method is based on determining the loss of mass of the compost sample after calcination in a muffle furnace at a temperature of 800 °C.

The total nitrogen was determined based on the State Standard 7911:2015 by spectrophotometric method (at the wave lengths of 430 nm) with Nessler's reagent. The total phosphorus content in the compost was determined according to the State Standard 26717-85 by photometric method. The total potassium content in compost was determined according to the State Standard 7949:2015 by flame-photometric method.

The content of heavy metals was determined with the atomic absorption spectrometric method (AAS) on a C-115 MI.

The results of chemical analyses were processed statistically using the standard statistical package. Results expressed as mean values ± standard deviation (n=9).

RESULTS AND DISCUSSION

Physical and Chemical Properties

The physical and chemical properties of compost are strongly dependent on particle size. Thus, bulk density of the compost increases as particle size decreases. However, with the decrease of particle size there is a trend to decrease some soil parameters as pH, porosity, saturated water holding capacity, organic content, and Ca, Fe, Mg, and Mn contents. Based on the physicochemical properties of different composts, the coarse compost particles larger than 0,8 mm have considerable potential in agricultural applications as soil amendments [12].

Particle size affects oxygen movement, as well as microbial and enzymatic access to the substrate. Smaller size particles of organic material increase the surface area available for microbial attack. Large size particles reduce surface area for microbial attack which slows down or may stop composting process altogether [13].

The Ukrainian Standard limits the content of large fractions in compost at the level less than 2 %. The studied compost contains particles larger than 50 mm in the amount of 1,5 % (Table 1). Thus, it is allowed to be used as an organic fertilizer.

TABLE 1. The physical and chemical properties of MWS compost.

Parameters	MSW Compost Test Sample (Lviv Composting Station)	Limits for MSW Compost According to the Ukrainian Standard
Content of Particles Larger than 50 mm, %	1,5±0,2	no more than 2
Organic Matter Content, %	43,0±2,3	no less than 40
Moisture Content, %	38,0±3,1	20-80
pH	7,0±0,3	6,5-8

The quality of compost as an organic fertilizer is closely related to the content of organic matter. The organic matter content depends on the quality of raw materials and composting conditions.

The content of organic matter affects the physical structure of the soil and biological activity, which, in turn, affects other properties and thus determines the suitability of the soil for various activities, mainly agricultural.

Soil organic matter consists of a variety of simple and complex carbon compounds and thus provides food for a variety of organisms. It provides much of the cation exchange and water-holding capacities of surface soils. Certain components of soil organic matter are largely responsible for the formation and stabilization of soil aggregates [14]. Soil organic matter also contains large quantities of plant nutrients that act as a slow-release nutrient storehouse, especially for nitrogen. Furthermore, organic matter supplies energy and body-building constituents for most of the microorganisms. However, the reduction of soil organic matter content is of worldwide concern. An increase in soil organic matter can be obtained by external organic amendments. Among these, compost belongs to the most stable sources of organic matter [15]. Organic matter and N are associated with macro aggregates [16]. Coarse compost size fractions could be used in increasing soil organic matter and total N content of soil more effectively than fine fractions [12].

The quality of compost as an organic fertilizer is closely related to the content of organic matter. The organic matter content depends on the quality of raw materials and composting conditions. The average bio-compost must contain about 33,3 % organic matter, but not less than 20 % [17].

The test compost is characterized by a high content of organic matter – 43 % (Table 1).

The humidity of compost is very important and can change widely.

Moisture management requires a balance between microbial activity and oxygen supply. Moisture content lower than 30% or higher than 75% inhibits microbial activities due to early dehydration or anaerobiosis. This in turn would create anaerobic conditions and brings about putrefaction, resulting in disagreeable odor and undesirable products [13].

In the present study, moisture content is at the optimal level – 38 % (Table 1).

The quality of compost and its use is limited by the pH value. The range of pH values suitable for bacterial development is 6,0-7,5, while fungi prefers an environment in the range of pH 5,5-8,0. A rise in pH beyond 7,5 could make the environment alkaline, which may cause loss of nitrogen as ammonia [18]. The optimum pH for most microorganisms is between 6,5 and 7,5 [13].

The pH value of the studied compost accords to the requirements of the Ukrainian standard of MSW compost (Table 1).

Agrochemical Parameters

Remarkably, compost contains significant amounts of nutrients, especially the macronutrients [19].

Nitrogen, phosphorus, and potassium (NPK) are macroelements available in the soil for plant health and play a major role in plant metabolism.

Compost has been reported to contain optimum N content required for plant growth [20]. High accumulation of nitrogen in compost fertilizer is not a common occurrence because due to mineralization, nutrients in compost fertilizer are released gradually [7].

The total nitrogen is contained in the studied compost with in an acceptable limit according to the requirements of the Ukrainian Standard (Table 2).

TABLE 2. Agrochemical parameters of MSW compost.

Parameters	Content of Nutrients, % (Dry Matter)		
	MSW Compost Test Sample (Lviv Composting Station)	[1]UA Standard	[2]UA Standard
Total N	2,0±0,2	no less than 1,8	no less than 1,5
Total P(P_2O_5)	2,7±0,3	no less than 2,0	no less than 1,8
Total K(K_2O)	0,5±0,1	no less than 0,1	no less than 0,1

[1]Limits of Ukrainian Standard for MSW compost intended for use in agriculture
[2]Limits of Ukrainian Standard for MSW compost intended for use in forestry, green building and land reclamation

As macronutrient, phosphorus is essential for plant growth. Phosphorus is important in plant's cell division generation of new tissue and complex energy transformations in the plant. Adding phosphorus to soil low in phosphorus promotes root growth, winter hardiness, stimulate stilling, and often has tens maturity in plants.

Compost has been reported to contain optimum phosphorus concentration necessary for plant growth [7, 20].

Potassium is amacronutrient necessary for proper plant growth. It plays a wide variety of roles in plant biochemistry and ecophysiology. Potassium increases plant growth, carotene, and chlorophyll contents.

Potassium is needed for the plant to create sugars. It is also essential because it helps the plant to resist disease and survive adverse weather conditions such as drought and cold [7].

P and K deficiency could be improved by adding fertilizers to soils.

Phosphorus mainly exists in the organic matter component, which is higher in coarse compost size fractions. High potassium concentration in fine compost fractions is attributed to K presence in the mineral elements as inorganic form. As compost particles decrease, inorganic components increase, thus mineral content increases [12].

Due to received data, macronutrients content in test compost samples is sufficient to increase phosphorus and potassium content by compost applying into the soil.

Heavy Metals Content

Concentrations of heavy metals in the formed compost compare with the permissible norms for fertilizers [11] are presented in Table 3.

TABLE 3. Heavy metals content in MSW compost.

Element	Content, mg/kg on Dry Matter		
	MSW Compost Test Sample (Lviv Composting Station)	[1]UA Standard	[2]UA Standard
Cd	0,50 ±0,08	30	250
Co	4,47 ±0,53	100	300
Cu	67,48 ±13,69	1500	6000
Ni	18,98 ±2,60	200	900
Mn	214,55 ±16,25	2000	7000
Pb	8,31 ±0,94	750	2000
Sr	0,81±0,17	300	600
Cr	3,45±0,58	750	5000
Zn	383,22 ±13,46	2500	9000
Hg	0,03 ±0,01	15	50
Fe	2185±65,55	25000	45000

[1]Limits of Ukrainian Standard for MSW compost intended for use in agriculture
[2]Limits of Ukrainian Standard for MSW compost intended for use in forestry, green building and land reclamation

The high concentration of heavy metals in composts can exclude the possibility of their use in agriculture [21].

The potential risk of heavy metals in compost is related to their uptake by plants and the entry of these elements from the soil into the food chain. Therefore, the assessment of such toxicological parameters is necessary before using compost as a fertilizer.

The results of studies of the heavy metals content in compost did not show exceeding the limits set in the Ukrainian Standard for fertilizers (Table 3).

The study indicates that such toxicological characteristics of compost, as heavy metals content, are much lower than the requirements for fertilizers (according to Ukrainian Standard), and therefore formed MSW compost of Lviv city can be used as fertilizer in agriculture.

CONCLUSION

Composting of organic matter is a necessary measure of the sustainable MSW management strategy. Physical and chemical properties, agrochemical parameters of the MSW compost of Lviv city agree with the requirements of the Ukrainian Standard for fertilizers formed from organic matter of MSW. The content of organic matter and basic macronutrients (N, P, K) in compost is sufficient to increase soil productivity. The studies of the heavy metals content in compost did not show exceeding the limits set in the Ukrainian Standard for fertilizers. The results of the assessment of the quality of MSW compost of Lviv city indicate the possibility of its use as a fertilizer in agriculture. Therefore, the introduction of composting of organic matter in the cities of Ukraine should be considered as a necessary condition for their sustainable development.

REFERENCES

1. The World Bank. Solid Waste Management. 2019. Available online: https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management (accessed on 5 March 2021).
2. H. I. Abdel-Shafy and M. S. M. Mansour, *Egyptian Journal of Petroleum*, **27** (4), 1275-1290 (2018).
3. L. Meng, W. Li, S. Zhang, C.Wu and L.Lv, *Bioresour Technol*, **226**, 39-45 (2017).
4. L. Zhang, and X. Sun, *Bioresource Technology*, **218**, 335-343 (2016).
5. T. Sayara, R. Basheer-Salimia, F. Hawamde and A. Sanchez, *Agronomy*, **10** (11), 1838 (2020).
6. S. Elagroudy, T. Elkady and F. Ghobrial, *Journal of Environmental Protection*, **2** (5), 555-563 (2011).
7. M.S. Ayilara,. O.S. Olanrewaju, O.O. Babalola and O. Odeyemi, *Sustainability*,**12** (11), 4456 (2020).
8. X. Gai, H. Liu, J. Liu, L. Zhai, H. Wang, B. Yang, T. Ren, S. Wu and Q. Lei, *Sci Total Environ*, **650**, 2251-2259 (2019).
9. J. K. Saha, N. Panwar and M. V. Singh, *Waste Manag*, **30** (2), 192-201 (2010).
10. M. Sardarmehni, J. W. Levis, and M. A. Barlaz, *Environmental Science & Technology,* **55** (1), 73-81 (2021).
11. UA.SOU HCS 03.09-014:2010 Municipal solid waste. Technology of processing of organic fraction of municipal solid waste.
12. S. Zhao, X. Liu, and L. Duo, *Polish Journal of Environmental Studies*, **21** (2), 509-515 (2012).
13. E. Vanlalmawii, and M. Awasthi, *International Journal of Advances in Science, Engineering and Technology*, **4** (2), 160-163 (2016).
14. R. S. Swift, Soil Science, **166** (11)**,** 858-871 (2001).
15. A. J. Termorshuizen, S. W. Moolenaar, A. H. M. Veeken, and W. J. Blok, *Reviews in Environmental Science & Bio-technology,* **3** (4), 343-347 (2004).
16. G. S. Sodhi, V. Beri and D. K. Benbi, *Soil & Tillage Research*, **103**, 412-418 (2009).
17. K. Azim, B. Soudi, S. Boukhari, C. Perissol et al.,*Organic agriculture*, **8** (2),141–158 (2018).
18. S. Gajalakshmi and S. Abbasi, *Critical Reviews in Environmental Science and Technology*, **38** (5), 311-400 (2008).
19. G. Adugna, *Acad. Res. J. Agric. Sci. Res*., **3** *(*4), 93-104 (2016).
20. G. Khater, *Int. J. Waste Resources*, **5** (1), 172 (2015).
21. C. Jasiewicz, J. Antonkiewicz and A. Baran, *Polish Journal of Chemical Technology*, **9** (3), 15-19 (2007).