EKOLOGIJA. 2008. Vol. 54. No. 1. P. 51–56
DOI: 10.2478/V10055-008-0010-4

Investigation of temperature dynamics in composted waste

Pranas Baltrėnas [1],

Audronė Jankaitė [2]

Department of Environmental Protection, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania
E-mail: [1] pbalt@ap.vgtu.lt;
[2] audronej@ap.vgtu.lt

Waste management is a relevant issue for Lithuania. The municipal waste collection systems are not efficient, the equipment is worn out. The majority of waste that could be reused is disposed in the landfills. One of waste utilisation ways is composting. However, in Lithuania composting is not widely spread, there are just a few enterprises composting food, wood and vegetable wastes. One of such enterprises uses film to accelerate the aerobic process. At the beginning of the aerobic process, the temperature does not rise within the pile for several days, but on the fourth day of the process the temperature starts rising and its recording begins. During 32 days of the aerobic process the temperature in the pile increases to 65–72 °C. On average, 7% of oxygen is necessary for the aerobic process of composting to take place.

Key words: organic waste, composting, aerobic process, oxygen

INTRODUCTION

One of the aims of the Strategic Waste Management Plan is to reduce the amount of biodegradable waste disposed in landfills (Staniškis, 2006). When adopting respective decisions on waste management, it is necessary to have knowledge of the present-day and future influences on waste generation and the collection of certain fractions (Baltrėnas, 2006). Due to unfeasible management of waste, people and animals face the treat of infections (Rimkevičius, 2002). The anthropogenic impact, increasing at an enormous pace, changes not only the natural environment, but also a human being (Olechnovičienė, 2005).

The key long-term objectives of waste management are to develop a system of hazardous and non-hazardous waste management, most feasible from the environmental and economic standpoints, to reduce waste streams and their adverse effect on the environment and human health, and to ensure the rational utilization thereof for recycling and energy recovery (Staniškis, 2004).

Sorting, treatment and utilisation are the functional elements that encompass waste differentiation and treatment, recycling of separate materials and waste utilisation performed in the places away from waste generation sites (Dietrich, 1990).

So far, the most widely spread and the cheapest method of waste management has been waste disposal in landfills (Baltrėnas, 2004). However, apart from other adverse factors, the environment is negatively affected by leachate and landfill gases. The leachate forms when precipitation and other liquids migrate through the layer of waste. It is a concentrated pollutant, and on getting into the soil without control it can greatly pollute groundwater (Vrubliauskas, 2002). Landfill installation providing an expert protection of groundwater and atmosphere is a very expensive thing, therefore first of all attempts are made to reduce, using various methods, the amount of wastes disposed in landfills. In the first place, the reuse of waste as a raw material by treating it in a skilled manner is applied (Baltrėnas, 2005).

Organic waste generated in households or industries can be composted (Amalendu, 2004). Composting is a biological process during which micro-organisms and invertebrates convert organic materials (leaves, paper, food waste, etc.) into organic matter of a new quality called compost (Eitminavičiūtė, 2001). Sometimes, different additives such as wooden sawdust, animal manure and vegetable waste are added during composting. Since Lithuania has joined the European Union, the waste management system has to be reorganized according to EU requirements. Composting becomes relevant to our country because in the European Union wastes are sorted, while the landfilling of organic waste is very expensive. Lithuania has not old traditions of applying composting technologies, the country has just a few waste and wastewater sludge composting companies. However, some companies compositing food, wooden and vegetable (straw, grass) wastes are already functioning in Lithuania (Stackevičienė, 2004; Vasarevičius, 2005).

The purpose of enterprises utilising food and wood wastes is to accept vegetable, fruit, meat and other food waste from stores and canteens and process it by composting in the aerobic manner. Composting is the process of organic substance degrading in the air, which results in the formation of a material similar to humus (Den Boer, 2005). With the purpose to produce humus, the most valuable element of the soil, Californian earthworms are raised.

The aim of this paper is to analyse temperature changes during composting of organic waste. The recording of temperature changes during the aerobic process is necessary because most efficient decomposition of organic waste occurs at a temperature of 50–55 °C.

METHODS

Composting is a controlled biological process when hazardous biodegradable substances are decomposed into non-hazardous inert metabolites. This technique requires rather high temperatures – usually 50–55 °C. This temperature is achieved when micro-organisms in the soil decompose organic substances (polluted soil cleaning technologies).

Fig. 1. Waste composted in a pile

Waste was placed in piles in sections accommodating 250 m^3 (5.0 × 25 × 2.0 m). These are roofed sections with open sides; 50% of a section's waste is structural waste (e. g., wood) and another 50% food waste. Food waste contains 50% of fruit and vegetable waste, 20% of food waste from canteens, 20% of meat, and 10% of fish and shrimp waste (Fig. 1). The research was carried out at a waste utilization company in spring, under natural outdoor conditions when the outdoor temperature varied from −2 to + 15 °C. When the ambient air temperature is lower, the aerobic process is slower because the pile has contact with the outdoor temperature.

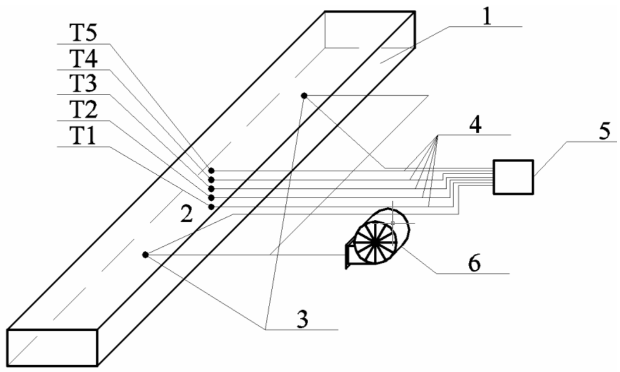

Fig. 2. Layout scheme of temperature sensors. *1* – a waste pile; *2* – temperature sensors (T1 – temperature at the depth of 200 cm; T2 – at the depth of 150 cm; T3 – at the depth of 100 cm; T4 – at the depth of 50 cm; T5 – on the surface); *3* – sensors of oxygen amount; *4* – connection with the central computer; *5* – central computer; *6* – ventilator

During the aerobic process, which lasted 32 days, the waste was covered with a special film which takes the heat and humidity in but does not let them out. The temperature was recorded throughout the entire process and, when necessary, an additional amount of oxygen was supplied. With the help of special sensors the temperature was recorded in five spots of the pile: at the depths of 200 cm, 150 cm, 100 cm and 50 cm and on the surface (Fig. 2). Temperature sensors were connected by wires to a central computer which recorded temperature every 15 minutes.

The visual material of the process is presented below. The average data of temperature measurements made every 15 minutes show the daily temperature fluctuations in the pile.

RESULTS AND DISCUSSION

At the beginning of the process, the initial temperature in the pile was conditionally equal to zero, which can be related to the start of the process and a lower ambient air temperature since at that time the temperature at night would fall to −2 °C, and no additional heating was supplied to the pile. On the fourth day the temperature started rising, and the process began. The highest temperature, 24 °C, was recorded at the bottom of the pile; in the middle of the pile the temperature varied from 16 °C to 3 °C, and on the surface it was still equal to zero. When the process progressed, the temperature started rising within the entire pile more rapidly. During these days the temperature showed the highest increase, i. e. from 0 °C to 24 °C on the pile surface. This can be related to the warmer weather and sunny days. After 9 days of the process the temperature within the pile was around 27–29 °C. During these days the temperature on the pile surface was also the highest: within 9 days it rised from 0° to 29 °C (Fig. 3).

On the 10th–11th days of the process the temperature in the pile still increased by 1–2 °C. The highest fluctuations were recorded on the pile surface having the biggest contact with the ambient air: at night it fell to 27 °C, but during the daytime rose to 35 °C. After 15 days of the process the temperature increments at the bottom were insignificant, while in the middle and on the surface of the pile the temperature rose to 35 °C. During these days the temperature on the pile surface increased by 1 °C. The increasing temperature closer to the surface can be explained by the warm ambient air at that period (Fig. 4).

On the 16th–18th days of the process, the temperature on the pile surface slumped because the ambient air became cooler with the start of the colder springtime. During these two days the temperature on the pile surface changed from 39 °C to 33 °C. When more than half of the process time was over, a temperature in the pile started rapidly rising. At the bottom of the pile it went up to 49 °C, on the following day increased by another 5 °C and reached 54 °C. In the middle of the pile the temperature was 38–44 °C. The lowest temperature was recorded on the top of the pile. Such an increase in temperature shows an intensive progress of the process during these days (Fig.5).

On the 22nd–27th days of the process, the temperature rose within the entire pile. During these days the thermophilic phase when the process of composting was most efficient was achieved – the temperature rose to 50–60 °C. The highest temperature was recorded at the bottom of the pile, i. e. the process of biodegradation is most efficient there. Within the entire pile the temperature was proportionally ascending, on average by 8 °C; thus, the average temperature of the pile was 55 °C. The lowest temperature was recorded on the top of the pile and within these days varied in the range of 32–40 °C (Fig. 6).

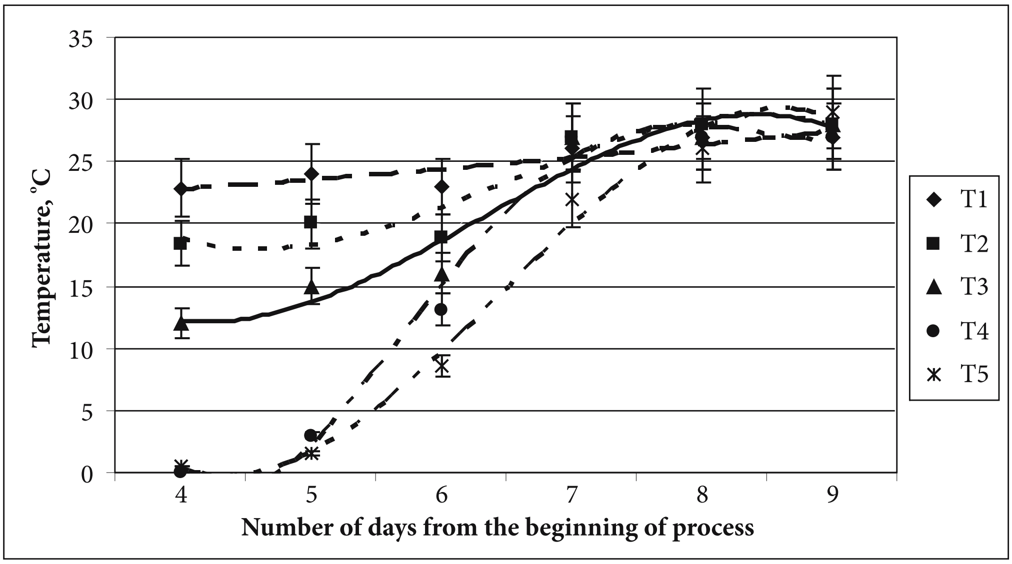

Fig. 3. Change of temperature depending on time (4th–9th days of the process)

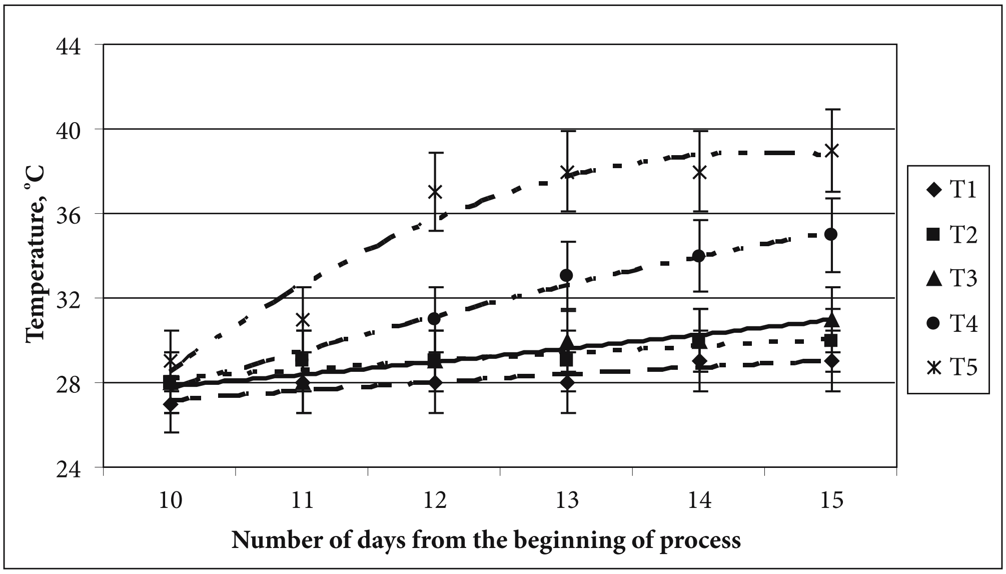

Fig. 4. Change of temperature depending on time (10th–15th days of the process)

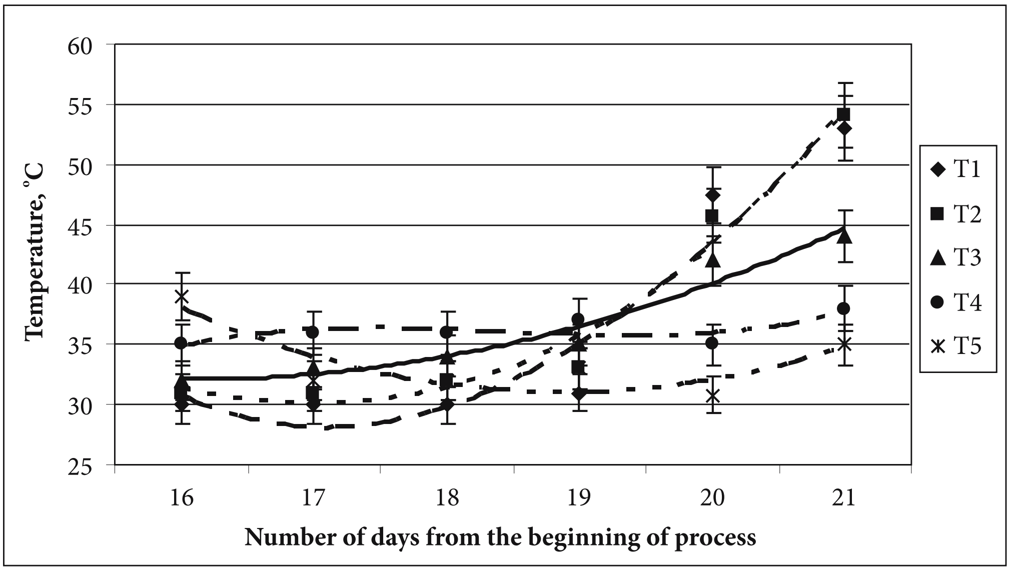

Fig. 5. Change of temperature depending on time (16th–21st days of the process)

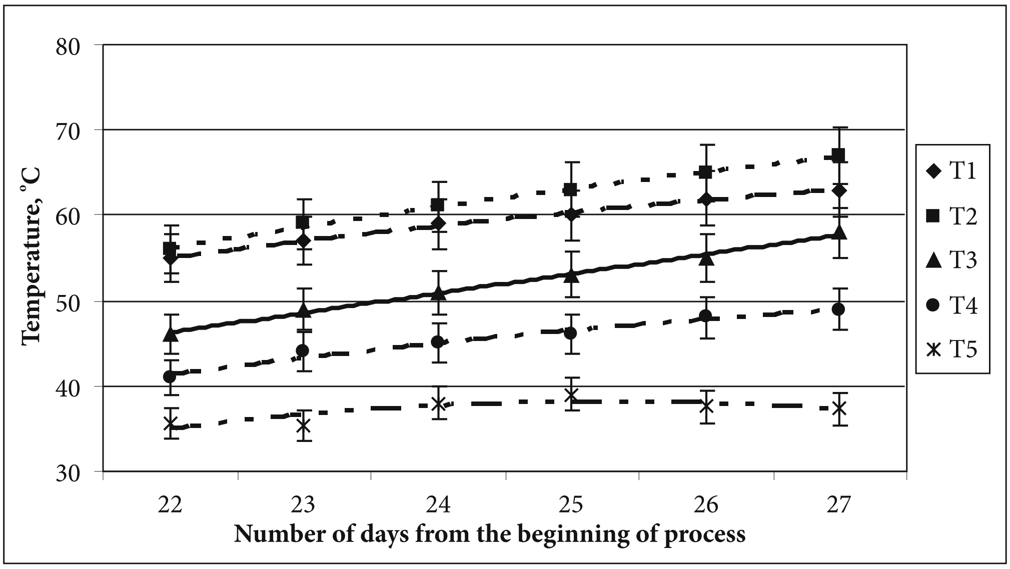

Fig. 6. Change of temperature depending on time (22nd–27th days of the process)

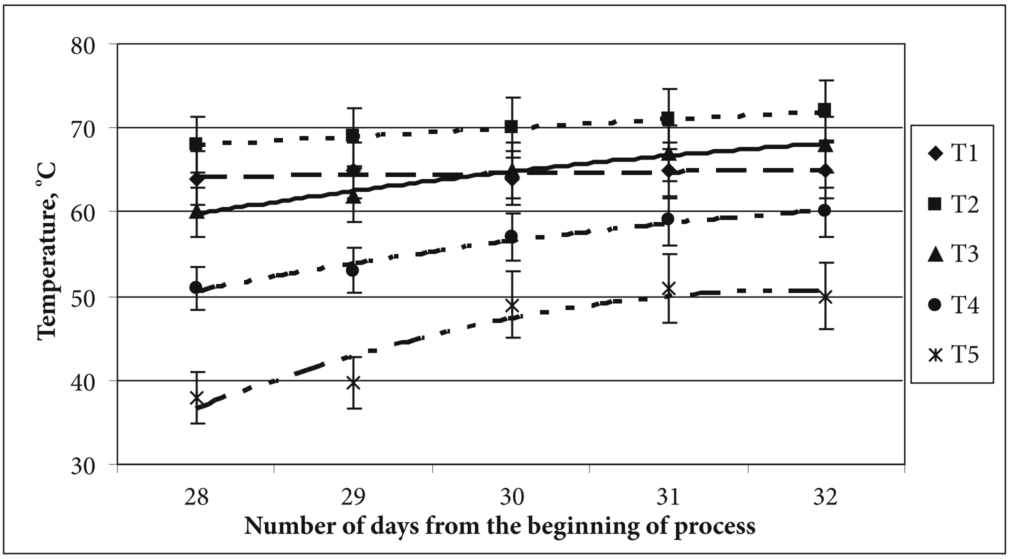

Fig. 7. Change of temperature depending on time (28th–32nd days of the process)

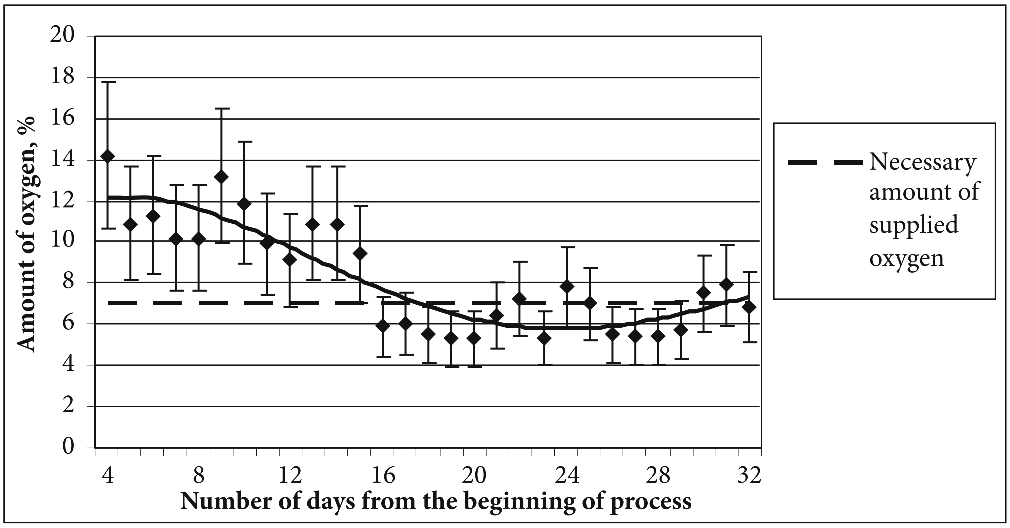

Fig. 8. Amount of supplied oxygen necessary to the aerobic process to take place

With end of the observed aerobic process approaching the rise of temperature within the entire pile was recorded. During the last days temperature at the bottom of the pile reached 65 °C, in the middle of the pile (at the depth of 50 cm) – 68 °C. On the surface of the pile temperature fluctuated in the range of 47–50 °C. A higher temperature on the pile surface can be related to the warmer ambient air during these days (Fig. 7).

When analysing the process from the beginning, the highest rise of temperature was noted at the bottom of the waste pile; it was proved by the sensors recording temperature at a depth of 1 meter. The highest change in temperature was recorded on the surface of the pile which is in the biggest contact with the ambient air, therefore, due to temperature fluctuations during the daytime and night, a bigger difference of temperatures was recorded on the surface of the waste pile.

Oxygen is necessary for the aerobic process to occur. Special sensors that signal about decreased quantity of oxygen within the pile are introduced into the waste pile. When a certain limit is approached (no less than 7% of oxygen within a waste pile), a ventilator supplying oxygen to the waste pile under the film automatically switches on. On average, 7% of oxygen under the film is required for the aerobic process to take place in the recycling processes performed by the enterprise. The quantities of oxygen supplied to the pile during 32 days of the process are shown in Fig. 8.

The largest quantity of oxygen (14.2%) was determined during the first days and the lowest (5.3%) on the 23rd day of the process. The quantity of oxygen at the beginning of the process was the highest because the waste was freshly piled for composting and microorganisms had not yet used up the full quantity of oxygen for the process to occur. When the process takes place, the amount of oxygen decreases, and when it goes halfway the amount of oxygen falls and varies insignificantly. On the last day of the process, the content of oxygen in the pile was 6.8%.

During the anaerobic process, oxygen content decreases (Baltrėnas, 2005). The findings of research show that in a laboratory anaerobic experiment study the quantity of oxygen in the food waste drops to 0.5%, while during the aerobic process the required amount of oxygen is around 7%. During both the anaerobic and the aerobic processes the temperature rises. During the anaerobic process the temperature increases to 34 °C, while during the aerobic one it increases more significantly – up to 70 °C. The optimum temperature for the propagation of mesophilic organisms is 25–37 °C, while the temperature of the thermophilic phase varies within 50 to 60 °C. The best composting results are achieved when the thermophilic phase lasts several days and the temperature is maintained at this level, which is achieved when soil micro-organisms decompose organic substances (Baltrėnas, 2004; polluted soil cleaning technologies).

CONCLUSIONS

1. At the beginning of the process, the initial temperature in the pile is conditionally equal to zero for several days, which can be related to the starting period of the process and a lower ambient air temperature. On the fourth day of the process the temperature starts rising, therefore its recording begins.

2. With the progress of the aerobic process the temperature in the pile rises more rapidly: at the mid-point of the process the average temperature recorded in the pile is 32 °C.

3. On the 22nd–27th days of the process the temperature increases within the entire pile. During these days the thermophilic phase is achieved when the composting process is most efficient, the temperature being 50–60 °C.

4. In the last days of the process, the temperature within the pile rises insignificantly (by 2–5 °C), and at the end of the process the average temperature is 65 °C.

5. During the whole process, a higher temperature was recorded at the bottom of the pile. The highest change in temperature range was recorded on the surface of the pile. This can be explained by changes in ambient air conditions during these days because the film used during the process is heat-conductive.

6. When the aerobic process takes place, oxygen is required, therefore during the recycling processes performed at the enterprise oxygen is supplied by special ventilators that switch on automatically when the amount of oxygen under the film significantly slumps.

7. On average, 7% of oxygen under the film, is necessary for the process to take place. On the last day of the process the content of oxygen in the pile was 6.8%.

ACKNOWLEDGEMENT

The study is funded under implementation of the cost program activity no c18 "performance assessement of urban infrastructure services: the case of water supply, wastewater and solid waste" funded by agency for international science and technology development programmes in lithuania.

Received 10 September 2007
Accepted 12 October 2007

References

1. Amalendu Bagchi. 2004. *Design of landfills and integrated solid waste management*. Third edition. John Waley & Sons, Canada. P. 293–330.
2. Baltrėnas P., Jankaitė A., Raistenskis E. 2005. Natūralių biodegradacijos procesų, vykstančių maisto atliekose, eksperimentiniai tyrimai. *Journal of Environmental Engineering and Landscape Management*. Vilnius: Technika. Vol. XIII. No. 4. P. 167–176.
3. Baltrėnas P., Jankaitė A., Raistenskis E. 2006. Natūralių biodegradacijos procesų maisto atliekose, esant skirtingam drėgmės kiekiui jose, eksperimentiniai tyrimai. *Journal of Environmental Engineering and Landscape Management*. Vilnius: Technika. Vol. XIV. No. 4. P. 173–181.
4. Baltrėnas P., Raistenskis E., Zigmontienė A. 2004. Organinių atliekų biodestrukcijos proceso metu išsiskiriančių biodujų eksperimentiniai tyrimai. *Journal of Environmental Engineering and Landscape Management*. Vilnius: Technika. Vol. XII. P. 3–9.
5. Den Boer E., den Boer J., Jager J. 2005. Lietuviška redakcija: Denafas G., Rimaitytė I., Račys V., Kliučininkas L. Atliekų tvarkymo planavimas ir optimizavimas. *Komunalinių atliekų*

susidarymo prognozavimo ir atliekų tvarkymo sistemų tvarumo vertinimo vadovas. Kaunas: Technologija. P. 304.
6. Dietrich G., Winter J. 1990. Anaerobic degradation of chlorophenol by an enrichment culture. *Appl. Microbiol. Biotechnol*. Vol. 34. P. 253–258.
7. Eitminavičiūtė I., Bagdanavičienė Z., Kisielis V., Janeliauskienė D. 2001. *Vilniaus miesto nuotėkų valyklos dumblo ekologinis įvertinimas*. Vilnius: Aldorija. P. 100.
8. Olechnovičienė J. 2005. Ekologinių veiksnių įtakos žmogaus sveikatai tyrimai. *Ekologija*. Nr. 1. P. 27–30.
9. Rimkevičius A. 2002. Infekuotų medicininių atliekų tvarkymo problemos Vilniuje ir galimi sprendimo būdai. *Aplinkos inžinerija*. Vilnius: Technika. T. X. Nr. 2. P. 1a–1h.
10. Stackevičienė E., Ruseckaja Z. 2004. Vermikomposto įtaka stambiauogės spanguolės (*Oxycoccus Macrocarpus*) augimui. *Botanica Lithuanica*. Vilnius: Botanikos institutas. Suppl. 6. P. 55–61.
11. Staniškis J. K., Česnaitis R., Juškaitė R., Miliūtė J., Bagdonas A. 2006. *Organinių ir biodegraduojamųjų atliekų surinkimo ir perdirbimo galimybių studija*. Taikomasis mokslinio tyrimo darbas. Vilnius. P. 55.
12. Staniškis J. K. 2004. *Integruota atliekų vadyba*. Kaunas: Technologija. P. 368.
13. *Užteršto grunto valymo technologijos*. http://www.asa.lt/cgi-bin/str1.cgi?grp=51
14. Vasarevičius S., Čegariova J., Sližytė D. 2005. Investigation and evaluation of landfill leachate permeability in the soil. *Journal of Environmental Engineering and Landscape Management*. Vilnius: Technika. Vol. XIII. No. 3. P. 108–115.
15. Vrubliauskas S. 2002. *Sąvartynų dujos – energijos šaltinis*. http://ausis.gf.vu.lt/mg/nr/2002/03/03dujos.html

Pranas Baltrėnas, Audronė Jankaitė

TEMPERATŪROS REŽIMO DINAMIKOS KOMPOSTUOJAMOSE ATLIEKOSE TYRIMAI

Santrauka

Atliekų tvarkymas Lietuvoje kelia daug rūpesčių. Komunalinių atliekų surinkimo sistemos neefektyvios, įranga nusidėvėjusi. Daugybė atliekų, kurios galėtų būti panaudotos kaip antrinės žaliavos, patenka į sąvartynus. Vienas atliekų perdirbimo būdų – kompostavimas. Tačiau Lietuvoje kompostavimas nėra labai paplitęs, nėra daug įmonių, kompostuojančių maisto, medienos ir augalinės kilmės atliekas. Viena tokių įmonių aerobiniam procesui paspartinti naudoja plėvelę, uždėtą ant atliekų kaupo. Aerobinio proceso pradžioje keletą dienų temperatūra kaupe nekyla, tačiau nuo ketvirtosios proceso dienos temperatūra pradeda kilti, todėl pradedama fiksuoti temperatūra. Per 32 aerobinio proceso paras temperatūra kaupe pakyla iki 65–72°C. Nustatyta, kad aerobiniam kompostavimo procesui vykti reikia vidutiniškai 7% deguonies.

Raktažodžiai: organinės atliekos, kompostavimas, aerobinis procesas, deguonis