HOUSEHOLD WASTES CHARACTERIZATION AND SEASONAL VARIATIONS IN BIHOR COUNTY, ROMANIA

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The management of household solid wastes is a constant concern for any community, and the preparing and putting into practice alternative management strategies need updated data regarding their quantitative and qualitative features. Thus, this study presents the household wastes characterization from Bihor County, Romania for the purpose of identifying and quantifying the materials likely to be recovered energetically or economically. The study was conducted in 6 areas (3 urban areas, 2 rural areas, 1 touristic area) of the county, for one year (during the 4 seasons), where variations of the wastes features were highlighted depending on the economic activities and lifestyle of the population in the area from whom samples were taken, as well as depending on the season. The results show that: the content of organic matter is 45.89%, combustible materials – 13.48%, recyclable materials – 20.26%, inert – 20.09% and hazardous wastes in smaller quantities (0.3%). Also, average humidity is 47.81%, higher in the summer season (58.27%). The generated wastes quantity is 0.825 kg/capita/day in urban areas and 0.44 kg/capita/day in rural areas.

Keywords: household solid waste characterization, waste management, seasonal waste variation, waste generation rate

1. Introduction

Population growth, urbanization, economic and industrial development, the lifestyle (culture and traditions) of the population and the season [1, 2] are closely related to both the quantity of solid waste generated per capita (quantity of wastes generated / total population) called waste generation rate expressed in kg/capita/day, and the Household Solid Wastes (HSW) composition. The amount and composition of waste generated varies by country, region or even in different areas of a city. Thus, in countries with middle and high income wastes production is between 0.8 – 2.2 kg/capita/day, compared to those low-income countries

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which generate between 0.3 – 0.9 kg/capita/day [3, 4, 5]. On the other hand, depending on the constituent elements (putrescible, paper, cardboard, plastic, metals, etc.) worldwide wastes composition is roughly the same, but the proportions of these components are different, thus in countries with low-incomes, the organic matter (biodegradable) represents 40% – 85% of the total mass of waste compared to countries with high-incomes where the organic fraction is less than 40% [3, 5].

Bihor County is located in the North-West of Romania and has a total area of 7,544.27 km^2. The Bihor County administrative organization is made up of: 4 municipalities, 6 towns, 91 communes and 430 villages; 50.5% from the population are from urban areas and 49.5% from rural areas [6]. Regarding the wastes disposal, currently, the HSW are disposed by Oradea Municipality landfill, as well as 2 open dumps which will close in 2017. The total capacity of the landfills is estimated to be at about 3.8 million tons until 2025 [6, 7, 8].

Waste composition at county level is based on estimations and is divided on 8 fractions (putrescible, paper and cardboard, glass, plastic, metals, wood, textiles, others) out of which the putrescible fraction has the largest share (62% of the total wastes mass) and waste generation rate is averaged about 0.65 kg/capita/day [6].

The most common method for HSW disposal on nationwide as well as in Bihor County is landfilling (93% of wastes collected are disposed in landfills) while composting and recycling are less used methods [6, 9]. Therefore, currently the waste management in Bihor County is based, generally, on three activities: collection, transportation and storage. If this waste management is used in short time, large areas of land would be needed for their storage. On the other hand, the coverage of sanitation services in 2006 was 74.1% in urban areas and 29.5% in rural areas; and it is estimated that by 2013 to reach 99% [6].

The European Commission has issued new policies and regulations regarding the implementation of integrated HSW management systems, encouraging the use of alternative waste treatment technologies, among which can be mentioned the biological (anaerobic digestion) and thermal processes (combustion) with / without energy recovery, pyrolysis or gasification [9, 10, 11, 12].

Knowing the waste generation rate as well as the HSW composition allows the determination of certain factors involved in waste collection systems, such as: collection equipment design, operational costs, identification of energetically or economically recoverable materials types [13]. Based on this it enables the development of a sustainable integrated solution for solids waste management [11] and choosing the most suitable technology for wastes treatment [8]. In this regard, the literature describes about 20 methodologies [13, 14, 15, 16] used for determination of the waste generation rate and HSW composition. The differences

between these methodologies consist in: sampling (from garbage trucks, door-to-door); stratification of study area by socioeconomic or demographic; number of samples; weight of samples; sorting manner; study duration; as well as the number of categories and subcategories of each faction of solid wastes.

In this context, field waste characterization have been conducted on site location, consisting in determination of HSW composition based on the French MODECOM methodology, waste generation rate, as well as waste fractions humidity in order to identify and quantify the materials likely to be energetically or economically recovered. The study was conducted in urban and rural areas in 6 representative zones of Bihor County from socioeconomic point of view, for one year (4 seasons), so that any possible seasonal variations to be highlighted. Therefore, the paper presents experimental results supplying the necessary information for companies in charge of management and exploiting landfills, as well as Bihor County authorities in the decisional process regarding the management and treatment of waste. Thus it can be chosen the most suitable methods of disposal / treatment of HSW and/or the modification of current methods, updating the current waste characterization data.

2. Sampling and characterization of household wastes

Bihor County was intentionally selected for this study due to the fact that it has several representative areas from socioeconomic point of view, number of people and their incomes, educational level (studies), lifestyle, etc. When choosing the studying areas, were taken into account: the type of locality (urban, rural, balneotherapeutic); the number of inhabitants; the coverage with sanitation services. Based on this, 6 areas were chosen representative for waste characterization: urban area – apartments; urban area – commercial; urban area - houses; rural area – suburban; rural area - houses; touristic area – balneotherapeutic.

Sampling is the most important stage for the waste characterization in terms of composition. The heterogeneity of wastes (granulometry, categories and subcategories) and the subjected study areas makes sampling more or less complex [13, 15, 17]. In this regard, the on-site experimental campaigns for sampling were made randomly from the dump waste trucks arriving at the landfill with raw wastes from the above mentioned areas. The sampling process was repeated during 6 days (an area per day) and in each season, thus resulting 24 wastes characterization campaigns.

Regarding samples weight, MODECOM French methodology [18, 19, 20] is using samples of about 500 kg (divided into 10 lots of 50 kg each due to the used scale) of fresh wet wastes to be analyzed, thus 24 samples of about 500 kg/sample have been taken. This mass of waste has been submitted to sorting by

grain size. The separation was achieved by sieving using 2 large sieves of 2 x 1 m; one with 100 mm round holes and the other with 20 mm round holes, thus obtaining three granulometric sizes of materials [19]: coarse (over 100 mm); medium (20 – 100 mm) and fine (under 20 mm). In respect of the number of categories, most methods set a limited number of categories and subcategories depending on the research purpose [2, 13, 17, 19, 21], thus, 5 categories have been considered in this study (organic materials, combustible materials, recyclable materials, hazardous materials and inert materials) divided into 13 subcategories: putrescible; paper and cardboard, composites; textiles; sanitary textiles/diapers; hazardous wastes from HSW; plastic; wood; glass; ferrous metals; nonferrous metals; construction wastes; and unspecified wastes. Also, from paper, cardboard and plastic subcategories were considered recyclable the ones with large granulometric sizes (>100 mm), and the ones with medium sizes were classified as combustible materials. On the other hand, these subcategories contain other types of waste components [13]. This classification will allow more detailed information about HSW entering the landfill and which can be recovered.

After the sorting process, each category has been weighted to establish their percentage contents. The sampling and sorting were conducted by a team formed by a supervisor and 5 persons in charge of sorting. As equipment, 2 sieves have been used (one with 100 mm holes and another with 20 mm holes), small excavator, 5 shovels, 60 kg scale balance and 10 bins of 110 litter samples storage on pallets.

Another feature to be determined is the amount of waste generation per capita [kg/place/day] which is calculated as the ratio between the total mass generated in one day in the studied area per number of inhabitants [2, 8].

The determination of moisture of HSW was based on the following procedure: the samples taken from each component of the wet HSW are cut and shredded, and then they are dried in the oven, at 105° C, for 24 hours. These temperature and time are used in order to produce the full dehydration of the materials and to limit, at the same time, the vaporization of volatile materials. In purpose of determining the moisture content, the samples have been weighted before (W_1) and after drying (W_2) with an analytical balance. The humidity of component parts of HSW has been calculated with the formula (Eq. 1) [1, 8]

$$H[\%] = \frac{W_1 - W_2}{W_2} \cdot 100 \tag{1}$$

3. Results and Discussions

The results presented in the following sections have been achieved depending on the sampling area, as well as according to season, to highlight

seasonal variations. For this purpose, in all the 24 characterization campaigns, about 12008.25 kg of unsorted wastes (500 kg/sampling area/season) have been gathered. The first classification was made by the granulometric size (coarse, medium and fine) of waste in order to facilitate the identification of aforementioned categories and subcategories.

3.1 Wastes composition

After data compilation the mass variation in percentages of HSW components depending on the area sampling, as well as season is presented in Fig. 1 and Fig. 2. The annual average HSW composition based on waste categories, expressed in mass percentage of sorted samples for the studied areas is presented in Fig. 1.

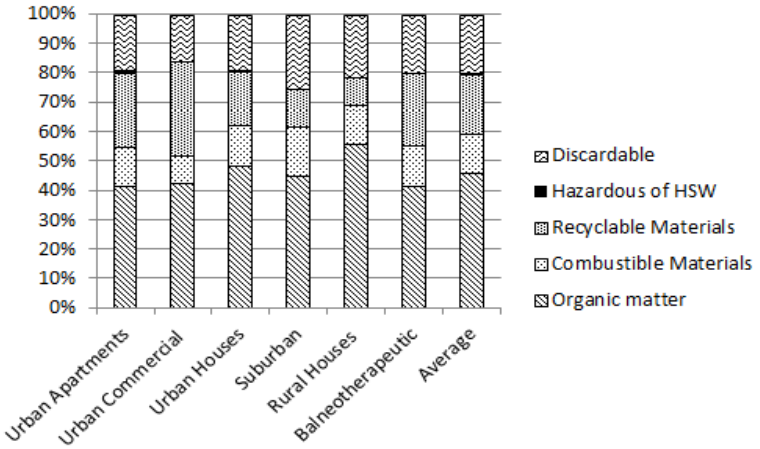

Fig. 1. The variations of HSW composition on studied areas

The HSW components variation is greatly due to the lifestyle (educational level – studies, diet) as well as economic activities being developed in the respective areas. Thus, in rural houses area the organic matter has a high percentage (55.79%) compared to the other areas, which is due to the lifestyle of the inhabitants, mainly the way of preparing food which is based on cooked food. Regarding the combustible materials, the urban commercial area generates the lowest percentage (9.37%) because of the presence of recyclable materials – 31.83% (generally cardboard and plastic of coarse granulometric sizes). Combustible materials in commercial urban area compared to the rural house are in the rate of 4:1, due to the specific commercial activities of the commercial area. Hazardous materials present in HSW do not show considerable variations, but urban apartment area has the highest percentage (0.59%) almost twice that of the other areas. Finally, inert materials are present in high proportion in suburban area

(25.23%) followed by rural houses area (21.34%) and balneotherapeutic area (19.84%). This is due mainly to the constructions activities conducted in these areas and the domestic heating with wood during winter.

Seasonal variations of HSW composition are presented in Fig. 2.

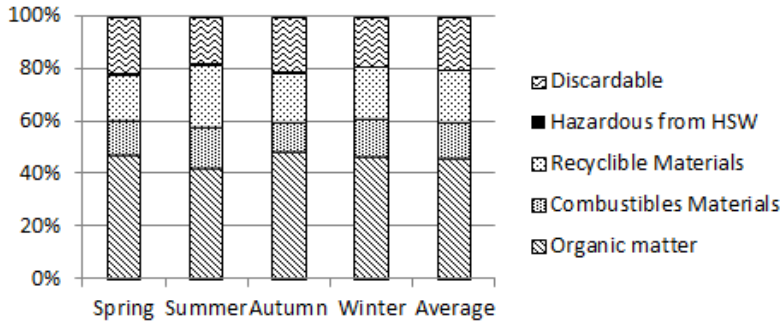

Fig. 2. The variation of HSW composition on season

In the spring and summer seasons the organic matter shows a slight increase in comparison to autumn and winter, as in these seasons the inhabitants alimentation is based on vegetables and fruit. Also, recyclable materials increase during summer season, which is due to the consumption of packed soft drinks, mainly in urban and balneotherapeutic areas. Combustible materials and respectively hazardous materials do not show a significant fluctuation. In respect of inert materials, they decrease during the summer period due to the absence of heating in rural areas (ash reduction), but compensated by the presence of construction activities and repairs of homes in the urban areas.

The annual general average of HSW composition is presented in Fig. 3.

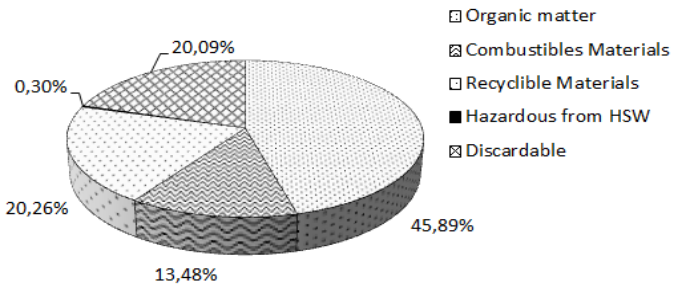

Fig. 3. Annual general average of HSW composition

Bihor County HSW consists mainly of organic matter (45.89%) which can be used for compost production (agricultural recovery) or biogas production

(energetic recovery). Economically recoverable recyclable materials represent 20.26%. In order to maximize their recovery, they should be separated at the source. Combustible materials are in proportion of 13.48% by weigh of wastes, waste to energy processes can be used for energy generation. A very small amount is represented by hazardous wastes from HSW, but they must be neutralized, according to the laws in force (Directive 91/689/EC). Inert materials that can be sent to landfill represent 20.09%. Thus, the percentage of usable materials would be 79.63%.

On the other hand, by comparing the paper results (Fig. 3) with the estimated ones great differences can be observed. Thus, the estimated putrescible fraction (62%) is greater than the measured one (45.89%); in respect of component recyclable materials, in case: paper, cardboard and plastic estimated would be considered fully recyclable, the percentages are similar (measured – 20.26%, estimated – 21.0%). The fraction of combustible materials, which according to estimations would be textiles and wood, there are small differences (measured – 13.48%, estimated – 11.5%). The percentage of inert materials, considered as unspecified waste, there is a difference of about 1:4 in comparison to the measured one (estimated – 5.5%; measured 20.09%). These disproportions are due to the procedure applied in determining the composition, the percentages of fractions presented in estimations being roughly determined by strictly qualitative methods and comparisons with the situations of neighboring countries, while the fractions presented in this study are determined by quantitative methods (experimental measurements on site).

3.2 Household waste generation rate

Regarding the waste generation rate, the results show differences in the case of total amount waste generated per capita according to the specific season analyzed (Fig. 4). In this regard, the difference is about 3:1 between the waste generation rate for the balneotherapeutic and urban apartment area (0.85 to 0.82 kg/capita/day) and the generation rate corresponding to the rural houses area (0.35 kg/capita/day). This highlights the fact that in the rural area there is no record of total amount of HSW, due to the coverage of sanitation services in the rural area [8]. The largest share of wastes generation is in the balneotherapeutic area (0.88 kg/capita/day) in summer due to the tourists' inflow.

The total average quantity of generated wastes during one year is 0.825 kg/capita/day in the urban area and 0.44 kg/capita/day in the rural area.

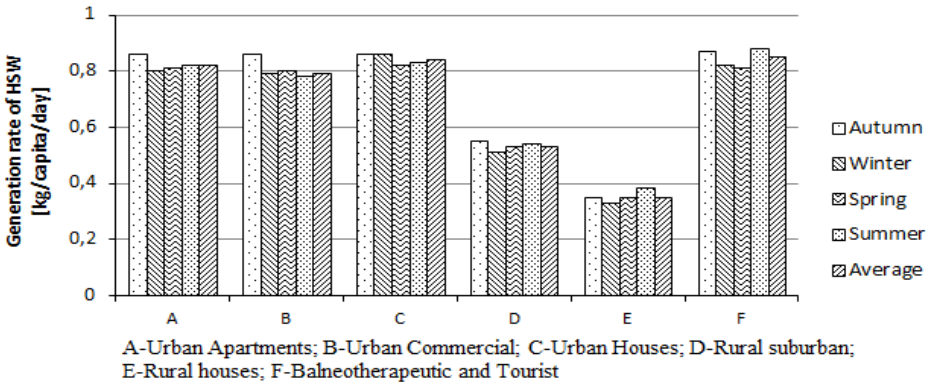

Fig. 4. HSW generation rate

Also, there is a variation of waste generation rate determined in this study compared to the one estimated (0.9 kg/capita/day in urban areas; 0.4 kg/capita/day in rural areas), due to the ones mentioned above.

3.3 Wastes humidity

The laboratory analysis showed that the average humidity of HSW is 47.81%. It can be appreciated in Figure 5 the variation of humidity content of HSW depending on season. The humidity values are influenced on one hand by rainfall (environmental humidity) in each season and on the other hand by the population's diet. Thus, the highest percentage is in the summer season (58.24%) followed by the autumn season (55.17%), and the lowest value is in the winter season (35.47%). These results highlight the influence of the population's diet as well as the environmental conditions (rainfall and temperature) on the wastes humidity, as autumn is the rainiest period of the year, while spring and summer are seasons when more vegetables and fruit are consumed.

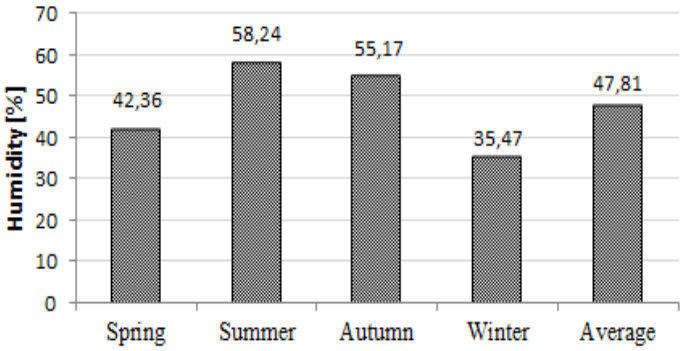

Fig. 5. Variation of waste humidity content

4 Conclusions

The field household wastes characterization campaigns conducted for one year in Bihor County – Romania, show that household solid wastes contain, in average, biodegradable organic matter – 45.89%, combustible materials – 13.48%, recyclable materials – 20.26% and inert materials – 20.09% and hazardous materials in small quantities – 0.30%. Also, the average humidity is 47.81%, being higher in the summer season (58.27%). The generated wastes quantity is 0.825 kg/capita/day in urban areas and 0.44 kg/capita/day in rural areas. It was observed that the economic activities and the lifestyle of the population determine the characteristics of the generated waste; therefore they vary depending on the area where the samples were taken as well as on the season. Also, this characterization can be considered as reference for choosing the possible treatment process, so that methods such as composting – agricultural recovery, biodegradation in reactors – energetic recovery, the recycling of metals and glass or other recyclable materials (paper, cardboard, plastic) – economic recovery, etc. could be optimized.

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