

POSSIBILITIES OF USING STONE WOOL WASTE IN COMPOSTING

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Abstract. The aim of research is to check the possibility of composting stone wool waste using sewage sludge. The problem is huge amounts of dumped waste (sewage sludge, production waste in the stone wool) without any treatment. There is no practice to compost production waste in the stone wool in Lithuania. Stone wool waste can be one of bulk materials in the process of sewage sludge composting and can improve the quality of the prepared compost. Production waste in the stone wool contains phenol and formaldehyde that are very hazardous pollutants, and therefore it is important to follow its concentration during the composting process. The paper analyses the degradation of formaldehyde concentration. Adding stone wool waste made no degradation in the composting process. The most remarkable reduction in formaldehyde concentration is observed during the first half of the composting period. The average composting duration is two months which is a sufficient period for formaldehyde degradation.

Keywords: composting, stone wool waste, wastewater sludge.

Introduction

Becoming friendly to the environment is a very important issue nowadays. There is a growing interest in investing in environmentally responsible companies and non-polluting technologies. Cutting waste and using natural resources more efficiently have proven to reduce costs and boost profits.

Compost is a general term for the end result of the controlled aerobic decomposition of organic matter known as composting. The composting process can be a good possibility for treating a number of waste groups.

The problem is huge amounts of dumped waste (sewage sludge, production waste in the stone wool) without any treatment. The more complex is the production process, the bigger are the amounts and there is more different waste (Baltrėnas *et al.* 2008). From 1995, few companies have been involved in composting activity in Lithuania. They compost food waste, wood, garden waste and other structure materials, including sewage sludge. Plenty of materials useful for composting could be found in the world and one of them can be wool scouring sludge or stone wool waste. There is no practice in composting stone wool waste in Lithuania. Moreover, information about this possibility is very poor. Scandinavian countries had similar practice a few years ago. They made compost with stone wool waste in the simplest way, i.e. stone wool waste was mixed with sludge and wood and left for quite a long period (about 1 year) once mixing following 6 months. Stone wool waste can be one of bulk materials in the sewage sludge composting process and can substitute wood waste

and improve the quality of the prepared compost. The structure material becomes deficit because a big amount of wood waste is fired as biofuel (Tracevičius 2008). Production waste in the stone wool contains phenol and formaldehyde that are very hazardous pollutants, and therefore it is important to follow its concentration during the composting process (BAT for glass manufacturing 2001).

Stone wool is made of natural stone – basalts, limestone or dolomite. Raw materials are melted in a very high temperature of 1300–1600 °C. The main processes are the following (BAT for glass manufacturing 2001):

- raw material preparation (stone and coke are screened and transported to cupola);
- melting (coke burns and stones melt);
- fiberizing (fibres are formed from liquid melt);
- collection (fibres are collected into wool mat and the binder is added);
- curing (the binder is cured in a high temperature);
- cutting (the wool mat is cut into products with different dimensions);
- packing (slabs are stacked and packed using a polyethylene film and pallets).

For fossil fuelled furnaces, such situation results in the emission of the products of combustion and the high temperature oxidation of atmospheric nitrogen; i.e. sulphur dioxide, carbon dioxide and oxides of nitrogen. Furnace emissions also contain dust. There are two further important emission sources in this sector – fiberizing (where the fiber is formed and the binder is applied to the fibres) and the curing oven (where the product is dried and the binder

is cured). Fiberizing area emissions contain significant levels of particulate matter, phenol, formaldehyde, ammonia and water. Curing oven emissions will contain phenol, formaldehyde from the binder and combustion products from the oven burners (BAT for glass manufacturing 2001). Technical solutions are possible for minimizing all these emissions; however, each technique has associated financial and environmental implications. The major environmental improvements have been made in mineral wool production, and thus emissions have been substantially reduced.

As a binder, phenol-formaldehyde resins are used in stone wool production.

There are a few types of waste in stone wool production. A chemical composition of all waste from technological processes is very similar to a chemical composition of stones. Nevertheless, different types have a different amount of organic matter (including hazardous materials phenol and formaldehyde) and different humidity.

Stone wool contains hazardous materials from binder – phenol and formaldehyde. During the composting process, formaldehyde concentration decreases. Only stone fibres stay in the prepared compost. Stone fibre is a natural material and improves the quality of the soil.

Formaldehyde (IUPAC name methanol) is a chemical compound having the formula H_2CO which is colourless gas. It is irritating and has a sharp odour. Formaldehyde is widely produced around the world and used as a disinfectant and preservative. It is also employed in textile finishing and in the production of resins that act as adhesives and binders for wood products, pulp, paper, glass wool and stone wool as well as for some plastics, coatings, paints and varnishes and industrial chemicals (Formaldehyde council 2008).

The main objective of this research is to find a possibility of composting sewage sludge using stone wool waste and to reduce formaldehyde pollution applying this method of waste treatment. The analysis of composting parameters such as humidity, temperature and the loss of ignition (amount of organic) was performed in the run of the conducted experiment.

Description of the Composting Process

Composting is one of the methods for biological treatments. The main principle of composting is aerobic biodegradation. It combines chemical, physical and biological treatments. Composting is a controlled biological process when hazardous biodegradable substances are decomposed into non-hazardous inert metabolites. This technique requires

rather high temperatures usually reaching 50–55 °C and achieved when microorganisms in the soil decompose organic substances (Baltrėnas *et al.* 2008). Also, a temperature of 55 °C for at least 72 hours is necessary to ensure pathogen destruction and inactivate weed seeds (Pichtel 2005). Typical trends towards temperatures during the composting process are presented in Fig. 1.

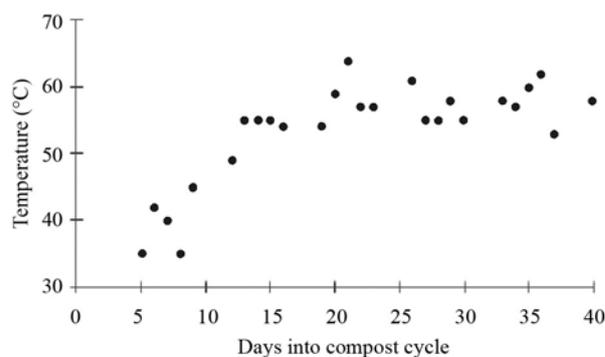


Fig. 1. Temperature trends at early stages of composting (Pichtel 2005)

The efficiency of the composting process depends on the amount of the air and the balance of nitrogen and carbon. The simplest way to increase the amount of the air in compost heaps is frequent mixing. Another possibility is forced aeration that shortens the composting process during which the following actions are taken out (BAT for waste treatment 2003):

- breakdown of solid particles;
- desorption of waste from solid particulates;
- contact between organic waste and microorganisms;
- oxidation of the sludge by aeration;
- volatilization of contaminants.

The main materials are sludge from the wastewater treatment plant and materials having other structure. Sludge having water content higher than 15% is easily compostable, particularly when mixed with bark, wood chips or other structuring materials making the compostable mixture porous.

All three composting methods require the use of structural materials (bulking agents); however, the type of an agent may vary. Wood chips, saw dust and shredded tires are commonly used, though many other materials are also available. The USA Composting Council lists the following materials as suitable ones for using as bulking agents:

- agricultural by-products, such as manure and bedding from various animals, animal mortalities and crop residues;

- yard trimmings, including grass clippings, leaves, weeds, stumps, twigs, tree prunings, Christmas trees and other vegetative matter from land clearing activities;
- food by-products, including damaged fruits and vegetables, coffee grounds, peanut hulls, egg shells and fish residues;
- industrial by-products from wood processing, forestry, brewery and pharmaceutical operations;
- paper goods, paper mill residues and biodegradable packaging materials;
- municipal solid waste (EPA 2009).

As to a typical sample we can refer to Vilnius water treatment plant having about 100 000 m³ (Vilniaus vandenys 2008) of sludge per year. Due to quite a high content of Cd, Cu and Zn metals, Vilnius sewage sludge falls into the 2nd category (Eitminavičiūtė *et al.* 2008).

It has a contract with a waste handling company having permits for preparing compost from sludge and structural material. The composting area is arranged in the territory of the water treatment plant. The prepared compost with some restrictions is used for roadsides and agriculture.

There are some possibilities of reducing a negative impact, to make the composting process easier or to get the compost of higher quality. One of the possibilities is using sorbents in the composting process. They can be used as a raw material and mixed together with sludge or applied as a covering layer for compost heaps. Research on using natural sorbent ZeoVit that can be used for radioactive waste, pollution control, odour control, removing heavy metals from wastewater and sewage and wastewater treatment was carried out in Lithuania. Zeolite is natural aluminous silicate with a crystal structure.

Methods of the study

Compost was prepared including the following components:

- sludge 45%,
- wood and other green waste 45%;
- stone wool waste 10%.

During the experiment, the heaps were kept in the open air yard under Lithuanian air conditions. The length of a heap is about 60 m, width (close to ground) is 5 m and height is 1,9 m.

The first sample was taken from stone wool waste (not mixed with other components) and all other samples were taken from the compost heap.

In the beginning of the composting process, the heap was remixed 2–3 times per week while later, it took once a week. The samples were taken before mixing every week.

Methodology of Taking Compost Samples

There are two basic types of sampling: composite sampling in order to obtain material representing the general mass and grab sampling for a specific region of the mass. Almost in all cases, composite-sampling is a correct approach. Grab sampling should not be used unless a special reason calls for it.

To sample compost we need:

- a long-handled spading shovel;
- a container (10 l pail) in which sub-samples are mixed and trowel;
- 2 plastic bags (5 l) for every sample;
- a marker to identify bags.

The stone wool composting process involves well mixed heaps. In this case, it is necessary to take 5 sub-samples from each side of the heap, to mix well in a bucket and put into a plastic bag. The following diagram illustrates compositing sampling techniques for well mixed heaps (turned within 4 hours) used in the experiment.

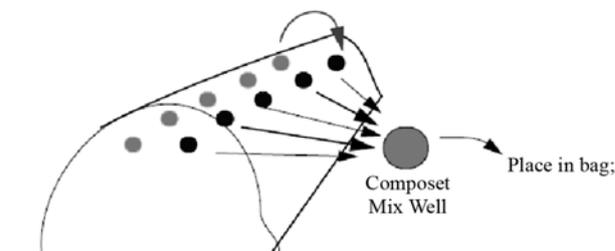


Fig. 2. The scheme of compost sampling for well-mixed heaps (Woods End 2009)

The process of sample taking is as follows:

1. The samples are taken before compost turning.
2. Take sub-samples from 5 locations evenly spaced on each side of the heap. Each sub-sample should be about 250 g taken from 30–60 cm depth below heap surface.
3. Thoroughly mix sub-samples in 10 l pail by tumbling the bucket or stirring with a trowel.
4. Fill in a plastic bag with the mixed sample (about 1500 g), tie it very well when putting into other plastic bag and tie again;
5. Label the bag with a marker (date) and provide for a laboratory.

After taking compost samples, the temperature inside the heap and air temperature outside have to be measured.

For measuring temperature inside the heap, a thermometer that can reach a depth of 60 cm should be used.

For measuring outside temperature, a typical thermometer is used.

During the experiment, the following laboratorial measurements were done:

- humidity;
- formaldehyde concentration ;
- loss of ignition (amount of organic).

Humidity Measurement

The sample (about 10 g) is weight M_1 and dried in the oven at a temperature of $100\text{ }^\circ\text{C} \pm 2\text{ }^\circ\text{C}$ until the mass of the sample becomes constant. After drying, dry compost is weighed again obtaining M_2 and humidity in % is calculated:

$$H = \left(\frac{M_1 - M_2}{M_2} \right) \cdot 100. \quad (1)$$

Loss of Ignition (Amount of Organic) Measurement

The determination of organic matter is a more routinely applied laboratory procedure for composts and provides an estimate of all substances containing organic carbon. Organic matter composition and content decline during composting as described for organic carbon. However, the measurement of organic matter is only an indirect estimate of organic carbon (EPA 2009). The following is the most common procedure for measuring organic matter in composts. The sample is weight (M_3) and dried in the oven at a temperature of $500\text{ }^\circ\text{C} \pm 2\text{ }^\circ\text{C}$, until the mass of the sample becomes constant. After heating, the burned compost is cooled and when weighed again, we get M_4 . Then, the loss of ignition in % is calculated:

$$LOI = \left(\frac{M_3 - M_4}{M_3} \right) \cdot 100. \quad (2)$$

Measurement of Formaldehyde Concentration

Formaldehyde concentration will be measured applying the photocolometric method using chromotropic acid.

For testing, we prepare an aqueous solution from compost to measure formaldehyde concentration in the solution and accordingly, recalculate primary formaldehyde concentration in compost. The main steps are described below.

1. Sample preparation. A sample taken to the laboratory is:

- crashed and sieved (using sieve with a hole of 5 mm);
- weighed as received 50 g;
- mixed very well with 100 ml of water;
- left for 24 hours;
- filtered (paper filter, size of pores – 14–17 μm);
- if a solution is not transparent, distillate it.

2. Necessary reagents and solutions (Instruction 1985):

- concentrated H_2SO_4 96%;
- fresh solution of chromotropic acid $\text{C}_{10}\text{H}_6\text{Na}_2\text{O}_8\text{S}_2 \cdot 2\text{H}_2\text{O}$ 2%
– dionised water.

3. Drawing a calibration curve showing the reliance of optical density on formaldehyde concentration. This curve is prepared according to 3–5 series of the measurements of optical densities of calibrating solutions. One series consists of 10 different concentration solutions.

4. Formaldehyde concentration establishment.

Take 3 ml of solution from compost. Pour 0,5 ml of chromotropic acid and 2 ml concentrated H_2SO_4 to every test-tube. Cover the test-tubes, shake and put into boiling water for 30 minutes. Cool and measure the optical densities of solutions in 10 ml cuvettes at 584 nm wavelength. For comparison, use an empty sample, pour 0,5 ml of chromotropic acid and 2 ml concentrated H_2SO_4 . Draw a chart of the reliance of optical density on formaldehyde concentration (Instruction 1985).

5. Results of calculating formaldehyde concentration

Formaldehyde concentration C (mg/kg) in compost is calculated using the formula

$$C = \left(\frac{D}{3K} \right) \cdot a \cdot \frac{b}{m}, \quad (3)$$

where C – formaldehyde concentration (mg/kg); D – optical density; K – the coefficient of relation between optical density and formaldehyde concentration (from the calibration curve); a – dilution coefficient; b – the amount of water, ml; m – the mass of compost used for testing, mg.

Results and Discussions of the Experiment

Experimental composting took place in the composting yard of UAB “Biastra plus”, the territory of Vilnius wastewater treatment plant.

The samples of compost were taken during the period from October to November, 2009. Outside temperature during the above mentioned work was balanced from +8 to +1.

Experimental composting lasted about 9 weeks. Formaldehyde concentration was measured every week.

In total, 10 samples (1 – stone wool waste and 9 – compost) were taken. From one sample, 2 solutions were prepared and 3 measurements of formaldehyde concentration from every solution were done. With reference to 6 measurements, the average value was calculated and compared with separate values (Fig. 3).

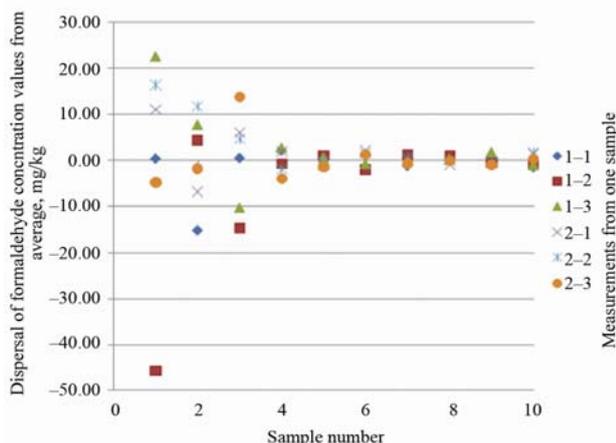


Fig. 3. Dispersal of values from average

The solution from compost and water during all measurements was diluted due to very high formaldehyde concentration. Dilution relation was 1:100 for the 1st sample, 1:50 for the 2nd sample, 1:10 for the 3rd sample and 1:5 for the rest of the samples. Dilution is one of the reasons for the dispersal of high values in the beginning (Fig. 3).

Data on measuring formaldehyde concentration was also processed employing statistical methods. Absolute errors were established using Student's distribution. Only for the first sample, the absolute error was higher than 10%, whereas for the 2nd and 3rd sample it made 9–10% and for the 4th–10th it was 1–2%.

Primary concentration in stone wool waste was 1027 mg/kg. This stone wool waste was mixed with wastewater sludge and wood chips and primary concentration in compost made 87 mg/kg. The final concentration in the compost prepared for usage was 15 mg/kg. The obtained results are presented in Fig. 4. The fastest reduction in formaldehyde concentration was noticed during the first half of the composting period. Reduction became slower on the second part of the composting period.

Experimental formaldehyde concentrations were compared with the earlier data received from tests on stone wool factory in 2007 and 2008. During the test in 2007, 10% of stone wool waste was added to compost while in 2008, it made 20% (Paroc test 2008).

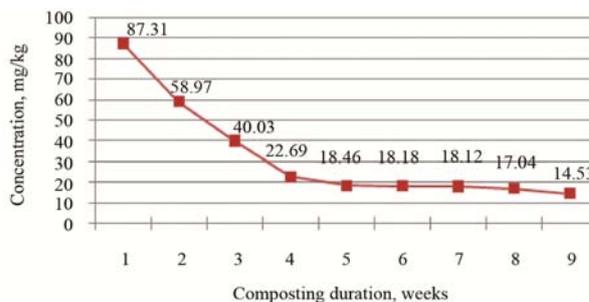


Fig. 4. Variations in formaldehyde concentration, mg/kg

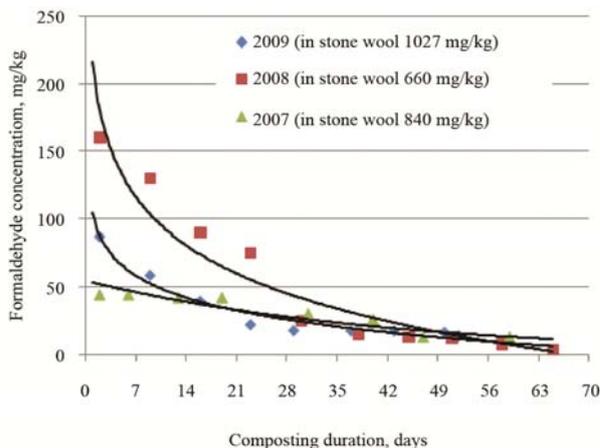


Fig. 5. Variations in formaldehyde concentration

The top picture shows no influence of primary concentration on the final concentration in the prepared compost. The speed of formaldehyde degradation in the started composting process depends on primary formaldehyde concentration. The average composting duration is two months which is a sufficient period for formaldehyde degradation.

Variations in formaldehyde concentration were compared with those in compost heap temperature (Fig. 7), humidity and organic content (Fig. 6). According to the results presented, the direct relation between variations in these parameters was not found.

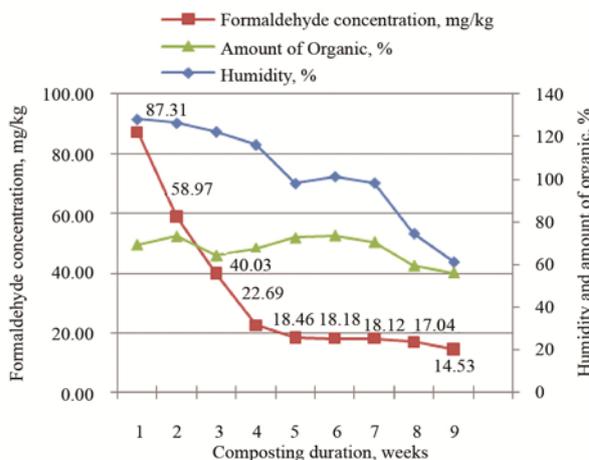


Fig. 6. Variations in humidity and the amount of organic content

The amount of organic fluctuates between 40–53%. Relation humidity decreased from 128 to 61%.

During the experiment, the temperature of the compost heap was compared with that of compost without stone wool waste at different periods (Fig. 9). The achieved results show no difference whether compost includes stone wool waste or not. We can compare composting using stone wool waste in October–November and composting without stone wool waste in April–May.

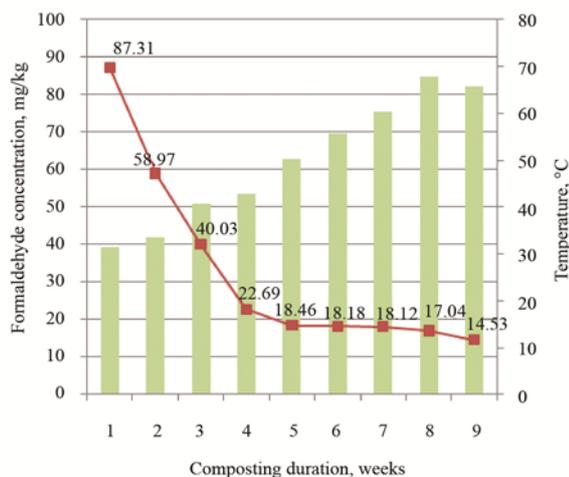


Fig. 7. Variations in formaldehyde concentration and compost temperature

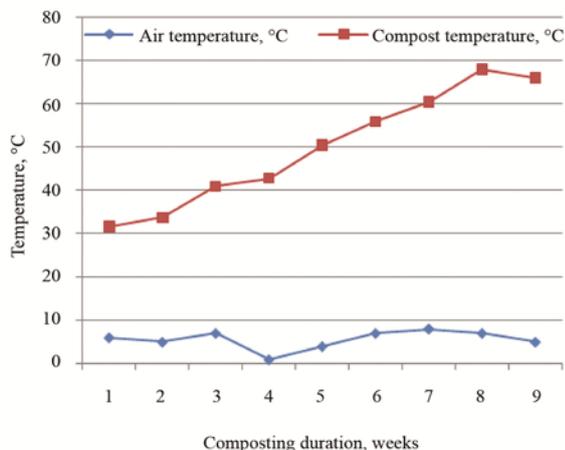


Fig. 8. Variations in compost and air temperatures

The curves are very similar and show no substantial differences. Lower outside temperature has an influence on rise in temperature: when outside temperature is low, compost temperature increases more slowly as it needs a longer period to achieve maximum temperature.

Conclusions

It is useful to put additives of natural origin in composting and production waste in the stone wool is one of those. Unfortunately, it contains some hazardous materials like phenol and formaldehyde.

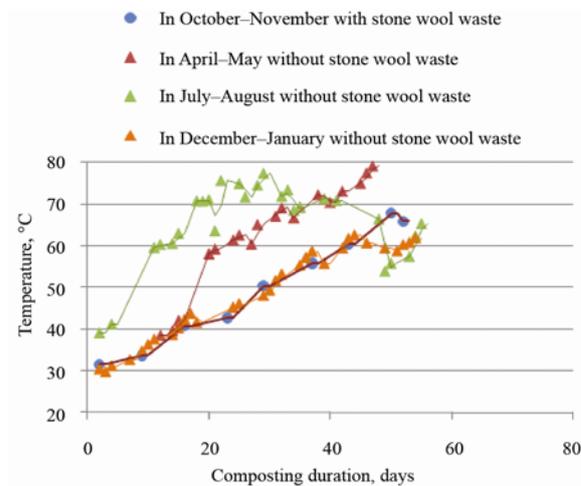


Fig. 9. Variations in compost temperature

1. Measurements of the basic compost parameters (air and compost temperature, humidity, organic content) indicate that there is no difference for the composting process when adding stone wool waste or not.
2. The fastest reduction in formaldehyde concentration occurs during the first half of the composting period.
3. No influence of primary concentration on the final concentration in the prepared compost is observed. The speed of formaldehyde degradation in the beginning of the composting process depends on primary formaldehyde concentration. The average composting duration is two months which is a sufficient period for formaldehyde degradation.
4. Taking and preparing a compost sample is a very important step in conducting similar experiments. Compost in different places of the heap cannot be homogenous, especially in the beginning of the composting period.
5. The precision of diluting compost and water solution has a high influence on the final results of formaldehyde concentration.

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AKMENS VATOS ATLIEKŲ PANAUDOJIMO GALIMYBĖS KOMPOSTUOTI

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Santrauka

Šiame darbe nagrinėtos akmens vatos atliekų kompostavimo galimybės kartu naudojant nuotekų valymo dumblą. Dideli sąvartynuose deponuojamų nuotekų dumblo, akmens vatos gamybos atliekų kiekiai yra aktuali problema. Lietuvoje nėra akmens vatos atliekų kompostavimo patirties. Akmens vata gali būti naudojama kaip viena iš struktūrinių medžiagų nuotekų dumblo kompostavimo procesuose. Ji galėtų pagerinti paruošto komposto kokybę. Akmens vatos gamybos atliekose yra fenolių ir formaldehidų – labai pavojingų teršalų, todėl labai svarbu kompostavimo metu stebėti ir matuoti jų koncentracijas. Šiame darbe analizuojamas formaldehido degradavimas kompostavimo procese. Kompostavimo metu naudojant akmens vatos atliekas, žalingos įtakos proceso parametrams nepastebėta. Intensyviausiai formaldehido koncentracija mažėja pirmojoje kompostavimo ciklo pusėje. Vidutinis kompostavimo ciklas trunka apie du mėnesius. Tai pakankamas laikas formaldehido degradacijai.

Reikšminiai žodžiai: kompostavimas, akmens vatos atliekos, nuotekų valyklų dumblas.