

Article

# Municipal Urban Waste Management—Challenges for Polish Cities in an Era of Circular Resource Management

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**Abstract:** Municipal authorities increasingly view environmental protection as one of the goals of city management. The pro-environmental orientation of cities can, therefore, foster the creation of new management methods and instruments and promote reorganization of determining material flows in a municipal system. Activities of this kind should result not only in the reduction of generated waste but also in the creation of closed material cycles. Considering the tasks of Polish local governments, municipalities should pay the most attention to municipal waste. Accordingly, the goal of this study was to identify the problem of mixed municipal waste in cities and assess the influence of investments into fixed assets for environmental protection in the scope of waste management on the quantity of mixed municipal waste in cities. This article also identifies activities for circular resource management that need to be realized by Polish municipalities. The analysis was performed using the panel model, dynamic indexes, and critical analysis of city documents. The conducted research revealed positive trends in cities with respect to the amount of waste collected non-selectively that is conducive to circular resource management. The fact that municipal waste quantity is on the increase should encourage urban authorities to promote pro-environmental waste management behaviors among city dwellers.



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## 1. Introduction

### 1.1. Theoretical Frameworks and Motives for Undertaking the Research

Development of cities and generation of waste are interrelated. In the past, waste was perceived as a cost, and landfilling was the usual method of managing it [1], becoming a destination for all non-valorized waste [2]. Today, however, the significance of the potential value of waste is growing in the minds of city dwellers [3–11]. Creation of waste is the result of the development of cities. Urbanization, caused mainly by the increase in the number of inhabitants and in the level of consumption, has a negative impact on urban communities. This makes the introduction of the principles of sustainable development in the functioning of cities challenging, not only in the context of protecting the urban community but also the entire ecosystem. These sustainable practices are important as the development of a city largely depends on natural and environmental conditions. The implementation of the idea of sustainable development in cities is intended to improve the quality of the environment and, consequently, the quality of urban life [12]. The ecosystems and biodiversity should be protected primarily by green infrastructure [13], intelligent planning and development [14], as well as transitioning to a circular economy [15]. Therefore, it can be assumed that the theoretical frameworks for the problem of waste management in cities are sustainable development and circular resource management.

Cities are the largest consumers of global resources and the largest producers of waste [16]. This makes them a crucial element of the concept of sustainable development [17–24]. Sustainable cities and societies have become goal number 11 of the UN's concept of sustainable development. Achieving sustainability of cities and societies involves:

- Renewing and planning cities and other settlements in a way that ensures that all residents have access to basic services, such as energy, housing, transport, and public green spaces, simultaneously improving the use of resources and reducing environmental impact;
- Treating cities as environmentally resistant human settlements that drive sustainable development, stimulate innovation, and foster community cohesion and personal safety;
- Calling for protection of the world's cultural and natural heritage and supporting positive economic, social, and environmental links between urban, suburban, and rural areas.

Strengthening the urban dimension of the post-2020 EU Cohesion Policy framework relates not only to the overall goals of sustainable urban development but also addresses issues such as capacity-building, education and employment, and innovative investment strategies for the transition of cities to a circular economy. On 10 February 2021, the European Parliament adopted resolution 2020/2077 (INI), the New Circular Economy Action Plan, with respect to the Commission communication of 11 March 2020 entitled "A new circular economy action plan for a cleaner and more competitive Europe" (COM (2020) 0098). As part of the Action Plan presented, measures are proposed, inter alia, to reduce waste. Activities will focus on avoiding waste entirely by converting it into high-quality secondary raw materials in a well-functioning market for secondary raw materials. In addition, the Roadmap to a Circular Resource Efficiency Management Plan was published on 15 May 2020. It shows that cities and regions are key partners in achieving a circular economy. Cities are responsible for waste management at the local level; they have a unique capacity to help solve complex problems related to resource efficiency [25]. Support and commitment from national and local authorities determines the successful implementation of waste management solutions, especially technological solutions to recover value from waste [26]. Therefore, it is necessary to adapt to the existing initiatives, norms, and practices in resource recovery in local communities and to co-create the relevant knowledge [27]. Prevention of the constant generation of municipal waste is a priority of legislation and environmental policy in developed countries, and the proper management of solid waste is therefore a necessary condition for achieving environmental sustainability [28].

The circular system, taking into account the three key pillars of sustainable development, is the basis of current economic processes [29]. Circular resource management includes not only innovative technology system configurations but also new management and planning models. The transition to sustainable resource management requires the joint effort of many stakeholders and the support of different decision models to tailor solutions to a specific local context. The challenge for urban areas will therefore be to increase the circular material and energy flow in cities to improve resource efficiency and minimize waste, thus reducing the negative impact on sustainable development [30]. As a result, in the area of waste management, goals can be defined, such as encouraging residents to act favoring the circular economy and building relevant knowledge and methods, implementing available systems, repairing and trading used products, and switching to closed-loop collection systems. A challenge for large cities in the context of waste management and the circular economy is also the implementation of large installations for the treatment of mixed waste [31]. Hence, in line with the thinking in terms of circular resource management, city management entities should take all measures to reduce the amount of mixed waste collected in favor of selective collection. The transition from waste to resources is therefore an indispensable tool for the implementation of strategies and sociotechnical tools to mitigate the impact of flows on the environment [32], including cities.

### *1.2. Literature Review and Research Purpose*

The problem of the increasing quantity of solid waste in big cities requires a constant search for strategies and methods for correct waste handling and is a growing environmental, economic, and social challenge for cities [33,34]. Research proves the significance

of urban policy in the effectiveness of waste management [35–37]. The funds at the disposal of local authorities are also an important factor in eco-effectiveness [38]. It is also important to find solutions for selective waste collection, as it plays a fundamental role in recycling waste and increasing the rate of this process, which is the main goal of circular resource management. A consequence of the tendency in the organization's approach to environmental problems is the allocation of significant resources to the protection of its individual elements [39]. Environmental protection expenditure is part of the European System for the Collection of Economic Information on the Environment—SERIEE [40]. Most studies analyze the impact of environmental protection expenditure on air and water pollutants or ecological footprint [41,42] or on economic performance [43]. However, there is a lack of research on the impact of environmental protection expenditure on the quantity of waste generated in cities. This study was conducted using the example of Polish cities. According to the Human Development Report, Poland is in the group of countries characterized by very high human development [44]. The level of socioeconomic development and the resulting common standards in the field of waste management can be considered representative in European countries, and especially in the European Union. Poland's accession to the European Union forced Polish administrative units to adjust their waste management activities to the EU requirements. Unfortunately, the existing legal acts are mainly connected with methods of safe disposal of waste, without specifying the level of reintroduction of waste into the economic system. It is challenging, therefore, to organize waste management in a way that ensures the creation of closed-loop systems. An additional difficulty in Poland is the limited ability to obtain external sources of financing environmental protection projects [45]. The main source of financing environmental protection projects in Poland is still the own funds of investors such as enterprises and local governments [46]. This is due to the fact that the financial policy in the field of environmental protection in Poland is based primarily on the "polluter pays" and "resource user pays" principles, according to which the entity using the environmental resources and making changes to them is obliged to finance protective measures.

The COVID-19 pandemic created an opportunity to verify the methods and tools used in solid waste management in cities [47–52]. Conducted research helped identify key challenges in research and development in the field of solid waste management, such as [53]:

- Factoring in the socioeconomic uncertainty with respect to the possibility of financing activities and changing human habits in the process of decision making;
- Developing adequate approaches towards sustainable management of solid municipal waste in countries with low income during the pandemic;
- Providing necessary training programs and decent regulations with the aim of improving people's knowledge, attitudes, and practices in connection with solid waste management during the pandemic;
- Development of selective storage and collection of waste from households involved in healthcare or from small healthcare units;
- Creating feasible and controllable plans for collecting, processing, transferring, and eliminating infectious and non-infectious hospital waste during the pandemic in developing countries;
- Assessment of the sustainability of the life cycle for different scenarios of storing and managing municipal waste during the pandemic.

There are many methods of managing and organizing an effective, innovative, and sustainable system of municipal waste management [54]. Technological evolution has also brought about considerable changes. It is now possible to automatically sort, measure, transport, and press waste as well as monitor and report waste management. All increase the effective use of time, resources, and energy and improve the availability, transparency, and traceability of current waste and the process of collecting information [55].

Collecting and processing data on the quantity of waste is an important aspect of the urban waste management process. Public waste management policy, supported by state

and European Union funds, aims to improve resource and sustainable development efficiency and minimize the environmental impact. Collecting data on the generation of waste aids decision-makers in creating and implementing more effective waste management policies [56]. Effective waste management relies on the cooperation of many entities [57,58]. Research shows that preserving material value across economic cycles can be promoted through better waste data sharing and enhanced dialogue and collaboration between key actors [59]. Reduction of the negative effects of the entire waste management system can be achieved by measures such as:

- Citizen–government partnership, e.g., the Advanced Locality Management Program of Mumbai [60];
- Identification of factors influencing successful implementation of solid waste management in the city, in particular: citizen participation, adequate resource availability, a successful waste management plan, public awareness, training and awareness of staff, market availability, and political commitment [61].

The experience of European cities indicates the need for the following actions:

- Making decisions at the local level with direction to develop waste management in the context of a circular [31,62,63] and integrated economy [64];
- Restructuring of the waste management sector towards compliance with the circular economy principles [65];
- Developing a set of indicators as the basis for setting long-term visions and goals concerning the city's material resources and promoting the zero waste idea [66];
- Analysis of the impact of the zero waste strategy on greenhouse gas emissions [67];
- Promoting urban agriculture as part of a waste management strategy towards the circular economy [68];
- Taking into account decision-making processes considering both environmental and economic sustainability [69];
- Promoting the circular economy, especially in cities with high tourist traffic [70];
- Developing new management strategies, taking into account the environmental efficiency of waste management [71].

Sustainable development of cities should be the key goal of waste management. This means that waste management entities should plan and organize their activities in a way that guarantees the achievement of economic, environmental, and social goals. This study concentrated on waste management challenges faced by Polish cities. Unfortunately, landfilling is still the main method of managing waste in Poland. Nevertheless, current legal regulations and the growing ecological awareness of society should contribute to the creation of waste management systems based on the circular economy aimed at increasing the amount of segregated municipal waste.

Taking into account the indicated research gap, the aim of this study was to assess the use of expenditure on fixed assets for environmental protection in the area of waste management in the direction of reducing the amount of mixed municipal waste collected and to identify actions taken by the authorities of Polish cities to reduce the amount of generated waste and its proper treatment by the urban community. The conducted research will help to answer the following questions:

1. Does the expenditure on waste management really translate into a reduction in the amount of waste in urban areas?
2. Are there any positive trends in municipal solid waste management in cities?
3. Are city authorities making sufficient efforts to create a circular economy in the context of municipal solid waste?

Therefore, the research results will help city managers to verify their waste management decisions towards circular resource management and, possibly, develop good practices in this area.

## 2. Methods

### 2.1. Econometric Model

In order to determine the relationship between effects achieved in the quantity of collected mixed waste and outlays on waste management, it was necessary to analyze the influence of investment into fixed assets for environmental protection in the scope of waste management on the amount of municipal waste generated in cities by households and other sources. The following variables were used in the analysis:

- *WASTE\_UA*—municipal waste collected (excluding collected separately) in urban areas (thousand tonnes);
- *POPULATION*—population in urban areas (persons);
- *OUT\_TRANS*—outlays on municipal waste collection and transport (thousand PLN);
- *OUT\_LAND*—outlays on rendering non-hazardous waste harmless and disposal of non-hazardous waste, including combined storage (thousand PLN);
- *OUT\_RECYC*—outlays on recycling and utilization of waste (thousand PLN);
- *OUT\_RECLA*—outlays on reclamation of waste landfills and devastated and degraded lands (thousand PLN).

The data came from the database of the Central Statistical Office [72]. Data for individual Polish voivodeships from the years 2011–2019 were analyzed. The voivodeship is the highest administrative division unit in Poland. There are 16 voivodeships in total. It was assumed that 2011 will be the first analyzed period, because in that year changes were made to the existing municipal waste management system [73]. The relationship between the analyzed variables was determined using a panel model. The literature indicates many benefits resulting from the use of panel data [74,75]. The variables connected with outlays on fixed assets for environmental protection and the population in urban areas are the potential explanatory variables. The model was, therefore, formulated as follows:

$$WASTE\_UA_{it} = \beta_0 + \beta_1 POPULATION_{it} + \beta_2 OUT\_TRANS_{it} + \beta_3 OUT\_LAND_{it} + \beta_4 OUT\_RECYC_{it} + \beta_5 OUT\_RECLA_{it} + \varepsilon_{it} \quad (1)$$

where  $\beta_0$ – $\beta_5$  are vectors of the parameters to be estimated, and  $\varepsilon_{it}$  is error term.

The use of the levels of outlays on fixed assets for environmental protection in the field of waste management as explanatory variables was dictated by the fact that their purpose is primarily to make waste disposal processes less burdensome for the natural environment. Fixed assets are understood in the conducted analysis as part of the entity's fixed assets that have a material form. Outlays on fixed assets include purchase of land (including permanent usufruct of land), buildings, apartments, civil and water engineering structures (including outlays on construction and installation works, design and cost estimation documentation), technical equipment and machines, means of transport, tools, accessories, movable goods and equipment, and other fixed assets aimed at environmental protection and water management. Outlays for fixed assets in the field of waste management have a specific goal, namely to minimize effects on the environment. As part of waste management, processes are implemented to reduce waste, such as collection, transport, disposal, recycling, utilization, and reclamation [76]. Outlays on fixed assets enabling the implementation of these processes should translate into greater efficiency and effectiveness of waste management and, consequently, into an increase in the amount of recycled and reutilized waste, and thus into a reduction in the amount of mixed waste collected.

One of the basic requirements in the process of model formulation is testing the integration rank and determining a potential cointegration vector [77–80]. For this reason, unit root tests for the panel data were conducted. The analysis used the Levin, Lin, and Chu  $t^*$  test; Im, Pesaran, and Shin  $W$ -stat test, ADF–Fisher chi-square test, and PP–Fisher chi-square test. These tests assume no stationarity under the null hypothesis and under the alternative stationarity of all parts, or at least one series, depending on the test. Analysis of the results can help determine if there is a need to describe the influence of explanatory variables on the dependent variable using the error correction model.



In the next stage of the analysis, the parameters of the model were estimated using the ordinary least squares (OLS) method. In order to validate the use of the OLS method in the estimation of the model, the following tests were conducted: Breusch–Pagan, Hausman, and the combined significance of group mean inequalities test [81]. The Breusch–Pagan test verified the hypothesis on the existence of an individual effect, and the Hausman test was used to determine if there was a correlation between the explanatory variables and random effects.

## 2.2. Change Dynamics and Identification of Waste Management Activities in Cities

In order to determine the trend in the level of mixed municipal waste in Polish cities, the dynamics of change was analyzed using chain dynamic indexes and the parameter of the average change tempo. Measure dynamics were estimated for all selected variables. These activities should become the basis of circular resource management. In order to identify these activities, documents available on the Internet and concerning waste management in the following Polish cities were analyzed: Katowice, Warszawa, Szczecin, Białystok, Wrocław, and Częstochowa [82–86]. The cities selected for the analysis are located in various parts of Poland and are characterized by different area and population density. The waste management studies show the relationship between the amount and composition of waste generated and the socioeconomic status of citizens [87]. Hence, cities that differ in the financial condition of their inhabitants were selected for the analysis in order to check whether there are differences in the scope of activities aimed at creating closed waste management systems. The basic characteristics for selected cities are presented in Table 1.

**Table 1.** The basic characteristics for selected Polish cities in 2019.

Cities	Location	Area in km <sup>2</sup>	Population per 1 km <sup>2</sup>	Households Declaring that with the Present Income Position They “Make Ends Meet” (Data for Regions: NUTS 2) in %		Mass of Municipal Waste Generated per Capita
				With Difficulty	Easily	
Warszawa	Central Poland	517	3462	8.6	15.2	375
Wrocław	Southwest Poland	293	2195	10.2	14.5	546
Białystok	Northeastern Poland	102	2913	10.8	10.5	345
Częstochowa	South Poland	160	1380	11.0	15.7	425
Katowice	South Poland	165	1778			441
Szczecin	Northwest Poland	301	1337	14.9	11.2	419

Source: [88].

## 3. Results

Panel data are not free from the problem of the lack of stationarity of the time series of individual units present in the panel. Therefore, in the first step of the analysis, it was checked whether the tested time series were stationary. For this purpose, tests for the existence of the unit root were carried out. The results of the root unit tests (Table 2) were used to confirm that the variables used in the model were stationary.

**Table 2.** Results of unit root tests for given variables.

Variable	Method	Order of Integration $X_t \sim I(0)$	
		Statistic	$p$
WASTE_UA	Levin, Lin, and Chu $t^*$	−7.51815	0.0000
	Im, Pesaran, and Shin W-stat	−2.08448	0.0186
	ADF–Fisher chi-square	53.7525	0.0094
	PP–Fisher chi-square	57.1855	0.0040
POPULATION	Levin, Lin, and Chu $t^*$	−1.33957	0.0902
	Im, Pesaran, and Shin W-stat	2.06170	0.9804
	ADF–Fisher chi-square	16.0879	0.9914
	PP–Fisher chi-square	19.8945	0.9531
OUT_TRANS	Levin, Lin, and Chu $t^*$	−5.48660	0.0000
	Im, Pesaran, and Shin W-stat	−1.85135	0.0321
	ADF–Fisher chi-square	59.5104	0.0022
	PP–Fisher chi-square	79.9880	0.0000
OUT_LAND	Levin, Lin, and Chu $t^*$	−26.5702	0.0000
	Im, Pesaran, and Shin W-stat	−4.58090	0.0000
	ADF–Fisher chi-square	63.1474	0.0008
	PP–Fisher chi-square	79.7697	0.0000
OUT_RECYC	Levin, Lin, and Chu $t^*$	−4.80493	0.0000
	Im, Pesaran, and Shin W-stat	−2.09083	0.0183
	ADF–Fisher chi-square	52.1953	0.0135
	PP–Fisher chi-square	84.7374	0.0000
OUT_RECLA	Levin, Lin, and Chu $t^*$	−3.33736	0.0004
	Im, Pesaran, and Shin W-stat	−2.19875	0.0139
	ADF–Fisher chi-square	54.4144	0.0080
	PP–Fisher chi-square	83.7283	0.0000

Probabilities for Fisher tests were computed using an asymptotic chi-square distribution. All other tests assumed asymptotic normality. Source: own calculation in EViews—an econometric software package.

The Levin, Lin, and Chu test can be used to determine that all examined variables are stationary. Only in the case of the POPULATION variable, the other tests indicate a potential existence of root units. Considering the Levin, Lin, and Chu test results, however, the assumption was made that all analyzed variables are stationary. It was considered that the Levin, Lin, and Chu test is among the most used mainly because it was the first unit root test for data panels, and the authors examined its asymptotic properties in detail [89].

The objective of the next stage of the analysis was to determine if the parameters of the model could be estimated using the ordinary least squares method. The applicability of the method in the estimation of the parameters was confirmed after conducting the Breusch–Pagan, Hausman, and the combined significance of group mean inequalities tests. The results of the tests for individual models are presented in Table 3.

**Table 3.** Results of statistical tests for estimated model.

Breusch–Pagan Test Statistic		Hausman Test Statistic		Combined Significance of Group Mean Inequalities	
<i>LM</i>	<i>p</i>	<i>H</i>	<i>p</i>	<i>F</i>	<i>p</i>
1.78121	0.182	2.50166	0.776245	0.551295	0.905874

Source: own calculation in EViews—an econometric software package.

While analyzing the obtained results, it can be concluded that the ordinary least squares method should be used for the dependent variable *WASTE\_UA*, as was indicated by the results of the Breusch–Pagan and the combined significance of group mean inequalities tests. Table 4 presents the results of the estimation of the model.

**Table 4.** Estimation results of the model for response variable *WASTE\_UA*.

Variable	Parameter Estimate	Standard Error	Student's T Statistic	Significance Level <i>p</i>
<i>const</i>	−15.0912	7.19683	−2.097	0.0378 **
<i>POPULATION</i>	0.000302562	0.00000553	54.76	<0.0001 ***
<i>OUT_TRANS</i>	−0.000812666	0.000338637	−2.400	0.0177 **
<i>OUT_LAND</i>	−0.000252417	0.000113712	−2.220	0.0281 **
<i>OUT_RECYC</i>	−0.000267852	0.000193591	−1.384	0.1687
<i>OUT_RECLA</i>	−0.00175231	0.000643580	−2.723	0.0073 ***

Mean of dependent variable: 402.2013  
 Standard deviation of dependent: variable 262.7011  
 Residual sum of squares: 257003.0  
 Standard error of residual: 43.15484  
 R<sup>2</sup>: 0.973958  
 Adjusted R<sup>2</sup>: 0.973014  
 F(5, 138): 1032.217  
 Significance level *p* for *F* test:  $2.0 \times 10^{-107}$   
 Log likelihood: −743.3933  
 Akaike criterion: 1498.787  
 Schwarz criterion: 1516.605  
 Hannan–Quinn criterion: 1506.027  
 Residual autocorrelation—rho1: −0.169435  
 DW statistic: 1.966563

\*\*\* significant at the 1% level, \*\* significant at the 5% level. Source: own calculation in GRETL—an econometric software package.

On the basis of the conducted research, it is possible to state that the city population variable and the variables determining the level of outlays on fixed assets for environmental protection have a statistically significant influence on the quantity of municipal waste collected non-selectively. The only exception is the variable describing the level of outlays on recycling and reusing waste—the methods used for the analysis show that this variable has no statistically significant influence on the level of municipal waste collected non-selectively in cities. Due to the fact that the analysis covered the total quantity of municipal waste collected in cities, but without waste collected selectively, quantity reduction would be a positive observation. The signs of the estimated coefficients of the regression function are an indication of positive changes when it comes to the influence of outlays on fixed assets for environmental protection on the amount of collected municipal waste. Unfortunately, urban population is one of the factors influencing the amount of collected mixed municipal waste.

In order to examine the dynamics of change in the quantity of municipal waste collected non-selectively in cities and outlays on fixed assets for environmental protection,



chain indexes and annual average change rate for the years 2011–2019 were estimated. The results of the estimation are presented in Table 5.

**Table 5.** Annual average change rate for the years 2011–2019.

Voivodeships	WASTE_UA	POPULATION	OUT_TRANS	OUT_LAND	OUT_RECYC	OUT_RECLA
Dolnośląskie	−1.0%	−0.3%	17.2%	0.6%	14.7%	−19.7%
Kujawsko-Pomorskie	−2.2%	−0.5%	15.9%	−22.6%	−10.7%	−18.1%
Lubelskie	−2.7%	−0.4%	3.6%	3.9%	−32.4%	19.9%
Lubuskie	−0.7%	0.2%	14.9%	−28.4%	-	−100.0%
Łódzkie	−1.4%	−0.7%	−2.2%	−0.3%	−16.2%	−44.8%
Małopolskie	−0.4%	0.0%	35.5%	−25.9%	−20.3%	−29.9%
Mazowieckie	−1.3%	0.4%	36.5%	−9.2%	−4.4%	−28.1%
Opolskie	−2.5%	−0.2%	13.8%	35.1%	−100.0%	−9.8%
Podkarpackie	−0.4%	0.0%	1.7%	13.4%	−15.0%	−100.0%
Podlaskie	−1.4%	−0.1%	-	−2.8%	-	−100.0%
Pomorskie	−2.6%	−0.1%	13.1%	6.9%	46.6%	32.2%
Śląskie	−2.8%	−0.5%	6.4%	−17.9%	−12.2%	13.8%
Świętokrzyskie	0.6%	−0.3%	9.9%	38.4%	−100.0%	−100.0%
Warmińsko-Mazurskie	0.2%	−0.3%	−8.6%	−32.2%	−100.0%	−100.0%
Wielkopolskie	−1.7%	−0.2%	15.1%	5.4%	−20.1%	−31.6%
Zachodniopomorskie	−1.3%	−0.3%	16.4%	−19.3%	82.1%	−31.4%

The analysis of the dynamics shows that waste management activities realized in cities do not bring expected effects because:

- There is a minimal average annual decrease in the amount of mixed municipal waste collected in urban areas (from 0.5% to 2.8%);
- Outlays on fixed assets for environmental protection in the field of waste collection and transport, including collection and transport of municipal waste, show a faster annual average growth than the annual average quantity of waste collected non-selectively;
- The average annual outlays on fixed assets for environmental protection in the field of recycling and reuse of waste as well as reclamation of landfill sites and disposal facilities as well as devastated and degraded areas are decreasing.

A positive trend is observed in the annual average decrease in urban population that is slower than the average annual decrease in the amount of mixed municipal waste collected in cities (Table 5). The annual average level of outlays on the treatment and disposal of non-hazardous waste, including combined storage, is also decreasing, which can be treated as a positive trend due to the fact that landfilling is the least desirable method of managing waste. The decreasing levels of outlays on landfilling are the result of the decreasing amount of waste entering landfills.

Polish urban administrative bodies undertake all kinds of activities that influence urban waste management in a positive way. Activities realized in the selected Polish cities were identified on the basis of analysis of documents available on the Internet (Table 6).

**Table 6.** Actions for the zero waste philosophy in cities.

City	Activities
Katowice	<ul style="list-style-type: none"> <li>• Raising ecological awareness of the inhabitants through: <ul style="list-style-type: none"> <li>- Organizing contests and fostering pro-ecological behaviors in children through play;</li> <li>- Ecological games;</li> <li>- Educating inhabitants about eco-labels;</li> <li>- Organizing eco-picnics;</li> <li>- Conducting awareness-raising actions.</li> </ul> </li> <li>• Reduced rates for municipal waste management for numerous families entitled to a Large Family Card.</li> <li>• Collection of construction and demolition waste (rubble) from real estate renovations carried out by residents themselves as part of the municipal waste management fee.</li> <li>• Collection of Christmas trees.</li> </ul>
Warszawa	<ul style="list-style-type: none"> <li>• Introduction of a preferential program for inhabitants entitled to the Large Family Card and one-person households in difficult financial situations.</li> <li>• Directing waste to several facilities for purification, recovery of materials, disassembly, composting, or thermal treatment for the production of energy and heat.</li> <li>• Establishing a modern and ecological combustion plant.</li> <li>• Establishing facilities such as the Environmental Education and Recycling Center for recovery of raw materials.</li> <li>• Obtaining ecological approval for building a biogas plant where organic waste can be transformed into biogas and compost.</li> <li>• Free of charge acceptance of waste to be treated or recovered at the Points of Selective Collection of Municipal Waste.</li> <li>• Issuing guides: Ekosztuczki w ogrodzie (Eco-tricks in the garden) and Ekosztuczki w kuchni (Eco-tricks in the kitchen).</li> </ul>
Białystok	<ul style="list-style-type: none"> <li>• Producing electric energy and heat from waste with a high calorific value that is not suitable for recovery.</li> <li>• Organizing educational programs and excursions: lessons on waste segregation, visiting a combustion plant, visiting a waste-sorting plant, ecological contests, ecological games.</li> <li>• Availability of a mobile application that reminds the user of the waste collection date.</li> <li>• Linking fee rates for the collection of waste with the size of the household.</li> <li>• Exemption from a specific fee for the collection of waste from numerous families, owners of single-family residential buildings composting bio-waste constituting municipal waste in a household composter, and people in a difficult financial situation.</li> </ul>
Wrocław	<ul style="list-style-type: none"> <li>• Changing the system of selective collection of waste from the mixed type (“at the source” and “in the nests”) to “at the source” type only.</li> <li>• Strong diversification of fees, which motivates real estate owners to declare and practice selective waste collection; over 90% of owners chose to practice this type of selection.</li> <li>• Creating and extending the infrastructure for selective waste collection.</li> <li>• Providing the inhabitants with two Points of Selective Collection of Municipal Waste where they can dispose of problematic waste.</li> <li>• Conducting an extensive program of information and educational activities connected with municipal waste management, as well as the obligations of entities generating municipal waste.</li> </ul>
Częstochowa	<ul style="list-style-type: none"> <li>• Publication of information on important topics related to municipal waste management, waste processing and storage, and environmental education.</li> <li>• A 50% exemption from the waste disposal fee for numerous families including those in a difficult financial situation.</li> </ul>

Source: [82–86].

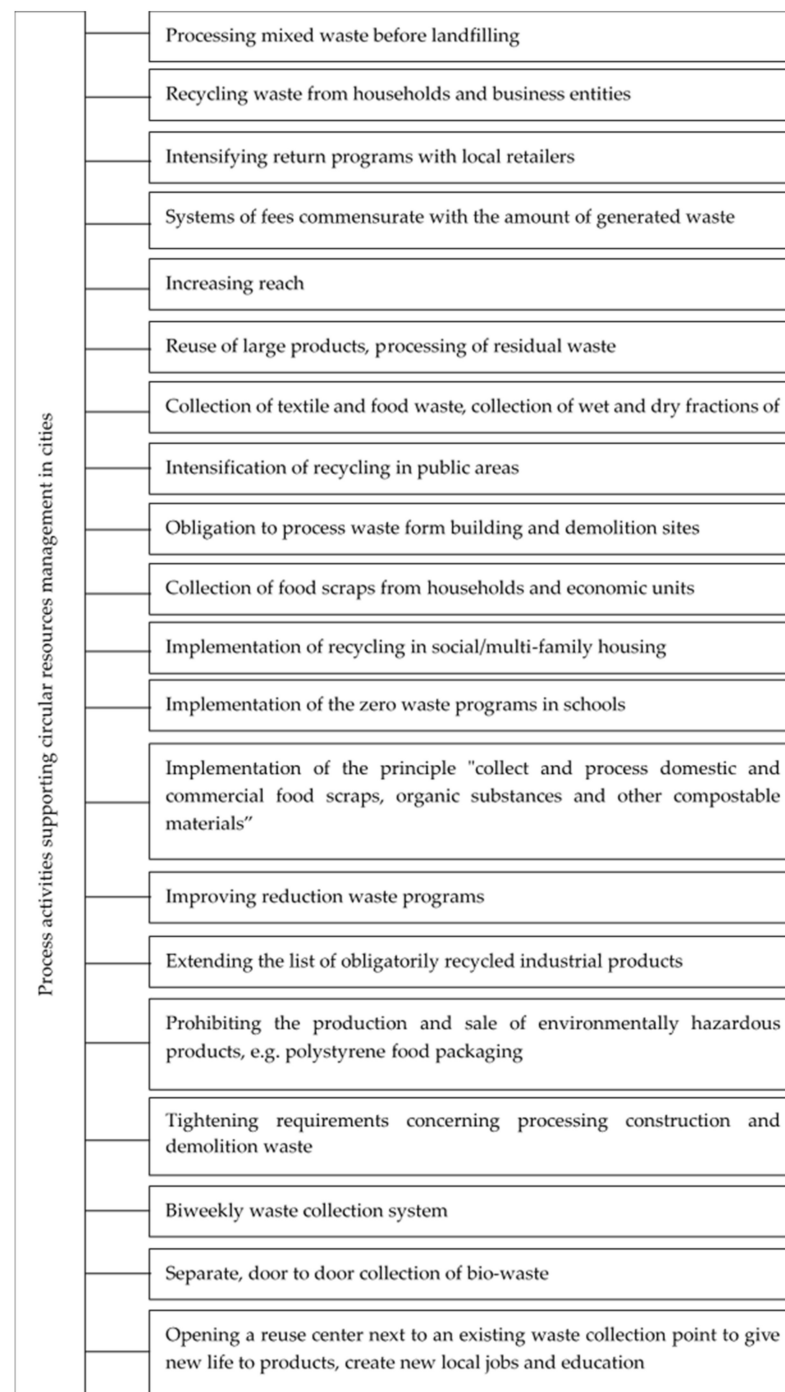
Activities carried out by cities in Poland are usually limited to the modernization of the existing waste management infrastructure, actions promoting pro-ecological behavior, and financial support in the field of waste disposal. There is a lack of activities for the intensification of the selective collection of waste, which, according to urban administrative bodies, is due to the fact that selling secondary raw material does not cover the cost of the functioning of urban waste management systems. There is an increasing number of raw materials on the waste management market either remain unsold or are bought for next to nothing, which means that cities cover the cost of processing them. Selling only some fractions of raw materials can bring profit because they are first purified at a waste-sorting plant. Following the introduction of new, demanding regulations and requirements, some of the waste recovery companies had to shut down.

#### 4. Discussion

In the EU's Seventh Environment Action Program to be achieved by 2020 entitled "Living well, within the limits of our planet", special emphasis is placed on turning waste into resources [90]. This change is to be led by such measures as prevention, reuse, and recycling and discontinuation of wasteful and harmful practices. These activities are consistent not only with the objectives of waste management but above all with their hierarchy. The main goal of a waste management system should be achieving the largest possible reduction of generated waste and the highest possible level of recycling. In other words, the system should contribute to the reduction of the quantity of waste that ends up in the natural environment. One way to prevent waste from entering the environment is to create closed-loop material cycles. In the context of closed material loops, the concept of waste goes beyond its usual definition. It is no longer defined as a useless product of processes carried out in an enterprise but rather as a valuable raw material that can be reused in the economic system. The creation of truly closed economic systems contributes to respecting the principle of sustainable development. City authorities no longer limit their activities to the mandatory organization of a municipal waste collection system in the city in the scope resulting from the Act of 13 September 1996 on maintaining cleanliness and order in communes, together with the Act's amendments. They go further to create environmental strategies with a broad range of goals and practices aimed at a significant reduction or even avoidance of waste. Such activities go hand in hand with the zero waste philosophy, which is gaining popularity in urban administrative units.

Improvements in waste management can be achieved through the effective approval and implementation of waste management policies [91,92]. In European cities, the initiatives undertaken in this area are bringing positive results [93]. Understanding the role of small and medium-sized enterprises in shaping the policy of sustainable development of cities can also contribute to effective waste management [94–96]. Research on the lifestyle and social behavior of residents is also necessary, as there is a need for fostering participation in waste management at the community level [97–101]. The research has shown that consumer behavior is a crucial factor in determining the long-term success of sustainable production and consumption initiatives [102].

Most urban waste management strategies feature both executive and organizational tasks. These tasks concern all groups of city stakeholders involved in producing, collecting, processing, and neutralizing municipal waste and organizing the waste management system. An important goal of these activities is to raise awareness of the urban community in the context of pro-environmental behavior. Unfortunately, these activities were not implemented in Polish cities to the same extent as in cities of other countries. Even though the actions taken go beyond the obligations resulting from the waste management legislation, they are still limited to standard solutions. Examples of cities reveal there is a need to undertake the activities supporting circular resource management in cities in the context of waste management [103–106]. These activities, broken down into process, awareness-raising, and aid, are presented in Figures 1–3.



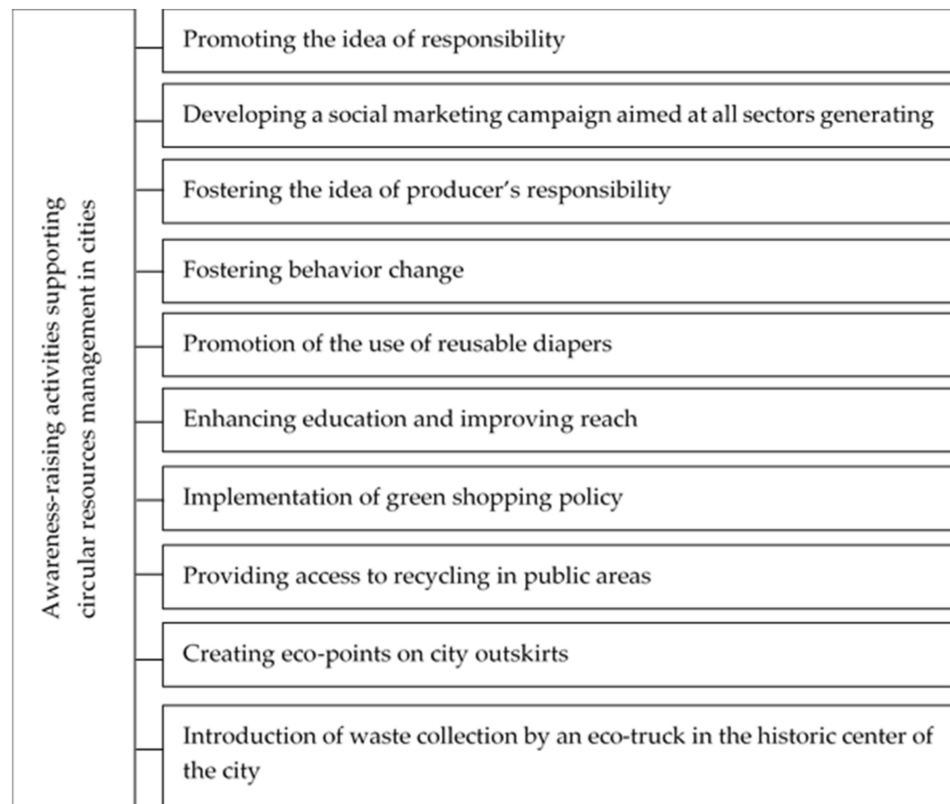
**Figure 1.** Process activities supporting circular resource management in cities.

It is, therefore, necessary to direct the activities of urban administrative bodies towards more innovative and effective solutions in the scope of waste management.

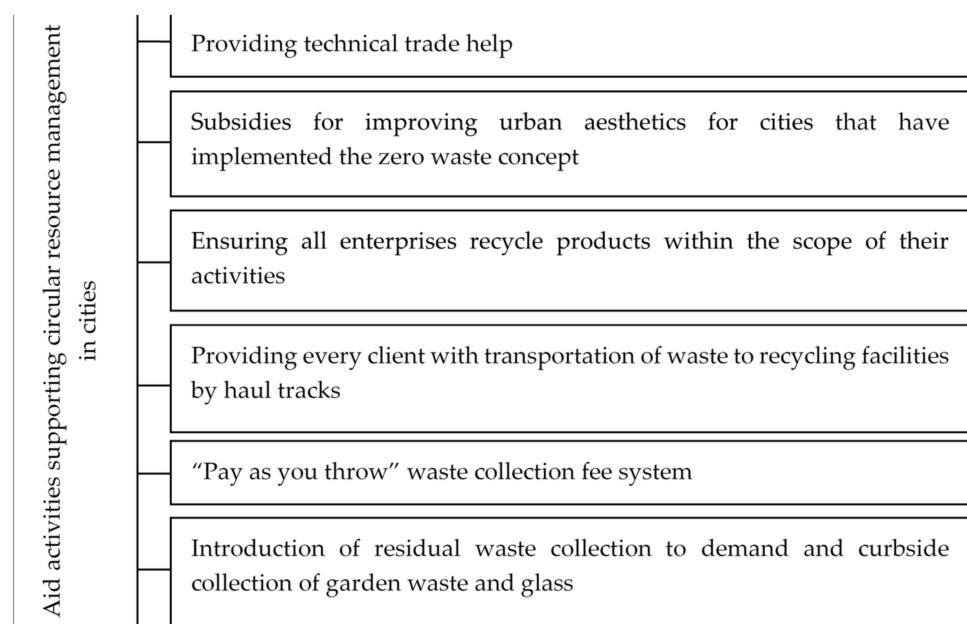
Polish cities should aim their activities at the reduction of the share of mixed municipal waste in the entire stream of collected waste (increasing the share of waste collected separately). This goal can be achieved by:

- Including all residential real estate owners in the system of selective collection of municipal waste;
- State-wide introduction of consistent standards for selective municipal waste collection to prevent the unacceptable division into dry and wet waste;

- Ensuring the highest quality of collected waste using appropriate systems of selective waste collection to make the recycling of collected waste as effective as possible.



**Figure 2.** Awareness-raising activities supporting circular resource management in cities.



**Figure 3.** Aid activities supporting circular resource management in cities.

Another challenge is introducing systems of selective collection of bio-waste at the source to help to reduce the quantity of biodegradable municipal waste to be landfilled. The research conducted in the area of circular economy in cities areas allows for the formulation

of guidelines supporting urban systems in supporting the principles of a circular economy, thus increasing their role in solving global problems of sustainable development [107].

## 5. Conclusions

Non-selective waste collection continues to be an issue that requires the implementation of systemic solutions, which involve financial outlays. Accordingly, the goal of this study was to assess the influence of outlays on fixed assets for environmental protection in the scope of waste management on the quantity of mixed municipal waste collected in cities. The conducted research showed that there is a statistically significant relationship between outlays on fixed assets for environmental protection and the quantity of municipal waste collected non-selectively in cities.

The problem of municipal waste in cities prompts urban administrative bodies to seek solutions for the reduction of waste quantity. The implementation of pro-environmental solutions in city strategy makes it possible to create closed economic circuits in which waste is returned to the system as full-value products. The introduced solutions result in the reduction of general quantity of waste but also in the increase in the levels of waste collected selectively for recycling and reuse. It should be noted that the properties of municipal waste make it suitable for processing or disposal in a manner other than by landfilling. For this reason, the activities realized by cities, which should translate into an increase in the quantity of waste collected selectively, were identified. Unfortunately, the solutions used in this field in Polish cities are not as innovative as in other countries. Selective waste collection points in Polish cities are not as widely available as in foreign cities, and the lack of understanding of the mechanisms of nature and the limits of its exploitation leads to improper use of available solutions or even their rejection.

A major limitation of the research is the adoption of the expenditure for the entire voivodeship as a variable determining the level of expenditure on fixed assets for environmental protection in the field of waste management, without distinguishing the outlays on waste management in cities. Therefore, it would be reasonable to examine how the financial resources of cities will translate into effects in the field of waste management, especially with respect to the quantity of collected waste, both selectively and non-selectively. Research should also cover cities from other countries. Even though there are common guidelines in the field of waste management, e.g., within the framework of the European Union, individual countries realize different waste management policies, which are connected with different economic, social, cultural, and geographical conditions. Therefore, research should not be limited to options for financing projects. It is also important to compare the practices in terms of waste management implemented in the cities of different countries.

Furthermore, future research will focus on the assessment of the influence of specific actions undertaken by urban administrative units on the pro-environmental behavior of city residents in the field of, above all, sustainable consumption leading to a reduction in the amount of waste generated in general, as well as in the field of selective waste collection. Moreover, the ratio of costs to profits, and more generally speaking, analysis of the costs incurred as a result of the benefits obtained are integral to city management. This relationship expresses the efficiency of the functioning of urban systems. For this reason, an econometric cost–benefit analysis using the DEA methodology is considered the direction of future research.

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