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Criteria for the quality of the effects of waste management targets in 2015-2017 in the countries of the European Union

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Abstract: For many years, the amount of waste generated on a global scale has shown an increasing tendency and their management and logistic is becoming a growing problem for most countries in the world. Waste management is an important issue to be addressed, as it concerns the three basic pillars of sustainable development: social, economic, and environmental. Therefore, it seems necessary to take initiatives to reduce the amount of waste generated and improve the waste management system. The article aims to analyse changes in the way of waste management and logistics in the European Union countries and the classification of these countries on the basis of the achieved effects in waste management. The article analyses three selected factors that reflect the effects of achieving environmental objectives in waste management. The cluster analysis method was used for the analysis. It found that EU countries differ in the quality of the results achieved in waste management, depending on the achievement of environmental

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management and sustainability objectives. In addition, the results of the analysis showed that the time factor has a significant impact on the classification of countries. High dynamics of the quality of effects in waste management were observed in the period under review.

Keywords: waste management, waste logistics, energy, classification, European Union, quality, cluster analysis

1. Introduction

Waste management covers an entire range of activities related to waste management, from production to management through the recovery of secondary raw materials to environmentally and human-safe disposal. The issue of waste management due to its quantity, diverse composition and properties is overly complex and, at the same time, complicated. This is mainly due to two closely related aspects. The first concerns the increase in the weight of waste along with the increasing population, economic development, as well as the increase in the well-being of society (Achankeng, 2003). The second is related to the nuisance and threat posed by waste, especially dangerous for the environment and thus for humans. Therefore, the aim should be to establish detailed and precise legal and organisational rules for treating different types of waste, which should also translate into the practical application of these provisions (Gaidajis et al., 2010).

Municipalities mainly carry out waste management as part of tasks in the field of maintaining cleanliness and order, which, like the Waste Act, has undergone multiple changes related to the implementation of EU regulations into Polish legislation (Ustawa, 2012).

The measure of the effectiveness of waste management can be the relationship between the mass of waste subjected to the recovery process, because only in this way can its mass be reduced and used as a secondary raw material, to the weight of the waste subject to landfilling, which is considered the least effective method of their management. In this situation, it is even difficult to talk about their disposal because it consists only of placing them in one place and lying for many years, and if it is carried out improperly, i.e., without appropriate safeguards, this waste poses a threat to the environment and human (Afroz, et al., , 2009; Anand, 1999; Cheremisinoff, 2003).

In addition to administrative and legal instruments, consisting of the entire system of administrative decisions and other obligations imposed on entities involved in waste management, economic instruments are also important, including various fees and subsidies for co-financing projects in the field of organising or improving waste management. Finally, it is impossible to mention the criminal law system, which includes administrative fines and offences relating to the illegal handling of waste. These instruments complement the waste management system (Peszko-Doktor, 2018).

The authors conducted spatial and temporal research in the article to increase care for the natural environment.

The basis of the research process was a systematic literature review (SLR). The systematic literature review process used an in-depth technique to analyse the total content of the articles. The primary data source was the Web of Science (WoS) database. The resulting content analysis of 311 articles was selected from the Web of Science (WoS) database according to conceptual categories related to the research objective (keywords:) Waste; Economy; Energy; Classification; European Union; Quality; Cluster analysis.

As a result of this literature search, the authors identified methodological and application gaps in the research. They found insufficient studies proposing methods and ways to assess the quality and degree of achievement of the numerous goals set for countries in implementing a comprehensive concept of sustainability in all its areas, fields and orders. This paucity of literature represents a gap in methodological research. In addition, the authors found an insufficient number of studies presenting a comparative analysis or classification of EU countries according to the criterion of the quality of the effects of measures implemented in different areas of the comprehensive concept of sustainable development, taking into account the time factor.

This is undoubtedly an application research gap.

The identified research gaps prompted the authors to formulate a research problem in the form of two research questions:

1) How can EU countries be classified according to their achievement of waste management targets?

2) What is the impact of the time factor between 2015 and 2017 on the above-mentioned classification?

In order to solve the two-component research problem, the authors relied on the following research hypotheses:

H1: EU countries differ in their level of quality in meeting waste management targets and can be divided into three classes.

H2: Municipal waste generated in kg per inhabitant, municipal waste stored in kg per inhabitant, and municipal waste incinerated in kg per capita are among the factors that differentiate well between EU countries in terms of the level of quality of waste management tasks.

H3: The time factor affects the classification of EU countries according to the criterion considered.

In order to verify the research hypotheses, set in this way and thus solve the defined research problem, the authors adopted the classification of EU countries as the basic objective of the study based on three selected factors reflecting the effects of achieving environmental objectives in the area of waste management in the years 2015-2017. The data provided by the European Union for the years 2017-2023 do not include the effects of achieving environmental goals in the area of waste management covered by the study.

2. Literature review

Waste accompanies us practically at every step during living and professional work. Many times, we are not aware of the fact that our functioning is related to the generation of waste. Even if we are aware of this, we do not always realise the scale of this phenomenon. Only a visit to a landfill can make us realise this on a measurable scale. Moreover, our understanding of waste often boils down to this "final stage" of its disposal, which is a mistake. The issue of 'waste' should be considered even before it occurs, for example, considering eco-design principles. When referring to them, it is important to remember issues such as avoiding packaging, reducing its weight, and ensuring reuse or biodegradation. On the other hand, the LCA philosophy emphasises the environmental impact of the product throughout its life cycle, where the last (which does not mean the least important) element is the issue of final management (Azbar et al., 2004). However, to deal with this issue consciously, it is necessary to start from the basic thing, namely the essence, the definition of waste.

In everyday language, waste is considered to be all things considered unnecessary, that have lost their use value for us or do not fulfil their functions or tasks. Importantly, waste can also be considered an item (object) that still meets certain requirements but is no longer necessary for us. This is often due to purchasing new models or versions of the item, which replace the old, although still fully functional. Examples of such items can be computers, electronics, or home furnishings. It is natural that with the increase in residents' wealth and the development of technology and changes in fashion, these items increasingly become unnecessary for us, becoming waste.

There are many definitions of waste in the literature. One definition is that waste is "a product that has no use in the production of a given plant" (Barr, 2009). The 'human' aspect is omitted from this definition because it could be concluded from this definition that waste was generated only as a result of production processes, which is untrue. Nevertheless, this illustrates a narrow perception of the issue of waste. An extended definition is presented in the Universal Encyclopedia (Nowa Encyklopedia Powszechna PWN, 2004) of 1997, which defines waste as "by-products of human activity, useless in the place and time in which they were created, harmful or burdensome to the natural environment". Waste is also defined as a by-product associated with human activity, released into the environment in large or small quantities together with the original product but not useful at the place and time at which it was generated (Bagchi, 2004). Any material, raw material or final product that is not managed, does not have the indicated purpose, and is not used for a specific purpose may become waste. You can also define waste as objects that have lost their use value are unnecessary and no longer fulfil their basic functions. However, if a given thing has not lost its functionality but only we do not need it, it can also become a waste.

According to the Waste Act of 12 December 2012 (Gaidajis et al., 2010) waste is defined as "any object or substance that the holder discards or intends to dispose of or is obliged to discard".

Waste management has been defined in the literature as the generation and management of waste. Waste management, on the other hand, includes the collection, transport, recovery, and disposal of waste, including the supervision and control of such operations, the follow-up handling of disposal sites and the act of waste dealer or broker (Smol et al., 2018). Waste management should be carried out in such a way as to protect human life and health and the environment, and in particular pollution of water, air, soil, plants or animals, causing a nuisance by noise or odour, as well as adverse environmental effects on rural areas or places of special cultural or natural importance (System gospodarki odpadami komunalnymi w gminie miejskiej Kraków, 2018) should be avoided.

On the other hand, waste collection means collecting, sorting or mixing waste for transport. Storage of waste is the temporary storage of waste, which includes initial storage of waste by its producer, temporary storage of waste by the waste collector and storage of waste by the waste processor (Bayer et al., 2007).

In the literature, a waste producer is any entity which, as a result of its activity or existence, contributes to the generation of waste (this is the so-called original waste producer) and anyone who carries out pre-treatment, mixing or other activities causing a change in the nature or composition of this waste (Matuszko et al., 2020).

On the other hand, the holder of waste within the meaning of the law is a waste producer or a natural person, a legal person, or an organizational unit without legal personality, disposing of waste, i.e., disposing of it. It is also believed that the owner of the land is the owner of the waste located there (Bertram et al., 2002).

3. Waste performance characteristics

Waste accompanies us practically everywhere, both in our lives and at work. Many times, we are not aware of the fact that our functioning is related to the generation of waste (Demirbas, 2011; El Haggar, 2010; El-Salam, 2010; Eriksson et al., 2002). Even if we are aware of this, we do not always realise the scale of this phenomenon. Only a visit to a landfill site can make us realise this on a measurable scale. Moreover, our understanding of waste often comes down to this "final stage" of disposal – and this is a mistake. The issue of "waste" should be considered even before its creation, for example, considering eco-design principles (Fatta et al., 2003; Fillaudeau et al., 2006; Bovea, 2006). When referring to them, such issues as avoiding packaging, reducing its weight, ensuring reuse or even biodegradation should be considered. In turn, the LCA philosophy behavior the environmental impact of the product throughout its life cycle, where the last (which is not the least important) element is the issue of final management (Lee et al., 2011; Buenrostro et al., 2003; Gajalakshmi et al., 2008). However, to consciously address this issue, it is necessary to start from the basic thing, namely the essence, the definition of waste. In everyday language, we consider wasting all things considered unnecessary, which have lost their utility value for us or do not fulfil their functions or tasks. An item (object) may also be considered waste when it still meets certain requirements but will be considered useless (Gentil et al., 2009; Gottinger, 1988; Kaza et al., 2018; Haastrup et al., 1998). This often results from purchasing new models or versions of an object that replace the old ones, although still fully functional. Examples of such items include computers, home appliances, and home furnishings. It is natural that with the increase in residents' wealth and the development of technology and changes in fashion, items are considered unnecessary after some time and become waste (Haastrup et al., 1998; Caruso et al., 1993).

In dealing with waste, apart from the purely technical aspect, the environmental aspect should be equally important, if not dominant (Choe et al., 1999). It is also necessary to be aware that the seemingly "simple" disposal of waste also has a legal and social dimension. On the one hand, the designated legal conditions must be observed, regulating and guarding the proper waste handling. On the other hand, the production and disposal of waste is part of our lives and is therefore characterized by such concepts as social responsibility or local community. A very important thing when dealing with the issue of waste is that the handling of waste cannot be considered as a single action. It is a specific chain of activities and conditions comprising waste management. Of course, each element of this chain is governed by its own rules, but only their interconnection ensures proper waste management.

Waste management falls within the scope of environmental policy (Article 192 TFEU), the aim of which is to preserve, protect and improve the quality of the environment, protect human health and utilise natural resources prudently and rationally, in accordance with the obligations of the European Green Deal and the review clauses contained in Article 9(6) and (9) and Article 21(4) of Directive 2008/98/EC on waste.

The Waste Framework Directive establishes a waste hierarchy that prioritises waste prevention over (in order): their preparation for reuse, recycling, other waste recovery options and waste disposal. The Waste Framework Directive obliges Member States to introduce measures to prevent waste generation and separate collection of certain types of waste. It also provides for review clauses on prevention measures, food waste and waste oils. The European Green Deal includes a political commitment to make it easier for citizens to manage their waste and to provide companies with cleaner secondary raw materials.

The Waste Framework Directive aims to protect public health and the environment through proper waste management. This is done by applying the EU waste hierarchy, which prioritises waste prevention and reuse over waste recovery and disposal.

Closed-loop and sustainability must characterise all stages of the value chain in order to achieve a fully closed-loop economy: from design to production to the consumer. The European Commission identifies seven key areas necessary for a closed-loop economy. These are plastics, textiles, e-waste, food, water and nutrients, packaging, batteries and vehicles, buildings and construction.

A new monitoring area – global sustainability and resilience – has been added for 2023, as well as new indicators, particularly material and consumption footprints, greenhouse gas emissions from production activities, and material dependence on imports. The revised monitoring framework is based on the priorities of the circular economy in the context of the European Green Deal, the Eighth Environmental Action Programme, the 2030 Agenda for Sustainable Development and the EU's security of supply and resilience objectives.

Thus, the current monitoring framework for the circular economy consists of ten different indicators aggregated in five areas: "production and consumption", "waste management", "secondary raw materials", "competitiveness and innovation" (areas present in the earlier framework) and "global sustainability and resilience" (Special report, 2023; New Circular Economy, 2020).

Assessing the circularity performance in Europe

Unfortunately, there is little indication that the European Union will be able to meet its 2030 GOZ targets, according to a European Court of Auditors report. The European Union has made little progress in transitioning to a closed-loop economy (GOZ). According to the ECA, the existing strategies in EU member states for implementing a circular economy are too focused on waste management and not enough on waste prevention activities. The EU has made little progress in transitioning to a circular economy. Between 2015 and 2021, the average closed-loop indicator for all 27 EU countries increased by only 0.4 percentage points. Significant variation in closed-loop indicators is noticeable among EU Member States, with some countries using many times more recycled materials than others. As indicated, the greatest progress on GOZ has been made in the Netherlands, Malta, the Czech Republic and Estonia. The least in Poland, Finland and Luxembourg. In addition, the analysis showed that in seven EU Member States. There was a decrease in the closed-loop indicator between 2015 and 2021. These are Lithuania, Sweden, Romania, Denmark, Luxembourg, Finland and Poland.

The Court concludes that the European Commission and Member States have not effectively used the €10 billion allocated to the closed-loop economy between 2014 and 2020. The funds have been allocated to waste management rather than investments focusing on designing products and production processes for a closed loop. Although there is a greater emphasis on the circular economy in the 2021-2027 financial perspective, Member States can still choose to spend significant amounts of EU funds on waste management but not on waste prevention through circular design (Special report, 2023).

Assessing the relation between waste management policies and circular economy goals

Closed-loop circuits are essential to the wider industrial transformation towards climate neutrality and long-term competitiveness. It can deliver significant material savings in value chains and production processes, generate additional value and unlock economic opportunities.

Sustainably sourced materials have great potential and contribute to further developing the bioeconomy agenda. Closing the loop in production processes will be hugely dependent on the development of new technologies.

The transition to a circular economy has the potential to deliver benefits such as reduced environmental pressure, increased security of supply of raw materials, increased competitiveness, boosting innovation, economic growth (an additional 0.5% of GDP) and employment (700,000 new jobs in the EU alone by 2030). It can also provide consumers with more sustainable and innovative products, resulting in savings and a better quality of life. Redesigning materials and products for closed-loop use would also stimulate innovation in various sectors of the economy (New Circular Economy, 2020).

4. Possibilities of using energy fractions obtained from waste

The ban on storing energetic parts of waste, combined with the hierarchy of activities towards waste, may result in the need to redirect these parts to waste incineration plants. Incineration is the most frequently used method of recovering energy from waste. In this process, any waste can be transformed while reducing its volume by as much as 90%. Places where energy fractions of waste are used are often waste incineration plants and cement factories. One potential way to manage municipal waste is to produce alternative fuels (e.g., RDF – fuel derived from waste). These fuels must meet specific physicochemical parameters, such as high calorific value, ash content, moisture and volatile components, as well as appropriate chemical composition. Alternative fuels are produced mainly from production waste, packaging waste and combustible parts of municipal waste (such as paper, cardboard, fabrics, etc.), as well as from biomass waste and sewage sludge. They can be treated as a substitute for traditional fuels. Fuels obtained from waste are usually much cheaper on the market than conventional fuels, which makes them popular in industries that require high energy consumption (Modrzejewski, 2016).

The simplest methods of producing alternative fuels from urban waste (RDF, BRAM, PAKOM, SRF, EBS) are mainly limited to mechanical sorting and recovery of flammable elements, while the rest is deposited in landfills. However, more advanced technologies, such as ORFA, allow the processing of almost 90% of waste, and in addition to the production of fuel (so-called INBRE), many raw materials and semi-finished products can be recovered. Separated waste fractions or their mixtures can be used as alternative fuels in the cement industry, replacing traditional fuels.

The use of waste to produce energy has many ecological benefits, such as reducing the environmental burden resulting from its storage and economic benefits related to energy production in urban waste thermal treatment installations, which allows for reducing the consumption of traditional fuels. In the face of increasingly restrictive climate protection regulations and growing ecological and energy requirements, it can be said that developing infrastructure for energy recovery from waste is becoming an important element of the European Union's energy policy (KPGO, 2014).

Analysis of the calorific value of morphological waste fractions

Taking into account the data on the amount of municipal waste provided in KPGO 2022 (KPGO, 2022) and Kpgo 2014 (KPGO, 2014), it is possible to determine the mass of waste with energy value (value fuel >12 MJ/kg) produced by a resident of a specific region. KPGO 2014 presents different production levels depending on the area's nature. For example, for a large city, the municipal waste generation rate in 2008 was 386 kg/inhabitant/year (kg/M/year), for a small city 346 kg/M/year, and for a rural area 234 kg/M/year. If we consider these data, the mass of potentially generated energy waste in the municipal waste stream would be 150 kg/M/year for a large city, 100 kg/M/year for a small city and 52 kg/M/year for a rural area. KPGO 2022 assumes standardization of the municipal waste generation rate, regardless of the nature of the area. However, it predicts an increase in the rate in the following years, in accordance with two scenarios: the low hypothesis (the annual increase in the amount of municipal waste per capita is 0.6%) and the high hypothesis (the annual increase is 1%). The assumptions made regarding production rates in accordance with KPGO 2022 suggest that the mass of energy fractions generated in the municipal waste stream by 2025, taking into account the high hypothesis, will be approximately 122 kg/M/year for a large city and 91 kg/M/year for a small city. and 69 kg/M/year for the rural area. Forecasts for 2030 indicate an increase in the mass of generated energy fractions, and in the case of the high hypothesis, it will reach the level of approximately 129 kg/M/year for a large city, 96 kg/M/year for a small town and 73 kg/M/year for a rural area.

Table 1: Estimated rates of production of energy fractions in waste by residents

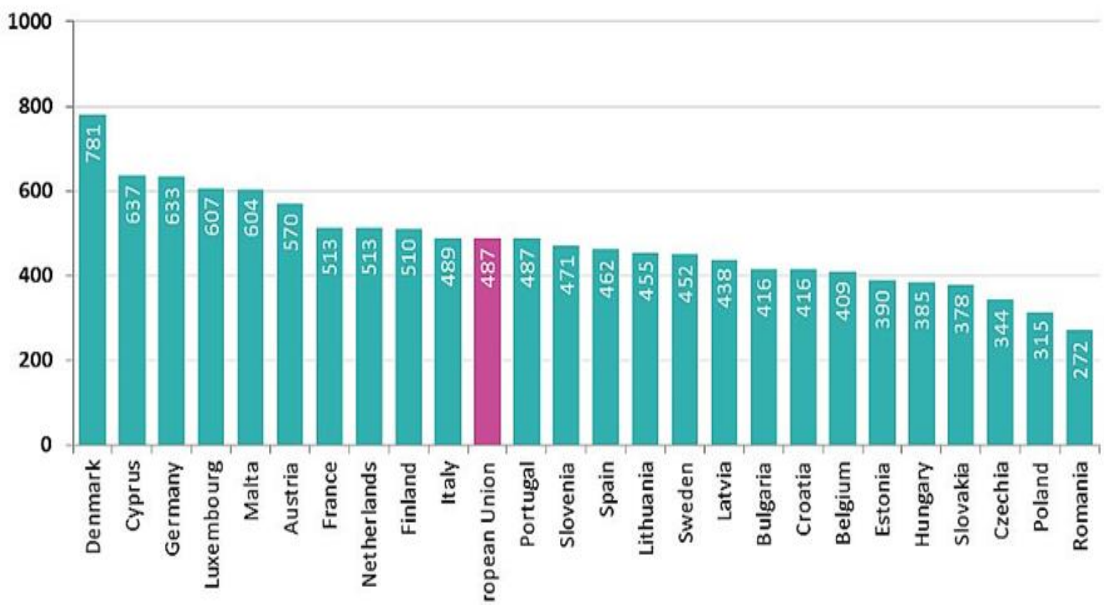
Parameter	Large city >50 000	Small city <50 000	Area Rural
Share of energy fractions (>12 MJ/kg) in the waste stream waste stream (paper and cardboard, plastics, multi-material waste, textiles, wood) [%].	39.0	29.0	22.2
The generation rate of energy fractions according to Kpgo 2014 [kg/M/year].	150.5	100.3	51.9
According to Kpgo 2022 [kg/M/year] in 2025, the generation rate of energy fractions.	117.8-122,1	87.6-90.8	67.0-69.5
Energy fraction production rate according to KPGO 2022 [kg/M/year] in 2030	122.5-128.7	91.1-95.7	69.7-73.3

Source: own study

5. Characteristics of waste in an international perspective

Despite a significant increase in the waste accumulation rate, the amount of municipal waste generated in Poland is still lower than in the European countries or the USA. The quantity of waste generated in European countries is as follows:

Figure 1: Amount of municipal waste per capita in the European Union in 2017



Source: Portal samorządowy 2023, https://www.portalsamorzadowy.pl/gospodarka-komunalna/unia-europejska-srednio-w-unii-487-kg-odpadow-komunalnych-na-osobe-w-polsce-315-kg,120289.html

The draft legislation imposes restrictions on the share of landfill sites in municipal waste disposal to a maximum of 10%, by 2035, in Poland, in 2016 it was 37%.

By 2025, textiles and hazardous household waste will be collected separately. By 2024, biodegradable waste will also be collected separately or recycled on-site through composting.

In line with the UN's sustainability objectives, Member States should aim to reduce food waste by 30%, by 2025 and 50%, by 2030. Member States should encourage collecting unsold food products and their safe redistribution to prevent food waste. Consumers should also be made more aware of the importance of the information on the labels on best before dates, "use by" and "best before", MEPs said (Christensen et al., 2007; Cointreau, 2006; Hassan et al., 2008; Hegde et al., 2007; Hoornweg et al., 2012).

In 2014, the total amount of waste generated in the EU-28 by all economic activities and households was 2,503 million tons, the highest amount recorded for the EU-28 between 2004 and 2014. Relatively large amounts of waste were generated in Bulgaria and Romania and relatively small in Italy. A large part of mining, quarrying, construction, and demolition waste is classified as main mineral waste. Almost two-thirds (64% or 3.2 tons per capita) of all waste generated in the EU-28 in 2014 was major mineral waste. The relative share of major mineral wastes in the total waste generation varied greatly between EU Member States. Figure 1 shows an analysis of the amount of waste generated in a standardized form in relation to population size. There is a high amount of waste generated in some of the smaller EU Member States, with a particularly high value in Bulgaria, with an average of 24.9 tons per capita in 2014, five times higher than in other EU Member States.

4.9 tons per capita on average across the EU28. Several Member States with particularly high levels of waste generated per capita reported a very high share of waste from mining and quarrying, while in other Member States, the share was often high for construction and demolition. In EU-28, 891 million tons of waste were generated in 2014, excluding the main mineral waste, corresponding to 36%. In the EU-28 in 2014, compared to the size of the population, an average of 1.8 tons of waste per capita was generated, excluding the main mineral wastes. Share of different economic activities and households in total waste generation in 2014. During the same period, an average of 1.8 tons of waste per capita, excluding the main mineral wastes, were generated in the EU-28. In the EU-28, construction represented 34,7 % of the total in 2014, followed by mining and quarrying (28,2 %), industrial processing (10,2 %), waste and water services (9,1 %) and households (8,3 %); the remaining 9,5 % was waste generated from other economic activities, mainly services (3,9 %) and energy (3,7 %) (Khetriwal et al., 2009).

Eurostat has been collecting and publishing data on municipal waste since 1995. In 2016, the total amount of municipal waste generated varies greatly, from 777 kg per capita in Denmark to 261 kg per capita in Romania. These differences are reflected.

6. Materials and methods

In order to solve a specific research problem, the paper's authors conducted a spatial-temporal study. Data from 28 countries belonging to the European Union were taken into consideration. The data concerned municipal waste management and were three characteristics of this area: municipal waste produced for one year per one inhabitant in kg, municipal waste stored in kg per one inhabitant and municipal waste incinerated in kg per one inhabitant. Due to the spatial and temporal nature of the research conducted, the data collected concerned two periods: 2015 and 2017. In total, observations on six variables were used in the study, which are collected in Table 2.

Table 2: Variables showing the effects of environmental activities in the area of environmental and spatial governance related to waste management (Xi – data from 2015, Yi – data from 2017)

Variable designation	Variable name
X_1, Y_1	municipal waste generated in kg per capita.
X_2, Y_2	municipal waste deposited in kg per capita.
X_3, Y_3	municipal waste incinerated in kg per capita

Source: own study

The survey was conducted on the population of EU countries. As the entire population (28 countries) was surveyed, the survey was complete. The data used in the survey come from the Central Statistical Office database.

The authors assumed that the overriding aim of the survey was to classify the EU countries according to the criterion of the quality of the effects of waste management activities based on the factors (variables) presented in Table 2 adopted in the survey. As a secondary aim, the authors determined to verify whether the proposed variables differentiate the countries according to the established criterion of assessing the quality of the environmental effects of waste management activities. In addition, the authors took into account the time factor in the study to check what effect it had on the change in the quality of the effects of the implemented environmental measures in individual countries.

Among the three variables selected as potential factors (variables) influencing the assessment of the quality of the environmental effects in the examined area, two pairs are stimulants, and one are destimulants. The variables that stimulate the quality of the effects of the environmental activities under consideration include X_2, Y_2, X_3, and Y_3. On the other hand, the variables whose higher values negatively affect the quality level of the effects of ecological activities in the examined area include X_1, Y_1.

The authors attempted to divide the population of EU countries into three classes, which will differ significantly in terms of the quality of the effects of implementing activities under the concept of sustainable development in the area of waste management, taking into account selected determinants. In addition, taking into account the time factor, the authors wanted to check whether it impacted the fact that some countries, through their actions, changed the group to a better or worse one in relation to the criterion taken into account.

In order to achieve the assumptions made before the study, the authors have chosen one of the methods of data exploration, which is the method of cluster analysis. Researchers in many fields of science and practitioners have long used this method. A list of applications of this method, together with its results, can be found in Hartingan's work. Based on the variables (characteristics) included in the study, the method distinguishes and groups objects in terms of their similarity to those variables. Similar objects classified into one group should maximally differ from objects classified into the other groups.

The cluster analysis method is a method of multidimensional statistical analysis. The method in question is a set of algorithms based on which the examined objects are grouped into clusters. Concentrations are created on the basis of calculated different measures of distance between objects. The distance measures used in cluster analysis include the square of Euclidean distance, Euclidean distance, Cherbyswald distance or urban distance. A detailed overview and characteristics of the distance function can be found in Grabiński's work (1992).

Objects in cluster analysis can be grouped by two independent methods: hierarchical and non-hierarchical. By dividing objects using hierarchical cluster analysis, clusters are created using iterative procedures. The most frequently used iterative procedure in hierarchical cluster analysis is the agglomeration algorithm combining successive objects into larger clusters until one cluster of all objects is obtained. Initially, the researcher does not know how many clusters should be divided into a set of examined objects. After the iteration procedure is completed, he makes decisions based on the analysis of a dendrogram or a graph of the course of the agglomeration. In the case of cluster analysis carried out using the non-hierarchical method, the researchers are forced to specify the number of clusters into which they want to divide the examined set of objects. These methods include grouping by the k-average method. This is the method most often used in practice. At the beginning, the number of clusters into which we want the set of examined objects to be divided is given a priori. Then, according to one of the available criteria, a set of objects is randomly divided into k random clusters. Next, the algorithm transfers objects between clusters according to the behaviour and behaviour variability criterion within a cluster.

An important issue to pay attention to is the assumptions required when using the cluster analysis method. Unlike many methods designed to analyse quantitative data, the cluster analysis method does not require variables to come from populations with normal distribution. However, researchers are forced to ensure that the sample taken for the study is representative. A lack of representativeness may lead to a distortion of the cluster structure. The second important restriction is that the variables (characteristics) on the basis of which objects are grouped should not be strongly correlated with each other (collinearity effect). The correlation of grouping variables, i.e., the effect of collinearity, makes it difficult to assess the real impact of individual variables on the division of objects. The last thing researchers have to consider before starting cluster analysis is to check for any outliers in the data. The cluster analysis method is very sensitive to outliers. Performing analysis without excluding outliers often leads to false cluster structure.

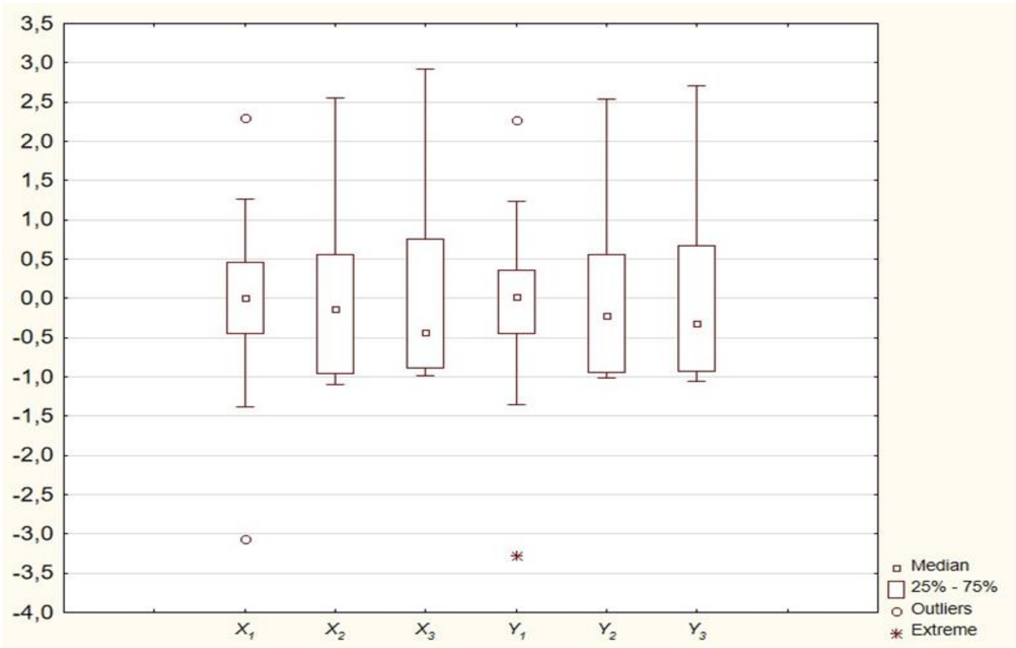
The realization of the study was carried out according to a previously drawn up study plan, which will be briefly presented. In the first step, observations on the variables from Table 2 for the years 2015 and 2017 were collected. The selection of the variables constituting potential factors differentiating and classifying countries in terms of the quality level of environmental effects in waste management was based on extensive literature studies and the author's experience in the studied area.

Using the selected observations on particular variables, the population of EU countries was divided into a specific number of groups (clusters). Each of the selected groups represents a group of countries which achieves a certain level of effects from implementing activities related to waste management within the framework of environmental and spatial order in the concept of sustainable development. The division of countries into a specific number of clusters was made using a non-hierarchical analysis of clusters carried out using the k – average method. The authors established that the countries would be divided into three clusters. The decision to divide the population of EU countries into three groups was supported by a previously conducted hierarchical cluster analysis taking into account different methods of cluster bonding.

7. Results

The first step in the study was to check one of the main assumptions of the cluster analysis method, namely whether there were any outliers among the observations on all the variables studied. There are many ways to check data for outliers in statistics. One is a frame diagram – a moustache, which the authors used.

Figure 2: Graphs of the moustache box on variables X_1, ..., X_3, Y_1, ..., Y_3 in order to meet. Identify outlying observations



Source: own study

The diagrams of the frame – the moustache for each variable are shown in Fig.2. It is clear that there are two outlier observations on the variable representing municipal waste in kg per capita both in 2015 and 2017. One is an outlier from above, and the other is from below. From the source data, the outlier is attributed to Denmark and the one from below to Ireland. For the reliability of the analysis results, the authors excluded these two objects from the study.

Table 3: Division of objects into clusters and the distance of each object from the centre of concentration. Data for 2015.

Concentration 1		Concentration 2		Concentration 3	
Object	**Distance**	**Object**	**Distance**	**Object**	**Distance**
Bulgaria	0.100209	Austria	0.107116	Belgium	0.431496
Croatia	0.230825	The Netherlands	0.146618	Estonia	0.519766
Cyprus	1.159825	Luxembourg	0.331929	Finland	0.455638
Czech Republic	0.615924	Germany	0.362820	France	0.388623
Greece	0.592522	Sweden	0.421745	Slovenia	0.322185
Spain	0.223917			Great Britain	0.188943
Lithuania	0.221440			Italy	0.293262
Latvia	0.173426				
Malta	1.265323				
Poland	0.713732				
Portugal	0.449870				
Romania	0.792229				
Slovakia	0.410955				
Hungary	0.366641				

Source: own study

Table 4: Division of objects into clusters and distances of each object from the center of concentration. Data for 2017

Concentration 1		Concentration 2		Concentration 3	
Object	**Distance**	**Object**	**Distance**	**Object**	**Distance**
Cyprus	0.233311	Austria	0.275807	**Bulgaria**	0.398551
Greece	0.410105	**Belgium**	0.462988	**Croatia**	0.535625
Malta	0.223881	**Estonia**	0.570028	**Czech Republic**	0.287768
		Finland	0.455272	**Spain**	0.332669
		France	0.348391	**Lithuania**	0.281782
		The Nether-lands	0.129369	**Latvia**	0.346585
		Luxembourg	0.505961	**Poland**	0.465124
		Germany	0.539629	**Portugal**	0.432456
		Sweden	0.286584	**Romania**	0.607549
		Great Britain	0.318171	**Slovakia**	0.238845
				Slovenia	0.588007
				Hungary	0.123646
				Italy	0.475449

Source: own study

Tables 4 and 5 contain the results of a non-hierarchical analysis of result clusters, which, for the 2015 and 2017 data EU countries were divided into three separate groups. Each of the designated groups is characterised by a different level of effects of implementing ecological activities in the area of waste management measured using three (variable) factors taken for research. In addition, Tables 4 and 5 contain for each country (object) the distance from the centre of their cluster to which the algorithm has allocated it. These distances are useful in assessing whether any of the countries do not differ from the cluster to which it was assigned or, in other words, whether it is not on the border of belonging.

Table 5: The average values of each dimension within the clusters. Data for 2015

Variable	Focusing 1	Focusing 2	Focusing 3
X_1	-0.217144	0.698111	0.045370
X_2	0.788470	-0.988276	-0.566087
X_3	-0.703476	1.194497	0.276150

Source: own study

Table 6: The average values of each dimension in the total cluster. Data for 2017

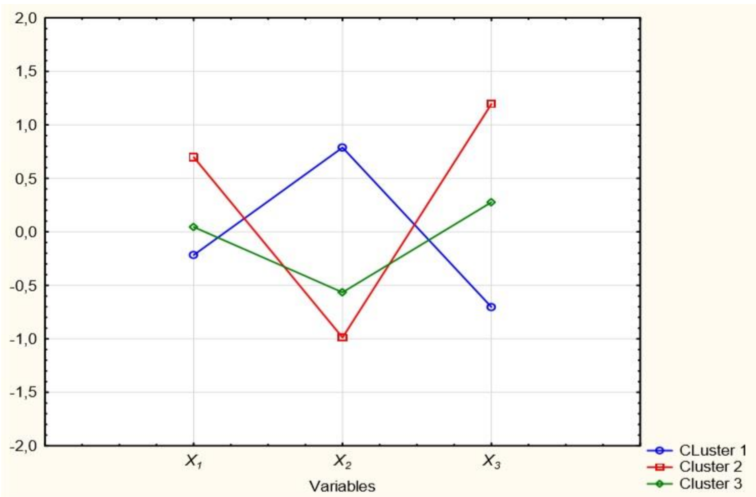
Variable	Focusing 1	Focusing 2	Focusing 3
Y_1	0.84923	0.316582	-0.361188
Y_2	2.19094	-0.776006	0.243102
Y_3	-1.03006	0.909621	-0.589613

Source: own study

Tables 5 and 6 contain the average values of three variables for each of the three clusters created, corresponding to the data from 2015 and 2017. In addition, to facilitate the analysis of the results, the data from Tables 5 and 6 are presented in the diagrams of average values in Fig. 2 and Fig. 3, respectively. The graphic presentation of these values facilitates the characteristics of individual clusters due to the variables studied.

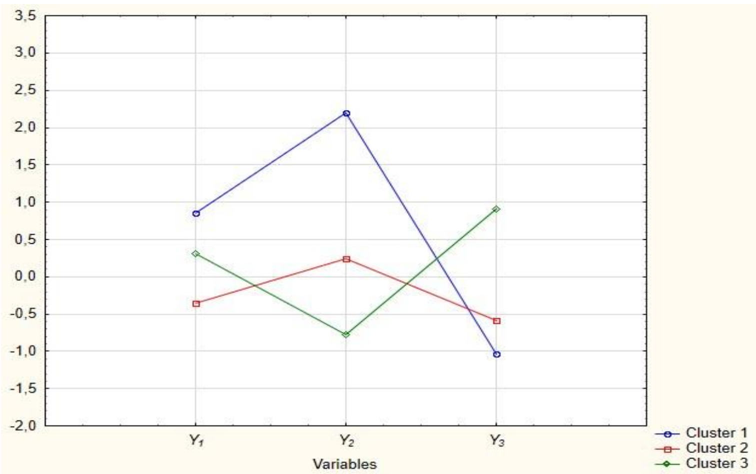
Based on the average values of individual variables and their nature in the aspect of the research problem being solved, a description of individual clusters will be made from the point of view of assessing the quality of the effects of environmental activities in the area of waste management. Before characterising individual clusters, it should be recalled that the variable regarding the amount of waste in kg per inhabitant is a destimulant as a factor illustrating the level of quality of environmental effects. On the other hand, the variable amount of waste stored and incinerated per capita as a factor illustrating the quality level of the effects of environmental activities are stimulants. This is synonymous with the fact that the higher the values reach stimulants, the higher the quality assessment of the effects of waste management activities.

Figure 3: A graph of the means of each dimension within each cluster. Data for 2015



Source: own study

Figure 4: A graph of the means of each dimension within each cluster. Data for 2017



Source: own study

Considering the above remarks and data from Tables 5 and 6 and the charts in Figures 2 and 3, it is possible to classify individual clusters for both considered periods. In 2015, the first cluster was classified the highest due to the fact that the average values for variables X1 and X2 are at the highest levels among all clusters, and only the average value of variable X3 is at the lowest level.

It also means that the countries that were included in the first cluster in 2015 are rated the highest in terms of the effects of ecological measures, taking into account the amount of municipal waste generated in kg per capita and the amount of waste stored per capita, but the worst take into account the amount of waste in kg per inhabitant burned in third place, the third cluster was classified in 2015. For this cluster, the average value for each of the three variables reaches the second level in relation to the other clusters. This can be said to be a cluster of countries which, on the background of the others, came out on average when it comes to the quality of the effects of waste management activities. The last place in 2015 was taken by the second cluster for which the average values of the variables X1 and X2 reached the lowest levels taking into account the nature of both variables, and the average value of the variable X3 reached the highest level among all clusters. It can be said that the countries classified in the second cluster achieved the lowest quality of waste management activities compared to other countries but achieved the highest quality of the effects of waste incineration activities.

By characterising clusters in the same way for data from 2017, it is obtained that this time, the third cluster is the best, with the average value for the first variable having the highest level in relation to the other clusters and for the other two variables, the average values reach the middle level. The second cluster came in second, and the first cluster last. In the first cluster, the effects measured by the number of wastes stored are at the highest level, and in the second cluster, the effect related to waste incineration is rated the highest.

Here, the impact of the time factor on the characteristics of the clusters and the migration of countries between the clusters should be analysed. Table 4 summarises the classification of countries into three groups according to data from 2017. In order to mark changes that took place between 2015 and 2017, the authors used the following symbols:

1) Bold typeface identifying the countries that changed the cluster in the period under consideration.

2) Countries in which the level of effects illustrating waste management activities have deteriorated over two years.

3) Countries in which the level of effects illustrating activities in the field of waste management have improved over two years.

Summing up the above signs, it should be emphasised that if the country is marked in bold black, it means that in 2017, compared to 2015, the focus changed, but the quality level of effects related to waste management activities remained at a similar level as in the year 2015. Among the countries that migrated between clusters during the period considered, two subgroups can be additionally distinguished: countries that have moved from the first to the third and the countries which have changed from the third to the second. In the first subgroup, there is a slight deterioration in the level of effects associated with waste storage and an improvement in the effects of waste incineration. However, in the case of the second subgroup, the opposite is true. Effects related to waste incineration activities have improved, and the effects related to storage have deteriorated.

The first subgroup included Bulgaria, Croatia, the Czech Republic, Spain, Lithuania, Latvia, Poland, Portugal, Romania, Slovakia, and Hungary. However, the second subgroup went to Belgium, Estonia, Finland, France, and Great Britain.

The countries marked in red in Table 4 without bold did not change their concentration, but the quality of waste management effects in 2017 compared to 2015 significantly deteriorated. These countries include Cyprus, Greece and Malta.

Table 4 contains another group of countries marked in green font without bold. This is how countries that did not change their concentration in the analysed period were marked, but the level of quality of effects related to waste management in 2017 compared to 2015 significantly improved. This group includes Austria, the Netherlands, Luxemburg, Germany, and Sweden.

Table 7: Results of variance analysis. Data for 2015

Variable	Intergroup variability	*df*	Intra-group variability	df	*F*	p_v
X_1	3.08863	2	9.229246	23	3.84855	0.036162
X_2	15.65496	2	8.889720	23	20.25171	0.000008
X_3	14.45100	2	2.896403	23	57.37685	0.000000

Source: own study

Table 8: Results of variance analysis. Data for 2017

Variable	Intergroup variability	df	Intra-group variability	df	F	pv
Y_1	4.82186	2	6.224011	23	8.90927	0.001365
Y_2	21.04110	2	3.861474	23	62.66328	0.000000
Y_3	15.87070	2	2.572703	23	70.94212	0.000000

Source: own study

At the end of discussing the test results, it is still necessary to briefly analyse the results of the variance analysis carried out for both periods, which are collected in Tables 7 and 8.

As a reminder, the analysis of variance carried out during cluster analysis is intended to confirm the correctness of the groupings received and thus confirm the correctness of the choice of grouping factors. In the analysis of variance carried out for cluster analysis, the results of factor variability within designated clusters are compared with the variability between clusters. The analysis assumed the significance level $\alpha = 0.05$. The p-value values calculated for each of the three factors in two periods are smaller than the assumed significance level. This means that the average values of all factors differ significantly in both periods. This is the basis for adopting the H2 research hypothesis that selected factors differentiate EU countries well regarding the quality of the effects of waste management activities.

8. Discussion

The research results conducted using the non-hierarchical method of cluster analysis with the support of the non-hierarchical method using data on the generation and disposal of municipal waste on the population of EU countries formed the basis for the two-component research problem defined in this work. Based on the obtained research results, it can be concluded that the EU countries implementing the objectives of the environmental and spatial order of the concept of sustainable development in the area of waste management are significantly different in terms of the level of quality of the effects of these activities. In addition, based on the obtained results, it was possible to divide the EU countries into groups that differed significantly in terms of the factors selected for division, illustrating the qualitative effects of the discussed activities in both analysed periods.

Based on the obtained results, the H1 hypothesis presented in the introduction that EU countries are differentiated in terms of the quality of the implementation of waste management objectives can be positively verified and can be divided into three separate groups.

In order to examine the impact of the time factor on the classification, research was carried out on data from 2015 and 2017. The test results described in detail in the previous section showed that the time factor had a significant impact on both classifications. The obtained results also showed a large migration of countries between clusters or, in other words. The results showed a high dynamic of the quality of effects related to the implementation of objectives in the area of waste management in the analysed period. These conclusions are the basis for accepting hypothesis *H3* presented in the introduction and, at the same time, constitute a solution to the second part of the research problem.

9. Conclusions

1. The study results showed that EU countries differ in terms of the quality of the effects of their actions in the field of waste management. There is considerable variation in the level of quality of these activities between countries.
2. EU countries have been divided into groups that differ significantly in the quality of waste management activities. The H1 hypothesis, assuming the diversity of EU countries in terms of the quality of implementation of waste management objectives, has been positively confirmed.
3. The results showed a large migration of countries between groups, which means high dynamics of quality effects of waste management activities.
4. The conclusions of the study confirmed the H3 hypothesis, assuming the impact of the time factor on the quality of achieving waste management objectives. The results of the research provide a solution to the second part of the research problem.

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Author contributions

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