

Specific waste generation rate of recyclable materials in households:

Time-series of eighteen months for three households in Greece

F. Tsagas^{1,2}, K. Liolios³ and A. Paschalidis

¹Department of Civil Engineering, School of Engineering, Democritus University of Thrace, Xanthi, 67100, Greece

²Waste Management Authority of Eastern Macedonia - Thrace, DI.A.A.MA.TH, S.A., Komotini, 69132, Greece

³Institute of Information and Communication Technologies, Bulgarian Academy of Sciences, Sofia, 1113, Bulgaria

Corresponding authors e-mails: ftsagkas@civil.duth.gr, ftsagas@diaamath.gr , kliolios@env.duth.gr

Corresponding Author tel and fax: Tel +30-25310-81400, Fax: +30-25310-81694

Abstract

Households are the main production source of Municipal Solid Waste (MSW), as well of recyclable materials, in a community or city. In small size cities or municipalities in Greece there is experience in the operation of source-separation of waste packaging recyclable materials (paper, cardboard, glass, metals and plastics) by a commingled bin (blue bin) system. Nonetheless, there is no extensive study of production of recyclables materials in a household level for a medium to long term period. This paper presents a study of the behaviour of three (3) households in the production of recyclable materials for a period of 18 months (from April 2013 until September 2014) and provides primary data. The recyclable materials were sorted from the rest of the households MSW and were weighted systematically in three households, in the small size city of Xanthi, in Northern Greece. The weighing data were recorded regularly by volunteers in the households. On average a specific waste generation rate of 37kg per capita per year is estimated. The estimation of the specific waste generation rate of recyclable materials in households could assist in planning the appropriate management of the recyclable materials, generated in household level, as well in the level of a small municipality.

Keywords: Recycling; municipal solid waste (MSW); households; blue bin system.

1. Introduction

The recycling of Municipal Solid Waste (MSW) is high on the waste hierarchy as a way for better management of MSW. Households are the main production source of waste packaging recyclable materials, in a community or city, among other sources like markets, hotels, restaurants etc. Many recycling campaigns at households aim to the source-separation of recyclable materials that will be sorted by a commingled bin (blue bin) system. Namely, these materials include paper, cardboard, glass, metals, like aluminum and tin, and a sort of kind of plastics. The blue bin system is operating in Greece for a period of over 10 years, especially in high populated cities (EOAN, 2014). In small size Greek cities or communities there is also experience in the operation of Integrated Solid Waste Management (ISWM) systems of separated sorting and recycling. For example Panaretou et al present an ISWM system applied in the small island Municipality of Tinos, in Greece for the first eight months of the ISWM system operation. The ISWM system included separation of MSW at source for paper/paperboard, glass, plastic & metal and biowaste 2014 [4].

According to the official results of recycling, provided by the Greek Organization of Recycling (EOAN), there was success concerning the recycling of paper, cardboard and plastics; the totally recycling capacity was above the targets which were set by the Greek and the European authorities. From the other side, the totally recycling capacities of metals and glass were below the targets. Generally in Greece, only the 17% of the materials are recycled, one average performance comparing with the other countries of European Union [1].

Also, there is extensive literature about the quality of the materials recovered by the blue bin system in Material Recycling Facilities (MRFs) throughout Greece as it is presented by Razis et al [5]. Approximately thirty MRFs are in operation currently in Greece and are serving the Greek Municipalities, installed in the mainland or in islands. In a year round basis the blue bin system serving the Greek municipalities provide results of operation and amounts of recyclable materials from packaging waste that are recovered and recycled. According to the annual report of 2014 of Hellenic Recovery Recycling Corporation (HERRCO) [3] an average result of specific recyclable materials waste generation rate of approximately 20kg per capita per year can be calculated for Greek mainland municipalities while in Greek island municipalities a waste generation rate of approximately 30kg per capita per year can be calculated. The dramatic effect of tourism and touristic activities is evident and obvious in the previous indicators. So it is evident that there is extensive knowledge on the waste generation rate of recyclable materials in a municipality or a city level in Greece. Nonetheless, there is no extensive study of production of recyclables materials in a household level for a medium to long term period of over 12 months in Greece. There is a study of monitoring the production of recyclable materials in a small city in Greece but only for duration of five months in which study an average production rate of 31kg/capita/year is estimated [6]. Consequently, this paper aims to add valuable experience and knowledge in this field of specific waste generation rate of recyclable materials in households in the Greek context.

In the following paper the materials and methods used for the estimation of the specific waste generation rate of recyclable materials in households are presented, then the results and the time-series of the specific waste generation rate for eighteen months for three households in the municipality of Xanthi in Greece are given together with a short discussion and finally some conclusions are given.

2. Materials and Methods

This paper presents a study of the behaviour of three (3) households in the production of recyclable materials, for a period of eighteenth (18) months, in the small city of Xanthi in Greece. The municipality of Xanthi lies in the Northeastern part of Greece and has a population of 65.133 inhabitants according to the Greek national consensus of 2011 [2]. The time period of the study was from April 2013 until September 2014. The three households that were chosen, named H1, H2 and H3 had a number of three (3), four (4) and one (1) residents respectively. A profile of the households is given in Table 1.

Table 1. Profile of the residents of the three households.

N. of household	Members	Sex		Age profile (years)				Education level		
		M	F	0-20	21-40	41-60	60<	Elementary	Secondary	Higher
1	3	2	1	0	1	0	2	0	1	2
2	4	3	1	0	2	1	1	0	0	4
3	1	1	0	0	1	0	0	0	1	0
Total	8	6	2	0	4	1	3	0	2	6

In these households small plastic open bins (like boxes) of a volume of 30 were used. The residents of the households H1, H2 and H3 were sorting the recyclables materials from the rest of the households' MSW and putting the recyclables in the small bins like-boxes. Then small bins full with the recyclable materials were weighted systematically every day or every time the bin like-box was full of its capacity. The recyclable waste packaging materials included common packaging materials from paper, Tetra Pak®, cardboard, glass, aluminum, tin and a different kind of plastics (PET, PP, HDPE, LDPE, etc). Following the weighing of the materials the weighing data was recorded regularly in tables in simple spreadsheets with the date (day/ month/year) of the recording and the weight of the materials in grams (gr). The collected recyclable packaging materials were directed in the blue bins, for recycling in a MRF.

Some photos of the small plastic collection bins and the weight scales which were used are shown in Fig. 1. The weight scales had a fraction of 0.01 g while the maximum weight that could be measured was five (5) kg. Representative photos of the recycling materials are shown in Fig.2.

**Fig.1** Photos of small bins and weight scale.**Fig.2** Photos of recycling materials.

The recorded data of every weighing of every day in a month were grouped and summed in a monthly basis so for each month from April 2013 to September 2014 the summed weight of recyclable materials collected for each household was known in [total grams/month]. This monthly weight then was divided by the number of residents in each household that was 3 for H1, 4 for H2 and 1 for H3. So, for each month the specific generation waste in [grams/(capita*month)] could be calculated. Finally for each month the specific generation waste was calculated in terms of [kg/(capita*year)].

3. Results and Discussion

The results of the methodology, described above, are presented in Table 2. For each month from April 2013 until September 2014 the monthly average generation rate of recyclable materials for the three households, in terms of kg per capita per year [kg/(capita*year)], are shown.

Table 2. Monthly average generation rate of recyclable materials, in kg/(capita*year) for 3 households.

		H1	H2	H3
	Month	[kg/(capita*year)]	[kg/(capita*year)]	[kg/(capita*year)]
1	April 2013	63	36	35
2	May 2013	50	29	35
3	June 2013	48	37	73
4	July 2013	45	15	51
5	August 2013	57	36	62
6	September 2013	78	29	35
7	October 2013	40	17	38
8	November 2013	60	20	20
9	December 2013	42	24	34
10	January 2014	39	20	40
11	February 2014	28	22	32
12	March 2014	25	29	18
13	April 2014	64	27	29
14	May 2014	49	16	78
15	June 2014	27	39	33
16	July 2014	33	37	30
17	August 2014	31	16	23
18	September 2014	37	17	35
	Average values	45	26	39

As it is evident from Table 2, for H1 the average value of generation rate of recyclable materials is 45 kg per capita per year, for H2 26 kg per capita per year and for H3 39 kg per capita per year. On average for all the households, a production rate of about 37 kg per capita per year is estimated. In Figure 2 the results presented in Table 2 are depicted as time series for each one of the three households. From Figure 2 great variations of production of recyclables inside a single household are clearly evident. For example for H1 the monthly generation rate of recyclable materials seems to vary from 25 to about 80 kg/(capita*year). Likewise the monthly rate for H3 varies dramatically from a minimum of about 20 to a high value of about 80 kg/(capita*year). The behavior of H2 is more constant with the monthly generation rate to fluctuate from 15 kg/(capita*year) to almost 40 kg/(capita*year). Variations of the generation rate of recyclable materials through time can correlate with behavior and practices of the households as consumers. For example peaks and highs of generation rate values can be explained by events of more products consumed by the households while lows of generation rate values can be explained likewise by events of less products consumed.

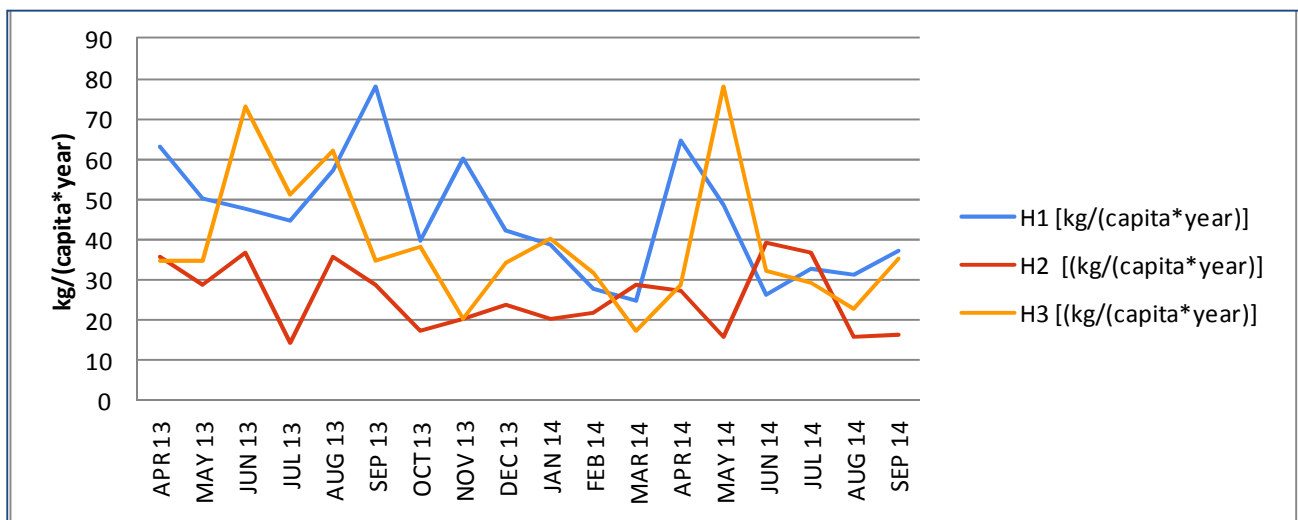


Fig. 2. Time series of monthly average generation rate of recyclable materials in 3 households for 18 months

The average value of 37 kg per capita per year that is estimated in this work is a fairly good estimation comparing with other similar studies. In Tsagas et al the researchers calculated the average specific waste of recyclable materials for 8 households in the city of Komotini in Greece finding for each household values of specific waste generation rates of

recyclable materials such as 32, 42, 4, 70, 28, 56, 43 and 26 with an average value of 31kg/cap/year. [6]. This result verifies that when the behavior of households is positively on sorting waste in the source, that is inside the household and make use of the blue bin system, the anticipated average specific waste generation rate of recyclable materials in Greece could be in the range of 31 to 37 kg per capita per year. Moreover, discussing and comparing those results, as primary data, with the average figure of the specific waste generation rate of recyclable materials of approximately 20 kg per capita per year induced by the total nationwide secondary data of the blue-bin system in Greece, presented in the introduction, one can assume that there are important margins of improvement of the national results of recycling. More information and more awareness campaigns are needed on the source separating practice of recyclables inside the households and the use of the blue bin system. Education system and special events in schools can assist to this matter.

4. Conclusions

In this research, a study concerning the behaviour of three households in the production of recyclable materials is presented. The time period of the experimental procedure was 18 months and was realized in the Greek city of Xanthi. Primary data of weighing recyclable waste packaging materials are provided. On average a specific waste generation rate of recyclables of 37 kg per capita per year is estimated. Variations of the generation rate of recyclable materials through time can correlate with behavior and practices of the households as consumers. The results confirmed the dynamic nature of the households as municipal solid waste producers. The estimations of specific waste generation rate of recyclable materials in households could assist in planning the appropriate management of the recyclable materials, generated in household level, as well in a small municipality level. Generally, by comparing the presented values of primary data of specific waste generation rate of recyclables in household level with secondary data of national level it is clearly evident that there are margins of improvement of the indicators of percentage of recycling of the blue bin system in the Greek Municipalities. The percentage of recycling of packages should increase in Greek cities, not only in order to follow the European instructions, but mostly because it is going to contribute positively in the protection of the environment. The role of information and awareness campaigns is crucial to contribute to this direction.

Reference list

1. EOAN: Report of recycling in Greece, Athens. Hellenic Organization for Recycling, (In Greek) <http://www.eoan.gr/el/content/291> <http://www.eoan.gr/el/content/310/etisia-ekthesi-ellinikoy-organismoy-anakyklosis-2014> <http://www.eoan.gr/uploads/files/310/1858129f9a58cfa0291dd59a4a00fb731f607c7b.pdf> (2014)
2. Greek National Consensus (2011) <http://www.statistics.gr/el/statistics> Accessed 02 April 2016
3. Hellenic Recovery Recycling Corporation “12 Years of HERRCO - Annual Report 2014” (2015)
4. Panaretou, V., Malamis, D., Moustakas, K., Valtas, K., Margaritis, M., Loizidou, M.: Setup, monitoring and evaluation of MSW management scheme in Pyrgos and Panormos communities in Tinos Island, Greece. 2nd International Conference on Sustainable Solid Waste Management, 12–14 June 2014, Athens, Greece (2014)
5. Razis, I., Korre, M., Arvanitis, A., Dimou, E., Makridis, B., Tsolou, S., Malapetsas, A., Komis, L., Lekkas, T.: Recovery and utilization of packaging materials from waste in Greece from HERRCO. In: Proceedings of the 4th International Conference HSWMA: Solid Waste Management in Crisis Athens, November 30 - December 1, 2012 ISBN: 978-960-6865-54-1 pp 205-223 (In Greek) (2012)
6. Tsagas, F., Papazoglou, K., Petalas, A., Maladaki, M.: Pilot monitoring of three (3) waste streams of municipal solid waste (MSW) produced at household level in Northern Greece. 2nd International Conference on Sustainable Solid Waste Management, 12–14 June 2014, Athens, Greece (2014)