Considerations upon natural degradability of waste from the perspective of the state of the environment and the development of circular economy

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Abstract. The paper aims to determine the impact that material degradability has on the environment by estimating the duration of their non-functional existence. Starting from a classification system of municipal waste in terms of natural degradability and from generated quantities, we will calculate the footprint, “the legacy” left by a man during his lifetime and the duration of its existence. At the same time, the paper shows the impact on the environment, by estimating the level of emissions generated by easily degradable waste. Based on the results, the reasoning we develop in this paper emphasizes the relevance of circular economy in the context of current developments.

Notations used: NDD - natural degradation duration; EDWC - easily degradable waste category; MDWC - medium degradable waste category; DDWC - difficult to degrade waste category; VDDWC - very difficult to degrade waste category; HDWC - hardly degradable waste category; NPDWC - nuclear process degradable waste category; ADHWD - average duration of household waste degradation; qi - an amount “i” of the total amount of household waste generated by one citizen during his lifetime; Q - amount of household waste generated by one citizen during his lifetime; ATDWi- the average time to degrade the “i” component of the household waste.

Key Words: municipal waste, natural degradability, classification system, waste footprint over time, circular economy.

Aims and background. One of the most important issues concerning the production of materials and products is related to the underlying criteria to obtain them. Looking at the technological process under the specific conditions of the market economy, we find that the following criteria underpin the design and realization of materials: the criterion of functionality; the criterion of workability; the criterion of economy; the criterion of sustainability of usage or functionality; the criterion of degradability at the end of the lifecycle; the criterion of the environmental footprint throughout the lifecycle.

Had this paper been written in the 1970s, it would have only dealt with the first four criteria, the 5th and 6th criteria would not have been considered, as the pressure on the environment was not yet an issue in the human agglomerations and in the technological processes. Without minimizing the importance of the first four criteria, this paper aims to analyze the fifth criterion, the degradability of waste, an increasingly more important criterion as the pressure on the environment and population health has grown, favoring the emergence of elements that threaten its quality.

At the same time, the degradability criterion has begun to be researched as new materials appeared that were becoming harder to control in terms of elimination by natural decomposition, a phenomenon which formed the basis of the elimination processes that prevailed in communities until the middle of the 20th century. Therefore, the accumulation of waste which is made up of various mass production materials, brought about as a result of the scientific and technological developments in the last century, endangered the environment by increasing the quantities of generated waste and significantly increasing the required time for their transformation through natural degradation. This prompted, in view of the above mentioned criteria, a new approach to the management of materials and products, pertaining to the research of degradation processes and the measurement of their effects upon the environment and the natural resources degradation.

This paper is intended as an introduction to the correlation between waste degradation and the state of the environment and as a plea in support of circular economy.

Waste degradability from the perspective of component materials. Given that the current situation of waste is a “veritable tide”, in which the recycling costs amount to 10 billion euros each year, the rate of natural degradation of waste continues to remain crucial. Based on this, a classification criterion consolidates itself, in various forms, which classifies waste according to its natural degradation duration, comprising the following categories:

- the easily degradable waste category (EDWC), especially biodegradable waste, for which the natural degradation duration is less than one year;
- the medium degradable waste category (MDWC), for which the natural degradation duration is between 1-10 years;
- the difficult to degrade waste category (DDWC) is described by a natural degradation duration of 10-100 years;
- the very difficult to degrade waste category (VDDWC) is described by a natural degradation duration of 100-1,000 years;
- the hardly degradable waste category (HDWC), for which the natural degradation duration is more than 1,000 years;
- the nuclear process degradable waste category (NPDWC).

An illustration of the classification suggested by us can be made by using the data offered in specialized literature on the degradability of various types of materials found in the waste (http://adeic.fr; http://www.consoglobe.com; Merkariann 2004).

Thus, the first category of biodegradable waste comprises the following groups of materials: corn starch bag - with a NDD (natural degradation duration) of 2 weeks to 2 months, orange peel - NDD is about 1 month, pieces of cotton fabric - NDD is between 1 to 5 months, paper - NDD is between 2 to 5 months, toilet paper - natural degradation duration (NDD) is between 2 weeks to 1 month, vegetable waste - NDD is between 1 to 5 months, paper napkins - NDD is about three months, fruit scraps and peel - NDD is between 3 to 6 months, banana skins - NDD is between 8 to 10 months, newsprint - NDD is between 6 to 12 months, milk cartons - NDD is up to 5 months, magazines and journals - NDD is between 3 to 12 months, metro or bus tickets - NDD is up to one year.

The second category, MDWC, includes the following types of materials: unburnt cigarette ends - NDD is between 1 to 2 years, woolen socks or gloves - NDD is over a year, pieces of wood - NDD is between 2 to 4 years, cigarette filters - NDD is between 1 to 5 years, candy wrapping paper - NDD is about 5 years, chewing gum - NDD is about 5 years, engine oil - NDD is between 5 to 10 years.

The third category, DDWC, includes the following types of materials: nylon fabric - NDD is between 30 to 40 years, steel coils - NDD is about 100 years, aluminum coils - NDD is between 10 to 100 years, rubber tyres - NDD is about 100 years, plastic lighters - NDD is about 100 years, painted wood products - NDD is between 13 to 15 years, tins - NDD is about 50 years, polystyrene containers - NDD is about 50, polystyrene items - NDD is about 80 years.

The fourth category of waste, VDDWC, includes the following types of materials: aluminum packaging - NDD is about 200 years, aluminum boxes and coil - NDD is between 100 to 500 years, steel cans - NDD is about 100 years, electric batteries - NDD is over 50 years, electric batteries with mercury - NDD is about 200 years, plastic containers - NDD is about 100 years, textiles - NDD is between 100 to 500 years, disposable diapers - NDD is between 400 to 450 years, sanitary pads and tampons - NDD is between 400 to 450 years, plastic bags - NDD is about 450 years, modern fishing net - NDD is about 600 years.

The fifth category, HDWC, includes the following types of materials or products: phone cards - NDD is about 1,000 years, expanded polystyrene - NDD is about 1,000 years; plastic bottles - NDD is between 100 to 1,000 years, ski kit - NDD is 1,000 years, glass - NDD is between 4,000 and 5,000 years.

The impact of waste natural degradability upon the environment. The impact of waste degradability upon the environment is assessed according to two structures, one that presents the duration of the environment footprint without being incorporated in nature, and a second one which presents the effects of the natural degradation of waste upon the environment.

The first structure that quantifies the impact on the environment has been built on elements pertaining to the generated amounts, to the weighting of the different types of waste out of the total generated amount and their degradability. In order to vizualize this impact, we use the average amount of waste generated by a European citizen and a historical state accumulated in a non-compliant landfill.

Based on the state of non-compliant landfills of municipal waste, one in which the waste disposal was done without selective collection, there are indications that these landfills incorporate materials in various stages of natural degradation. Analyzing the footprint left by man over the course of a lifetime from the waste point of view, we found that in the European Union a man generates directly, due to consumption, approximately 350 kilograms of waste per year. Considering an average lifespan of 75 years, a European citizen generates 26,250 kilograms of waste. By storing all this waste, assuming that these materials are not recycled and taking into account the weighting of different types of waste presented by the European Joint Research Center (ACR + Association of Cities and Regions for Recycling and Sustainable Resource Management 2009), the distribution of the quantities of waste generated over a lifetime would be as follows:

- biodegradable organic waste (39%) = 10,237 kg, which gets degraded in less than 1 year;
- paper and cardboard waste (28%) = 7,350 kg, which gets degraded in less than 1 year;
- glass waste (8%) = 2,100 kg, which gets degraded in 4,000 to 5,000 years;
- plastic waste (7%) = 1,837 kg, which gets degraded in 80 to 100 years;
- metal waste (5%) = 1,312 kg, which gets degraded in 50 to 100 years;
- textile waste (1%) = 265 kg, which gets degraded in 1 to 5 years, depending on the materials in their composition;
- others (12%) = 3,150 kg, which gets degraded in an average of 10 years.

In order to identify the footprint left, we introduce the notion of degradation duration of household waste. To calculate this quantity, we will use the following formula:

$$ADHWD = \frac{\sum_{i=1}^{n} q_i \text{x} ATDWi}{Q} \quad (1)$$

Using the data on the quantities generated by a European citizen, the weighted averages for specific waste categories and the average lifetime, the average duration of household waste degradation (ADHWD) generated by a man during an average lifetime is:

ADHWD = (10,237x1 + 7,350x1 + 2,100x4,500 + 1,312x75 + 265x3 + 3,150x10) : 26,250 = 9,598,282 : 26,250 = 365,648 years.

As a consequence, the average degradation duration of this waste is 366 years.

The footprint left by a generation, summarized in Table 1, is 75 m^3, is based on the fact that 1 m^3 is approximately equal to 350 kg of household waste in a normally compacted state.

Table 1

Quantities of waste generated by a European citizen over 75 years and its natural degradability

No	*Indicator*	*Volume*		*Quantity*	
		Unit	*Value*	*Unit*	*Value*
1	Average quantity of household waste generated in a lifetime	m^3	75	kg	26,250
2	Weighting of household waste that gets degraded in the first year	%	67	Kg	17,587
3	Weighting of household waste that gets degraded in 1-10 years	%	13	kg	3,415
4	Weighting of household waste that gets degraded in 10-100 years	%	12	kg	3,149
5	Weighting of household waste that gets degraded in more than 100 years	%	8	kg	2,100

Out of the total amount of generated waste, 50.25 m^3 would disappear within the first year, 9.75 m^3 would disappear in 5 to 10 years, 11.25 m^3 after 100 years, and 6 m^3 after 1,000 years. Consequently, each of us leaves to posterity the equivalent amount of approximately 17 m^3 of waste, if we consider only the quantities that persist longer than 100 years.

The information presented above shows that the favorable situation is the one in which we generated waste with a short duration of biodegradability, during their lifetime.

From the perspective of the second structure that affects the environment, the one that influences the environment factors, we find that reality is not consistent with the statement made earlier.

The qualitative analysis done on municipal waste shows that 67% of the generated quantity will get degraded within the first year. Therefore, if we take the 75 m^3 of household waste generated over a lifetime, we find that 50.25 m^3 will get degraded within the first year.

The decomposition of 1 m^3 of deposited household waste, if we only take into account only major emissions of carbon dioxide and methane, will generate the following major effects: 60 m^3 of CO_2 and 130 m^3 of CH_4 (http://www.agir.ro/buletine/244.pdf). Based on this approximation, it appears that a European citizen, throughout his approximate lifetime of 75 years, will generate the following, in terms of household waste: 4,500 m^3_N of CO_2 and 9,750 m^3_N of CH_4.

In order to gain a better insight into the impact of domestic waste generated by a European citizen, we find that the quantities of CO_2 emissions are equivalent to the emission of a car over 56,000 km, and the quantities of CH_4 emissions could ensure the necessary fuel for a household, for approximately 40 years.

If we summarize in a spreadsheet the findings on the effects of household degradation on the environment for a European community with a population of 300,000 inhabitants, the impact is shown in Table 2.

Table 2

The quantities of materials from household waste that could be recycled and their equivalent of prime materials that could be preserved in a community of 300,000 inhabitants over 75 years (Rande 2004; http://biblioteca.regielive.ro; http://www.rec.md/sites/; http://www.autobook.ro/emisii-consum/fiat)

No	*Indicator*	*Quantity*		*Equivalent*	
		Unit	*Value*	*Unit*	*Value*
1	Quantity of paper generated in household waste	tons	2,205,000	m^3 wood mass	11,025,000
2	Quantity of glass generated in household waste	tons	630,000	tons of prime materials	756,000
3	Quantity of plastics generated in household waste	tons	551,100	tons of petrol	991,980
4	Quantity of metal generated in household waste	tons	393,600	tons of prime materials	472,380
5	CO_2 emission	m^3	1,350,000,000	no. of cars*	18,750

* number of cars which can be operated annualy, producing the same amount of emissions as the household waste generated by a community of 300,000 persons over a period of 75 years.

If the virtual community of 300,000 had functioned in compliance with the institutional rules configured by various European countries, we would have had the situations presented in Table 3. The data used for the configured assessment is consistent with the data presented by BiPRO (BiPRO 2012) and the values presented are estimates, considering the difficulty of applying some viable approximations for a period of 75 years. Rather than evaluating the past, the scope of this paper is to mobilize present resources in order to prevent future losses, which may not be insignificant, considering the data in the research. There is only one solution, which is the implementation of circular economy.

Table 3

Quality indicators and virtual quantities generated according to the waste processing data in some EU member states, adjusted to the level of a population of 300,000 over the course of 75 years

No.	*Indicator*	*Austria*	*Hungary*	*Poland*	*Romania*
1	Recycling rate, %	69.8	21.4	25.6	1.3
2	Recovery rate, %	29.5	9.8	0	0
3	Storage rate, %	0.7	68.7	74.4	61.9
4	Total expenditure on storage, Euro / ton	96	35	94.6	no data
5	Coverage rate of collection services, %	100	92.4	79.8	70
6	Amount of recycled paper, tons	1,543,500 out of 2,205,000	463,050 out of 2,205,000	551,375 out of 2,205,000	263,250 out of 2,205,000
7	Amount of recycled glass, tons	441,000 out of 630,000	132,300 out of 630,000	157,500 out of 630,000	8,190 out of 630,000
8	Amount of recycled plastic, tons	385,770 out of 551,100	115,731 out of 551,100	137,775 out of 551,100	7,164 out of 551,100
9	Amount of recycled metal, tons	275,520 out of 393,600	82,656 out of 393,600	98,400 out of 393,600	5,116 out of 393,600
10	CO_2 emissions avoided, $m^3{}_N$	630,000,000 out of 1,350,000,000	189,000,000 out of 1,350,000,000	225,000,000 out of 1,350,000,000	11,700,000 out of 1,350,000,000

Values used: 1 ton of waste releases 400-600 $m^3{}_N$ biogas containing 10-40% 50-90% CO_2 and CH_4; 1 ton of paper recycled prevent the felling of 5 m3 of wood mass; 1 ton of iron waste recovered achieved a saving of 1-1.2 tonnes of iron ore; 1 ton of pieces of glass saves 1.2 tons of raw material; 1 kg plastic requires 2 kg of crude oil; the average value of CO_2 emissions for Fiat is de158.3 g/km.

Conclusions. This paper, using a method of putting institutional data to proper use, suggests the effects of household waste on the environment. Two types of effects have been analyzed, one which quantifies the material footprint of the household waste and a second one which influences the environment. In order to get a more concrete view of the global impact, we used the average waste generated by a European citizen and his average lifetime. The calculations made for a population of 300,000 persons, close to that of Cluj Napoca, for a period of 75 years, highlight some dramatic data, which is not so easily perceived when analyzing daily activities. If the paper and cardboard contained in household waste had followed the recycling cycle, we would have basically spared 11,025,000 m^3 of wood from processing, in the case of glass we would have avoided the extraction of 756,000 tons of raw materials and we would have prevented emissions equivalent to driving 18,750 cars per year.

The comparions made between different European countries demonstrate a lack of common grounds and the huge steps that European citizens need to take.

These are only a few solid arguments that determine the adoption of solutions specific to circular economy which should, in compliance with the European requirements, become the norm by 2020 and reality by 2030.

For this reason, this paper is intended to be an argument that can determine the university community to promote research programmes which include topics that favour the transformation of waste into material and energy resources for the increasingly higher needs that development requires from the environment and its sustainability.

References

ACR + Association of Cities and Regions for Recycling and Sustainable Resource Management, 2009 Municipal waste in Europe - towards a European recycling society. Victoires Editions, Paris.
ADEIC, The decomposition of waste. Available at: http://adeic.fr. Accessed: March, 2015.
BiPRO, 2012 Screening of waste management performance of EU Member States. Report submitted under the EC project „Support to Member States in improving waste management based on assessment of member States' performances. Report for the European Commission, DG ENV, Jully 2012.
Conso Globe, The life span of the waste in nature. Available at: http://www.consoglobe.com. Accessed:January, 2015.
Merkariann M., 2004 Bioreaction applied to waste management in Quebec: technical and environment. FCQGED.
Mc Rande P., 2004 The green guide in State of the world. Ed Ambiente Milano, pp. 136-137.
Rusu T., Bejan M., 2015 A renewable energy source - biogas from organic waste. Available at: http://www.agir.ro/buletine/244.pdf. Accessed: March, 2015.
*** http://biblioteca.regielive.ro/cursuri/metalurgie-si-siderurgie/tratarea-prelucrarea-valorificarea-deseurilor-metalice-179043.html. Accessed: March, 2015.
*** http://www.rec.md/sites/all/themes/daycare/Documents/Publicatzii/brochure_ro.pdf - Guide of selective collection of waste. Accessed: March, 2015.
*** http://www.autobook.ro/emisii-consum/fiat. Accessed: March 2015.

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