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THE COMPARATIVE ANALYSIS OF MUNICIPAL SOLID WASTE MANAGEMENT IN THE EIGHT CITIES OF UKRAINE

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Abstract
A simplified solid waste management system has existed for many years in Ukraine being. The system factually coming to MSW collection and their removal to landfills and dumps. This has resulted in accumulation of 223 million tons MSW on territory of more than 8.5 ha.
Signing on 27th June 2014 EU-Ukraine Association Agreement obliged Ukraine to approximate legislation to EU demands in the Field of Waste Management [1]. On 8th November 2017 National Waste Management Strategy has been accepted for this purpose binding until 2030 [2].
This paper makes a comparative study of Municipal Solid Waste (hereinafter referred to as MSW) Management in Ukraine. This paper represents the analysis of the waste composition from the eight cities from different regions of Ukraine. The comparative analysis takes into account dependence of the amount and waste composition on income and population level. The approaches of the World Bank basic report are used in this study [3]. The study reveals prospects for development of techniques on material and energy use of MSW potential in Ukraine.

Keywords: **Municipal solid waste; Income level of population; Waste composition; Recovery potential of MSW.**

1. INTRODUCTION

The increase in the amount of waste is a concern for many countries in the world.

Accumulation of municipal solid waste (MSW) threatens to become a global problem for Ukraine. Recently only one incineration plant is functioning in the country giving heat energy for heating and hot water supply to the Kiev district heating system.

European principles of waste management laid the basis for a National waste management strategy in Ukraine till 2030, approved by the Cabinet of Ministers of Ukraine [2].

The Strategy defines the basic directions on state regulation in sphere of waste treatment with taking into account the EU approaches on waste management [4]. The Strategy determines also priorities of development in secondary use for material and energy resources of wastes components. According to Strategy 5,000 centers for separate collection MSW, 250 centers for reuse, about 800 MSW processing plant and 20 waste-to-energy plants are to be built by 2030. For the Strategy implementation the National Waste Management Plan is being developed.

By 2020 the regional centers should develop regional plans on wastes management. Now the local administrations are working on local programs of MSW management. The selection of MSW management system should be based on studying of social and demographic situation in each settlement, volume and MSW composition, ecological and energy characteristics of MSW components. After analysis of the current situation an optimum system for collection, processing and waste removal is accepted. For the system implementation should revising the practical means.

This paper shows the composition analysis as to the

eight Ukrainian reference cities located in four different regions (western, southern, southeast and central), with various number and official incomes of population.

The aim of the study: the estimation of MSW components secondary use potential.

2. RESEARCH FIELD CHARACTERISTICS

2.1. Methodology. Analytical framework

According to the World Bank's researches (hereinafter referred to as the WB) [3], MSW volume and structure depend on volume of population and its incomes. Table 1 shows basic economic indices of the country:

– Gross domestic product per capita (GDP) [5]

– Gross national income per capita (GNI) [6]

– UNDP Human Development Index [7]

– Average national incomes of Ukrainian population [8].

Table 1.
The reference cities choice is spent on following parameters

Year	Total Population	GDP per capita [current US$]	GNI per capita [2011 PPP$]	Human Development Index [HDI]
2017	42,584,542[1]	2,639.8	8,130.4	0.743

[1]Without temporary occupied territories of Crimea and some eastern parts of Ukraine

The reference cities choice is spent on following parameters:

– Population [8]

– Incomes of population [8]

Statistical analysis [8] represents the information on incomes of population as average in the a region. Because of data lack of population incomes in each city, the population incomes in the reference cities equal to ones of the corresponding regions. The calculated income is estimated as a probable minimum. This results from the fact that the actual incomes in the cities are always above those of the rural inhabitants.

Statistics of the Ministry of Regional Development, Building and Housing and Communal Services of Ukraine presents the data on the MSW volumes collected in a region as a whole [9]. The MSW generation is also updated according to the information of regional statistical offices [10].

The monitoring spent by the National Energy and Utilities Regulatory Commission (NEURC) has defined percent of population using the service of centralized waste collection in a region [11].

MSW generation W_g^{city} in each analyzed city was determined by the formula:

$$W_g^{city} = S^{city} \times \frac{W_g^{region}}{S^{region}} \quad \text{[tons]} \qquad (1)$$

where:

S^{city} – population of the reference city in the reporting year [people],

W_g^{region} – MSW generated in the reference region in the reporting year [tons],

S^{region} – population of a reference region in the reporting year [people].

In per capita waste generation rates m_g^{city} was determined by the formula:

$$m_g^{city} = \frac{W_g^{city} \times 1000}{S^{city}} \div 365 \quad \text{[kg/capita/day]} \qquad (2)$$

where:

W_g^{city} – MSW generated in a reference city in the reporting year [tons] ,

S^{city} – population of the reference city in the reporting year [people],

365 – number of days per year [day/year].

3. RESULTS AND DISCUSSION

3.1. Comparison of the reference cities

For comparison there were chosen eight cities with similar population and real incomes, but located in various regions of Ukraine.

Ukraine has 36 cities over 100,000 people [8]. These cities host 35% of the population of the country. Small towns and urban-type settlements with population less than 100,000 inhabitants host 34% more.

According to State building codes of Ukraine [12], cities with population over 100,000 people are divided into the four groups: the small cities with a population of 100,000-250,000 inhabitants, the medium-sized cities with population of 250,000–500,000 people, the large cities with population of 500,000–1 million people and the largest cities with population over 1 million people. Table 2 shows the classification of the cities with population over 100,000 people from different regions of Ukraine.

Table 2.
The classification of the cities by population and regions of Ukraine

The classification of the cities	Small	Medium-sized	Large	Largest	Total
Population of the reference cities [thousands]	100-250	250-500	500-1000	>1000	
Number of cities [cities] including by regions:	18	11	4	3	36
in Western region [cities]	5	1	1	0	7
in Southern region [cities]	2	2	0	1	5
in Southeast region [cities]	5	1	3	1	10
in Central region [cities]	6	7	0	1	14
Population of the reference cities [thousands]	2,995	3,539	3,091	5,375	15,000
City population as a proportion of the total population of the country [%]	7	8	7	13	35

Table 3.
The classification of the cities by incomes of population in the regions of Ukraine

The classification of the cities	Small	Medium-sized	Large	Largest	Total
Real incomes in cities relative to the average incomes per person in the country [%]	> 90	90-100	100-125	>250	Total
Number of the cities in Ukraine [cities], including by regions:	8	8	8	1	25
in Western region [cities]	6	0	1	0	7
in Southern region [cities]	0	2	1	0	3
in Southeast region [cities]	2	0	3	0	5
in Central region [cities]	0	6	3	1	10

As shown in Table 2 the biggest number of small cities placed in the western and central region.

The population was divided into next four groups by the annual income levels: low-income (less than 90% from the national average per person), lower middle-income (from 90 to 100%), upper middle-income (from 100 to 125%) and high-income (more than 250%) (Table 3).

The analysis of Tables 2, 3 has shown that the people with the lower official incomes live in small cities with population up to 250,000 inhabitants, and the high official incomes – in the capital and the large cities with developed industrial output (Dnipropetrovsk, Zaporizhzhya and Odesa Oblast).

For MSW analysis for the first group sized 18 small cities there was chosen the city from the western region – Uzhgorod (the regional center of Zakarpatska Oblast (Transcarpathian region) and the city Nikopol from the southeast region (Dnipropetrovsk Oblast) having similar population.

From the second group 11 medium-sized cities (Table 2) there were chosen 2 cities with close subgroup of population and incomes (Table 3), but from different regions (the regional centers of Cherkasy Oblast – Cherkasy from the central and the regional center of Kherson Oblast – Kherson from the southern region).

From the third group 4 the large cities with official incomes exceeding national average (Table 3) there was chosen the city from the western region (the regional center of the Lviv Oblast – Lviv) and the large city from the southeast region (the regional center of Kharkiv Oblast – Kharkiv).

From the fourth group that consists of the national high incomes the largest cities having population of more than 1 million inhabitants the regional center of southern Odesa Oblast – Odesa was chosen. An individual interest represents the largest city in the central region – capital Kiev where population and its incomes twice exceed corresponding figures of the rest cities in this group.

The information on reference cities presented in Table 4. Waste Generation Per Capita produced by inhabitants of the cities per day is also presented in the same place.

Table 4.
Characteristics of the reference cities

No	City	Region	Urban Population, [thousand people]	Official Income Level [% of national average]	Current Waste Generation [thousand tons]	Waste Generation Per Capita [kg/capita/day]
1.	Uzhgorod	Western	114.0	76	22.9	0.55
2.	Kherson	Southern	293.3	92	55.9	0.52
3.	Nikopol	Southeast	113.9	124	31.2	0.75
4.	Cherkasy	Central	281.6	93	59.7	0.59
5.	Lviv	Western	728.0	101	211.1	0.79
6.	Odesa	Southern	1,010.8	111	392.7	1.06
7.	Kharkiv	Southeast	1,439.0	107	434.2	0.82
8.	Kyiv	Central	2,925.8	257	1,176.3	1.10

The data shown in Table 4 confirm dependence in wastes generation on incomes. The official incomes in the reference cities depend on development degree of the industry, tourism etc.

Comparison of two cities (Uzhgorod and Nikopol) with close population (difference 0.1%) but with difference level of official incomes showed, that the income excess in Nikopol by 40% has led to increase of MSW volumes at 30%.

However, in other two cities (Kherson and Cherkasy) having not only a close population (difference 4%) but also similar incomes (difference close to 0.1%) MSW volumes difference equals 12%.

Comparison of Lviv, Odesa and Kharkiv (having difference on population by 30%, and the incomes by 5 and 10%) shows difference in waste generation rates per capita by 25%.

IMSW generation rates per capita in Kiev corresponds to ones in the countries having top level of national average incomes [3].

3.2. Flows Waste generation

The author studied the waste composition in the reference cities for the estimation of MSW components of secondary use.

There is no official statistical information on MSW composition taken for each city of Ukraine. However, the researches on MSW composition in the cities were being developed during the preparation of "Solid Waste Management Strategy", "Program of Solid Waste Management", "Investments Program in Waste Management", "The Sanitarian Cleaning Schemes in Cities". The research on MSW composition in the reference cities has been carried out in compliance with "Methodological Recommendations for the Determination of the Morphological Composition of Solid Waste" [13].

In The Methodological Recommendations MSW composition is divided into the 11 categories: organic waste, paper and cardboard, plastic, glass, black metal, non-ferrous metal, textiles, wood, hazardous waste, leather and rubber, solid waste residue after removal of components (small debris, stones, street garbage, etc.). The waste composition data is available as percentages. In World Bank Report [3] waste composition is divided into the 6 categories. To meet the World Bank Report data, present Ukrainian classification of MSW composition requires some changes: category "other waste" has included some other categories, such as textiles, rubber, ash, etc, amount of which in MSW of the reference cities is extremely little.

The author has used the data for the MSW composition analysis regarding the reference cities [14–22].

Change in urban waste composition of waste in the reference cities is shown in Table 5.

Table 5.
Change in Waste Composition depending on incomes

	City	Uzhhorod	Kherson	Nikopol	Cherkasy	Lviv	Odesa	Kharkiv	Kyiv
1	Organic [%]	48	40	29	38	26	67	33	38
2	Paper [%]	12	12	40	7	10	5	22	13
3	Plastic [%]	12	20	5	19	13	8	11	10
4	Glass [%]	5	3	6	11	4	4	9	13
5	Metal [%]	2	4	4	2	2	1	3	1
6	Other [%]	21	21	16	23	45	15	22	25
	Total [%]	100	100	100	100	100	100	100	100

The data shown in Table 5 demonstrates prevalence of organic waste in all cities regardless of incomes. Increase content of organic in MSW of Odesa compared to other cities testifies the fact that city is the main resort in Ukraine with resort season lasting about 5 months. More than 2 million tourists come there and raise number of population by 3 times respectively raising volume of food waste.

Also the content of such components as paper, plastics and glass in MSW of all cities correspond to ones in cities of the countries with the average incomes on WB classification [3]. The average composition of the analyzed cities has been presented in Table 6.

Table 6.
MSW composition of the population in countries with differing incomes on WB classification [3] and the average composition of the reference cities in Ukraine

Incomes in 2012	MSW composition [%]					
	Organic	Paper	Plastic	Glass	Metal	Other
High Income[1]	28	31	11	7	6	17
Upper Middle Income [2]	54	14	11	5	3	13
Ukraine, 2017[3]	40	15	12	7	2	24
Lower Middle Income[4]	59	9	12	3	2	15
Lower Income[5]	64	5	8	3	3	17

[1] Countries classified into four levels according to World Bank estimates of 2017 GNI per capita (current US$). High income: $12,235 or above;
[2]Upper middle income: $3,956-12,235;
[3] Ukraine (2017) $2,39;
[4] Lower middle income: $1.006-3,9555;
[5] Lower: $1005 or less.

Table 6 shows that the share of paper and glass in MSW of Ukraine corresponds to ones of the countries with maximum national average incomes. As for the share of plastic and metal – to ones of the countries with lower middle average incomes. As for the share of glass it corresponds to the countries with high national average incomes. Some excess in the part of inert materials testifies about low level of separation and sorting techniques implementation in Ukraine.

The analysis of Table 5 and 6 shows the advisability of processing enterprises implementation for secondary use of MSW material potential. Since Ukraine is an energy dependent country, the National Strategy of waste management provides utilization for MSW energy potential.

4. CONCLUSIONS

1. The National Strategy of waste management Adopted in Ukraine aimed at creation of processing industry using MSW material and energy potential.
2. The volumes of recyclable waste in MSW of Ukraine are comparable with ones of economically developed countries. This indicates that there is space for development in waste treatment field to provide secondary use to components of waste material resources in the country.
3. To simplify the decision-making during the planning process, when it concerns the exact quantity and quality of the waste generated in dispersed sources, the organization of a logistics system, distribution and solving problems related to the location of new facilities, it is advised to use the mathematical model developed in [23].
4. The prevailing share of food bio-waste testifies advisability of their separate collection and subsequent production of compost and biogas.
5. For appropriateness of use of MSW energy potential in a settlement it's necessary to determine net calorific value of mixed MSW as well as MSW separate components.
6. A thorough analysis of waste composition and process characteristics is necessary for thermal solid waste treatment. Because of the intricacy of the waste incineration process and high-priced laboratory experiments, the best solution is to use the mathematical model developed in [24].
7. For successful realization of the tasks put by the National Strategy it is the needed to improve the system of waste processing in Ukraine.

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