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## WASTE MATERIAL FLOW ANALYSIS IN THE ŁÓDŹ METROPOLITAN AREA

**Abstract.** The main sources of waste generation are: industry, municipal sector, and agriculture. Municipal waste is solid and liquid waste that arise in households, public utilities (trade, services, handicrafts) and municipal services (e.g. street cleaning and maintenance of green areas). The main aim of this paper are the analysis of the flow of municipal solid waste in Łódź Metropolitan Area, its composition, presentation of the process towards a more selective waste system, and the extraction of biodegradable waste from the MSW. The article is based on a report prepared within the Horizon 2020 project REPAiR “Resource Management in Peri-urban Areas: Going Beyond Urban Metabolism”.

**Key words:** municipal solid waste, waste management, Łódź Metropolitan Area.

### 1. INTRODUCTION

Research on waste management in Poland had already commenced in the 1980s when researchers sought to reuse waste, employing the term “circular economy”. Publications that were crucial in this field were released by the Institute of Geography and Spatial Organisation, Polish Academy of Sciences, i.a. works devoted to the issue of environmental protection (Leszczycki, 1974; Kamiński and Szyrmer, 1981a), waste flow models (Kamiński and Szyrmer, 1981b) or a waste-free economy (Cała, 1985). Currently, this term is commonly used in the context

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of waste management (e.g. Tundys, 2015; Szyja, 2016; Turoń and Golba, 2016; Pieńkowski and Kośmicki, 2016). International literature (e.g. Lacy and Rutqvist, 2015; Haas *et al.*, 2015; Singh and Ordoñez, 2016; Tisserant *et al.*, 2017; Malinauskaite *et al.*, 2017; Winans *et al.*, 2017, and numerous others) places great emphasis on circular economy. It is difficult to identify the creators to the concept of a circular economy, but its formulation dates back to the 1970s (Winans *et al.*, 2017). Although research on a waste-free economy was undertaken in Poland as early as in the 1980s, there are few publications which have dealt with its spatial aspect. Despite this, more and more publications emphasise the necessity of creating a circular economy, especially in the context of material flows within metropolitan areas (e.g. Vittiglio *et al.*, 2018).

New waste management regulations came into force in 2013, after the Waste Act (of 14 December 2012) had been introduced. The entire waste management system has been reorganised. According to the Act, municipal waste should be selectively collected and local government bodies are responsible for compliance with the principles introduced in the Act. Local government authorities are therefore responsible for managing the processes involved in local waste management; they also make the most important decisions as to the form and method of their implementation.

Waste is a by-product of human activity, introduced into the environment in quantities both large and small, including the primary product, but in which the time and place of creation is deemed unsuitable (Encyklopedia Powszechna, 1999). According to the Waste Act of 12 December 2012, waste is “any substance or object, the holder of which disposes, is going to dispose, or is obliged to dispose.” Waste is, therefore, any material, raw material or final product which is not employed, has no designated purpose, and is not used for a specific purpose (Lipińska, 2016). Waste is then considered as any substance or object which the holder discards or intends to discard or is obligated to discard. Yet a producer of waste is understood as any person or organisation whose activity or existence results in the generation of waste (initial waste producers) and anyone who performs pre-treatment, mixing or other activities causing a change in the nature or composition of this waste.

Waste is classified on the basis of various criteria. Each classification is based on carefully set norms of a physical and chemical, biological, technological, and economic nature, such as: origin, state of matter, raw material criterion, chemical composition, toxicity, harmfulness to people and the environment, and suitability for further use. The general classification, which considers the origin of waste, its nature and its properties, divides waste into: municipal, industrial, liquid, and hazardous waste (Lipińska, 2016).

The main sources of waste generation are: the industry, the municipal sector, and agriculture. Industrial waste is generated in production processes (e.g. from the mining industry, as a result of wastewater treatment, or emissions of gases

into the atmosphere). Municipal waste is solid and liquid waste that emerges from households, public utilities (trade, services, handicrafts), and municipal services (e.g. street cleaning and maintenance of green areas). Hazardous waste is generated as a result of the direct or indirect impact of aggressive substances that can negatively affect living organisms. Hazardous waste may be toxic, harmful, carcinogenic, flammable, etc.

The main aim of this paper is to analyse the flow of municipal solid waste in the Łódź Metropolitan Area, its composition, and to present the process of moving towards a more selective waste system and extracting biodegradable waste from MSW. The article is based on a report prepared within the Horizon 2020 project REPAiR “Resource Management in Peri-urban Areas: Going Beyond Urban Metabolism” (Czapiewski *et al.*, 2018).

## 2. THE OVERALL SITUATION IN POLAND AND THE ŁÓDZKIE REGION

According to the Regulation of the Polish Minister for the Environment of 9 December 2014, the waste portfolio comprises 20 groups of waste, separated on the basis of the source of waste. The regulation specifies a waste portfolio which divides waste into groups, subgroups, and types.

Municipal waste is waste generated in households and retail, by enterprises, office buildings, and educational institutions, as well as healthcare institutions and public administration which is of a similar nature and composition to waste generated in households. However, it should be noted that in 2017 more than 85% of the total weight of municipal waste was generated by households.

The amount and morphological composition of municipal waste depends to a large extent on the place where it was formed, particularly on the social status and the related level of product consumption, but also on the time of the year. It should be noted that the amount of municipal waste collected per inhabitant annually is strongly correlated to the economic status of individual regions of the country. The Łódźkie region is not one of the most economically developed areas in Poland and this is visible in the weight of municipal waste collected *per capita* – in recent years the value for the region was 10% lower than the average for Poland (Fig. 1). Slightly higher values were observed in the Łódź suburban area, however, the highest amounts are definitely collected in the city itself.

The nature and the overall mass of waste generated is also strongly determined by the land use and the predominant type of area (urban vs. rural) in which the waste is produced, population density, type of housing (single or multi-family), the number of tourists, public facilities, as well as the type, size and number of commercial enterprises, small industries or services. For instance, the differences

between particular types of areas are especially noticeable in Poland when considering the “paper and cardboard” fraction – there is a gradual decline in the share of this fraction along the “big cities – small towns – rural areas” axis. By contrast, when considering “kitchen and garden waste”, a continuous increase may be observed along the “big cities – small towns – rural areas” axis and for the “finest fraction – below 10 mm” the share increases in rural areas when compared to the amount observed in cities.

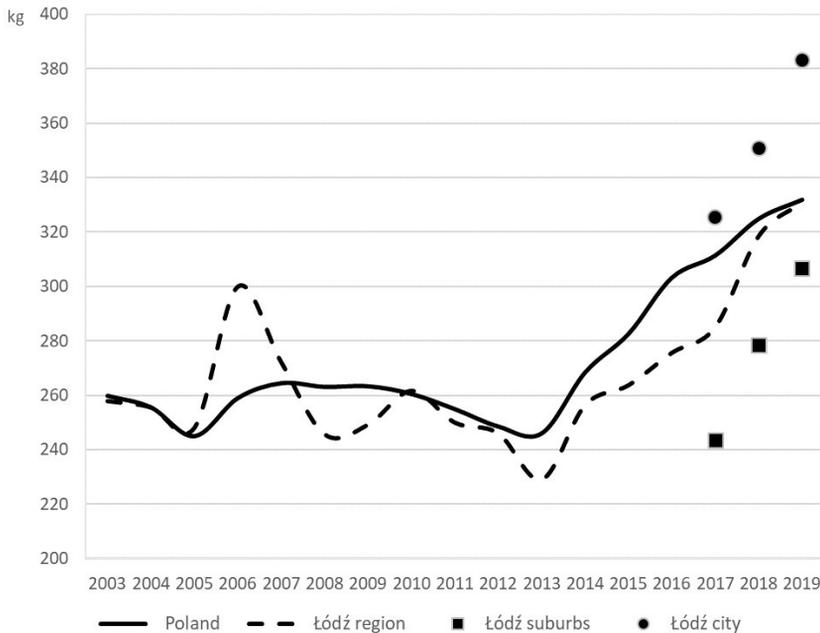


Fig. 1. Weight of municipal waste generated *per capita* in Poland, the Łódzkie region, Łódź suburban area and the city of Łódź in 2003–2019

Source: own work based on data from Statistics Poland.

The waste management system divides the Polish territory into 123 waste management regions within which modern facilities were to be established, i.e. Regional Municipal Waste Treatment Plants (RIPOK), whose construction has been assumed to produce an effective waste management system. Regional Municipal Waste Treatment Plants, in accordance with the principle of regionalisation, are responsible for accepting specific groups of waste from the region in which the waste is generated. In order to ensure a constant inflow of waste and following one of the basic principles of waste management, the so-called “Proximity principle” has been adopted highlighting the need to treat and/or dispose of waste in reasonable *proximity* to its point of generation. This means that waste is processed in the place where it is produced and,

if this is impossible, it is transferred to the nearest place where it can be processed, bearing in mind, however, that it is forbidden to transport it outside the region of origin. The Łódzkie Voivodeship is divided into four waste management regions.

After the introduction of the new Waste Management Act in 2013, a number of indicators of the society's approach towards waste have improved, and changes concerning the treatment of the waste collected have produced improvements (Fig. 2).

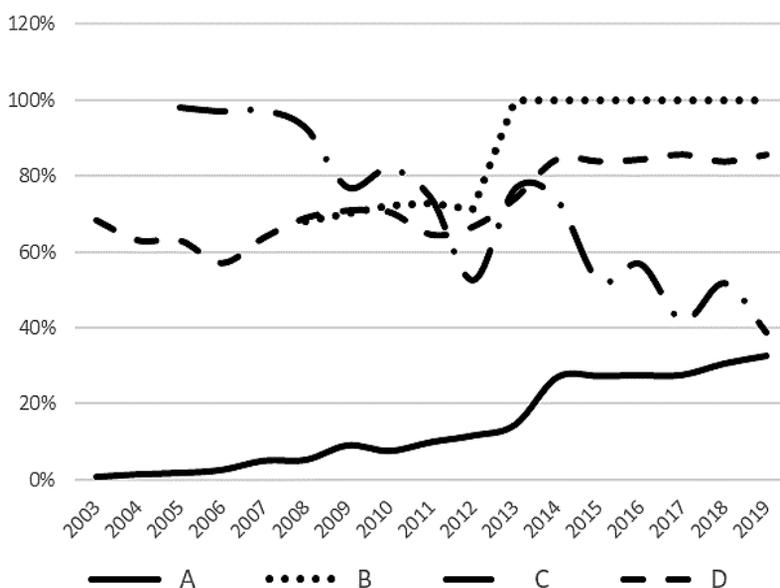


Fig. 2. Change in the values of selected indicators of waste management in the Łódzkie Voivodeship

A – Selectively collected waste in relation to the total waste

B – Percentage of population covered by municipal waste collection

C – Waste deposited in landfill compared to the total amount of mixed waste collected

D – Share of household waste in the total municipal waste

Source: own work based on data derived from Statistics Poland.

First of all, the change involving the taking over of responsibility for waste collection by local authorities has resulted in all residents being covered by compulsory municipal waste collection, although in 2012 the indicator for the entire Łódzkie Voivodeship was 75%. Concurrently, the number of illegal waste tips, i.e. places not intended for landfill, has decreased significantly (from 234 in 2008 to 136 in 2016) as has their area (130,000 sq. m in 2008 to 53,000 sq. m in 2016). At the same time, educational campaigns and financial incentives have led to a considerable increase in the share of collective selection of waste “at the source”, i.e. in

households, from a few percent a decade ago to over 27% today. With the introduction of obligatory collection of household waste, its share in the total mass has increased from around 60% in the pre-implementation period (prior to 2013) to 85% today. Moreover, the methods for further collection of waste and processing of the municipal waste brought in have also changed significantly. As recently as 2007, almost all mixed municipal waste collected was deposited in landfills, whereas today this share has decreased to 40%. Yet it should be emphasised that the share of all municipal waste (not only mixed waste) utilised in landfills is distinctly higher in the Łódź region than the Polish average.

Municipal waste continues to be the key challenge in the field of waste management both in Poland, the Łódzkie region and in its conurbation – this has been indicated not only by various strategic documents, research or field studies, but also by participants in the PULL workshops conducted under the REPAiR project. Therefore, for the purpose of this analysis, Municipal Solid Waste will act as the basic type of waste examined.

### **3. DATA AND METHODS**

In order to determine the material scope, i.e. the range of materials that will be subjected to the study, (waste) material(s) and their relevant possible applications have to be selected and defined. This selection is based on the interests of stakeholders, which in turn originate from local challenges and “personal” values, and are also required to ensure that there are traceable and justifiable reasons for the selection of the waste materials.

The table below summarises the structure of the waste collected in 2016 in the communes of the Łódź Metropolitan Area (ŁOM). An analysis of the data presented unambiguously proves that mixed municipal waste is the dominant category – up to 71.8% of the whole in weight terms. Packaging and biodegradable waste comprise a marginal share in this regard.

Considering data availability and the overall objectives of the REPAiR project, we decided to conduct a material flow analysis of biodegradable municipal waste in the Vegetable, Fruit and Garden (VFG waste) fraction. The study topic selected may serve as a good example in light of the need to solve issues resulting from the need to reduce the vast amount of waste collected in a non-selective manner. Biodegradable waste is entirely in line with the ideas of circular economy. Moreover, it is a crucial requirement that the mass of accumulated waste from households falling in this category (VFG waste) is sufficient to allow a statistical analysis of flows. As indicated above, one of the most important challenges which waste management in the Łódź Metropolitan Area (and Poland as a whole) faces is to offer more accurate information on the morphological composition of the generated waste.

Table 1. Structure of municipal solid waste collected in the Łódź Metropolitan area in 2016 per fractions

Waste subgroup		Waste fraction	
Packaging waste	11.2%	<i>of which:</i>	
150107 Glass packaging		150106 Mixed packaging waste	8.4%
			1.5%
Municipal wastes including selectively collected fractions	88.1%	<i>of which:</i>	
		200301 Unsorted (mixed) municipal waste	71.8%
		2001xx Non-biodegradable municipal waste segregated and collected selectively	4.6%
		200201 Biodegradable waste (green waste from gardens and parks)	4.3%
		200108 Biodegradable kitchen waste	3.4%
		200307 Large-sized waste	2.4%
Waste from construction, renovation and dismantling of construction works and road infrastructure (including soil from contaminated areas)	0.7%		

Source: own work based on municipal reports.

Table 2. Details of the waste flow investigated.

Waste group	Municipal Solid Waste
Waste category	Biodegradable municipal waste within Vegetable, Fruit and Garden (VFG waste)
Waste fraction by category	200108 – Biodegradable kitchen waste 200201 – Biodegradable waste (waste from gardens and parks) 200302 – Waste from marketplaces
Actors/generators of waste involved	Households, local government, waste management companies
Steps involved in the supply chain	Production, wholesale, retail, consumption, waste treatment

Source: own work based on municipal reports.

As has previously been emphasised, the new regulations that came into force in 2013 have restructured all existing waste management practices. According to the Act, municipal waste ought to be collected selectively, and communal authorities (local government authorities) are responsible for compliance with the

principles adopted in the Act. Local authorities are therefore in charge of managing the processes related to local waste management; they also take the most important decisions regarding the forms and methods of their implementation. A system of containers for three categories of waste has been widely introduced: mixed waste, glass, and plastic/paper. However, depending on the commune, the number of segregated waste categories varies, ranging from three to six. Local authorities have established the categories into which waste is segregated.

Therefore, for the purpose of the analysis, the basic reference unit of area was the municipality (commune). We decided that all (28) such units within the Łódź Metropolitan Area should be considered – thus the entire region was examined. The analysis was made for the year 2016.

Every six months enterprises receiving municipal waste from property owners submit a report to the head of the commune, mayor or town president concerning the treatment of municipal waste they collect. By contrast, bodies responsible for operating points for selective collection of municipal waste submit annual reports on the treatment of the collected municipal waste to the head of the municipality, the mayor or the president of the city. The mayor or president is obliged to submit an annual report on the implementation of their tasks in the field of municipal waste management to the marshal of the voivodeship and the voivodeship inspector for environmental protection. Subsequently, the marshal of the voivodeship reports the fact of the completion of the assigned tasks to the government minister for the environment. On the basis of the reports submitted by the bodies receiving municipal waste from property owners, those who operate selective municipal waste collection points, and based on the annual report on implementation prepared by municipal waste management undertakings, the head of the commune, mayor or city president draw up analyses of the municipal waste management situation. This document is compiled annually to verify the technical and organisational capabilities of a commune in the field of municipal waste management. It is open for public examination.

#### **4. WASTE PRODUCTION**

Municipal waste is a crucial part of waste management. According to the Waste Act of 12 December 2012 municipal waste is “waste generated in households, excluding end-of-life vehicles, as well as wastes not containing hazardous waste originating from other waste generators, which due to their nature or composition are similar to waste generated in households”. Municipal waste features numerous unfavourable characteristics that cause obstacles in its management. These include temporal variability in the quantity and quality of waste, heterogeneity of the morphological and chemical composition, possible sanitary and epidemiolog-

ical threats, the problem of the odour, the occurrence of dangerous substances in certain fractions (e.g. heavy metals), as well as the presence of hazardous waste (e.g. expired medicines, used batteries, chemicals).

In 2016, a total of 337,300 tonnes of municipal waste were collected from the Łódź Metropolitan Area. The largest amount of waste was collected from the Łódź commune (224,200 tonnes). This accounted for about 66.5% of the total mass of waste collected from the entire Łódź Metropolitan Area. The mass of municipal waste produced by individual communes depends, of course, on the number of inhabitants and population density.

The mass of municipal waste collected per inhabitant in the Łódź agglomeration varied throughout the communes (Fig. 3). The average weight of municipal waste collected per inhabitant in 2016 was 290 kg. The largest amount of municipal waste per capita was collected in the commune of Ksawerów (425 kg/person), Konstancin Łódzki (422 kg/person) and Andrespol (401 kg/person). The communes of Łódź, Rzgów, Nowosolna, and Brzeziny (330–370 kg/person) also featured relatively large quantities of municipal waste collected per capita by weight. In other communes of the Łódź Metropolitan Area, the weight of municipal waste was significantly lower – below 260 kg/person.

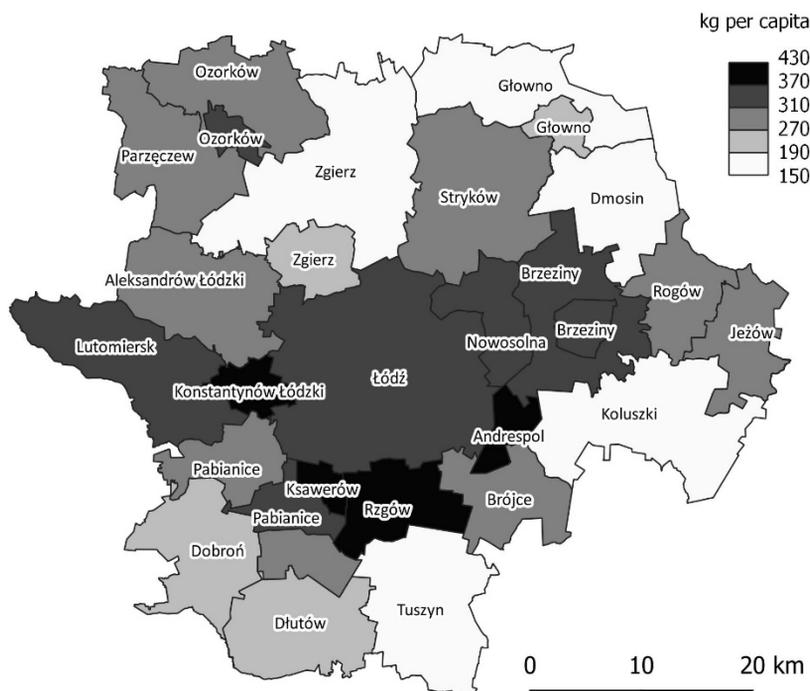


Fig. 3. Weight in tonnes of municipal waste collected per capita in communes of the LOM in 2016

Source: own work based on data from communal reports for 2016.

Non-biodegradable waste is waste that is not decomposed by microorganisms. In 2016, a total of 306,300 tonnes of such waste were collected in the Łódź Metropolitan area. Non-biodegradable waste accounted for approximately 90.8% of the total waste generated that was collected in the conurbation. The largest amount of non-biodegradable municipal waste was collected from the Łódź commune (204,200 tonnes) comprising 66.6% of the total non-biodegradable waste collected from the agglomeration. A considerable weight of non-biodegradable municipal waste was also collected from the urban communes of Pabianice (20,400 tonnes), and Zgierz (13,300 tonnes).

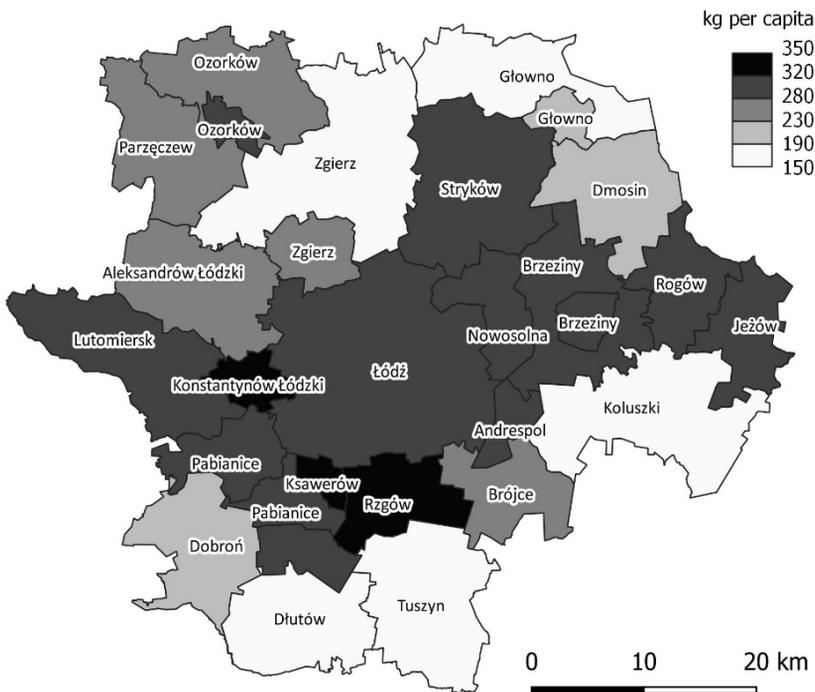


Fig. 4. Mass of non-biodegradable municipal waste per capita in the communes of the ŁOM in 2016

Source: own work based on data from communal reports for 2016.

The average weight of non-biodegradable municipal waste per capita was 260 kg. The largest amount of municipal non-biodegradable waste generated per inhabitant was collected from the urban communes of Konstantynów Łódzki (353 kg/person), Rzgów (332 kg/person), and Ksawerów (320 kg/person). The mass of non-biodegradable municipal waste collected from the communes of Lutomiersk, Pabianice, Stryków, Brzeziny, Łódź, Rogów, Andrespol, Brójce, Jeżów, Nowosolna, and Ozorków ranged from 280 to 310 kg/person. In other

communes in the metropolitan area, the average weight of non-biodegradable municipal waste per capita was in 2016 below 270 kg. The values for each commune are presented on Fig. 4. The largest quantity of non-biodegradable municipal waste collected comprised non-segregated municipal waste (waste code 200301), of which 242,3500 tonnes were collected in the Łódź Metropolitan area in 2016.

Biodegradable waste is a type of waste that undergoes aerobic or anaerobic decomposition, with the use of microorganisms. Biodegradable municipal waste includes:

- paper and cardboard (including packaging waste),
- clothing made of natural fibres,
- textiles made of natural fibres (including packaging waste),
- edible oils and fats,
- wood not containing hazardous substances (including packaging waste),
- biodegradable waste (including biodegradable kitchen waste),
- waste generated in marketplaces.

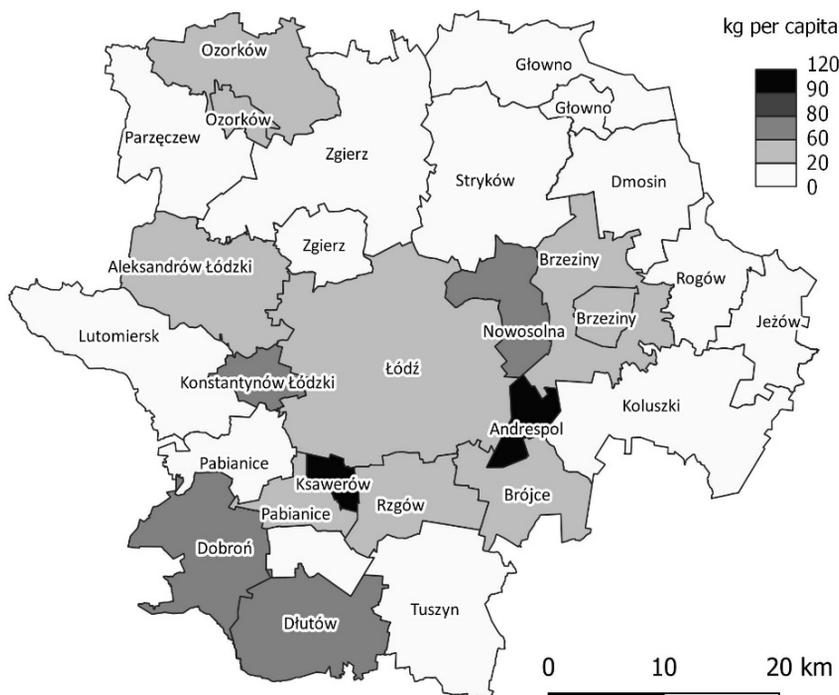


Fig. 5. Mass of biodegradable municipal waste per capita in the communes of the ŁOM in 2016

Source: own work based on data from communal reports for 2016.

In 2016, as many as 30,980 tonnes of biodegradable waste were collected from the Łódź Metropolitan Area. This accounted for 9.2% in weight terms of all municipal waste collected in the area. The largest quantity of biodegradable municipal waste was collected from the Łódź commune (20 tonnes). Approximately 2,100 tonnes were collected in the urban commune of Pabianice, 1,500 tonnes in Andrespol, and 1,200 tonnes in the Konstantynów Łódzki commune. The remaining communes collected less than 900 tonnes of biodegradable waste. The average weight of municipal biodegradable waste collected per capita in 2016 was 30 kg. The largest amount of municipal biodegradable waste per inhabitant was collected in the communes of Andrespol (112 kg/person), and Ksawerów (109 kg/person). The communes of Nowosolna (78 kg/person), Konstantynów Łódzki (69 kg/person), Dłutów (63 kg/person), and Dobroń (62 kg/person) also had relatively high masses of biodegradable waste per capita. In other communes in the Łódź Metropolitan Area, the mass of biodegradable municipal waste was below 42 kg per inhabitant. The spatial differentiation of these amounts are presented on Fig. 5.

## 5. WASTE FLOW

The generated municipal waste is collected from those who produce it by collecting companies appointed by the municipal authorities following a tendering process. Depending on the manner in which the waste is collected, a distinction is made between mixed municipal waste and selectively collected waste. The waste received is then directed to installations for municipal waste treatment where it undergoes recovery or disposal processes. In municipal waste treatment plants, the material undergoes a thermal or mechanical-biological transformation. Mixed municipal waste, which comprises the largest percentage of municipal waste received, is mainly channelled to an installation for mechanical and biological treatment of municipal waste. At that stage, the first process to which waste is subjected is separation of the waste material fractions (glass, paper, plastic, and metal), which are then sent to the sorting plant for separately collected waste (for cleaning purposes). The mechanical processing of mixed municipal waste consists of isolating specific fractions that can be used as a material or source of energy, as well as a fraction requiring additional biological processing. Fractions intended for further use include, i.a. paper, cardboard, ferrous metals, non-ferrous metals, plastic, and rubber. The mechanical treatment of mixed municipal waste involves the processing of waste for the purpose of preparing it for recovery, including the recycling or treatment of waste, after which stage there remains waste intended for disposal. Selectively collected waste (paper, glass, metals, plastics), as well as mixed municipal waste, is also directed to the mechanical and biological treatment

plant, where it passes through a cleaning process on waste segregation lines and is then recycled. Green and other biodegradable waste that is selectively collected is transferred to a composting plant. Hazardous waste selectively collected from property owners or collected at points for selective collection of municipal waste is transferred to installations where appropriate recovery and recycling processes are applied, adapted to the given type of waste.

In 2016, municipal waste from the Łódź Metropolitan area was collected by 82 plants located in 13 voivodeships in Poland. About 99% of the weight of municipal waste produced in the Łódź Metropolitan Area was collected by plants operating in the field of waste collection in the Łódzkie Voivodeship. The remaining 1% of the total weight of municipal waste produced in the agglomeration was collected by installations located outside of the voivodeship. The results of municipal waste flow analysis are presented on Fig. 6.

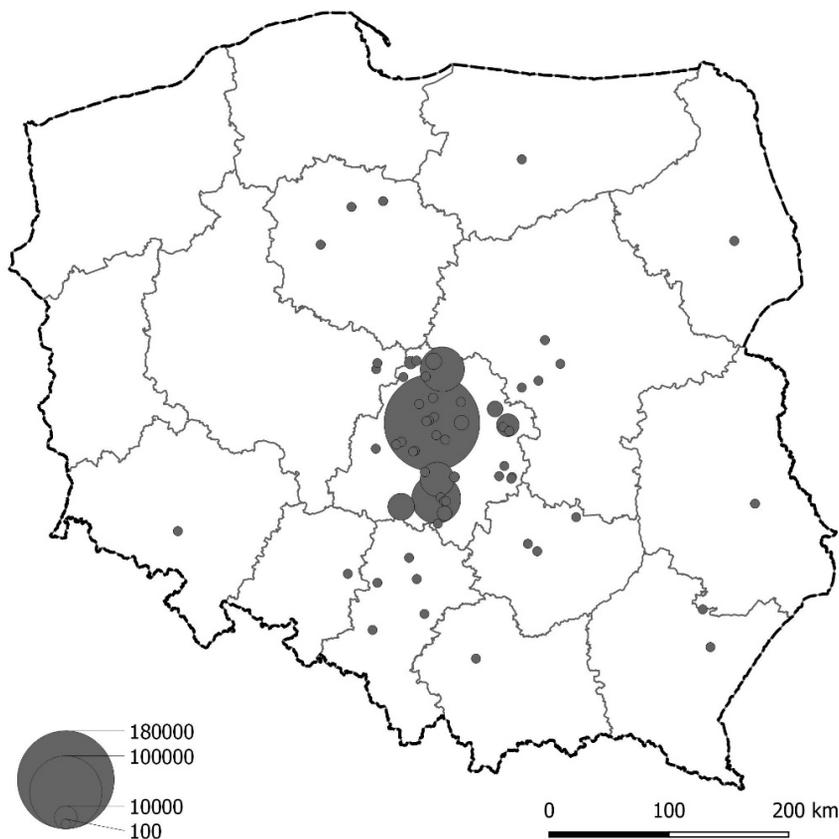


Fig. 6. Total weight of municipal waste collected from the ŁOM by individual installations in 2016

Source: own work based on data from communal reports for 2016.

Approximately 53% of municipal waste collected in the Łódź Metropolitan Area were collected by enterprises operating within the area. The largest quantity of municipal waste was collected by installations operating in the Łódź area, accounting for 51.5% of the total quantity of municipal waste collected from the metropolitan area. As much as 13.7% of the municipal waste from the Łódź Metropolitan Area was collected by enterprises based in Kamieńsk (Radomsko powiat, Łódzkie Voivodeship), 8.4% by an enterprise in Krzyżanówek (Kutno powiat, Łódzkie Voivodeship), 7.5% by an enterprise in Bełchatów (Bełchatów powiat, Łódzkie Voivodeship), 4.2% by an enterprise in Kutno (Kutno powiat, Łódzkie Voivodeship), 3.5% by an enterprise in Dylów (Pajęczno powiat, Łódzkie Voivodeship), 2.9% by an enterprise in Pukinin (Rawa powiat, Łódzkie Voivodeship), and 1.4% by an enterprise in Franki (Kutno powiat, Łódzkie Voivodeship). In total, approx. 6.9% of municipal waste from the Łódź Metropolitan Area was gathered by other enterprises.

In 2016, the municipal waste collected in the Łódź Metropolitan Area was treated by 80 plants located in 13 voivodeships. Approximately 99% of municipal waste was managed by plants operating in the Łódzkie Voivodeship, while the remaining 1% was managed by external installations. The management of such a large proportion of municipal waste collected in the Łódź Metropolitan Area by installations operating within the voivodeship has resulted from the provisions of the Waste Act of 14 December 2012. Pursuant to this legislation, waste is first processed at the place where it is generated. In situations where waste cannot be processed there, it is transferred to the nearest place where it can be processed. In 2016, more than half of the municipal waste by weight (53.3%) was received by installations operating within the area of the Łódź Metropolitan Area.

In 2016, non-biodegradable municipal waste was received by 70 plants. About 99% of the non-biodegradable municipal waste by weight were managed by plants operating in the Łódzkie Voivodeship. The amounts of non-biodegradable waste collected by plants from Łódź Metropolitan Area are presented on Fig. 7. The majority of this type of waste (54.8%) was feedstock for installations operating in the area of the Łódź Metropolitan Area. The largest quantity of non-biodegradable municipal waste was processed by installations operating in Łódź, which in 2016 managed to process 53.1% of this type of waste collected within the metropolitan area. Non-biodegradable waste is mainly treated by the R12 system, i.e. dismantling, sorting, crushing, compacting, granulation, drying, crushing, conditioning, repacking, separation, blending or mixing before submission to any of the processes listed in item R1-R11. Other processes are seldom used.

In 2016, biodegradable municipal waste was managed by 31 installations. About 99% of the biodegradable municipal waste were utilised by plants operating in the Łódzkie Voivodeship. About 38.3% of this type of waste were managed by installations operating in the Łódź Metropolitan Area. Biodegradable waste is

mainly treated by the R3 system, i.e. recycling of waste paper and board; reprocessing and recycling of plastic waste; composting of bio waste and green waste; and fermentation of biodegradable waste for biogas production (biogas plants). The amounts of treated biodegradable waste and ways of waste management are presented of figure below (Fig. 8).

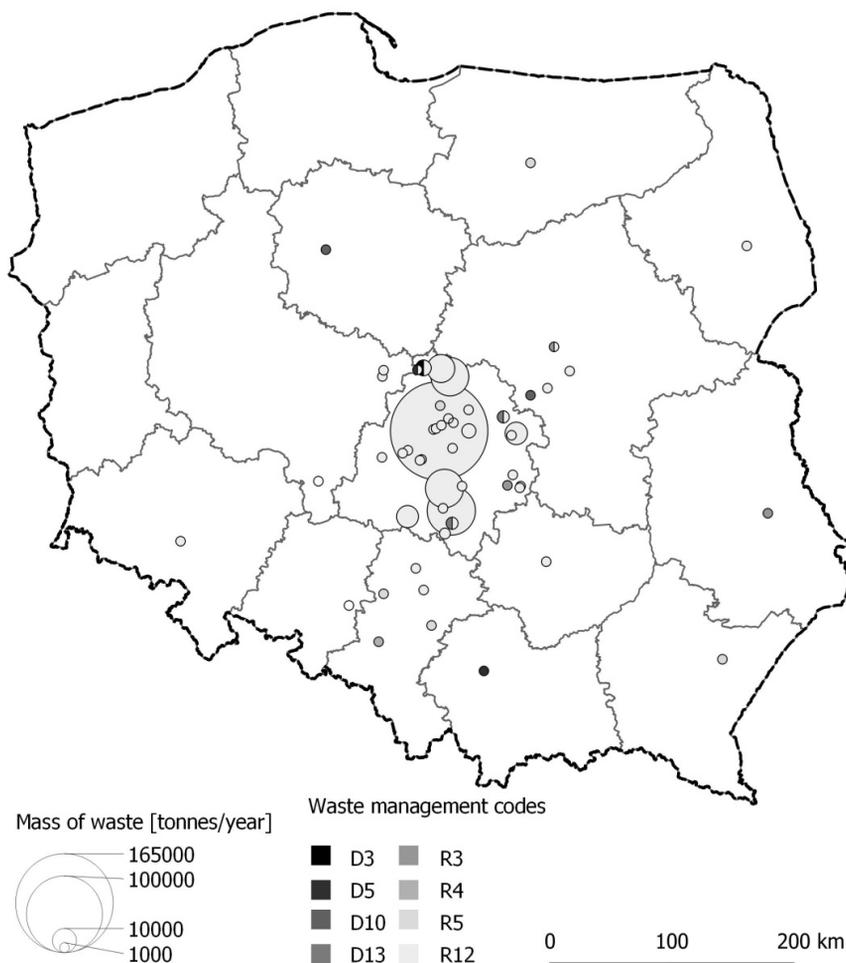


Fig. 7. Weight of non-biodegradable municipal waste collected from the Łódź Metropolitan Area treated by individual installations per the form of treatment

D3 – Deep injection, D5 – Engineered landfill, D10 – Incineration on land, D13 – Blending or mixing prior to submission to any of the operations numbered D1 to D12, R3 – Recycling/reclamation of organic substances, R4 – Recycling/reclamation of metals, R5 – Recycling/reclamation of inorganic substances, R12 – Exchange of waste for submission to any of the operations numbered R1 to R11

Source: own work based on data from communal reports for 2016.

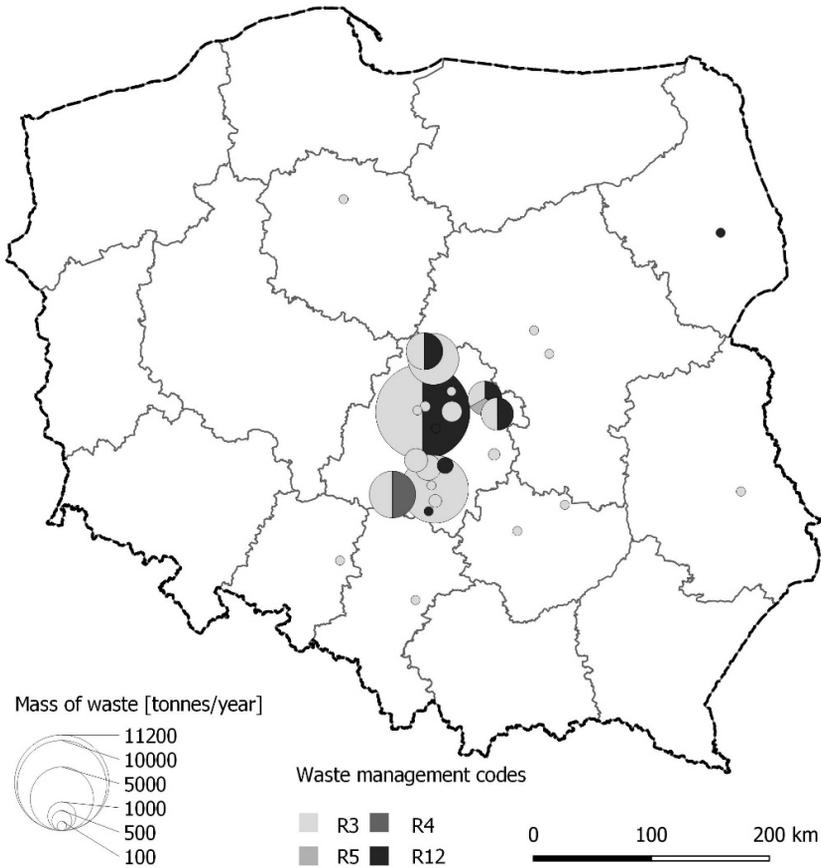


Fig. 8. Weight of biodegradable municipal waste collected from the Łódź Metropolitan Area treated by individual installations per the form of treatment

R3 – Recycling/reclamation of organic substances, R4 – Recycling/reclamation of metals, R5 – Recycling/reclamation of inorganic substances, R12 – Exchange of waste for submission to any of the operations numbered R1 to R11

Source: own work based on data from communal reports for 2016.

A detailed flow diagram of biodegradable waste in the communes of the Łódź Metropolitan Area is presented below. The following three categories of waste have been considered in the flow analysis of the Vegetable, Fruit and Garden (VFG) waste: 200108 (biodegradable kitchen and canteen waste; separately collected fractions as part of municipal solid waste), 200201 (biodegradable waste from garden and park wastes, including cemeteries), and 200302 (bio-waste from markets). As over 70% of the waste collected in the Łódź Metropolitan Area in 2016 was classified as part of the mixed waste category, it was

decided to estimate this value based on national data and information obtained from communal reports on the implementation of tasks related to municipal waste management and concerning the weight of biodegradable waste collected from the municipal waste stream within the area of the commune in the accounting year, and transported to storage. As a result of these calculations, the total mass of VFG waste was estimated to be 76,570 tonnes, which comprises 22% of all municipal waste. It is worth indicating that in the above-mentioned study of Poland, the share of this type of waste varied from 20% to 37% depending on the type of municipality and the period examined, therefore the estimated value for the Łódź Metropolitan Area seems to be correct. The map below (Fig. 9) illustrates the VFG waste flows between communes in the Metropolitan Area and the treatment points – a very distinct geographical regionalisation is visible in terms of spatial proximity.

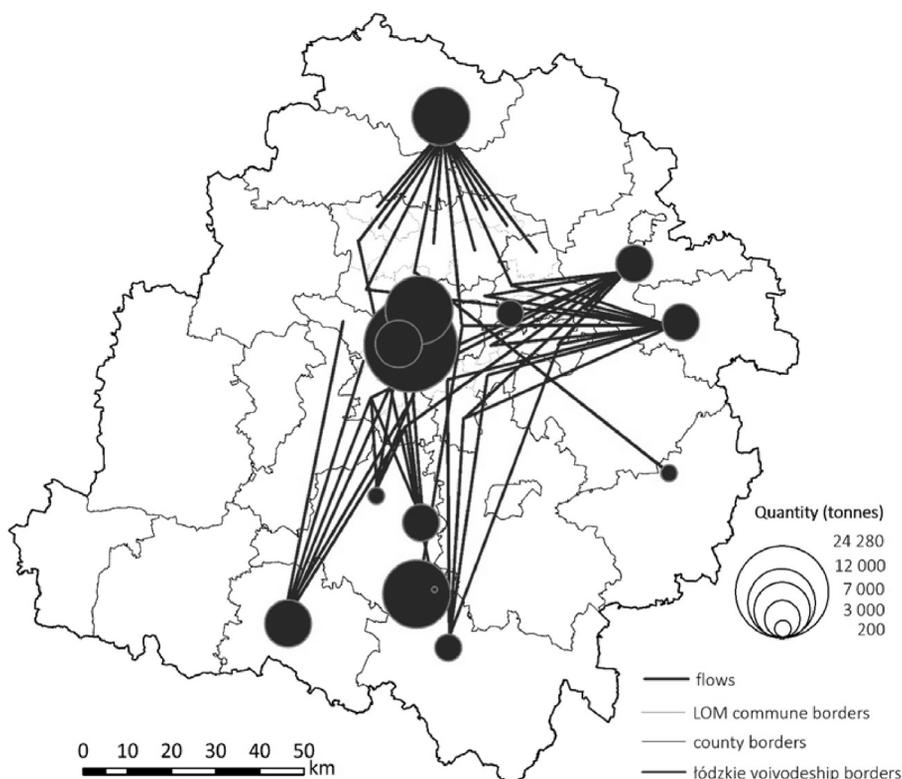


Fig. 9. VFG flows from communes in the Łódź Metropolitan Area in 2016

Source: own work based on data from communal reports for 2016.

## 6. CLOSING REMARKS

It is very difficult to determine the accuracy of the assessment of the current waste management system due to the relatively short period of applicability of the new rules which, from 2013 onwards, have transferred responsibility for this to local governments. The coming years will be decisive for the stabilisation of the waste collection and treatment system. A big responsibility lies with the legislative and executive authorities at the highest, state level that should, in a short time, verify the instruments used to achieve the effects of using waste for the production of new goods. An important role in this respect should apply to local government associations, which articulate the need for change and modernisation of the approach to waste management, including the creation of new legal regulations. However, achieving the success of the rules of circular economy will depend to a great extent on the strengthening of the ecological awareness of urban and rural residents who need to understand both social needs (collective responsibility) as well as individual needs based on the economic benefit of reusing waste in the production of new goods.

The amount of municipal waste generated should be determined following the changes in EU and national policies implemented through increasing pressure to prevent and limit waste generation, develop and promote “circular economy”, as well as to raise environmental awareness in the society.

One should strive to reduce the amount of waste generated, increase public awareness of how to efficiently manage it, including food waste and other kinds of biodegradable waste. It is crucial to channel the functioning of waste management systems towards the hierarchy of waste handling methods and, above all, to diminish the share of mixed municipal waste in the entire waste collection stream. In addition, it is advisable to discontinue the storage of selectively biodegradable waste, cease the storing of mixed municipal waste without treatment, reduce the number of illegal municipal waste storage sites, and establish a monitoring system for municipal waste management. The last issue is of particular concern. It should be indicated that there are currently insufficient activities conducted by communal authorities associated with the monitoring of enterprises in the field of collection and management of waste from the area of a commune. Today’s legal conditions preclude proper cooperation between the private and public sectors in the field of waste management systems.

Furthermore, the future of waste management also ought to be considered. It will be necessary to verify the existing and planned capacity of plants conducting the processes of mechanical waste treatment. The hierarchy for waste management methods and the objectives to be achieved by 2030 impose the need to significantly reduce the amount of waste deposited and to constrain storage to previously treated waste sites.

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