DYNAMICS OF ORGANIC FRACTION OF MUNICIPAL SOLID WASTE IN VINNITSA (UKRAINE)

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SUMMARY: The problem of analysis and forecasting the formation of municipal solid waste organic fraction depending on various factors, primarily on the level of public welfare, is extremely important today. The fact is that over 50% of the total volume of waste produced by households is accounted for the organic fraction. Therefore, the study of factors influencing the phase of formation of these types of waste will make it possible to provide effective control and management of waste in the future. There are relatively few studies that assess the trends of organic waste produced by household. The objective of this study is to bring together the observations of producing waste organic fraction by families with different income levels in Vinnytsia. We have collected the data from 28 households within 2014 – 2016. The results of this study present multiple relationships between organic waste, industrial production and population growth, and dependence of morphological composition of MSW produced by people on their welfare. We have analyzed the trends in formation of organic fraction of municipal solid waste, which would allow to provide effective control over the waste management system of the city and contribute to waste reduction.

1. INTRODUCTION

Municipal solid waste (MSW) management is one of the most important environmental problems of Ukrainian cities. Environmentally unsafe disposal of municipal solid waste poses health and daily activities of local inhabitants to danger. Growing population of the city, industrial output, and urbanization level lead to further increasing production of municipal solid waste (hereinafter - MSW). Moreover, development of local industry contributes greatly to changing the chemical composition of waste to more complicated compounds. Therefore, the question of predicting the trends in MSW formation is extremely important.

The volume of MSW, produced in the city depends on a number of factors, the most important of which are socio-economic, scientific-technical, and natural-climatic ones. The impact of socio-technical aspect under conditions of unstable economy is quite changeable. This stipulates the need to search into a matter in order to determine the impact of changing population of the city on accumulation of household waste organic fraction, and public welfare factor on the nature of MSW formation.

1.1. Study context

Processing or recycling the organic fraction of MSW is a pressing issue of present day.

Ukraine has done many steps for utilization of organic matter in the industrial sector. For example, a number of companies transform organic matter into energy, thus reducing the environmental footprint. Most of systems operating by the companies are equipped with heat generating or cogeneration units designed for burning in-house energy by-products. Small enterprises resort to a composting method (Stepanov, 2012).

As for MSW processing, i.e. waste generated by households, the communities are not dealing with its processing. The overall MSW organic fraction is disposed to landfills. By the way, in the most cases such facilities are not equipped with appropriate technical means, causing frequent accidents and even lethal cases. It is proved, that burial of organic matter in landfills is extremely inefficient and incredibly harmful to human health (Dudar, 2006).

Production of large quantities of organic waste increases the impact on the environment. The most dangerous adverse impact on humanity is the greenhouse gas emission (Dorward, 2012; Gentil et al., 2011). Economically, formation of large quantities of organic matter that is not recycled in due course is also an inefficient use of the resources, including agricultural land (Kummu et al., 2012), used not only for useless growing of food, but also remained without fertilizers, energy, water and fuel consumed for food production (Cuéllar and Webber, 2010). Moreover, dumping of such waste into landfills causes overspending for their maintenance. Generally, producing much organic waste has a number of environmental, economic and social consequences, indicating the great urgency of the issue. Therefore, it is not surprising that the problem of food waste production has been covered in many regional studies. Among them, the question of waste production dependence on a number of social factors, including the culture of consumption, beliefs, food habits, etc.,has been raised. (K. Parizeau, et al.).

The problem of disposal at the industrial production phase, including the issue of over-production that exceeds the existing demand has been also spotted (Darlington and Rahimifard, 2006; Godfray et al., 2010; Gooch et al., 2010). The question of waste reduction has been highlighted in a number of studies (Kaipia et al., 2013; Maxime et al., 2006; Mena et al, 2011. Schliephake et al., 2009). The regional studies have also come into the spotlight (Ganglbauer et al., 2013).

2. MATERIALS AND METHODS

The study assessed the change in the rate of solid waste formation in 2014 - 2016 depending of the city population growth and dependence of MSW morphological content produced by local inhabitants on the their welfare. The first indicator was evaluated against the official statistics data. The dependence of waste production was assessed according to population monitoring results.

To determine the morphological contentof MSW, we took samples on the territory of the city for monitoring purposes. The study involved 28 families from Vinnytsia with different income and geography of living in Vinnytsia neighborhoods, such as Vyshenka, Podillia etc.

The monitoring was performed twice a year during three days (April 18 - 21 and September 6 – 9, 2014; May 10 - 13 and September 7 – 10, 2015;May 20 - 23 and September 1 – 3, 2016). The study took into account the seasonality factor K1. Each study sample was assessed by content of resource-useful fractions, including organic waste. All households were invited to participate in the study by invitation letters and at individual home visits. Respondents accurately summarized the entire volume of generated waste by filling out appropriate form. Our study evaluated a number of variables, including the general impression of a household wastemanagement system, shopping and cooking habits, ecology traditions and socio-demographic properties. Our study was limited by a fact that we were not always able to adequately assess the food waste that have been disposed of in householdsby some other methods, as respondents often did not mention them (for example, flushing in a sink,

independent composting,feeding animals with food waste, etc.).

The average family size was 3.3 persons (median = 3 individuals), and the average family had one child under 18 years (median = 0). All adult residents with stable income were evaluated individually.

For study data analysis, we used mathematical statistics method - the method of least squares. The purpose of drafting approximating dependence was evaluation of regularities, observed on the background of random fluctuations, and usingthe model for further calculations, including, inter alia, the prediction of MSW production driven by growth of the city population.

The calculation involved parametric evaluation of regression function,which described the dependence of a variable Y, which values (yi) were observed with random errors (θi - 0.000335016982854 and 124.231406097),on a group of non-random variables X1, X2, ..., Xk. The regression function was linear function k of variables x1, x2, ..., xk (population of the city, people), which was the mathematical expectation of Y value (MSW volume, tons) when X1 = x1, X2 = x2, ..., Xk = xk .

3. RESULTS

3.1. Study factors

According to the last data, the daily formation of MSW varies between 0.5 and 1.8 kg per a person. These indicators have a permanent tendency to grow driven by economic development of the countries. There are also periods when production of MSW increases significantly. In general, it is believed that the rate of daily MSW formation per one person is equal to 1 kg.

An important factor influencing the system is a seasonal change of the MSW composition. The increase of food wastes content from 20-25% in spring to 40-55% in fall is quite typical for MSW due to the great amount of fruit and vegetables in the ration of people in this period of the year. In winter and in fall, the contents of small-screened waste items in the cities of the middle climatic zone to which Vinnytsia belongs drops from 11% to 5%.

The MSW composition is significantly dependent on collecting recyclable material, such as paper, food wastes, glass, polymers and, most of all, metals by collection stations of the city.The analysis and findings of some authors show that composition of MSW is changing in time, presenting more paper and polymeric materials (Dudar et al, 2010).

In our study, the content of samples was subdivided into the following components: organic, including food wastes, fallen leaves, mown grass; recycled paper, including paper and cardboard items, packaging; plastics, including all high- and low-density polymers, that is plastic items, film, etc; metal - all ferrous and non-ferrous metals; glass - all items consisting of whole glass; construction waste - wastes resulting from repair and demolition of residential buildings, except for plastics, glass, metal, and paper.

MSW composition study was conducted among residents of apartment buildings and private houses with different levels of income.

The results of the study were analyzed by comparing with the official data provided by the municipality.

The results obtained suggest that the average measuring error was less than 5%. Since the measuring error was within permissible range, we could take the results of the study for further calculations.

The analysis of MSW accumulation process in Vinnytsia revealed the dependence of their structure and volume on major factors. We took under control factors, which significantly influenced the production of MSW, including social stratification of the population. This is due to the policy of the city aimed at welfare growth and negative impact of inflation of income of population in case of regression.

Considering the positive scenario, we can sum up: changes in the population structure, such as an increase of the middle class share among the inhabitants of the city, lead to changing the morphological composition of wastes owing to different levels of consumption.

This indicator relates not only to wastes produced by private households and apartment buildings, but also by to the waste generating by various service institutions (out of the study in this particular case).

No doubt, the volume of MSW formation in the city is influenced by many factors, such as climatic conditions, geographical location, number of children, religion, lifestyle, etc. Since climatic conditions and location of Vinnytsia are permanent factors, they were removed from the study. However, most of them are impossible to explore due to low respondent representation of the study.

During the study we explored the population and its income according to the data provided by the General Directorate of Statistics in Vinnytska oblast.

3.2. MSW formation volumes and their dependence on the population

This study intended to explore the properties and composition of MSW produced in the city with an average population of Vinnitsa (370 thousand people) to the fullest extent possible.

See the results of the study in Tables 1 and 2.

Table 1. The population and corresponding amount of waste produced in Vinnytsia

Year	2008	2009	2010	2011	2012	2013	2014
Population, ths. people	364.931	365.918	367.230	367.652	368.860	369.860	372.189
Amount of waste, ths. tons	118.39	118.51	118.98	119.02	119.21	119.92	120.56

3.3. MSW formation rate depending on public income

We built a graph of approximating dependence, using the results of the study of MSW accumulation depending on population of the city (Fig. 1).
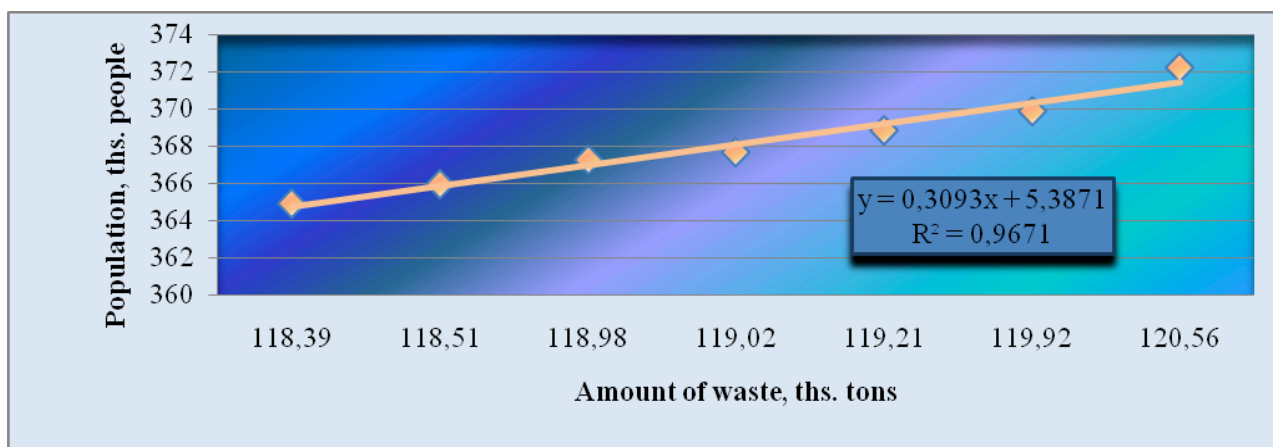

$$y = 0,3093x + 5,3871$$
$$R^2 = 0,9671$$

Figure 1. Mathematical modeling of MSW volume depending on Vinnytsia population growth.

Table 2. The morphological composition of MSW - official and actually investigatedones

MSW component, kg/day	Income of individuals involved in the study, UAH/month								The morphological composition of MSW		Measurement error, %
	lower 1200	1200 – 1560	1560 – 1920	1920 – 2280	2280 – 2640	2640 – 3000	3000 - 3720	› 3720	According to research	Official (according to the municip.)	
The specific share of population, %	7,20	19,80	29,80	19,60	8,40	5,50	5,80	3,90			
Organic fraction, kg/day	0,05	0,30	0,35	0,47	0,58	0,70	0,83	1,10	47,69	45,8	0,65

See the approximating dependence of organic fraction of waste on individual income of respondents in Fig. 2.
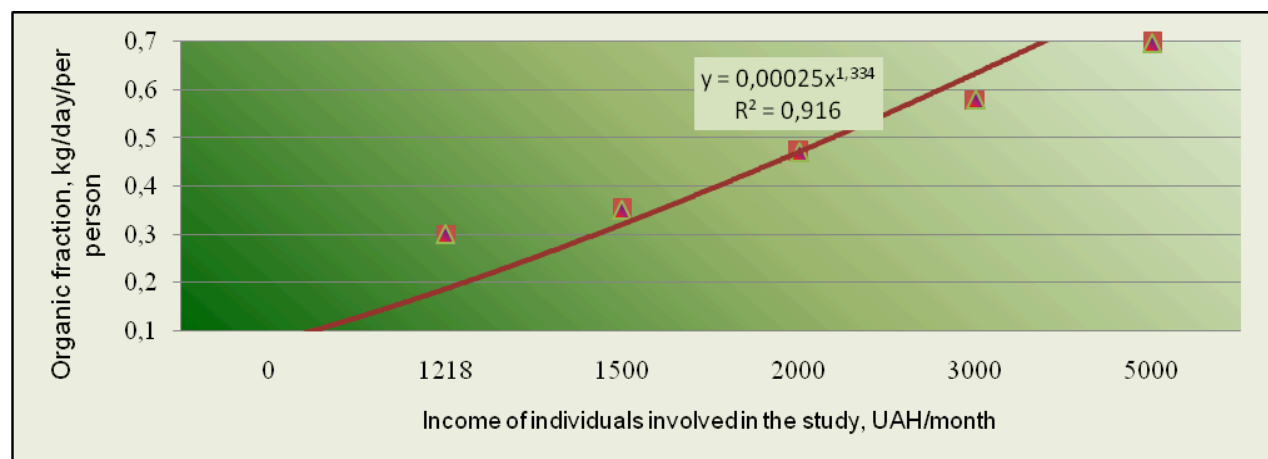

Figure 2. Mathematical modeling of daily formation of MSW organic fraction against public income in Vinnytsia.

4. DISCUSSION

On the basis of the studies of MSW accumulation dependence on population of the city, we obtained approximating dependence of square functions (formula 1) for Vinnytsia (R - 0.9671):

$$y = 0.3093x + 5.3871, \qquad (R - 0.9671) \qquad (1)$$

where, y – MSW volume, tons;
x – population of the city, thousand people.
This regression equation makes possible to obtain prognostic values of MSW accumulation depending on population growth in Vinnytsia.
Therefore, we can conclude on the direct dependence: MSW volume is growing in linear dependence with the growth of population in Vinnytsia.
Approximating dependence of the organic waste fraction on income of people is represented

in formula 2:

$$y= 0.00025x^{1.334} \qquad (R - 0.916), \qquad (2)$$

where y is the amount of daily produced waste, kg;
x –income of people, UAH/month.

5. CONCLUSIONS

We conducted the study of morphological content of MSV in the city of Vinnytsia. The controlled factors were those significantly influencing the MSW production, namely - the number of residents and social stratification of population.

We identified a number of regularities in our study. We noticed that there were social, cultural, economic and institutional factors that may influence the practice of household food waste production. These factors manifest themselves differently in each household, and, therefore,there is no uniform strategy or influence, which could meaningfully address the problem of effective waste management throughout the city. We stressed upon two major factors –the population and its social stratification.

Having compared the income of people and waste composition, we built the approximating dependence that allowed us to analyze the composition of MSW and served for monitoring the MSW organic fraction production depending on changes insocial stratification and income level of the population.

Reducing food waste by means of the municipal policy. Our study clearly shows that there are several policy levers, able to influence various aspects of food waste management practice at the household level. Forecasting may give us a possibility to promptly modify the conditions of MSW management for more effective control of the system. Resource-important organic fraction of MSW is a potential energy source, therefore, it is absolutely unreasonable, both in economic and ecological aspects, dispose of this important raw material, suitable for use.Using the organic fraction of MSW will reduce the negative impact on the environment. There are many options of further processing the organic fraction, the most common of which is composting. Being aware of the approximating dependence, city planners may promptly change the ways of MSW disposal depending on the population growth and the changes in its welfare. This method of forecasting volumes of solid household waste formation in the city is also important for determination of a demand in new waste containers for initial collection of MSW, sanitation trucks for waste transportation, sorting stations, recycled waste collecting stations, etc.Considering the morphological composition of MSW depending on the population income in the city allows us to project potential income from sales or recycling of resource-important MSW fractions. Forecastingthe volumes will enable us to continuously control the volume of MSW formation, and modify the elements of system control.

For example, when the organic content dominates among others, it is recommended to encourage development of enterprises dealing with processing the organic matter and composting through various grants and privileges. Conversely, in case of reduction of the organic matter content in municipal waste, we should stimulate enterprises, which change the line of their business for the most common type of processing the resource-important wastes.

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