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REPEATED RESEARCH OF BIODEGRADABILITY OF PLASTICS MATERIALS IN REAL COMPOSTING CONDITIONS

Dana Adamcová, Magdalena Vaverková, František Toman

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Abstract

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The aim of this paper was to verify information obtained by repeated research provide in 2011 and 2012 in real composting conditions and check information about biodegradability of plastics bags in real composting conditions. In both cases samples were placed into frames and inserted into one clamp within the compost pile to investigate the biodegradation. The plastics bags were obtained from chain stores in the Czech Republic and Poland. The shopping bags were made of HDPE with the TDPA additive (sample 2), PP with an addition of pro-oxidants (d_2w) (sample 1, 3) and materials certified as compostable (starch, polycaprolactone) (sample 4, 5, 6, 7). Control sample (cellulose filtering paper, sample 8) was to check the potential of biological decomposition in the tested environment. At the end of the 15-week experimental period it was found that the polyethylene samples with the additive (sample 1, 2, 3) had not been decomposed, their colour had not changed and that no degradation neither physical changes had occurred (did not biodegrade). Samples certified as compostable (sample 4, 5, 6, 7) were decomposed. The results at the municipal compost facility demonstrate that the compostable plastics biodegrade and polyethylene samples with the additive did not biodegrade in compost.

biodegradation, 100%-degradable bags, compostable bags, composting, real conditions verification of research

1 INTRODUCTION

The discovery of the chemical process for manufacturing synthetic polymers (plastics) from crude oil was a breakthrough in chemistry and in material sciences, and it paved the way to the production of one of the most versatile groups of materials ever produced. These new materials combined features exhibiting strength, flexibility, light weight, and easy and low-cost production. However, these materials were found to be extremely durable and were considered among the most non-biodegradable synthetic materials. These traits facilitated the application of plastics to almost any industrial, agricultural or domestic market. The most consumed synthetic polymer is PE, with a current global production of ca. 140 million tons per year (Sivan 2011, Vaverková *et al.*, 2012). Plastics production exceeds 180 million tons per year, with a yearly increase in supply and demand. These plastics turn to solid waste after their end of life and will accumulate in the environment. Hence, from an environmentally friendly point of view, the production of biodegradable plastics is important to reduce the accumulation of plastic waste in the environment (Iovino *et al.*, 2008; Vaverková *et al.*, 2012). Petroleum-based plastic products are characterized as not easily degradable because of their relatively high stability and hydrophobic characteristics (Iovino *et al.*, 2008, Vaverková *et al.*, 2012). Plastics are inert (that is, resistant to biodegradation), durable, hygienic, lightweight, cheap, and malleable. However, the main environmental disadvantage of plastics materials is that they do not readily break down in the environment and therefore can litter the natural environment (Mohee & Unmar, 2011; Vaverková *et al.*, 2012). Consequently, considerable attention has been given to the development of degradable plastics materials derived from agricultural resources or, alternatively, to petroleum-based plastics modified with degradable additives. Degradation is an important process in the environmental breakdown of polymer substrate into organic waste. For biodegradable materials, composting is being used as an alternative technology to conventional disposal in landfills or incineration. By this process, biodegradable wastes or organic material are transferred into humic substances, which are valuable as high quality fertilizer for agricultural proposes (Leejarkpai *et al.*, 2011; Vaverková *et al.*, 2012).

The relatively high number of reports describing the biodegradability of a wide range of plastics may lead to the inaccurate conclusion that most plastic polymers can be readily biodegraded. In fact, in terms of amounts, the production of the polymers PE and PS is, by far, greater than that of the rest of the other plastic compounds that are considered biodegradable. Furthermore, not all types of degradable plastics are destroyed completely in natural environments, raising the question of the definition of biodegradable (Sivan, 2011; Vaverková *et al.*, 2012).

The aim of this paper was to verify information obtained by repeated research provide in real composting conditions and check information about biodegradability of plastics bags advertised as 100%-degradable or certified as compostable in real composting conditions. Original research of biodegradability of plastic bags was carried out in real conditions in the Central Composting Plant in Brno in 2011 (Vaverková *et al.*, 2013) and repeated in 2012.

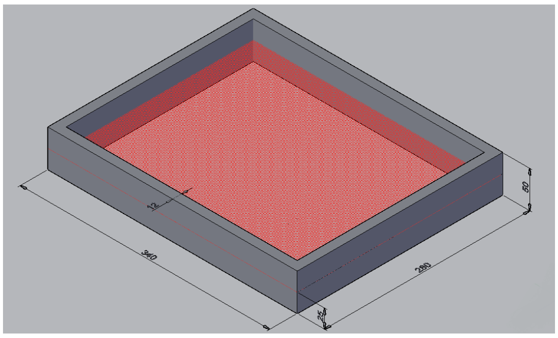
2 MATERIAL AND METHODS

In original research which was conducted in 2011, we tested seven single-use plastic bags (biodegradable, compostable, oxodegradable and control) samples available in various networks of shops on the Czech and Polish markets, advertised as 100%-degradable or certified as compostable (sample 4, 5, 6, 7). The same samples were used in research in 2012. The material composition of samples in both experiments in 2011–2012 is presented in Tab. I.

The shopping bags were made of HDPE with the TDPA additive (sample 2) and some bags were made of polyethylene with an addition of pro-oxidants (d_2w) (sample 1,3). The eighth, control sample was cellulose filtering paper (sample 8). This last sample was to check the potential of biological decomposition in the tested environment (Vaverková *et al.*, 2013).

2.1 Biodegradation test: procedure

Samples (1, 2, 3, 4, 5, 6, 7, 8) were placed into frames. Frames have been designed and manufactured in 2011. Use frames are author's utility models registered in Czech Industrial Property Office. A 3D image of the wooden frame is presented in Fig. 1.

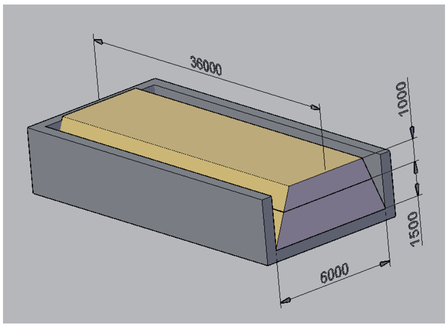


1: *Image of the wooden frame (Vaverková et al., 2013)*

The frames were made of wooden slats as follows: width = 280 mm, length = 340 mm and height = 50 mm. A 1x1mm polyethylene mesh was fixed onto the frames. The frames were designed so that they would facilitate the placement and identification of the samples in the compost pile and at the same time the removal of the samples from the given environment. The experimental samples, as in the original study, were inserted into the produced frames; in seven cases, the experimental samples were complete plastic bags (sample 1, 2, 3, 4, 5, 6, 7) and the eighth (control) sample was represented by cellulose filtering paper. The frames with the

I: *Material composition of samples (Vaverková et al., 2013)*

Sample	Type	Description
1	N/A	BIO-D Plast
2	HDPE+TDPA	100% degradabel
3	N/A	100% degradabel
4	Starch	Compostable 7P0147
5	Starch and Plycaprolactone	OK Kompost AIB VINCOTTE
6	N/A	Compostable 7P0202
7	Natural material	Compostable 7P0073
8	Cellulose (blank)	-



2: *Schematic representation of the composting clamp (Vaverková et al., 2013)*

samples were properly marked and photographed to document future visual comparison.

The experiment started in May 2012. Like in the original research carried out in 2011 in repeated research in 2012 samples were brought to Composting Plant in Brno. All eight samples were inserted into one clamp within the compost pile. The samples were installed at a height of 1m from the upper side of the compost file and at 1.5m from the lower side of the pile (Fig. 2, Fig. 3). Dimensions of the clamp into which the compost pile was placed were 6x36m and its height was ca. 2.5m. In these conditions, the experimental period was estimated to be 15 weeks. In the original study conducted in 2011 the experimental period was 13 weeks.

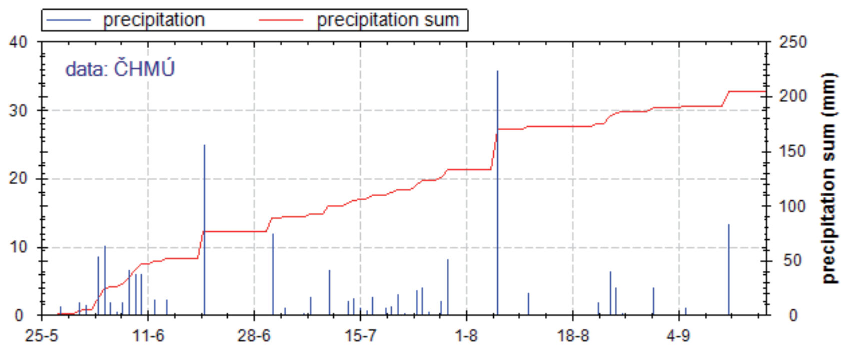
In the experiment conducted in 2011 the samples were checked visually at regular intervals of about 14 days. Based on the findings of the previous experiment, the samples checking in 2012 were less frequently. The schedule of testing dates and operations is presented in Tab. II. The checks were also used to record possible changes of appearance.

In order to be able to analyze possible effects of weather on the compost pile, composting process and decomposition of disposable plastic bags, we analyzed the records of average daily temperatures and precipitation amounts in the concerned area for the given period. The data on daily precipitation amounts in millimeters and average daily air temperatures in degrees Celsius (T) in the monitored experimental period are presented in the diagrams (Fig. 4, Fig. 5). Fig. 4 characterizes daily precipitation amounts for the months of May, June, July, August and September 2012. As shown in the graph, the highest daily precipitation amounts were recorded

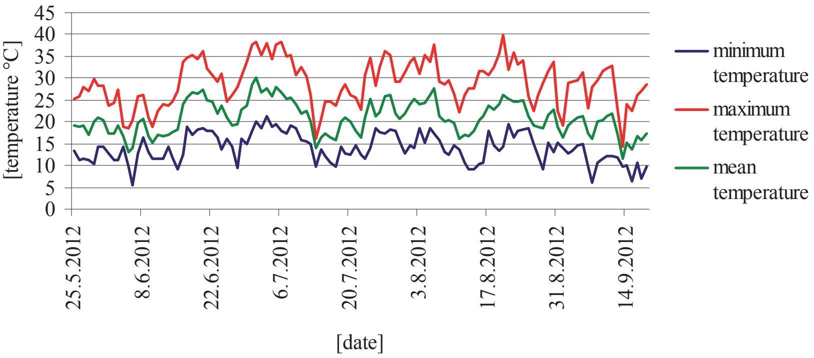
3: *Placement of samples in the compost pile (Adamcová, Vaverková, 2012)*

II: *Experiment schedule of works*

Time from start (days)	Date	Operation
0	25. 05. 2012	Start-up of the test
46	11. 07. 2012	Sample checking
106	18. 09. 2012	End of test



4: *Daily precipitation amounts for the experimental period (http://grafy.plaveniny.cz)*



5: *Average daily air temperatures for the experimental period (http://www.meteo.jankovic.cz/zaznamy/rok-2012/kveten/, modified Adamcová,Vaverková, 2012)*

in August: 35.9 mm (06.08.2012). The sum of daily precipitation amounts for that period was 204.2 mm. Number of days with precipitation was 47.

Fig. 5 illustrates the development of average daily air temperatures during the experimental period. As shown in the graph, the highest daily air temperatures were reached in the month of June when the average temperature amounted to 22.13 °C.

The experiment ended in mid-September 2012, i.e. the experimental period lasted 15 weeks. After the end of the experiment, the samples were lifted from the compost pile and all eight samples were subsequently photographed and assessed.

3 RESULTS

Upon the end of the experiment (Fig. 6) in composting plant as in the original experiment the samples were taken to laboratories of the Department of Applied and Landscape Ecology at Mendel University in Brno where they were subjected to detailed evaluation.

In all samples, a visual comparison was made of their initial and final states. In terms of this visual assessment, in the original experiment conducted 2011 samples 4 and 5 exhibited the highest degree and rate of decomposition. In the year 2012 sample 4 did not showed high degree of decomposition

6: *Samples after the experiment (Adamcová, Vaverková, 2012)*

comparing to year 2011. Photographs of the initial condition of the sample and the final condition of the sample upon the end of the experiment are presented in Fig. 7.

The manufacturer of sample 5 informs that it was made of starch and polycaprolactone. As in the year 2011 in the 2012 sample 5 showed the highest degree of decomposition. Photographs of the initial condition of the sample prior to being placed in the compost pile and the condition of the sample upon the end of the experiment, i.e. in week 15, are presented in Fig. 8.

Upon the end of the experiment, samples 6 and 7 were decomposed to about 90% of their initial condition. The material composition of sample 6 was not available. The manufacturer of sample 7 informs that it was made of natural material with no detailed specification. Photographs of the initial condition of the two samples and after 15 weeks when the experiment was finished are presented in Fig. 9 and Fig. 10.

The remaining samples 1, 2 and 3 (as in the original experiment) did not show any significant visual changes or signs of decomposition and did not appear to experience any degradation. In both years 2011 and 2012 sample 3 however exhibited some changes in pigmentation. The material composition of sample 1 was not available. Photographs of the initial condition of the sample and at the end of the experiment after 15 weeks are presented in Fig. 11.

The manufacturer of sample 2 informs that it was made of HDPE + TDPA. Photographs characterizing the condition of the sample during the experiment at intervals mentioned above for other samples are presented in Fig. 12.

The material composition of the last assessed sample 3 was not available. Photographs characterizing the initial condition of the sample prior to being placed in the compost pile and after having been lifted from the compost pile at the end of the experiment in week 15 are presented in Fig. 13.

A detailed analysis of the effect of weather conditions was not made. Nevertheless, it can be stated that total daily precipitation amounts for the

7: *Sample No. 4 (Adamcová, Vaverková, 2012)*

8: *Sample No. 5 (Adamcová, Vaverková, 2012)*

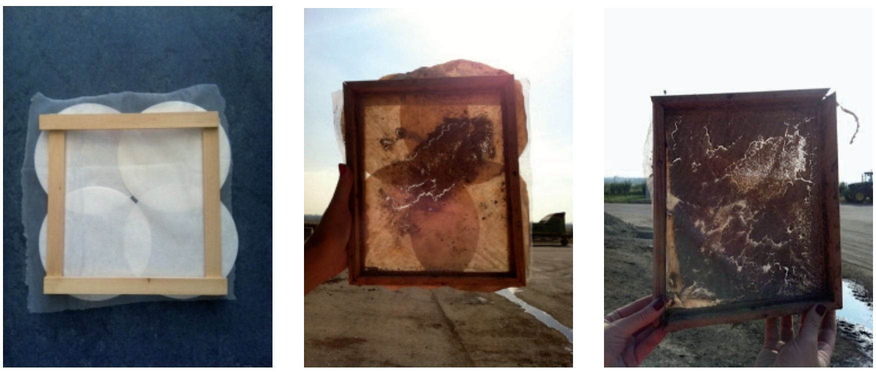
9: *Sample No. 6 (Adamcová, Vaverková, 2012)*

10: *Sample No. 7 (Vaverková, Adamcová, 2012)*

11: *Sample No. 1 (Adamcová, Vaverková, 2012)*

12: *Sample No. 2 (Adamcová, Vaverková, 2012)*

13: *Sample No. 3 (Adamcová, Vaverková, 2012)*



14: *Sample No. 8 (Adamcová, Vaverková, 2012)* experimental period were low and the temperatures were high. These low precipitation amounts and high temperature reflected in the rate and degree of decomposition of the experimental samples namely in sample 8 (cellulose filtering paper – Fig. 14) that served as a reference sample.

4 CONCLUSION

The corroboration of decomposition in laboratory conditions according to current standards answers only the question whether the plastic wrapping material is biologically degradable. However, it does not answer the crucial question whether the wrappers are successfully degradable in the environment of industrial composting plant (Vaverková *et al.*, 2012). The goal of our experiment was to verify and test methodology of decomposition of the above-described samples in real conditions of the industrial composting plant. In the original research conducted in 2011 experimental samples were placed in the compost pile operated by the Central Composting Plant in Brno and were checked and visually assessed during the experiment which lasted 13 weeks (standards for the laboratory test required 12 weeks) (Vaverková *et al.*, 2012). The same procedure was repeated in 2012 but the length of the experiment was 15 weeks and the samples checking were less frequently.

All existing norms related to this issue describe tests in laboratory conditions. Standards for compostability have been developed by the American Society for Testing and Materials (ASTM), the International Standards Organization (ISO) and the European Committee for Standardization (ECN) for evaluation of the compostability of biobased polymeric materials. ASTM standards, ISO standards and ECN standards allow evaluation of materials under laboratory conditions. As such and until now, no standard has focused on the compostability of complete packages under real conditions (Kale *et al.*, 2012).

Research in real conditions is not supported by norms neither exist methodologies describing procedures for the research of the decomposition of these materials in real conditions. Up to now, no laboratory tests were capable of copying the conditions of industrial composting plants (Vaverková *et al.*, 2012).

After the expiration of the experimental period we found out neither in 2011 nor in 2012 that the polyethylene samples with the additive (samples 1, 2 and 3) had not been decomposed, their color had not changed and that no degradation neither physical changes (thickness) had occurred. Repeated research has confirmed that the samples made of polyethylene with additives cannot be claimed to be compostable as they do not meet requirements of the existing standards and did not decompose within the time stipulated by the norms. Those plastics do not degrade or disintegrate during composting operations in 12 weeks (in our case, 13 and 15 weeks). They should have exhibited at least some changes or signs of the occurring decomposition (similarly as common organic waste), which were however not observed in the tested samples in the years 2011–2012.

Samples 5, 6 and 7 (certified as compostable) biodegrade very well in commercial compost operations in 12 weeks. Sample 5 and 7 exhibited the highest decomposition rate (before the expiration of the set-up 15 weeks). Sample 4 showed a lower degree of decomposition compared to 2011. Sample 8 was a control reference sample to confirm that the conditions of decomposition were suitable during the experiment, which was the case.

The experiment was carried out in real conditions for the first time in 2011 and its repetition was carried out again in 2012 in the Central Composting Plant in Brno in order to verify the achieved experimental results. The results confirmed the findings from the 2011.

SUMMARY

The aim of this paper was to verify information obtained by repeated research provide in 2011 and 2012 in real composting conditions and check information about biodegradability of plastics bags in real composting conditions. In both cases samples were placed into frames and inserted into one clamp within the compost pile to investigate the biodegradation. The plastics bags were obtained from chain stores in the Czech Republic and Poland. The shopping bags were made of HDPE with the TDPA additive (sample 2), PP with an addition of pro-oxidants (d_2w) (sample 1, 3) and materials certified as compostable (starch, polycaprolactone) (sample 4, 5, 6, 7). Control sample (cellulose filtering paper, sample 8) was to check the potential of biological decomposition in the tested environment.

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In commercial compost operations samples 5, 6 and 7 (certified as compostable) biodegrade very well. Sample 5 and 7 exhibited the highest decomposition rate (before the expiration of the set-up 15 weeks). Sample 4 showed a lower degree of decomposition compared to 2011.
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Address

Bc. Ing. Dana Adamcová, Ph.D., Mgr. Ing. Magdalena Vaverková, Ph.D., prof. Ing. František Toman, CSc., Department of Applied and Landscape Ecology, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: dana.adamcova@mendelu.cz, magda.vaverkova@uake.cz, tomanf@mendelu.cz