Łukasz POPŁAWSKI • Aleksander GRZELAK • Paweł DZIEKAŃSKI

STILL TRADE-OFF OR ALREADY SYNERGY BETWEEN WASTE MANAGEMENT AND THE ENVIRONMENT? IN THE LIGHT OF EXPERIENCE AT THE LEVEL OF THE VOIVODESHIP IN POLAND

Łukasz **Popławski** (ORCID: 0000-0002-4147-3272) – *Department of Public Finance, Cracow University of Economics*
Aleksander **Grzelak** (ORCID: 0000-0002-4290-4740) – *Department of Macroeconomics and Agricultural Economics, Poznań University of Economics and Business*
Paweł **Dziekański** (ORCID: 0000-0003-4065-0043) – *Department of Economics and Finance, Jan Kochanowski University in Kielce*

Correspondence address:
Uniwersytecka Street 15, 25-406 Kielce, Poland
e-mail: pawel.dziekanski@ujk.edu.pl

ABSTRACT: The paper aims to identify the influence of waste management on the natural environment, taking into account spatial differentiation voivodeships in Poland. The article presents the results using a synthetic measure analysis. The research results refer to the mean for the years 2009-2011 and 2019-2021. The relationships between waste management and the environment in light of the presented research results are not yet synergistic or trade-off. No statistically significant regularities were found in this respect. Spillover effects for waste management between voivodeships from the perspective of Moran's spatial statistics were not observed either. In the case of the state of the environment, an increasing concentration of voivodeships with similar values of the synthetic coefficient on the state of the environment was noted. Low levels of waste management have a negative impact on the environment, so it is important to improve waste management towards a circular, closed economy model.

KEYWORDS: waste management, environment, voivodeship, synthetic measure, TOPSIS-CRITIC method

Introduction

The contemporary economic system faces the challenge of how to respond to development and increasing local needs, changes in quality of life and climate, depletion of resources, and deterioration of environmental quality (Heshmati, 2018). Overexploitation of resources and environmental degradation waste management problems deplete national wealth and can prove to be an ecological barrier to social development and affect the state of the environment. In recent decades, developed countries have experienced rising living standards coupled with increasing environmental problems. Economic development and increasing levels of consumption are associated with increased waste generation, which in turn contributes to climate change and resource depletion (Minelgaitė & Liobikienė, 2019) and increased negative environmental impacts.

The issue of waste management is part of the concept of sustainable development (Prus & Marszewska, 2009). The waste management system and its changes shape the impact on the environmental, economic, and social elements of the local economy, which in turn shape regional policy (Pires et al., 2011). Sustainable waste management requires a systemic treatment of waste, taking into account economic, social and, above all, environmental aspects. Waste has measurable values – material and energy (Famielec, 2017). Reducing waste landfills in favour of increased recycling leads to lower environmental impact, less energy resource consumption and lower economic costs (Eriksson et al., 2005). Waste is a symbol of the inefficiency of any modern society and a representation of misallocated resources. Although progress has been made in waste management, it differs from region to region (Zaman & Lehmann, 2013).

As the waste volume increases with economic development and, moreover, waste management is spatially differentiated, the question arises as to how waste management affects the environment at the level of regions (voivodeships). Therefore, the paper aims to identify the influence of waste management on the natural environment, taking into account the context of spatial differentiation (voivodeship level) in Poland. A research hypothesis is formulated: waste management has a significant positive impact on the state of the environment in Poland at the provincial level. The question is whether a higher level of waste management is associated with a better state of the environment at the regional level. Admittedly, the state of the environment depends not only on anthropogenic factors but also on natural factors. This is why we also took into account the dynamics of the phenomena under study in our research to diagnose whether a trend is developing related to the trade-off nature between waste management and the environment or already the synergistic nature of these relationships.

The addressed problems have both a scientific and an applied dimension. The first comes down to enriching the concept of the green economy (Ryszawska, 2013). The application dimension, on the other hand, concerns the formulation of recommendations for policymakers in the field of waste and environmental management.

This article presents the results using a synthetic measure analysis (TOPSIS-CRITIC method) to classify provinces by waste management and environmental status. The research results refer to the means for the years 2009-2011 and 2019-2021. It allowed the dynamic aspects of the studied phenomena to be captured, as well as the control of the phenomenon of deviations related to economic changes (occurring in the regional economy, i.e. at the level of voivodeships).

So far, the research topic undertaken has mostly been analysed separately, except for a few studies (Ozga, 2017; Kukuła, 2014). Therefore, this article is intended by the authors to fill the existing research gap. In addition, the motivation for undertaking the research was the practical application of the proposed research methodology by assessing the waste management of regions in Poland. The obtained results may be relevant for monitoring the progress of the impact of waste management on the natural environment at the voivodships level.

An overview of the literature

Traditional waste management schemes have been based on what is known as the linear economy model, involving resource extraction, production, consumption and disposal phases in strict sequence. Landfilling of waste leads to methane emissions, explosions and the release of harmful

DOI: 10.34659/eis.2024.91.4.886

chemicals that can pollute groundwater, surface water and soil, threatening biodiversity and human health (Agovino et al., 2024). The need to change the approach to waste management is also driven by the need to reduce the valuable space required for waste disposal, treatment and storage (Michniewska & Grodkiewicz, 2017). This fits in with sustainable development as well as the concept of a green economy.

To improve resource efficiency, countries are moving from a linear economy to a circular economy, which aims to keep products, components and materials at their highest utility and value. The waste stream from many different sources in the economy, which is not properly managed, can lead to significant resource losses and cause serious environmental damage as underlined by Dong et al. (2019).

Slater et al. (2006), in a study based on experience in Greece, indicate that a waste stream that changes in composition over time and space requires the rationalisation of municipal waste management, as well as the establishment of management systems that ensures safe and systematic collection, economically viable logistics and efficient waste management services at all levels. They also postulate cooperation between private sector companies. This minimises economic costs and maximises environmental benefits. A study by Eriksson et al. (2005) (conducted in three Swedish municipalities, Uppsala, Stockholm and Êlvdalen) shows that reducing landfill in favour of increased recycling of energy and materials leads to a lower environmental impact. When planning waste management, it is important to know that the choice of disposal method influences processes outside the waste management system, such as the generation of heat, electricity, car fuel, plastics, cardboard, and fertilisers.

Significant differences in waste generation (including municipal waste) have been observed in the EU countries, as pointed out by Minelgaitė and Liobikienė (2019). The amount of waste generated depended on economic development. Efforts to reduce waste have significantly influenced recycling behaviour. This may influence the fact that the relationship between waste management and the state of the environment may not yet be synergistic. It is often emphasised in the literature on the topic that improving waste management will minimise negative environmental impacts in the future (Rautela et al., 2021; Perkumienė et al., 2023). Over the past two decades, the EU has strengthened closed-loop economy strategies. This promotes the development of sustainable waste management, which reduces the pressure on the environment. More secondary raw materials, as highlighted by (Chioatto & Sospiro, 2023), should return to industrial production, and this requires stronger intervention that goes beyond the waste sector. According to a study by Le Pera et al. (2023), an average of 452 kg of waste was produced per EU resident at the household level, of which only 39.9% was recycled. Selective waste collection allows more recyclable waste to be collected while reducing pollution, thus decreasing the pressure on the environment. A study by Baud et al. (2001) shows that waste management must pursue objectives that promote sustainability, i.e. optimising collection and minimising production, promoting reuse and recycling of waste, and reducing the carbon footprint. Studies to assess the environmental impact of waste management are mostly carried out at the national level (Devadoss et al., 2021). Meanwhile, there is little research at the regional level that addresses these issues. This provided additional motivation for writing this article.

Research methods

Empirical data were collected spatially for voivodeships in Poland. The selection of variables for the study was determined by the substantive usefulness in assessing waste management and the state of the environment, the analysis of the literature on the topic (Kukuła, 2014; Ozga, 2017), the authors' research experience, the variability of the variables (minimum 10%), as well as the availability of secondary data collected by the Central Statistical Office for the years 2009-2011 and 2019-2021. The years adopted for the analyses are simultaneously part of the programming periods of the EU funds (2007-2013; 2014-2020), which affect the use of the EU funds for improving environmental well-being.

The article uses a synthetic measure, which allows an evaluation to be carried out using an unlimited number of criteria. The research carried out was done in several consecutive stages:

DOI: 10.34659/eis.2024.91.4.886

1. Indication of the observation matrix of a set of diagnostic variables in the form of :

$$X_{ij} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2m} \\ \dots & \dots & \dots & \dots \\ x_{n1} & x_{n2} & \dots & x_{nm} \end{bmatrix}, \quad (1)$$

where:

X_{ij} – means values j-th (j = 1, 2, ..., m) variables for i-th (i = 1, 2, ..., n) object, the matrix of diagnostic variables describing of the objects in terms of waste management and ecology and environment (Strahl, 2000; Zeliaś, 1991).

Statistical verification of the variables was based on the assessment of the coefficient of variation (threshold value =0.10) and correlation (based on the inverse matrix, diagonal value =10) (Młodak, 2006). The study distinguished the following diagnostic variables, shown in Table 1.

Table 1. Diagnostic variables describing waste management and the state of the environment on a voivodeship basis in Poland for the periods 2009-2011 and 2019-2021

	Waste management	units	D-destimulant S-stimulant
X1	total waste generated per year per 1,000 inhabitants	thousand tonnes / per 1,000 inhabitants	D
X2	wild landfills eliminated – per year per 100 km^2 of total area	units / 100 km^2	S
X3	wild landfills per 100 km^2 of total area	units / 100 km^2	D
X4	number of landfills where municipal waste is disposed of with degassing installations	units/10000 inhabitants	S
X5	waste collected selectively in relation to total waste	%	S
X6	the surface area of active landfills where municipal waste is disposed of	ha / 10000 inhabitants	S
X7	separately collected electrical and electronic wastes during the year	t / 10000 inhabitant	S
State of environment			
X8	devastated and degraded land requiring cultivation	In ha	D
X9	forests (use of the voivodeship's area)	%	S
X10	ecological land	%	S
X11	share of legally protected areas in the total area	%	S
X12	industrial areas	%	D
X14	total gaseous emissions (including carbon dioxide) per 1 km^2 of surface area	t / km^2	D
X16	water consumption for the national economy and population – water consumption per capita	m^3 / inhabitant	D
X17	Industrial and municipal wastewater treated as % of wastewater requiring treatment	%	S
X18	population using sewage treatment plants as % of the total population	%	S
X20	number of nature monuments per 100 km^2	units / 100 km^2	S
X21	share of renewable energy in total electricity production	%	S
X1	total waste generated per year per 1,000 inhabitants	thousand tonnes / per 1,000 inhabitants	D
X2	wild landfills eliminated – per year per 100 km^2 of total area	units/ 100 km^2	S

Source: authors' work based on GUS (n.d.).

DOI: 10.34659/eis.2024.91.4.886

2. Zero-based unitarisation of diagnostic variables according to their types $X_j \in S$ according to the formula (Kukuła, 2000):

$$Z_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}, \tag{2}$$

Normalizing for a variable Xj ∈ D, the zero-based unitization is done by the formula:

$$Z_{ij} = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}, \tag{3}$$

where:
S – stimulant,
D – destimulant,
max_{xij} – the maximum value of the j-th variable,
min_{xij} – the minimum value of the j-th variable j,
x_{ij} – denotes the value of the j-th variable for the i-th object,
Z_{ij} – the normalized value of the j-th variable for the i-th object, the value belongs to the interval [0;1] (Kukuła, 1999; Kukuła & Bogocz, 2014).

The transformations resulted in the j-variable's unitarised values for the i-th object, presented as a matrix of – Z_{ij}:

$$Z_{ij} = \begin{bmatrix} z_{11} & z_{12} & \dots & z_{1m} \\ z_{21} & z_{22} & \dots & z_{2m} \\ \dots & \dots & \dots & \dots \\ z_{n1} & z_{n2} & \dots & z_{nm} \end{bmatrix}, \tag{4}$$

3. Determination of the weights of the variables using the CRITIC method (Criteria Importance Through Intercriteria Correlation). The weights in the CRITIC method are determined by the standard deviations and correlations between the variables. The method gives more weight to criteria with high standard deviation, high coefficient of variation and low correlation with other variables (Polcyn, 2022). Variable weights were determined using the following formulas:

$$w_j = \frac{C_j}{\sum_{k=1}^{K} C_k}, j = 1,2,\dots,K, \tag{5}$$

$$C_j = S_{j(Z)} \sum_{k=1} (1 - r_{jk}), j = 1,2, \dots K, \tag{6}$$

where:
C_j – is the measure of the information capacity of the jth variable j,
$S_{j(Z)}$ – is the standard deviation calculated from the standardised values of this variable,
r_{jk} – the correlation coefficient between a characteristic j-th and k-th.

The normalised values of the diagnostic variables are multiplied by the weighting factor w_j ($Z^*_{ij} = Z_{ij} \cdot w_j$) (Wang et al., 2023).

4. Calculation of the Euclidean distances of individual objects from the benchmark (=1) and the anti-benchmark (=0) (Wang et al., 2021).
5. The synthetic measure for individual voivodships was determined based on the formula (7) (Kozera et al., 2021):

$$q_i = \frac{d_i^-}{d_i^- + d_i^+}, \tag{7}$$

whereby:
$q_i \in [0; 1]$; d_i^- – denotes the distance of the object from the anti-benchmark (from 0),
d_i^+ – denotes the distance of the object from the benchmark (Łuczak & Kalinowski, 2020).

DOI: 10.34659/eis.2024.91.4.886

Determination of 4 groups of voivodeships in terms of waste management and environmental status, according to the value of the synthetic coefficient, using the median (Me) and the deviation of the median (S_(Me)). Grouping was done according to the formula (8):

$$\begin{array}{ll} \text{Group 1} & Me + S_{Me} \le q_i \\ \text{Group 2} & Me \le q_i \; Me + S_{Me} \\ \text{Group 3} & Me - S_{Me} \le q_i < Me \\ \text{Group 4} & q_i < Me - S_{Me} \end{array} \tag{8}$$

Of the spatial relationship testing tools, the analysis of the Moran's was used (Moran, 1950; Longley et al., 2006), which was calculated using PQStat software. The Moran's I global statistic makes it possible to check whether **neighboring** regions form groups with similar values of the synthetic measure. It is determined by the formula (10) (Upton & Fingleton, 1985):

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} wij(x_i-\overline{x})(x_j-\overline{x})}{S_O\ \sigma^2} \tag{9}$$

where:
n – number of spatial objects,
x_i, x_j – are the values of the variable for the objects being compared,
x – is the average value of the variable for all objects,
w_{ij} – elements of the spatial weight matrix,

$S_o = \sum_{i=1}^{n}\sum_{j=1}^{n} wij$, $\sigma^2 = \frac{\sum_{j=1}^{n}(x_i-\overline{x})^2}{n}$ – variance.

This statistic takes a value in the range (-1, 1), with a value of '0' indicating no spatial autocorrelation. Negative values indicate negative autocorrelation, i.e. units with different values of the studied characteristic appear next to each other in space (Zeliaś, 1991).

Results of the research

The synthetic coefficient of waste management ranged from 0.34 (dolnośląskie) to 0.58 (kujawsko-pomorskie) in 2009-2011 and from 0.38 (dolnośląskie) to 0.64 (opolskie) in 2019-2021 (Table 2). What draws attention is the change in the position of many voivodeships in the ranking due to waste management (Table 2, Figure 1). This indicates different dynamics of these processes in the studied period.

Table 2. Ranking of voivodeships by synthetic coefficient of waste management and environmental status for the periods 2009-2011 and 2019-2021

Voivodeships		Waste management 2009-2011	position	Voivodeships		Waste management 2019-2021	position
I	kujawsko-pomorskie	0.58	1	I	opolskie	0.64	1
	zachodniopomorskie	0.55	2		lubelskie	0.55	2
	opolskie	0.55	3		wielkopolskie	0.53	3
II	mazowieckie	0.54	4		zachodniopomorskie	0.52	4
	lubelskie	0.52	5	II	pomorskie	0.51	5
	małopolskie	0.50	6		małopolskie	0.51	6
	wielkopolskie	0.49	7		kujawsko-pomorskie	0.49	7
	pomorskie	0.49	8		śląskie	0.48	8
III	łódzkie	0.49	9	III	świętokrzyskie	0.47	9

Voivodeships		Waste management 2009-2011	position	Voivodeships		Waste management 2019-2021	position
	lubuskie	0.47	10		podlaskie	0.47	10
	warmińsko-mazurskie	0.46	11		podkarpackie	0.47	11
	podkarpackie	0.45	12		lubuskie	0.43	12
	podlaskie	0.45	13		łódzkie	0.43	13
IV	świętokrzyskie	0.38	14	IV	warmińsko-mazurskie	0.43	14
	dolnośląskie	0.37	15		mazowieckie	0.42	15
	śląskie	0.34	16		dolnośląskie	0.38	16
I	kujawsko-pomorskie	0.67	1	I	pomorskie	0.69	1
	warmińsko-mazurskie	0.67	2		lubuskie	0.68	2
	pomorskie	0.65	3		warmińsko-mazurskie	0.68	3
	lubuskie	0.65	4		podkarpackie	0.67	4
	podlaskie	0.63	5	II	zachodniopomorskie	0.65	5
II	podkarpackie	0.60	6		podlaskie	0.65	6
	małopolskie	0.57	7		kujawsko-pomorskie	0.64	7
	zachodniopomorskie	0.56	8		małopolskie	0.59	8
III	lubelskie	0.52	9	III	wielkopolskie	0.55	9
	łódzkie	0.52	10		dolnośląskie	0.54	10
	dolnośląskie	0.50	11		lubelskie	0.53	11
	wielkopolskie	0.49	12		mazowieckie	0.52	12
IV	mazowieckie	0.44	13	IV	opolskie	0.46	13
	opolskie	0.41	14		łódzkie	0.44	14
	świętokrzyskie	0.37	15		świętokrzyskie	0.41	15
	śląskie	0.36	16		śląskie	0.37	16

Source: authors' work based on GUS (n.d.).

The kujawsko-pomorskie, mazowieckie, łódzkie, warmińsko-mazurskie voivodeships clearly worsened their positions. This was particularly true for the mazowieckie voivodeship. This was due to a relative decline in the position in relation to other regions, especially in the case of partial indicators such as: selectively collected waste in relation to total waste or selectively collected electrical and electronic waste during the year (Broniewicz et al., 2022). This was associated with a significant improvement in waste collection infrastructure in the other regions. In the case of the mazowieckie voivodeship, waste management is shaped by dynamic urbanisation processes in the areas of the Warsaw agglomeration itself, as well as in their neighbourhood. It is also about a significant increase of waste in this voivodeship between the studied periods, with relatively weaker dynamics of development of infrastructure in the area of waste management. It should be noted that the mazowieckie voivodeship is very diverse internally. On the one hand, Warsaw and the neighbouring municipalities are characterised by a high level of development and a growing population. On the other hand, the other areas of the voivodeship are considerably less developed. Hence, this region is atypical in terms of the processes discussed. In the case of the following voivodeships: opolskie, lubelskie, wielkopolskie, pomorskie, podlaskie, świętokrzyskie and śląskie, there has been an improvement in the position and value of the synthetic coefficient. Particularly noticeable changes have taken in śląskie voivodeship as a consequence of, among others, an improvement in selectively collected waste and electrical equipment.

DOI: 10.34659/eis.2024.91.4.886

In the group of voivodeships with a high level of waste management (group I), there were 4 voivodeships (opolskie, lubelskie, wielkopolskie and zachodniopomorskie, 2019-2021). The last group with the lowest synthetic measure included 3 voivodeships: warmińsko-mazurskie, mazowieckie and dolnośląskie (group IV). The last mentioned voivodeship particularly 'stood out' in the high amount of waste generated per capita, as well as in the absolute dimension (Dziawgo, 2022). Voivodeships in cluster I were characterised by a significantly higher level in terms of the area of active landfills where municipal waste is disposed of or the number of landfills with degassing facilities (Table 3). It is also noteworthy that the waste generated per capita was not the lowest in comparison with other voivodeships for the period 2009-2011, although it was significantly lower in comparison with cluster IV. Interestingly, the voivodeships included in this cluster did not stand out in terms of wealth by the GDP per capita or the level of expenditure per capita. This would initially show that these issues do not play a key role in shaping waste management. The weakest group (IV) was described by the relatively highest value of the measure concerning generated waste. The area of active landfills where municipal waste is disposed of was the lowest there. In addition, the share of selectively collected waste was low, and the relative saturation of landfills with degassing facilities was low (cf. Table 3). Because the cluster included the Mazowieckie and Dolnośląskie voivodeships (2019-2021), the highest level of wealth was recorded among the separated groups. This would imply that the level of wealth does not translate into a high level of waste management.

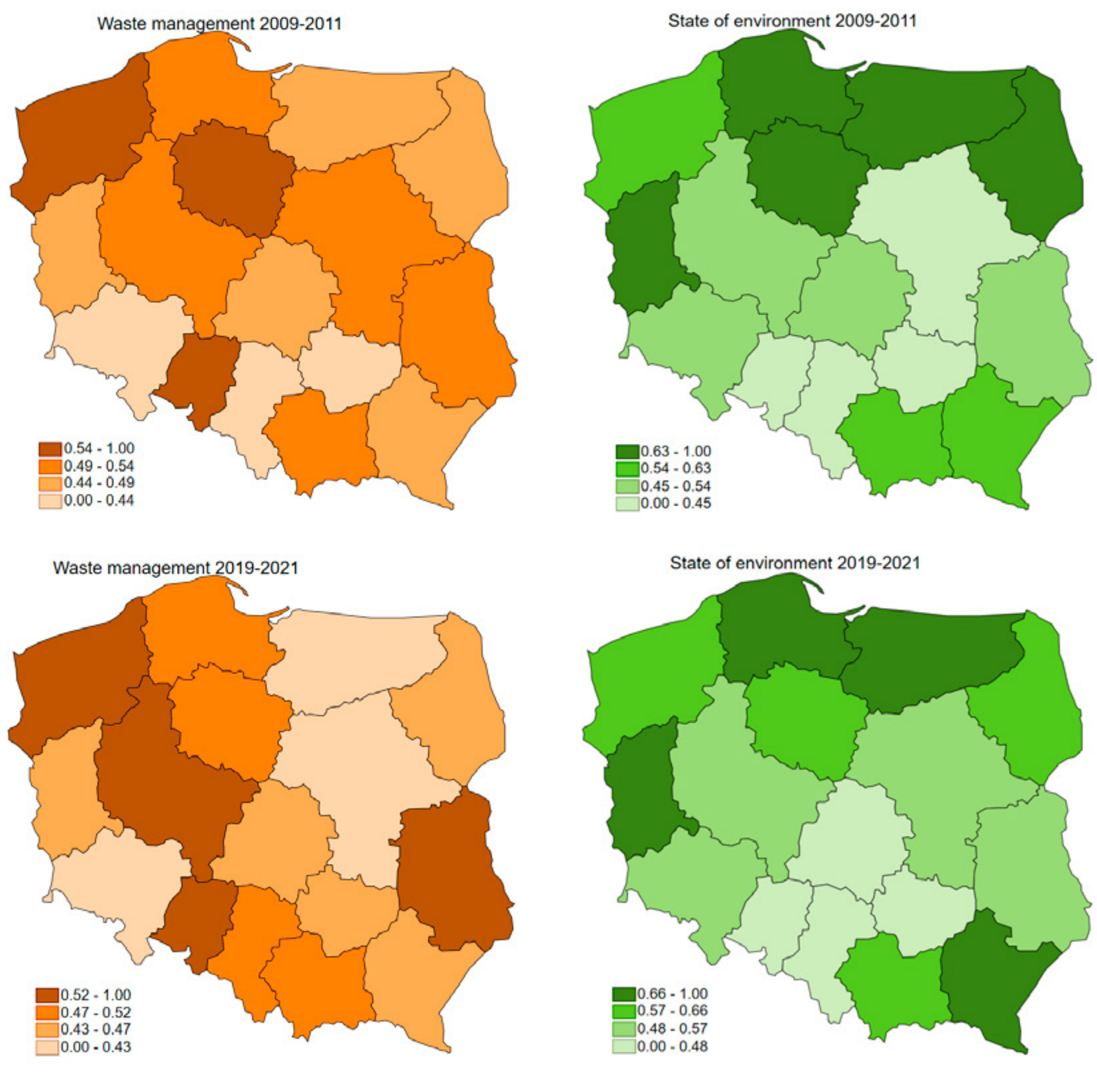

Figure 1. Spatial distribution of synthetic coefficient for waste management and the state of the environment in the voivodeships in Poland

Source: authors' work based on GUS (n.d.).

DOI: 10.34659/eis.2024.91.4.886

The state of the environment in the ranking of the voivodeships resulted from natural conditions as well as urbanisation and industrialisation processes. It is, therefore, not surprising that the śląskie voivodeship occupies the last place. This is due to the high emissions of gaseous pollutants in a relatively high proportion of industrial areas, including relatively developed mining. The unfavourable impact of this sector on the environment has already been raised many times in the literature (Zegardlo, 2022).

It should be noted that the Northern regions of Poland and the Podkarpackie region stand out positively in terms of the state of the environment (Figure 1). As in the case of waste management and the state of the environment, there were clear changes in the ranking of the voivodeships during the study period. The Kujawsko-Pomorskie and Łódzkie voivodeships clearly worsened their positions. On the other hand, Pomorskie, Zachodniopomorskie and Wielkopolskie voivodeships recorded an improvement.

Table 3. Selected characteristics of groups of provinces by synthetic waste management coefficient in Poland (cf. Table 1)

Specification	2009-2011				2019-2021			
	I	II	III	IV	I	II	III	IV
number of units	3	5	5	3	4	4	5	3
synthetic coefficient – waste management	0.56	0.51	0.46	0.37	0.58	0.5	0.45	0.41
synthetic coefficient – state of the environment	0.55	0.53	0.61	0.41	0.51	0.59	0.57	0.58
waste produced	1.84	1.63	1.08	6.92	1.82	2.51	1.88	4.66
surface area of active landfills where municipal waste is disposed of	1.25	0.63	0.72	0.53	0.68	0.5	0.49	0.4
wild landfills eliminated	1.95	5.33	2.52	5.51	2.04	7.39	1.97	2.36
wild landfills	1.08	1.36	0.69	1.89	0.58	1.25	0.57	0.55
waste collected separately	8.06	9.61	7.61	7.67	39.63	37.31	34.17	32.13
separately collected electrical and electronic waste per year	3.34	5.52	2.17	2.72	11.72	11.59	9.96	10.82
number of landfills with degassing facilities	0.16	0.11	0.1	0.09	0.12	0.06	0.08	0.06
forests	29.11	27.5	34.36	30.41	25.77	31.97	34.28	28.93
emissions of gaseous pollutants	747.1	526.68	500.92	1758.19	740.3	869.99	724.11	523.47
water consumption per capita	381.5	284.45	97.89	423	210.56	191.92	271.85	221.82
industrial and municipal wastewater treated as % of wastewater requiring treatment	93.89	95.84	98.38	84.29	99.73	95.21	96.66	96.65
emissions of gaseous pollutants	747.1	526.68	500.92	1758.19	740.3	869.99	724.11	523.47
population connected to wastewater treatment plants in % of the total population	71.51	60.81	66.47	66.28	69.71	77.99	71.9	77.93
share of renewable energy	24.1	10.14	22.71	6.31	19.58	35.77	30.48	34.38
population per 1 km^2	99.86	138.45	90.01	210.11	100.66	180	96.53	119.14
change in population per 1,000 inhabitants	1.52	5.59	3.17	1.51	-4.27	-2.53	-5.42	-2.29
GDP per capita	31527	39070	29726	373256	542287	574907	49709	71503
average monthly expenditures in households per capita	965	994	906	952	1224	1256	1124	1336

Source: authors' work based on GUS (n.d.).

Analysing the characteristics in terms of waste management (from the perspective of the synthetic coefficient) in Poland (Table 3), we note that in the groups of regions that stand out positively in this area, the highest values for the synthetic coefficient for the state of the environment were not recorded. Interestingly, its highest level was in the group of regions with a medium-low level of waste management (and thus in group III) for 2009-2011 and in group II (for the period 2019-2021). This

DOI: 10.34659/eis.2024.91.4.886

would indicate that the links between waste management and the state of the environment are not as obvious as they might seem. Attention is drawn to the improvements recorded in the reduction in the number of wild landfills, the increase in the share of selectively collected waste, or the increase in selectively collected electrical and electronic waste.

The signalled phenomena in the relationship between waste management and the state of the environment were also confirmed from the perspective of the Spearman rank correlation coefficient. For analysed periods, the coefficients were statistically insignificant. For the first (2009-2011) noted value 0.16 and slightly increased to 0.26 (2019-2021). Thus, it is not possible to conclude the occurrence of any regularity between these spheres, except that there was an increase in this relationship, despite the fact that it is still insignificant. Similar conclusions can be drawn from the research conducted in 2015 by Ozga (2017). They show that the relationship between waste management and the environment was very weak at the voivodship level.

The decrease from -0.11 to -0.19 in the value of Moran`s global spatial autocorrelation coefficient for waste management in the analysed periods means that the spatial dependence has worsened, i.e. the autocorrelation between voivodeships in this area has decreased (Table 4). This may mean that there is a tendency towards deconcentration in the area of the variable under study in a given region, although the correlations are weak and not statistically significant. Thus, in light of this, no spillover effects on waste management between regions were found. Meanwhile, as the results of other studies indicate, in the case of waste management, there may be effects of spillover for neighbouring cities (Zhang & Wang, 2020).

On the other hand, with regard to the environment (Table 4), the situation was the opposite, i.e. there was an increase in Moran's spatial autocorrelation from 0.225 to 0.370. Moreover, the correlations were statistically significant and slightly stronger in this case. This indicates a positive trend taking place in this sphere. Thus, there is an increasingly clear concentration of regions with similar values of the synthetic coefficient on the state of the environment.

Table 4. Moran's spatial statistics for the synthetic coefficient of waste management and state of the environment in voivodeships in Poland

Specification	waste management		state of the environment	
	2009-2011	2019-2021	2009-2011	2019-2021
Moran's global statistics	-0.110	-0.188	0.225	0.371
Significance level	p=0.773	p=0.414	p=0.049	p=0.0032

Source: authors' work based on GUS (n.d.).

Discussion and future research

The relationship between waste management and the environment is complex at the regional level in the following voivodeships: opolskie, wielkopolskie, and lubelskie (lower position in the ranking for the state of the environment and higher for waste management) (Table 2). On the other hand, in the following voivodeships, kujawsko-pomorskie, małopolskie, and łódzkie, the positions in these two analysed rankings were relatively similar. In the first two cases, the positions were high.

The lack of clear links between waste management and the state of the environment makes us reflect on the need to improve the first of these. The issue of waste management and its impact on the environment is particularly topical in Poland. This is not only due to the constant increase in the amount of waste but also due to the increase in the level of wealth of society or the limitations in effective management and utilisation (Grodzińska-Jurczak, 2001). This includes further methods of improving waste treatment through recycling, thermal waste conversion and neutralisation, increasing biogas production, or sustaining the trend of increasing the amount of waste recovered and recycled (Poniatowska et al., 2021). Also, causality analyses conducted for Switzerland (Magazzino & Falcone, 2022) demonstrate the presence of a unidirectional causal flow running from municipal waste and economic growth to greenhouse gas emissions. Thus, the synergistic nature of the links between waste management and the environment is only a perspective of the next decades.

DOI: 10.34659/eis.2024.91.4.886

An opportunity to reduce the negative impact of waste on the environment is the introduction of a closed-loop economy model. As indicated by the results of studies (Kotlińska & Żukowska, 2023), municipal waste management involves costs, and only a few municipalities in Poland manage to balance the income and costs of the municipal waste management system. Great attention should be paid to all pro-ecological activities, including those related to economically and ecologically justified new technologies (Drozda, 2009).

In order to evaluate the development tools used and policies implemented to date, the authorities can use knowledge of the relationship between the environment, waste levels and regional development. Empirical research on the relationship of the study area to CE, demographics and financial conditions is essential, which is related to the availability of diagnostic variables in Statistics Poland.

A limitation of the study was the insufficient availability of data on waste management at the regional level. Therefore, in order to effectively implement the circular economy, it is important to expand the collection of data by the GUS. This includes even more detailed data on recycling. Further lines of research in the relationship between waste management and the environment could proceed using structural models to diagnose latent relationships of sub-metrics. A microeconomic approach, i.e. examining these relationships at the level of municipalities with different levels of economic development and environmental state, also seems interesting.

Conclusions

Relationships between waste management and the environment in light of the presented results at the level of voivodeships in Poland are not yet synergic or trade-off nature (negative relationships). No statistically significant regularities were found in this respect; hence, the research hypothesis adopted in the introduction was rejected. On the other hand, the recorded trend in the growth of these relationships (between waste management and the state of the environment) is slightly increasing but still weak. There are examples of regions (e.g. Kujawsko-Pomorskie, Zachodniopomorskie) where a relatively high level of waste management coincided with a high position in the environmental ranking. On the other hand, we have the Łódzkie voivodeship, where both in terms of waste management and the state of the environment, distant rankings were recorded.

There were also no spillover effects for waste management between regions from a Moran spatial statistical perspective. In most situations, were voivodeships neighbouring to others with different levels of waste management, and trends in this respect, although weak and not statistically significant, did not indicate an improvement in the situation. In the case of the state of the environment, there was an increasingly clear concentration of regions with similar values of the synthetic coefficient of the state of the environment. This peculiar divergence in spatial autocorrelation between the voivodeships in these two spheres is due to the natural conditions, the advancement of urbanisation processes and the industrial development of the regions. It may also indicate that there is a greater need to coordinate activities in the waste management sphere at the central (or EU) level, even though it is mainly the local governments that implement the related policy. However, it is still difficult to conclude that there has been a breakthrough in this sphere of activity. Educational activities, social actions, and building the ecological awareness of society, as well as the field of waste management, are important.

Low levels of waste management have a negative impact on the environment, so it is important to improve waste management towards a circular closed economy model and thus increase recycling. The problem is all the greater as the volume of waste is expected to increase with further economic growth in Poland. Investment is needed in this regard, as well as the development of pro-environmental measures at the consumer (household) level. Improving waste management, therefore requires financial resources and active measures at the local government level, also including innovative solutions, e.g. smart waste containers.

The contribution of the authors

Conceptualization, Ł.P., A.G. and P.D.; literature review, Ł.P., A.G. and P.D.; methodology, Ł.P., A.G. and P.D.; formal analysis, Ł.P., A.G. and P.D.; writing, Ł.P., A.G. and P.D.; conclusions and discussion, Ł.P., A.G. and P.D.

The authors have read and agreed to the published version of the manuscript.

DOI: 10.34659/eis.2024.91.4.886

Acknowledgments

This research has been financed by the subsidy: of the University of Economics in Cracow (Program Potencjal nr 078/EFP/2022/POT and nr 23/EFA/2020/POT, of the Poznan University of Economics and Business (BS 2024 KMGŻ 51102-17-12); of the Jan Kochanowski University in Kielce.

References

Agovino, M., Cerciello, M., Musella, G., & Garofalo, A. (2024). European waste management regulations and the transition towards circular economy. A shift-and-share analysis. Journal of Environmental Management, 354, 120423. https://doi.org/10.1016/j.jenvman.2024.120423

Baud, I., Grafakos, S., Hordijk, M., & Post, J. (2001). Quality of Life and Alliances in Solid Waste Management: Contributions to Urban Sustainable Development. Cities, 18(1), 3-12. https://doi.org/10.1016/S0264-2751 (00)00049-4

Bećirović, S., Ibro, S., & Kalač, B. (2015). Environmental pollution and waste management. Balkan Journal of Health Science, 03, 2-10.

Broniewicz, E., Bukowska, J., Godlewska, J., Lulewicz-Sas, A., & Sidorczuk-Pietraszko, E. (2022). Climate change adaptation in ex-ante assessment of legal acts – a proposal of indicators for Poland. Economics and Environment, 82(3), 52-73. https://doi.org/10.34659/eis.2022.82.3.525

Chioatto, E., & Sospiro, P. (2023). Transition from waste management to circular economy: the European Union roadmap. Environment, Development and Sustainability, 25, 249-276. https://doi.org/10.1007/s10668-021-02050-3

Ciacci, L., Fishman, T., Elshkaki, A., Graedel, T. E., Vassura, I., & Passarini, F. (2020). Exploring future copper demand, recycling and associated greenhouse gas emissions in the EU-28. Global Environmental Change, 63, 102093.

Devadoss, P. S. M., Agamuthu, P., Mehran, S. B., Santha, C., & Fauziah, S. H. (2021). Implications of municipal solid waste management on greenhouse gas emissions in Malaysia and the way forward. Waste Management, 119, 135-144.

Dong, D. I., Tukker, A., & Van der Voet, E. (2019). Modeling copper demand in China up to 2050: A business-as-usual scenario based on dynamic stock and flow analysis. Journal of Industrial Ecology, 23(6), 1363-1380. https://doi.org/10.1111/jiec.12926

Drozda, M. (2009). Prawne, ekonomiczne i ekologiczne aspekty gospodarki odpadami niebezpiecznymi w powiązaniu z ochroną środowiska naturalnego. Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, 79, 52-63. https://dlibra.kdm.wcss.pl/publication/161235 (in Polish).

Dziawgo, E. (2022). Analysis of changes in waste generation and management in Poland against the background of EU waste management objectives. Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, 66(4), 41-56. https://doi.org/10.15611/pn.2022.4.03 (in Polish).

Eriksson, O., Carlsson Reich, M., Frostell, B., Björklund, A., Assefa, G., Sundqvist, J.-O., Granath, J., Baky, A., & Thyselius, L. (2005). Municipal solid waste management from a systems perspective. Journal of Cleaner Production, 13(3), 241-252. https://doi.org/10.1016/j.jclepro.2004.02.018

Famielec, J. (2017). Gospodarka odpadami komunalnymi jako działalność gospodarcza realizowana w ogólnym interesie gospodarczym. In M. Kożuch (Ed.), *Pomoc publiczna. Doświadczenia wybranych sektorów gospodarki* (pp. 117-150). Kraków: Fundacja Uniwersytetu Ekonomicznego w Krakowie. (in Polish).

Głowicka-Wołoszyn, R., & Wysocki, F. (2018). Problem identyfikacji poziomów rozwoju w konstruowaniu cech syntetycznych. Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, 508, 56-65. https://www.dbc.wroc.pl/dlibra/publication/64939/edition/44597?language=en (in Polish).

Grodzińska-Jurczak, M. (2001). Management of industrial and municipal solid wastes in Poland. Resources, Conservation and Recycling, 32(2), 85-103. https://doi.org/10.1016/S0921-3449(00)00097-5

GUS. (n.d.). *Database.* https://stat.gov.pl/en/databases/ (in Polish).

Heshmati, A. (2018). An Empirical Survey of the Ramifications of a Green Economy. International Journal of Green Economics, 12(1), 53-85. http://dx.doi.org/10.1504/IJGE.2018.092359

Kesri, M. (2021). Study on the Importance of Waste Management to Environment. International Journal of Advance Research and Innovative Ideas in Education, 7(1), 633-642.

Kim, Y., Chung, E.-S., Jun, S.-M., & Kim, S. U. (2013). Prioritizing the best sites for treated wastewater instream use in an urban watershed using fuzzy TOPSIS. Resources Conservation and Recycling, 73, 23-32. http://dx.doi.org/10.1016/j.resconrec.2012.12.009

Kotlińska, J., & Żukowska, H. (2023). Municipal waste management in municipalities in Poland – towards a circular economy model. Economics and Environment, 85(2), 175-197. https://doi.org/10.34659/eis.2023.85.2.565

Kozera, A., Dworakowska-Raj, M., & Standar, A. (2021). Role of Local Investments in Creating Rural Development in Poland. Energies, 14(6), 1748. https://doi.org/10.3390/en14061748

Kukuła, K. (1999). Metoda unitaryzacji zerowanej na tle wybranych metod normowania cech diagnostycznych. Acta Scientifica Academiae Ostroviensis, 4, 5-31. (in Polish).

Kukuła, K. (2000). *Metoda unitaryzacji zerowanej.* Warszawa: Wydawnictwo Naukowe PWN. (in Polish).

Kukuła, K. (2014). Regionalne zróżnicowanie stopnia zanieczyszczenia środowiska w Polsce a gospodarka odpadami. Przedsiębiorczość i Zarządzanie, 15(8), 183-198. (in Polish).

Kukuła, K., & Bogocz, D. (2014). Zero Unitarization Method and Its Application in Ranking. Research in Agriculture. Economic and Regional Studies, 7(3), 5-13.

Kuznets, S. (1955). Economic Growth and Income Inequality. The American Economic Review, 45, 1-28.

Le Pera, A., Sellaro, M., Grande, G., Bencivenni, E., & Migliori, M. (2023). Effect of quality of separately collected glass, paper plus cardboard and lightweight packaging waste on environmental, energetic and economic sustainability of the material recovery facility operations. Journal of Cleaner Production, 425, 138973. https://doi.org/10.1016/j.jclepro.2023.138973

Lenormand, M., & Deffuant, G. (2013). Generating a Synthetic Population of Individuals in Households: Sample-Free Vs Sample-Based Methods. Journal of Artificial Societies and Social Simulation, 16(4), 1-12. https://doi.org/10.18564/jasss.2319

Longley, P., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2006). *GIS. Teoria i praktyka.* Warszawa: Wydawnictwo Naukowe PWN. (in Polish).

Łuczak, A., & Kalinowski, S. (2020). Assessing the level of the material deprivation of European Union countries. PLoS ONE, 15(9), e0238376. https://doi.org/10.1371/journal.pone.0238376

Magazzino, C., & Falcone, P. M. (2022). Assessing the relationship among waste generation, wealth, and GHG emissions in Switzerland: Some policy proposals for the optimization of the municipal solid waste in a circular economy perspective. Journal of Cleaner Production, 351, 131555. https://doi.org/10.1016/j.jclepro.2022.131555

Malina, A. (2020). Analiza przestrzennego zróżnicowania poziomu rozwoju społeczno-gospodarczego województw Polski w latach 2005–2017. Social Inequalities and Economic Growth, 61(1), 138-155. https://doi.org/10.15584/nsawg.2020.1.10 (in Polish).

Michniewska, K., & Grodkiewicz, P. (2017). Zero odpadów – utopia czy rozwiązanie zbyt rozwiniętego konsumeryzmu? Logistyka Odzysku, 2(23), 39-43. (in Polish).

Minelgaitė, A., & Liobikienė, G. (2019). Waste problem in European Union and its influence on waste management behaviours. Science of The Total Environment, 667, 86-93. https://doi.org/10.1016/j.scitotenv.2019.02.313

Młodak, A. (2006). *Analiza taksonomiczna w statystyce regionalnej.* Warszawa: Difin. (in Polish).

Moran, P. A. P. (1950). Notes on Continuous Stochastic Phenomena. Biometrika, 37(1), 17-23. https://doi.org/10.2307/2332142

OECD. (2011). *Towards Green Growth.* Paris: OECD. https://www.oecd.org/en/publications/towards-green-growth_9789264111318-en.html

Ozga, P. (2017). Gospodarka odpadami a stan zanieczyszczenia środowiska naturalnego w Polsce w 2015 roku –przegląd regionalny. Metody Ilościowe w Badaniach Ekonomicznych, 18(2), 304-313. https://doi.org/10.22630/MIBE.2017.18.2.29 (in Polish).

Perkumienė, D., Atalay, A., Safaa, L., & Grigienė, J. (2023). Sustainable Waste Management for Clean and Safe Environments in the Recreation and Tourism Sector: A Case Study of Lithuania, Turkey and Morocco. Recycling, 8(4), 56. https://doi.org/10.3390/recycling8040056

Pires, A., Martinho, G., & Chang, N. B. (2011). Solid waste management in European countries: A review of systems analysis techniques. Journal of Environmental Management, 92(4), 1033-1050. https://doi.org/10.1016/j.jenvman.2010.11.024

Polcyn, J. (2022). Determining Value Added Intellectual Capital (VAIC) Using the TOPSIS-CRITIC Method in Small and Medium-Sized Farms in Selected European Countries. Sustainability, 14(6), 3672. https://doi.org/10.3390/su14063672

Poniatowska, A., Kisiel, M., & Panasiuk, D. (2021). Municipal Waste Management in Poland Compared to Other European Union Countries. Studia Ecologiae Et Bioethicae, 19(4), 85-95. https://doi.org/10.21697/seb.2021.19.4.07

Prus, P., & Marszewska, A. (2009). Perspektywy zrównoważonego rozwoju gminy Bytoń w opinii mieszkańców. Roczniki Naukowe Stowarzyszenia Ekonomistów Rolnictwa i Agrobiznesu, 11(4), 267-271. https://agro.icm.edu.pl/agro/element/bwmeta1.element.dl-catalog-dc51d214-90e8-4f34-bc8f-29fab43df925 (in Polish).

Rautela, R., Arya, S., Vishwakarma, S., Lee, J., Kim, K., & Kumar, S. (2021). E-waste management and its effects on the environment and human health. The Science of the total environment, 773, 145623. https://doi.org/10.1016/j.scitotenv.2021.145623

Ryszawska, B. (2013). Koncepcja zielonej gospodarki jako odpowiedź na kryzys gospodarczy i środowiskowy. Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, 318, 47-56. http://dx.doi.org/10.15611/pn.2013.318.04 (in Polish).

Slater, R., Frederickson, J., Thomas, C., Wield, D., & Potter, S. (2006). A critical evaluation of partnerships in municipal waste management in England. Resources, Conservation and Recycling, 51(3), 643-664. http://dx.doi.org/10.1016/j.resconrec.2006.11.008

Strahl, D. (2000). Możliwości wykorzystania miar agregatowych do oceny konkurencyjności regionów. In E. Sobczak (Ed.), *Gospodarka lokalna w teorii i praktyce. Prace Naukowe Akademii Ekonomicznej we Wrocławiu* (pp. 106-120). Wrocław: Akademia Ekonomiczna we Wrocławiu. (in Polish).

UNEP. (2011). *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication.* https://sustainabledevelopment.un.org/content/documents/126GER_synthesis_en.pdf

Upton, G., & Fingleton, B. (1985). *Spatial Data Analysis by Example.* New York: Wiley.

Wang, C., Wang, L., Gu, T., Yin, J., & Hao, E. (2023). CRITIC-TOPSIS-Based Evaluation of Smart Community Safety: A Case Study of Shenzhen, China. Buildings, 13(2), 476. https://doi.org/10.3390/buildings13020476

Wang, W., Qi, Y., Jia, B., & Yao, Y. (2021). Dynamic prediction model of spontaneous combustion risk in goaf based on improved CRITIC-G2-TOPSIS method and its application. PLoS ONE, 16, e0257499. https://doi.org/10.1371/journal.pone.0257499

Wójcik-Leń, J., Leń, P., Mika, M., Kryszk, H., & Kotlarz, P. (2000). Studies regarding correct selection of statistical methods for the needs of increasing the efficiency of identification of land for consolidation – A case study in Poland. Land Use Policy, 87, 104064. https://doi.org/10.1016/j.landusepol.2019.104064

Zaman, A. U., & Lehmann, S. (2013). The zero waste index: a performance measurement tool for waste management systems in a 'zero waste city'. Journal of Cleaner Production, 50, 123-132. https://doi.org/10.1016/j.jclepro.2012.11.041

Zegardlo, B. (2022). Ecological, technical and economic aspects of using flint wastes as aggregate for special concretes. Economics and Environment, 80(1), 125-148. https://doi.org/10.34659/eis.2022.80.1.441

Zeliaś, A. (1991). *Ekonometria przestrzenna.* Warszawa: Wydawnictwo Ekonomiczne. (in Polish).

Zeliaś, A. (Ed.). (1991). *Ekonometria przestrzenna.* Warszawa: Wydawnictwo PWE. (in Polish).

Zhang, Z., & Wang, X. (2020). Nudging to promote household waste source separation: Mechanisms and spillover effects. Resources, Conservation and Recycling, 162(9-10), 105054. http://dx.doi.org/10.1016/j.resconrec.2020.105054

Łukasz POPŁAWSKI • Aleksander GRZELAK • Paweł DZIEKAŃSKI

JESZCZE KOMPROMIS CZY JUŻ SYNERGIA MIĘDZY GOSPODARKĄ ODPADAMI A ŚRODOWISKIEM? W ŚWIETLE DOŚWIADCZEŃ NA POZIOMIE WOJEWÓDZTW W POLSCE

STRESZCZENIE: Celem artykułu jest identyfikacja wpływu gospodarki odpadami na środowisko przyrodnicze z uwzględnieniem przestrzennego zróżnicowania województw w Polsce. W artykule przedstawiono wyniki z wykorzystaniem analizy miar syntetycznych. Wyniki badań odnoszą się do średniej z lat 2009-2011 oraz 2019-2021. Relacje między gospodarką odpadami a środowiskiem w świetle przedstawionych wyników badań nie mają jeszcze charakteru synergicznego lub trade-off. Nie stwierdzono istotnych statystycznie prawidłowości w tym zakresie. Nie zaobserwowano również efektów spillover dla gospodarki odpadami pomiędzy województwami z perspektywy statystyki przestrzennej Morana. W przypadku stanu środowiska odnotowano rosnącą koncentrację województw o zbliżonych wartościach syntetycznego współczynnika stanu środowiska. Niski poziom gospodarki odpadami ma negatywny wpływ na środowisko, dlatego ważna jest poprawa gospodarki odpadami w kierunku modelu gospodarki o obiegu zamkniętym.

SŁOWA KLUCZOWE: gospodarka odpadami, środowisko, województwo, miara syntetyczna, metoda TOPSIS-CRITIC