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Municipal waste recycling in big cities in Poland in the context of ecologisation

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Abstract. The goal of the paper is to evaluate and analyse changes in selective municipal collection, recycling level, and recovery, of waste. The article indicates the Polish legislation currently in force to systematise the organisation of waste management systems. It presents the participation of selective waste collection in the total municipal waste at the voivodeship scale, as well as changes in the number of individually segregated fractions (i.e. categories of waste segregation) of selectively collected waste in Poland. Moreover, the levels of waste recycling and recovery were analysed for the country's ten largest cities, while also showing that the cities implement accepted goals of municipal waste recovery. On the example of Warsaw, the structure of collected waste was discussed and attention was paid to the problem of quality of collected waste, which results in it being sent to sorting facilities.

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1. Introduction

Present-day consumer society is generating increasing quantities of waste (Dyson, Chang, 2005; Szymańska et al., 2016). Households and the food industry, which most often use disposable packagings, are the source of the marked growth in waste production. Trying to identify places responsible for the situation we must undoubtedly point to cities, and realise that they are the entities that must cope with the great problem of waste management. Cities need to introduce proper waste economy strategies based on avoiding the generation of waste, decreasing the production of material, and increasing the recovery of resources (Lehmann, 2010; Zaman, Lehmann, 2013). It is cities that produce most of the municipal waste, which are the most complex stream of solid waste, as opposed to the more homogeneous waste streams created by industrial or agricultural activity (Wang, Nie, 2001).

Current changes in cities are aimed at sustainable development, which also results in a sustainable waste economy (Morrissey, Browne, 2004; Seadon, 2010; Leźnicki, Lewandowska, 2016; Lewandowska, Szymańska, 2018). Functional waste management is a factor in city ecologisation, i.e. the process of implementing pro-ecological solutions in various aspects of the operation of a city. Ecologisation also has a dimension in everyday life and relates to remodeling consumption behaviour to be more pro-ecological, hence limiting the production of waste and giving attention to its reuse (Lewandowska, 2018). Recycling in cities is supported by proper organisational legislation of the waste economy system, which is conducive to the tendency towards ecologisation. It should be noted that the benefits of waste reuse occur not only at the local scale, i.e. in cities, but also on the national level. In high-income countries, recycling has become not only a practical strategy in answer to the growing costs of removing increasing quantities of toxic and compound waste, but also a symbolic antidote to "over-consumption" and the throw-away society (Spaargaren, Van Vliet, 2000; Wilson et al., 2006; Scheinberg et al., 2011). We should remark that developing countries, on the other hand, are seeing a growth in informal recycling (Cointreau, 1987; Medina, 2008; Linzner, Salhofer, 2014), which is calculated to be effective in recovering up to35% of waste produced in low- and average-income cities (UN-Habitat, 2010). In these cities recycling is a source of livelihood for hundreds and thousands of individual and family-run small businesses, which are the base of the chain pyramid of recycling delivery (Wilson et al., 2006).

Therefore, we see that recycling has a huge potential that ought to be developed. To make this possible, we must be equipped with a functional and efficient system of selective waste collection. Transparent criteria for waste segregation allow us to obtain a high-quality substrate for further processing. The Act of the Ministry of the Environment from 29th Dec. 2016 contains a detailed procedure for the selective collection of particular waste fractions (i.e. categories of waste segregation) in Poland, and defines changes in the consistency of selective waste collection. It seems interesting in this context to analyse the present achievements of big Polish cities in this area, including selective collection and recycling levels.

The article's objective is to analyse and evaluate the systems of selective waste collection and recycling in Poland. The issue is presented on national and regional scales and – the key task for the paper – from the perspective of big Polish cities. The article also discusses organisational–legal aspects of the waste economy in Poland, with particular stress on selective municipal waste collection. The goal is to answer the questions of: whether Poland is efficient in selective waste collecting on regional and local scales; in what way and to what extent the system participates in the process and changes total quantity of waste; and whether Polish cities fulfil the assumptions of recycling levels and waste recovery.

2. Organisational–legislation conditions of waste recycling in Poland in the context of the European Union

Polish legislation concerning the waste economy is coherent with European Union legislation. The first acts forming the base of the waste economy in the EU were issued in 1975, together with the introduction of Directive 74/442/EWG, which defines the Union strategy in waste economy. In 2008 the

Directive of European Parliament and the Council 2008/98/WE appeared, referring to waste, revoking certain directives and changing the hierarchy in the waste economy to prevent the production of waste, and to promote its reuse, recycling, disposal and recovery. To adjust the standards of Polish legislation to the Union directives, the Act from 20th June 2001 concerning waste (Dz. U. 2001 nr 62 poz. 628, with changes) was replaced by the Act from 14th Dec. 2012 (Dz. U. 2013 nr 0 poz. 21), which implemented regulations concerning the waste economy that were obligatory in the EU. The Act defined, among others, waste recovery for usable purposes, replacing other materials. Recycling is one of these methods, where waste is processed into products, materials and substances used for original or other purposes. Recycling includes reusing organic material (organic recycling), but not energy recovery and its reuse producing materials for fuel or to fill excavation pits (Zębek, Raczkowski, 2014). Regulations concerning recycling levels, preparing waste for recovery by other methods, and various waste fractions were clarified by The Ministry of the Environment Directive (Dz. U. 2012 poz. 645), which defined that by 2020 recycling level and reuse processes for fractions such as paper, glass, plastic and metal should amount to 50%. Non-compliance with the requirements would result in a stiff penalty, and Poland should therefore develop recycling technologies (Hryb, 2015).

It is important to realise that recycling efficiency depends on efficient selective municipal waste collection. At present, Polish communes (including cities) are working out independent systems of selective waste collection, which is legally grounded in the Act of 25th Jan. 2013 concerning changes in the regulation for keeping communes clean and orderly. Communes have the obligation to work out proper systems of waste collection, including of fractions (kinds) such as paper, metal, plastics, glass, composite packaging and biodegradable municipal waste. They are obliged to determine segregation locations accessible to all commune inhabitants that are also suitable for collecting hazardous waste, used electric and electronic devices, bulky waste, used tyres, and construction and green waste (Zębek, Raczkowski, 2014). In response to there being some confusion in methods, The Directive of The Ministry of the Environment from 29th Dec. 2016 was implemented, which regulated in detail selective waste collection and directing the gradual unification of waste container colours (blue – paper; green – coloured glass; white – colourless glass; yellow – metals and plastic; brown – biodegradable waste), to contribute to higher quality of recycled material and waste recovery.

3. Materials and methods

In Polish public statistics, data concerning selective waste collection, recovery and recycling level is obtainable only on the voivodeship level (NUTS 2). To have more detailed information one must contact particular local self-governments directly and study annual reports on the issue. The article refers primarily to data from the Local Data Bank of the Central Statistical Office (LDB CSO) which demonstrate the participation of selectively collected waste in total of waste, as well as the structure of selectively collected waste in Poland, with particular attention given to achieved recycling levels and material recovery for cities. Poalnd's ten largest cities were selected for the survey (Fig. 1, Table 1), with populations ranging from 299,910 in Katowice to 1,744,351 in Warsaw, and relatively dense populations ranging from 1,765 per km^2 in Gdańsk to 3,372 in Warsaw (Table 1). On the European scale they are among average cities. Between 2005 and 2015, average mixed waste collection per inhabitant was from 282 kg in Lublin to 398.7 kg in Warsaw. To analyse recycling levels and material recovery in

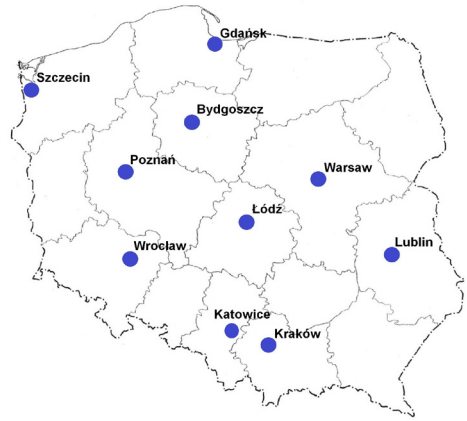

Fig. 1. Studied cities' locations within the country
Source: author's research.

Table 1. Basic characteristics of cities

No.	City	Voivodeship	Population	Population density [persons per 1km^2]	Quantity of mixed collected municipal waste per 1 inhabitant [kg]
			2015	2015	average 2005-2015
1	Warsaw	Mazowieckie	1,744,351	3,372	398.7
2	Kaków	Małopolskie	761,069	2,328	317.6
3	Lódź	Łódzkie	700,982	2,390	326.5
4	Wrocław	Dolnośląskie	635,759	2,171	364.0
5	Poznań	Wielkopolskie	542,348	2,071	362.1
6	Gdańsk	Pomorskie	462,249	1,765	336.1
7	Szczecin	Zachodniopomorskie	405,657	1,350	342.9
8	Bydgoszcz	Kujawsko-Pomorskie	355,645	2,021	307.8
9	Lublin	Lubelskie	340,727	2,310	282.0
10	Katowice	Śląskie	299,910	1,822	367.9

Source: author's own elaboration based on data from LDB CSO

these cities in accordance with The Directive of the Ministry of the Environment, the data was obtained by studying the relevant municipal documents. It was also possible to indicate which cities manage to implement new regulations defined in the Directive mentioned above.

To give a precise picture of the discussed problem, mathematical–statistical methods, case study and "desk research" were applied. The first were helpful in counting the obtained recycling and recovery levels and average quantity of mixed municipal waste per inhabitant. Case study referred to selected cities and the capital city of Warsaw directly, which was chosen for detailed analysis of the structure of selectively collected waste fractions and the ways of managing or depositing waste in 2013–2014. The desk research method referred to commune document analyses on the research issue in 2014–2016. Commonly accepted methods of quantification, processing and data presentation were also applied in the work.

4. Research results and discussion

Every year, the quantity of selectively collected waste grows systematically in Poland, from 243,374.3 Mg in 2004 to 2,942,256.9 Mg in 2016. It should be remarked, however, that its highest growth has been reported since 2013, i.e. since the new act was passed. From 2013 to 2016 the quantity of selected waste collected increased three-fold. The participation of segregated waste in total collected wasted also shows an increase from 2.5% in 2014 to 25.2% in 2016 (Table 2). In 2004 the lowest percentage was reported in Lubelskie voivodeship, although that was the region which registered the highest dynamics of changes in the field. Another aspect worth attention is the fact that Pomorskie voivodeship, which in 2004 had the highest participation of selectively collected waste in total waste production (3.8%), had the slowest growth of selective waste in total waste structure. The regions with the highest percentage in 2016 were: Śląskie, Łódzkie, Małopolskie, Swiętokrzyskie and Opolskie (Table 2), which results from better organisation of collecting systems and more intensive promotion of the action among inhabitants. What is alarming is that there are differences of over even 17% in collected quantities between voivodeships, which leads to the conclusion of disparities between various regions of Poland in implementing a sustainable waste economy .

Another aspect worth reporting is the change in the structure of selectively collected waste in the space of a decade in Poland. In the beginning, only five waste fractions were selected. In 2004, paper and cardboard constituted half of it by quantity (57.03%), the next waste fractions included plastic

Table 2. Percentage participation of selectively collected waste in total municipal waste by voivodeship [%]

Voivodeship	2004	2006	2008	2010	2012	2014	2016
Poland	2.5	4.1	6.8	8.6	10.5	19.8	25.2
Dolnośląskie	2.6	2.7	6.6	7.1	8.2	17.1	21.3
Kujawsko-pomorskie	2.3	4.4	5.2	9.6	9.7	18.6	23.8
Lubelskie	1.9	4.0	4.9	9.2	10.4	20.0	25.9
Lubuskie	1.0	3.6	5.7	6.6	10.5	21.4	21.5
Łódzkie	1.9	3.2	7.4	8.5	11.4	26.1	27.5
Małopolskie	2.8	5.5	8.9	11.6	14.5	21.6	27.3
Mazowieckie	2.4	3.4	7.2	8.9	12.2	17.7	26.4
Opolskie	3.4	3.1	4.7	7.0	8.8	23.6	27.2
Podkarpackie	2.3	4.5	8.5	10.7	12.1	18.6	24.4
Podlaskie	1.2	2.2	4.5	4.3	5.3	13.9	19.2
Pomorskie	3.8	4.6	5.2	6.7	8.5	18.9	23.8
Śląskie	3.0	5.3	7.1	8.7	10.2	23.5	34.7
Świętokrzyskie	2.1	2.9	4.8	7.0	7.8	25.9	27.3
Warmińsko-mazurskie	1.9	3.4	5.1	6.5	8.4	14.1	16.9
Wielkopolskie	2.5	5.4	8.9	10.3	11.8	18.3	20.2
Zachodniopomorskie	2.4	3.9	6.2	8.0	9.6	17.7	19.8

Source: author's own elaboration based on data from LDB CSO

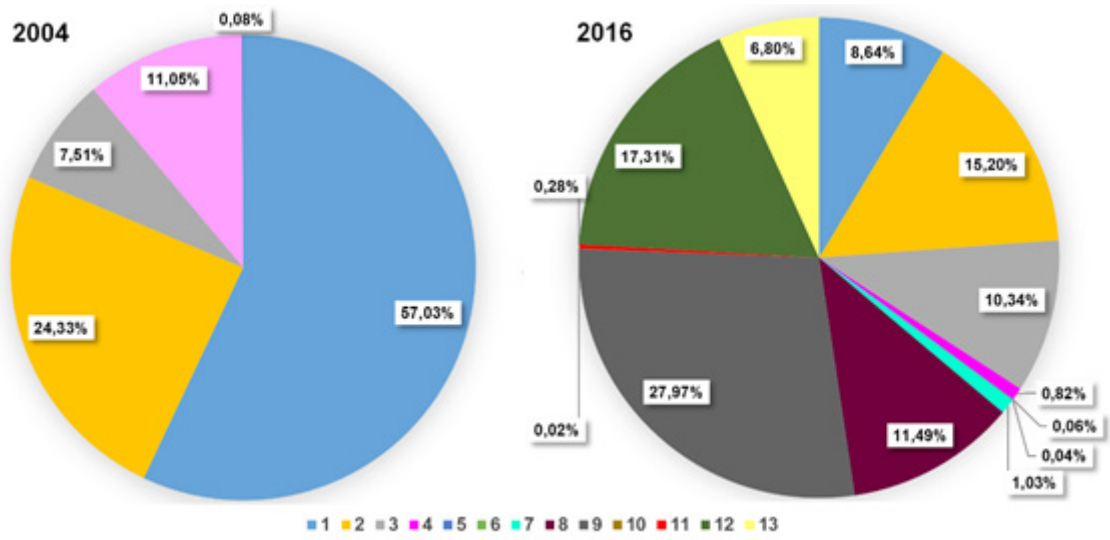

Fig. 2. Structure of selectively collected municipal waste in Poland in 2004 and 2016. Legend: 1 – paper and cardboard, 2 – glass, 3 – plastics, 4 – metals, 5 – textiles, 6 – hazardous waste, 7 – used electric and electronic devices, 8 – bulky waste, 9 – biodegradable, 10 – cells and batteries, 11 – composite packagings, 12 – mixed packaging, 13 – others

Source: author's own elaboration based on data from LDB CSO

(24.33%), textiles (11.05%) and metal (7.51%), with the smallest quantity in all selected waste being that of hazardous waste (Fig. 2). In 2016 the number of selected fractions grew to 13 (Fig. 2), with the highest participation being of biodegradabe waste (27.97%). The increase in number of fractions contributed to an increase in recycling and material recovery on the national scale (due to better selection).

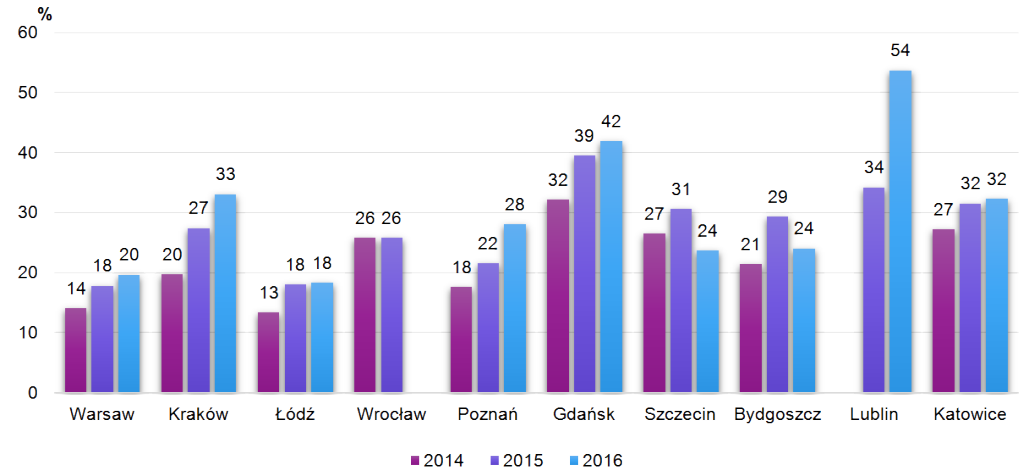

Fig. 3. Waste recycling levels and preparing for recovery: paper, metal, plastic, glass in big cities of Poland
Source: author's own study based on commune documents: analyses of state of waste management

GUS data informs us that in 2015 Poland collected nearly 10,900 Mg of municipal waste, over half of which (55%) was sent for recovery. More than 2,800 Mg of waste was recycled (26.4%). Following the EU directives discussed above, Poland is obliged by 2020 to be recycling or recovering 50% of municipal waste fractions like paper, metal, plastic and glass. The level of recycling of these four fractions in 2015 in Poland was only 26%, so there is still plenty to do in this matter, with the most challenging task being for self-governments, including cities.

Comparing the achievements of big Polish cities in 2014–2016, we must remark that each city under discussion reported increased recycling and recovery levels in paper, metal, plastic and glass (Fig. 3). In the years 2014, 2015 and 2016, each of these cities met the directives and recycling goals appointed by the Ministry Directive of 29th May 2012 (Dz. U. 2012 poz. 645). It is worth emphasising that, studying the levels of recycling and recovery of paper,

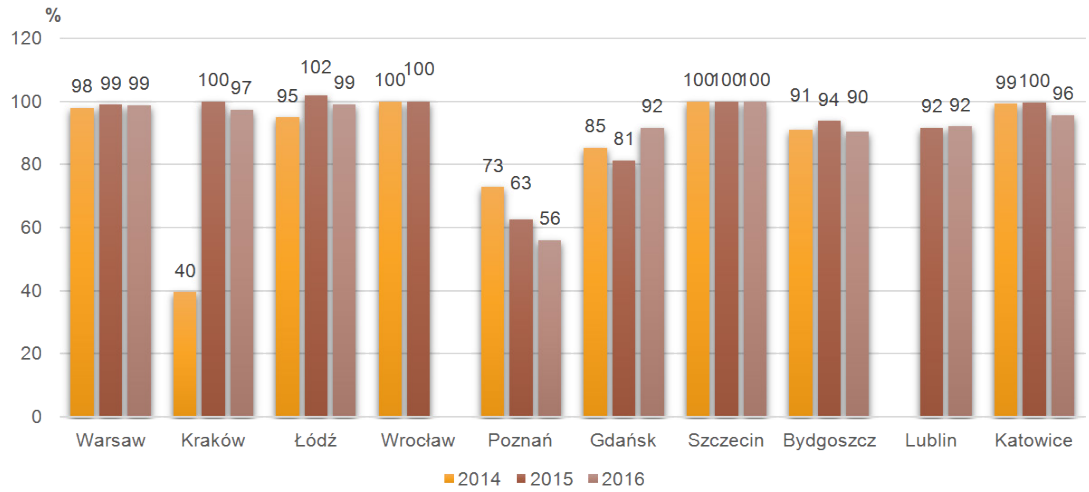

Fig. 4. Levels of recycling and preparing for reuse and recovery using other methods for all waste except hazardous construction and demolition wastein big Polish cities
Source: own author's study basing on commune documents: analyses of state of waste management

metal, plastic and glass, great differences between the cities are observed, reaching up to 36% in 2016 (Fig. 3).

On the other hand, the level of recycling and recovery by other methods for all types of waste, except hazardousconstruction and demolition waste , in the analysed cities amounted to over 90% (Fig. 4). Only Gdańsk had lower levels, amounting in 2014, 2015 and 2016 to 73%, 63% and 53%, respectively. It is the only city where a downward trend in construction waste recycling level was registered, although, despite that fact, Gdańsk reached the recycling level required for the period. Warsaw and Szczecin are among the cities with the best results in construction waste recycling and recovery; in the analysed period the level grew to over 99%.

Significant differences were reported in the case of mass of municipal biodegradable waste of the cities under discussion (Fig. 5). In 2014, Poznań was the only city that did not obtain the desired level of biodegradable waste mass sent for disposal (Fig. 5). In the following years the situation was not repeated. The lowest levels in this matter were reached by Warsaw, Wrocław, Szczecin, Bydgoszcz and Katowice. There, biodegradable waste was mostly sent for composting and natural processing.

In reference to the three discussed elements of recycling level, we must note that the analysed cities differ. Trying to explain these disproportions, we have to refer to the organisation of the selective waste collecting system, which was not coherent and unified. Cities frequently worked only with two fractions: dry and wet. This was the case with Gdańsk, which may have resulted in its relatively low recycling and recovery level compared to other cities. Other aspects are differences between self-governments in their attitudes towards the waste economy, because some regard this problem as a crucial issue, while others, faced with other current serious obstacles, put it aside.

Warsaw places in a relatively good position in comparison to other cities, although the mass of selectively collected waste is still insufficient and amounted to little over 18% in 2014 (Table 3). The share of segregated waste is not very high, either, as mixed packaging predominated in all the structure of collected waste (90%) (Table 4). The next fractions, characterised by a participation of over 1%, include packagings made of paper, cardboard, plastic and glass. The others represented only a small proportion in the general structure of waste collected in Warsaw.

The quantity and structure of collected municipal waste influences the way it is managed. In Warsaw, 84% of the waste was sent to a waste sorting plant (Table 5), which results from the fact that this is a waste type with impurities (not pre-sorted); then, the vast majority is processed mechanically, separating specific fractions for further material usage. The quantity of waste for composting and re-

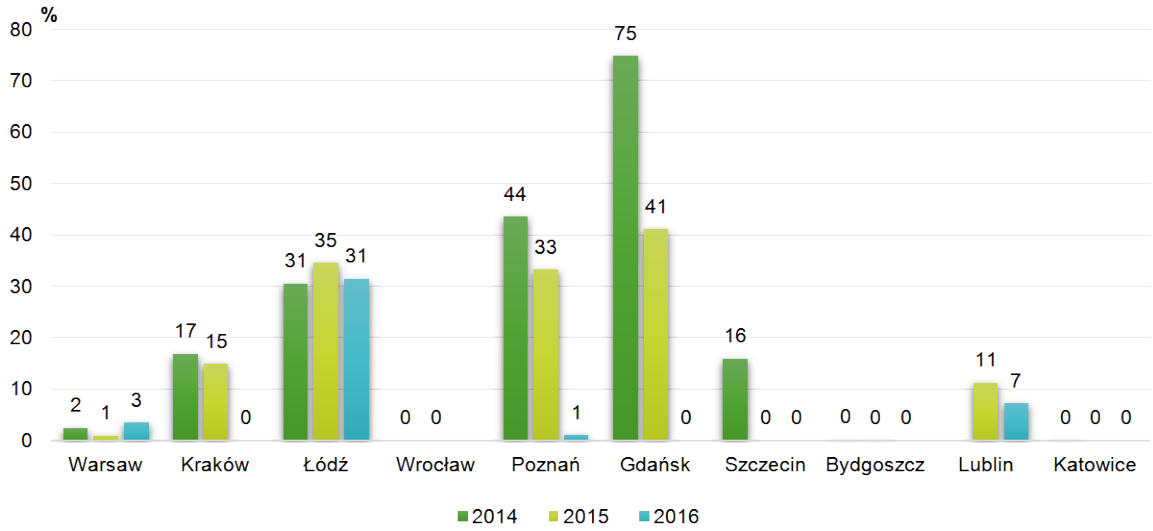

Fig. 5. Level of municipal biodegradable waste sent for disposal compared to mass of this waste produced in big cities*
*No data for 2014 for Lublin and 2016 for Wroclaw
Source: author's own study based on commune documents: analyses of state of waste management

Table 3. Mass of collected municipal waste from the capital city of Warsaw in 2013–2014

Waste type	2013		2014	
	[Mg]	[%]	[Mg]	[%]
Unsorted (mixed) municipal waste	531,296.78	82.33	528,801.10	81.62
Selectively collected waste	114,001.30	17.67	119,059.97	18.38
Sum	645,298.08	100.00	647,861.07	100.00

Source: own author's draft basing on data from LDB CSO

Table 4. Recovered materials from collections in the capital city of Warsaw in 2014

Waste type	Waste mass	
	Mg	%
Packages of paper and cardboard	2,584.40	4.94
Packages of plastic	1,133.00	2.16
Packages of wood	57.90	0.11
Packages of metal	155.70	0.30
Composite packages	0.20	0.00
Mixed packaging waste	47,149.80	90.06
Packages of glass	881.20	1.68
Paper and cardboard	350.30	0.67
Glass	13.50	0.03
Plastic	18.70	0.04
Metals	9.60	0.02
Sum	52,354.30	100.00

Source: author's own elaboration based on data from LDB CSO

Table 5. Ways of management or disposal of municipal waste in Warsaw in 2013 – 2014

Processes of recovery and/or disposal	2013		2014	
	Quantity of municipal waste [Mg]	Process percentage participation [%]	Quantity of municipal waste [Mg]	Process percentage participation [%]
Sorting	544,363.22	84.36	550,083.75	84.91
Composting	8,405.09	1.30	14,446.83	2.23
Combustion	44,372.57	6.88	31,224.86	4.82
Disposal	3,293.05	0.51	177.50	0.03
Recovery	34,988.84	5.42	42,186.38	6.51
Material recycling	9,875.31	1.53	9,741.75	1.50
Sum	645,298.08	100.00%	647,861.07	100.00

Source: The 2017-2020 Environmental Protection Programme for the City of Warsaw with a Perspective to 2023

covery increased as well. Waste mass designed for depositing diminished, which resulted in a low percentage of that type of material in landfills (0.03%).

In the years 2014–2016, Warsaw obtained the desired recycling and recovery level, but the waste stream is still very polluted, and the city is not equipped with sufficient regional facilities for municipal waste processing.

Reviewing waste management system in big cities of Poland in reference to recycling level, we must admit that at our disposal we only have formal state firms collecting and recycling waste. South American and Asian countries, for example, possess very well developed informal systems (Sembiring and Nitivattananon, 2010; Kumar et al., 2018; Hjemdahl and Balasubramanian, 2018), which are complementary to the formalised waste economy. In developed countries recycling is entirely privatised, emphasising its economical value (Spaargaren and Van Vliet, 2000; Scheinberg et al., 2011; Van Vliet et al., 2012). The same situation is observed in Poland, where recycling is formalised, thanks to which, reliable data on waste recycling level in particular cities can be obtained.

The increase in quantity of waste processed and reused in Poland in recent years is undoubtedly a positive phenomenon, although it has been brought about by the introduction of certain legislation. Arsovski et al. (2018) indicate that together with introducing new regulations ordering waste management in Poland in 2013, and thanks to information campaigns promoting selective waste collecting, there was a significant drop in, for example, collecting waste from illegal damps in cities of populations exceeding 100,000 (Warsaw, Kraków, Szczecin, Bydgoszcz, Rzeszów and Toruń).

The high impurity level of collected selectively waste from households reported not only in Warsaw, but also in the majority of Polish cities, is another problem. It results from poor popular habits in attending to segregation. In countries in which waste segregation culture is well developed, proper recycling activity is regulated by: normative factors (the expectations of household members, friends and neighbours), an altruistic factor (that recycling helps protect the environment), and an egoistic factor (that recycling is inconvenient) (Erwin, 2001). Poland suffers now from a lack of ecological education in popularising recycling and this is a challenge for those responsible for the waste economy of the country.

5. Conclusions

In the light of the obtained results, it should be remarked that Polish activity in selective waste collection and recovery should be intensified in the coming years, and we hope that the implemented legislation will serve a coherent waste economy policy and will influence selective waste collecting by, among others, unifying the colours of waste containers all over the country. All these actions can improve the quality of obtained material and its further recovery process.

The research has shown that all examined cities fulfil the directives of the Ministry of the Environment in this matter – some of the cities quite successfully, while the others are classified barely within the limits. The problem demonstrates the divergence in attitudes towards waste economy between particular cities' authorities. Where local governments tend towards city ecologisation, the regulations concerning sustainable waste economy are more easily implemented.

The example of Warsaw shows that poor-quality collected municipal waste, which must first be sorted into renewable fractions, results from the lack of proper education of inhabitants.

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