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Contents
Spis treści

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Logistics supplying farms with production inputs

Logistyka zaopatrzenia gospodarstw rolnych w środki do produkcji

Abstract. The aim of the study was to illustrate the logistics of supplying selected farms with things of production in the form of synthetic fertilizers, plant protection chemicals, as well as spare parts for machines and fuel. The research was conducted in 2019 on a group of 50 agricultural producers running farms in the Radomsko district in the Łódzkie Voivodeship. The realized research shows that most of the checked farms purchase fertilizers on an annual basis, and plant protection products twice a year or more often. The decisive factor in the purchase of specific means of production is the price as a first one, but non-price factors also gain importance. In most of the farms the direct distribution is developing, where farmers purchase individual means of production from sales representatives on farms.

Key words: supply logistics, means of agricultural production, farm

Synopsis. Celem opracowania było zobrazowanie logistyki zaopatrzenia wybranych gospodarstw rolnych w środki do produkcji w postaci nawozów syntetycznych, środków ochrony roślin, a także części zamiennych do maszyn i paliwa. Badania przeprowadzono w 2019 roku na grupie 50 producentów rolnych prowadzących gospodarstwa na terenie powiatu radomszczańskiego w województwie łódzkim. Przeprowadzone badania wskazują, iż większość badanych gospodarstw rolnych nabywa nawozy raz w roku, a środki ochrony roślin dwa razy w roku bądź częściej. Czynnikiem decydującym o zakupie konkretnych środków do produkcji jest w pierwszej kolejności cena, ale znaczenia nabierają także czynniki pozacenowe. Rozwija się dystrybucja bezpośrednia, w ramach której rolnicy nabywają poszczególne środki do produkcji od przedstawicieli handlowych na terenie gospodarstw rolnych.

Słowa kluczowe: logistyka zaopatrzenia, środki produkcji, gospodarstwo rolne

Introduction

The process of globalization and the related technological progress determine changes taking place in many branches of the economy, which are always supported by broadly understood logistics. Market development gives economic units the opportunity to

innovate in many areas directly or indirectly related to logistics. They take place in supply logistics, production, distribution, as well as reverse logistics, known as ecological (reverse logistics).

The functioning of the state requires an effective economy, in the area of which the development of the agricultural sector, which is the product base for the agri-food industry, is of particular importance. The task of an efficiently functioning state apparatus is to provide citizens with food security, the achievement of which is possible only through cooperation between agriculture and the processing sector. For the proper functioning of agriculture, the efficient functioning of supply logistics is of particular importance, which is responsible for equipping farms with means of agricultural production (plant protection chemicals, fertilizers, feed, seeds, lubricants, oils, fuel, as well as spare parts for machines and devices and materials). reusable), in the right place and time, taking into account the specificity of agricultural production, which depends on natural conditions.

The aim of the article is to illustrate the elements of logistics of supplying individual farms located in the Radomsko district (Łódzkie Voivodeship) with selected means of agricultural production. The above-mentioned farms conducted mixed production (plant and livestock) and were characterized by a diversified arable land area and production profile.

Research methodology

For the research done in 2019, farms located in the Radomsko district in the Łódź Voivodeship were deliberately selected, because so far no analyzes have been carried out in this area in terms of logistics of supplying farms with means for agricultural production. 50 selected agricultural producers, representing individual farms conducting mixed production intended for the market, participated in the research. In the studied group, there were no units conducting only plant production or only animal production; always plants were grown and animals were raised in the test subjects. The structure of the researched farms was as follows: 1.01–4.99 ha (4%), 5.00–9.99 ha (12%), 10.00––19.99 ha (42%), 20.00–49.99 ha (32%) and over 50 ha (10%). The owners of the surveyed entities had secondary agricultural (42%), secondary non-agricultural (24%), higher agricultural (16%), higher non-agricultural (8%) and professional agricultural (10%) education.

The research was conducted using the guided interview method in the group of agricultural producers who are owners or users of farms using an interview questionnaire. They were mainly closed in nature with the possibility of single and multiple choice, but also open questions were asked. They concerned the process of supplying farms with means for agricultural production, taking into account such factors as the date of purchase of the desired materials, frequency and structure of purchases, method of delivery, storage period and others. When collecting the research material, the method of systemic information analysis focused on the analysis of secondary sources was used [Kędzior 2005].

The research results were presented using a descriptive, tabular and graphic technique.

Logistics of farm supplies

Supply logistics is the process of sourcing products and services for the enterprise. It is the beginning of the internal logistic chain in the economic entity; includes projects related to ordering, storage, collection, transport, determination of recipients' needs and rational consumption of goods, as well as maintaining appropriate stocks – evaluation, protection, control [Galińska et al. 2014].

Supply logistics understood in this way forces the creation of material flows at systematic intervals. For a business unit, the proper functioning of supply logistics may lead to a reduction of the company's operating costs and an increase in its competitiveness. Therefore, it is important to optimize supply logistics on an ongoing basis in such a way that it is not only perceived as an efficient transport of materials from the plant to the business unit. It should be considered as part of integrated production, which is the customer of supply logistics. Therefore, production should pose requirements to supply logistics, which in turn should be based on line-back-planning, i.e. designing the production system that is subordinated to the constraints and needs of production [Tyslik 2011].

Costs arising in the area of supply logistics, which should be rationally optimized, are determined by the application of three principles of external material supply:

- individual supply when materials are needed – this principle eliminates the need to store materials and therefore excludes storage costs. Its disadvantage is the risk of production downtime due to delays in material deliveries, as well as ineffective use of technological lines;
- procurement with maintaining stocks – this principle boils down to maintaining a certain level of stocks in the economic unit in order to meet the internal material demand at any time when there is a need to carry out the production process;
- delivery synchronized with the production process – the supplier is obliged to deliver materials on time, determined by the production schedule. This principle allows for keeping safety stocks at a minimum level, which means that storage costs are minimal [Pfohl 2001].

The enterprise and the farm should maintain stocks at an appropriate and optimal level, which ensures the implementation of the production process.

Supply logistics, consisting of a cycle of activities related to the purchase of products or services needed by the enterprise and in accordance with its requirements [Szymańska et al. 2019], is responsible for the integration of the process of the flow of raw materials and materials in the business unit. This integration is responsible for the synchronization of supplies, which means that the raw materials and materials from which the finished products are made reach the economic entity at the right time, as well as the right amount and in the right place [Kempa 2011].

The procurement logistics is closely related to the procurement process itself, which includes all activities necessary to acquire goods and services that are in line with the purchasing entity's expectations. Regardless of the industry, there are four phases – stages of the procurement process; they include collecting information about potential suppliers, selecting suppliers and establishing terms of cooperation, as well as evaluating suppliers and improving cooperation and terminating cooperation [Urbańczyk 2006]. You should be aware of the differences between procurement and supply logistics. The main

difference is that supply logistics differs from the procurement process primarily by the integrated concept of acquiring the means of production, which is always accompanied by information flow processes [Dyczkowska 2012].

Well-organized logistics in the field of supply makes it possible to manage the supply chain of means for production in farms in an economically and technically rational way, regardless of their size and organizational structure. It is important that the supply logistics take into account the seasonality of production in agriculture, the unpredictability of individual production processes, especially in the protection of plants against pests, as well as the infrastructural possibilities of farms (presence of warehouses), their economic situation and human resources. Reliable supply logistics is of particular importance in the case of animal production, where the lack of stocks of materials (feed) leads to irreversible effects and lengthening the production cycle in a branch characterized by the inability to suspend production [Wasilewski 2010].

The logistic system of an organizational unit which is a farm may be very simple or very complex. It depends on farm size, attitude and direction as well as other factors. Logistics of farm supplies includes not only the provision of materials needed to secure the production process in plant cultivation or animal breeding, but also storage (taking into account storage susceptibility), packaging and moving these goods within individual production departments. Supply logistics on a farm must cover all material needs in order to maintain the continuity of the production process while generating minimal logistic costs, which will affect its economic situation [Kuziemska et al. 2016].

The market of suppliers supplying farms with means for agricultural production is characterized by a high degree of flexibility and adaptation to the needs of agricultural producers. In a market economy, where in the agricultural sector there are many competing concerns and dealers of agricultural production means (this mainly applies to plant protection products, fertilizers and animal feed), an agricultural producer can consciously compare commercial offers and choose the best solutions for himself. The criteria for selecting companies supplying farms include, first of all, the prices of the means of production provided, but also the waiting time for the ordered funds, the possibility of transport to the farm, which is now standard, but also the possibility of returning unused batches of material. In addition, the possibility of crediting the purchased products and services or barter exchange (the entity provides the farm with plant protection products, fodder or fertilizers, and the payment is made in grain collected from the farm). Agricultural producers also appreciate agricultural consultancy provided by suppliers of means of production and collection of used packaging, pallets or oils.

Research results

Plant production conducted in all researched farms requires the use of various means of production, among which plant protection products (pesticides) as well as artificial fertilizers are of particular importance. The aforementioned measures affect the yield of crops, and this determines the efficiency of production. Therefore, it is important to obtain pesticides, as well as artificial fertilizers on conditions favorable to the farm (price of means, transport cost, payment date, waiting time).

The surveyed agricultural producers supply farms with fertilizers; 80% of respondents declare that they purchase nitrogen, phosphorus, potassium, calcium and multi-component fertilizers (NPK). Only 20% of the respondents obtain from the market three (out of five) types of fertilizers (multi-component fertilizers containing nitrogen, phosphorus and potassium, nitrogen and calcium), excluding the use of single-component phosphorus and potassium fertilizers. Artificial fertilizers are purchased once or twice a year (Figure 1).

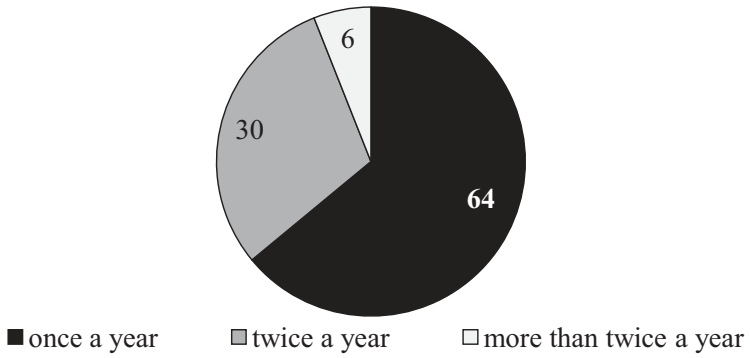

Figure 1. The frequency of purchase of artificial fertilizers by agricultural producers [%]
Rysunek 1. Częstotliwość nabywania nawozów sztucznych przez producentów rolnych [%]
Source: own study.

From among the researched farms, 64% of the farms supplied with fertilizers once a year, while 30% of the respondents made the purchase twice (before starting the spring vegetation and in autumn after sowing). Only 6% of agricultural entities purchase these funds three times. Interviews with agricultural producers and farm managers indicate that the frequency of purchase of fertilizers is determined by the economic condition of farms. Those in better economic condition purchase fertilizers once a year, while those less effective due to the lack of financial possibilities divide the purchase into two parts; spring and autumn. Among the surveyed producers, 70% indicated that the most important factor determining the frequency of purchase of synthetic fertilizers is the economic situation of farms defined at the time of their purchase, followed by the price of fertilizers (14% of responses), as well as the possibility of deferring the payment date or not (10 % of respondents) and no possibility of storage (4% of respondents); other factors were indicated by 2% of the respondents. It is important for agricultural producers to choose a supplier of synthetic fertilizers; the factors determining the selection of a specific farm operator in this respect are presented in Figure 2.

The dominant factor in choosing a supplier of artificial fertilizers is their price; such an answer was declared by 90% of respondents. 34% of the respondents indicated that an important factor in choosing a contractor is the possibility of barter exchange, which in their case consisted in replacing the grain produced on the farm with fertilizers. It is a practice that is increasingly used by agricultural producers; it requires adjusting the terms of delivering fertilizers to farmers and collecting crops from the farm; most often these processes are correlated to optimize transport costs. Supplying farms with fertilizers is always closely related to the logistic process, which is transport, the proper organiza-

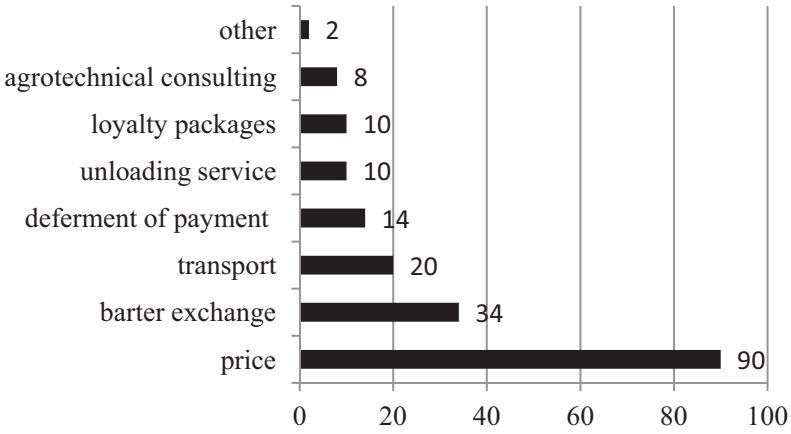

Figure 2. Determinants of selection of fertilizer suppliers for farms [%]
Rysunek 2. Determinanty wyboru dostawców nawozów do gospodarstw rolnych [%]
Source: own study.

tion of which can contribute to increasing the competitiveness of farms by optimizing the production volume and the costs of obtaining it [Wajszczuk 2016].

For 20% of the surveyed agricultural producers, an important issue is the possibility of delivering fertilizers to the farm, as they do not have their own means of transport, and 10% of farmers also expect to offer the service of unloading the delivered products, because these farms are not equipped with handling devices, and also that they do not have their own means of transport. They have manpower at their disposal to transship the purchased fertilizers. In the opinion of 14% of farmers/farm managers – the possibility of postponing the payment date for the purchased means of production is important in this area. The 10% of respondents point to loyalty packages used by the sector serving agriculture. For 8% of the respondents, agrotechnical advice provided by fertilizer suppliers is important, and other factors were indicated by 2% of respondents. The 70% of the surveyed farmers purchase fertilizers from sales representatives directly on the farm, 28% do it personally in wholesalers and other commercial entities; other sources were indicated by 2% of respondents.

The use of pesticides (plant protection products) is important for the functioning of a farm carrying out plant production. These, most often, are acquired twice a year – 70% of responses (Figure 3).

For 70% of agricultural producers declare that pesticides are purchased on farms twice a year. On the other hand, 10% of the respondents claim that they buy them once a quarter, and 4% once a year. The 16% of agricultural producers replied "more often", which means that plant protection products are purchased on the basis of field inspection based on the biological harmfulness threshold correlated with the economic profitability of treatments. Producers point out that this solution is rationale as the funds and economic resources are not frozen. Additionally there is no need to store pesticides on the farm premises (this would require specific conditions), and the situation when pesticides' expiration date during storage is no longer valid, can be avoided..

The researched farms mainly buy plant protection products from representatives of commercial enterprises who deliver pesticides directly to farms – 64% of respondents

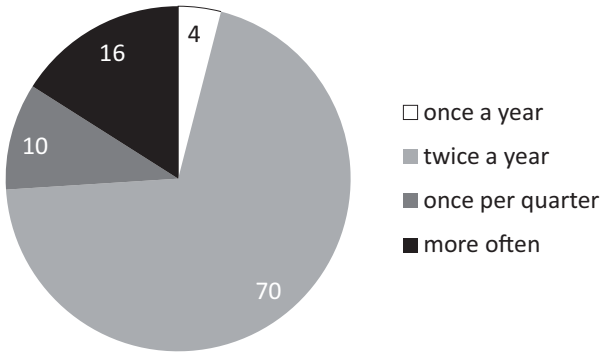

Figure 3.The frequency of purchase of plant protection products by agricultural producers [%]
Rysunek 3. Częstotliwość nabywania środków ochrony roślin przez producentów rolnych [%]
Source: own study.

choose this form of supply (Figure 4). The 22% respondents buy these products in shops and wholesalers, 8% of farmers make purchases online; others buy them directly from the producers; they buy from other farmers or indicate other sources of supply (2% of answers for each variant).

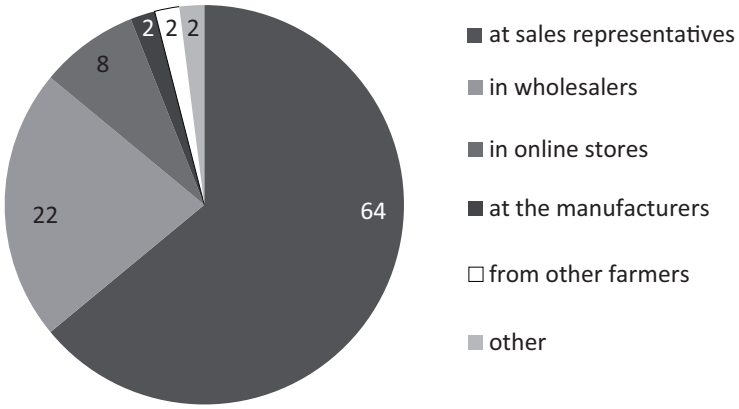

Figure. 4. Sources of supplying farms with plant protection products [%]
Rysunek 4. Źródła zaopatrzenia gospodarstw rolnych w środki ochrony roślin [%]
Source: own study.

For the functioning of farms, it is necessary to supply them not only with fertilizers and plant protection products, but also with spare parts for agricultural machinery and fuel. In the process of selecting suppliers of spare parts for agricultural machinery, the dominant criterion is the price, which was selected by 72% of the 50 surveyed agricultural producers (Figure 5). Purchase conditions (46% of indications) and the distance of the farm from the place of purchase (22%) are also an important factor in this area for farmers. The originality of the parts (12% of responses) and other factors indicated by 2% of respondents are less important.

In the group of factors determining the choice of the place of supplying the farm with fuel for agricultural machinery, the dominant factor is its price (90% of responses), as

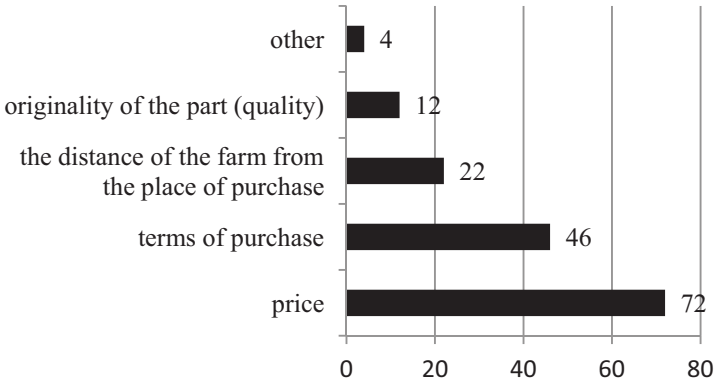

Figure 5. Determinants of selecting suppliers of spare parts for agricultural machinery on farms [%]
Rysunek 5. Determinanty wyboru dostawców części zamiennych do maszyn rolniczych w gospodarstwach [%]

Source: own study.

well as quality (84%), and then the distance from the fuel station to the farm (54%), the possibility of delivering fuel to the farm (48%) and the content of biocomponents (24%). Other factors were indicated by 2% of the respondents (Figure 6).

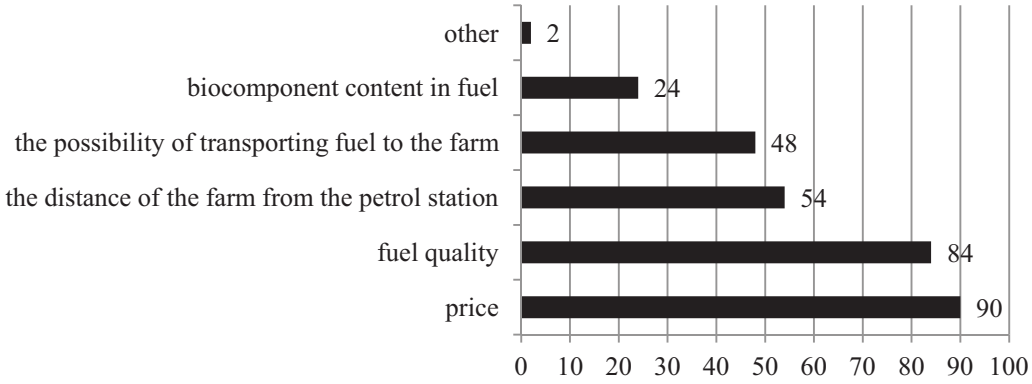

Figure 6. Determinants of the selection of fuel suppliers for tractors and agricultural machines on farms [%]
Rysunek 6. Determinanty wyboru dostawców paliwa do ciągników i maszyn rolniczych w gospodarstwach [%]

Source: own study.

The surveyed farmers declare that they order fuel from farms – 78% of the surveyed buy fuel on the farm from proven sources of supply. They have certified tanks as well as metal barrels enabling safe storage of diesel fuel for longer periods of time. The 14% of respondents purchase fuel at petrol stations, resigning from the service of delivering them to the farm, and 8% of farmers use a mixed system, in which they combine fuel supplies to the door with refilling them at filling stations. The 84% of agricultural producers purchase fuel twice a year, and 26% of the respondents declared that they do so more often.

In the opinion of the surveyed agricultural producers, the system of providing farms with means of production works correctly. Agricultural producers have no problems with the availability of fertilizers, plant protection products, energy drivers, consumables or other materials necessary for plant and animal production. Among the factors determining the choice of a supplier of means of production in agriculture, non-price factors (transport, the possibility of deferred payment terms, etc.) are playing an increasingly important role.

It should be remembered that supplying farms with means for agricultural production has a specific character, which results from the seasonality of production and its dependence on weather conditions. The frequency of deliveries is very often implemented based on the Just in Time concept (exactly on time); it mainly concerns plant protection products, the use of which is very precisely regulated by the development phases of plants and the rate of their infestation by pests (plant pests).

Summary and conclusions

Based on the research, the following conclusions were drawn:

1. Most farms obtain fertilizers once a year, while plant protection products (pesticides) are purchased by most operators twice a year.
2. The most important criterion for the selection of means for agricultural production in the researched farms is the price, but non-price factors (the possibility of barter size of crops – cereals – for means of agricultural production – fertilizers) are also gaining importance.
3. Agricultural producers more and more often purchase means of production directly on farms from sales representatives; it eliminates transport costs and saves their time.

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Economic and logistic conditioning of energy demand in logistics

Ekonomiczne i logistyczne uwarunkowania zapotrzebowania energetycznego w logistyce

Abstract. The study deals with economic and logistical conditions for the obtaining and use of various energy sources in the world. The first part presents the importance of energy in periods of human activity on Earth, from the time of gathering and hunting to modern times. It was pointed out how energy sources evolved based on successive innovations and inventions during subsequent periods of human development. The article presents the importance of individual energy sources in the modern world, indicating their logistical susceptibility in the field of extraction, storage and distribution. The length of periods of availability of non-renewable energy resources having the attribute of depletion was indicated using the Raw Materials Availability Index (RMAI). An analysis was made of the locations of individual energy resource deposits, stating that only a few countries have over 80% of global reserves, which means that other countries and societies depend on raw material monopolists.

Key words: energy, energy sources, economy, logistics

Synopsis. Opracowanie dotyczy ekonomicznych i logistycznych uwarunkowań pozyskiwania i wykorzystania różnych źródeł energii na świecie. W pierwszej części przedstawiono znaczenie energii w poszczególnych okresach ludzkiej aktywności na ziemi, począwszy od czasów zbieractwa i łowiectwa, aż po czasy współczesne. Wskazano, jak w trakcie kolejnych epok rozwoju ludzkości ewoluowały źródła energii poprzez kolejne innowacje i wynalazki. W artykule w szczególności zaprezentowano znaczenie poszczególnych źródeł energii we współczesnym świecie, wskazując ich podatność logistyczną w zakresie wydobycia, magazynowania i dystrybucji. Za pomocą współczynnika dostępności surowców (WDS) wskazano długość okresów dostępności nieodnawialnych surowców energetycznych mających atrybut wyczerpalności. Dokonano analizy miejsc występowania poszczególnych złóż surowców energetycznych, stwierdzając, iż zaledwie kilka państw dysponuje ponad 80% światowych rezerw, co powoduje, że pozostałe kraje i społeczeństwa są uzależnione od surowcowych monopolistów.

Słowa kluczowe: energia, źródła energii, gospodarka, logistyka

Introduction

All human activities and natural processes occurring in nature can be considered as energy transformations [Gradziuk 2015]. The progress of civilization is the pursuit of greater energy consumption, required to increase food harvest, to increase the efficiency and diversity of materials, or to produce more and more diverse goods and to create access to unlimited information. All this contributed to the increase in the population, organized into more complex social structures (states and transnational collectives) and contributed to the increase in the quality of life.

The long-term relationship between human achievement and dominant energy sources and changing prime movers is best seen when looked at in the context of epochs and energy transitions. The most obvious changes dictated by specific energy epochs can be observed in activities related to the extraction, transformation and distribution of energy.

Energy demand in hunter-gatherer societies was dominated by the provision of food, basic clothing and temporary shelters. Ancient, developed civilizations directed slowly increasing energy consumption into permanent shelters, the greater variety of cultivated and processed food, better clothing, transport and diversity of producers (charcoal was the dominant source of heat supply needed for smelting ores and firing bricks). In early industrial societies – with more pets, with the kinetic energy of water wheels and windmills, and with increasing coal mining – energy consumption per capita doubled, compared to that of the Middle Ages.

The divisions into specific energy epochs are unrealistic, however, not only because of the obvious national and regional differences during innovation and the widespread use of new fuels and engines but also because of the evolutionary nature of energy transformations [Melosi 1982, Smil 2010]. Specific energy sources and prime movers can be surprisingly constant, while new sources or techniques can only become dominant after a long period of gradual diffusion. As long as certain energy sources and prime movers work well in stable systems, they are easily available and highly cost-effective, their substitutes, even those whose attributes are better, will grow slowly. Draft animals, hydropower and steam engines have coexisted in industrialized Europe and North America for over a century. In the wood-rich United States of America, coal surpassed wood burning, and coke became more important than charcoal only in the 1880`s [Smil 2010].

By creating long-term patterns for the distribution of major prime movers in Old World pre-industrial societies, only suggestive approximations can be used. The most unusual feature of these patterns is the long dominance of human labor (Figure 1). Human muscles were the only source of mechanical energy from the beginning of the evolution of hominids to the domestication of draft animals, which began only about 10,000 years ago. Human strength was increased through the use of an increasing number of better tools, while the work of animals in the Old World remained limited for millennia by little use and inappropriate animal nutrition, and draft animals were absent in both the Americas and Oceania. Human muscles, therefore, remained indispensable prime movers in all pre-industrial societies.

The first inanimate prime movers began to make a noticeable difference in some parts of Europe and Asia only after 200 CE (waterwheels) and 900 CE (windmills).

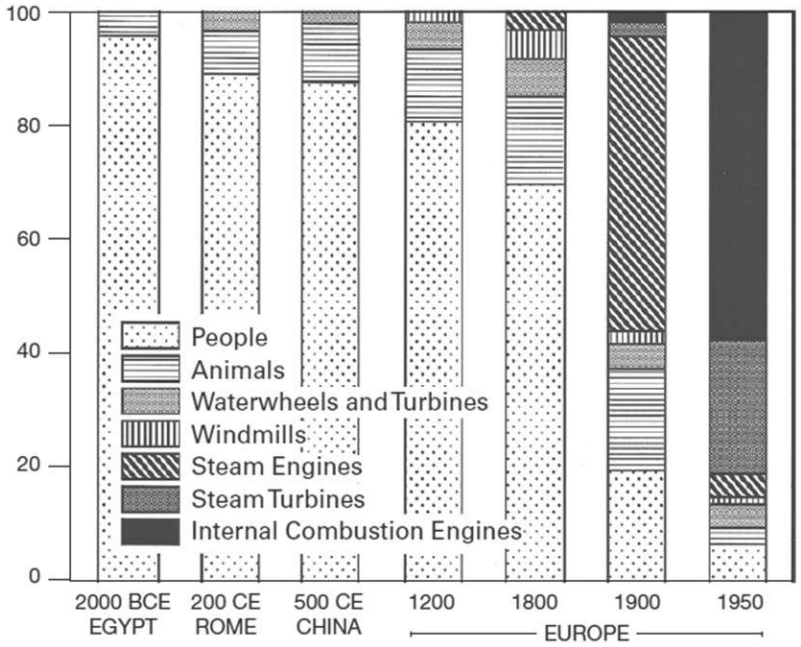

Figure 1. Approximate shares of prime mover capacities [%]
Rysunek 1. Szacunkowe udziały w głównych zdolnościach napędowych [%]
Source: [Smil 2017].

The gradual improvement of these devices allowed the replacement and acceleration of many tiring, repetitive tasks, but the replacement of animate work was slow and uneven. Except for pumping water, waterwheels and windmills can do little to facilitate fieldwork.

Despite some significant differences between continents and regions, typical fuel consumption levels and dominant ways of using prime movers in old cultures were quite similar. An ancient society that can be distinguished for significant advances in fuel consumption and the development of the main prime movers is China of the Han dynasty (from 207 BCE to 220 CE). The innovations they created were adapted elsewhere not only hundreds but thousands of years later. The most important Chinese contribution was the use of coal in the production of iron, drilling for natural gas, the production of steel from cast iron, the widespread use of curved moldboard iron plows, or the beginning use of collar harness.

Early Islam brought innovative designs for wind and water machines (windmills), while maritime trade in this kingdom benefited from the efficient use of triangular sails. But the Islamic world has not introduced any radical innovations in fuel consumption, metallurgy or the use of animals. Only medieval Europe, borrowing from earlier achievements of Chinese, Indian and Muslim societies, began to introduce many innovations. What made European medieval societies differ in terms of energy consumption was their increasing dependence on the kinetic energy of water and wind. These elements were used by more and more complex machines, ensuring an unprecedented concentration of power.

Late medieval and early modern Europe was thus a place of broadening innovation, but the overall technical efficiency of China at that time was more impressive. At the end of the 15th century, however, Europe was on the road to accelerating innovation and expansion, while a developed Chinese civilization was soon to begin its long and deep technical and social involution. Until 1700, Chinese and European levels of typical energy consumption and average well-being were still very similar [Allen 2011]. At that time, the progress of Western European countries significantly accelerated. In the energy sphere, this development was illustrated primarily by growing crops, new iron metallurgy based on coke, better navigation, new weapon designs, enthusiasm for trade and the pursuit of experiments. Others saw the basics of this success dating back to the Middle Ages. The positive influence of Christianity on technical progress in general, and the desire of medieval monasticism to be self-sufficient in particular, were important components of this process [White 1978, Basalla 1988].

The energy fundamentals of nineteenth-century progress included the development of steam engines and their widespread use, both as stationary and mobile prime movers, smelting iron with coke, large-scale steel production, the introduction of internal combustion engines and electricity generation. The scope and speed of these changes were the results of a combination of energy innovations with new methods of chemical synthesis and more efficient ways of organizing factory production. It was also important to develop new modes of transport and telecommunications, both to increase production and to promote domestic and international trade. The accumulation of technical and organizational innovations has given Western countries (which include the new power – the United States) a huge share of global energy. With only 30% of the world's population, Western countries consumed about 95% of fossil fuels. In the 20th century, the Western world increased total energy consumption by almost 15 times. Although the share of Western countries in global energy consumption fell in subsequent years, at the end of the 20th century the countries of the then European Union and North America, with less than 15% of the world population, used almost 50% of the primary energy obtained. Europe and North America remained the dominant consumers of fuels and electricity per capita. China's rapid economic growth brought several changes. In 2010, China became the world's largest energy consumer, and in 2015 China's share in total energy consumption was about 32% higher than in the United States, but energy consumption per capita was only 1/3 of the United States average [BP 2017].

The purpose and the research methods

The main purpose of the research was to present the importance of individual energy sources in the 21st century and to present the periods of availability of individual non-renewable energy resources. The Raw Materials Availability Index (RMAI) was used, calculated according to the formula:

$$RMAI = \frac{R}{P}$$

where:
R – world reserves of raw material k, remaining at the end of the year t,
P – global raw material production k, in year t.

The study uses secondary research materials – scientific literature, scientific publications, as well as press articles and reports.

The method of literature studies was applied, which included studies of Polish and foreign economic and industry literature.

Results

Logistics comprises the movement, storage and handling of products as they move from a raw material source through the production system to point of use. Energy is needed to operate all these logistics activities, used within various logistics. One such system is road freight transport, which can be powered with different energy sources (e.g. fossil fuels, biofuels, nuclear energy or renewable energy), however, fossil fuels are by far the most popular energy source [Wehner 2018]. The globalization of production, procurement and marketing in recent decades, however, has increased the 'freight transport intensity', resulting in increased energy consumption and, consequently, a dynamic increase in greenhouse gas emissions [McKinnon 2012]. It is worth noting that in 2017, 27% of total greenhouse gas emissions in the EU-28 came from the transport sector [EEA 2019]. Storage is also an important energy-dependent logistics system. Electricity is necessary for the operation of both manually operated warehouses and automated warehouses. Without it, products and services offered by enterprises would not reach consumers. Currently, organizational activities and technical measures are used to reduce energy consumption and improve the efficiency of its use.

To reduce production costs, enterprises strive for greater automation of all repetitive processes occurring within the production chain. This creates a contradiction because the introduction of automatic devices means more energy consumption. Therefore, it is important to look for solutions that will be profitable and energy-saving at the same time.

In some countries, companies may benefit from state subsidies for investments leading to energy savings or increased energy efficiency. The goal of such a policy is to reduce energy consumption globally, which results from two important premises: firstly, the resources of non-renewable energy sources are limited and will be exhausted in several dozen years (this aspect was discussed in the paper), secondly, the consumption of energy based on non-renewable sources causes gas emissions greenhouse that threaten the stability of life on earth.

In the modern world, five main energy sources can be distinguished: crude oil, natural gas, coal, renewable energy, nuclear energy (Figure 2).

Despite the steadily decreasing importance in favor of other raw materials, over 30% of the world's energy comes from crude oil [Młynarski and Tarnowski 2016]. The crude oil market is one of the most developed. It is characterized by a high level of demand and supply law functioning. The costs of transporting crude oil over long distances are relatively small relative to the prices of the raw material itself and the volume of transmission. This means that crude oil is freely available in all parts of the world and competition on the market is very high. One of the key aspects is the security of supply and its diversification. Countries that are not dependent on regional suppliers can purchase raw material of almost any origin.

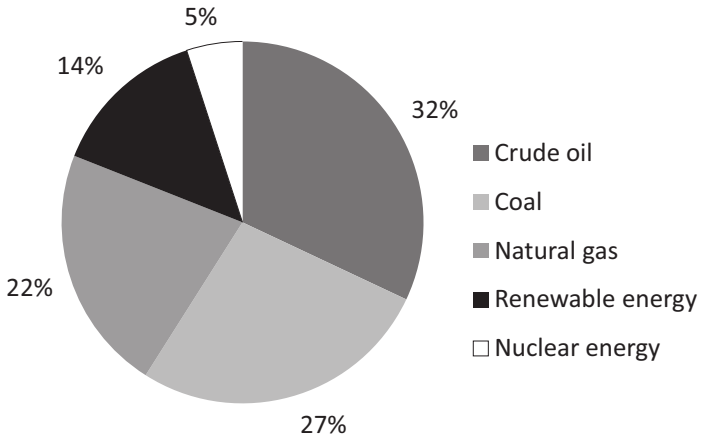

Figure 2. Structure of primary energy sources in the world in 2016
Rysunek 1. Struktura pierwotnych źródeł energii na świecie w 2016 roku
Source: own study based on [Key World Energy Statistics 2016].

Venezuela has the largest crude oil reserves. The resources in this country amount to approximately 47 billion tons (17.6% of global reserves). It is currently one of the poorest countries in the world, plunged into political and economic chaos. Saudi Arabia and Canada also have at least a 10% share in global resources. The world leaders also include Iran, Iraq, Russia, Kuwait, United Arab Emirates, Libya and the United States. The ten countries with the largest crude oil reserves hold over 85% of the global resources of this raw material (208.7 billion tons). Therefore, in the case of crude oil, there is a very high level of concentration of deposits in only a few countries.

In the context of the total dependence of humanity on non-renewable energy resources, the period of availability of these resources is very important information – each of them has the attribute of depletion. The question is, how long will humanity use these sources. In the case of crude oil, the RMAI is 50.6, so it can be assumed that with current resources, the period of its availability in the world will be less than 50 years, as the needs for this raw material are constantly increasing. This is a real example of a limited resource depleted.

Coal is the second most important in the energy mix – it causes a lot of controversy in the modern world and its assessment is ambiguous. It is a relatively cheap raw material (in particular as a fuel for electricity production), easily available regionally (high geographical dispersion) and relatively easy to extract, and therefore is a "convenient" source of energy. At the same time, its use causes environmental pollution, in particular when using its lower quality fractions. Thus, we are dealing here with a conflict between the need to protect the environment, energy security (diversification of energy sources) and ensuring the supply of cheap energy (in particular in developing countries), which translates into economic growth. Balancing these components and including some kind of compromise in energy policy is not an easy task. Also, this is complicated by the fact that the demand for coal is constantly growing (in 2014 its share of the energy mix was 30% – second position after crude oil), which makes it difficult to fight environmental pollution. A high degree of regulation of the coal market, investments in its mining and

processing imposes high restrictions and increases investment risk in this area [Młynarski and Tarnowski 2016]. World coal reserves at the end of 2016 amounted to 1139.3 trillion tons.

The largest coal reserves are in the United States – almost a quarter of the world's deposits. China has equally high reserves. Poland is in 10th place – 2.1% of the world reserves. In the case of coal, the highest concentration of reserves was found compared to oil and gas – 10 countries account for 91.3% of global resources. The average RMAI for all countries in the world is 153.3. Polish reserves, with current production of around 131 million tons, will be enough for the next 184 years.

Natural gas is another key energy resource for the world. Its main disadvantage as an energy raw material is its gas form, which hinders both extraction and transport. Therefore, its use depends, to a much greater extent than crude oil, on the regional availability of its resources. According to Młynarski and Tarnawski [2016], the use of natural gas in national economies increased only due to shifts in the structure of demand (wider availability of raw material in the form of LNG) and adjustment of supply (unconventional resources).

The country with the largest reserves of natural gas is Iran, which together with Russia and Qatar is responsible for almost 50% of the world's resources. The first ten countries with the largest gas reserves hold 79% of the global resources of this raw material (147.2 trillion m^3). After crude oil, this is another example of a very high concentration of deposits in several countries. In the absence of the possibility of excluding land inhabitants from energy consumption, there is a problem of uneven access to deposits. The average RMAI for all countries in the world is 52.5.

Table 1. Reserves of raw materials in regions of the world
Tabela 1. Rezerwy surowców w regionach świata

Region	Energy reserves by region					
	crudeoil		natural gas		coal	
	[billion t]	[%]	[trillion m^3]	[%]	[billion t]	[%]
NorthAmerica	34.5	13.3	11.1	6.0	259.4	22.8
Central and SouthAmerica	50.8	19.2	7.6	4.1	14.0	1.2
Europe and Eurasia	21.8	9.5	56.7	30.4	322.1	28.3
Middle East	110.1	47.7	79.4	42.5	1.2	0.1
Africa	16.9	7.5	14.3	7.6	13.2	1.2
Asia (Pacific)	6.4	2.8	17.5	9.4	529.4	46.5
World	240.7	100.0	186.6	100.0	1139.3	100.0

Source: [BP 2017].

Middle East countries have the largest reserves of crude oil and natural gas. The share of the countries of this region in the total structure of reserves of individual raw materials is 47.7 and 42.5%, respectively (Table 1). However, Middle Eastern countries are poor in coal. Significant reserves of natural gas are located in the countries of Europe and Eurasia (over 30%). Pacific Asia, which is scarce in crude oil, has the largest coal reserves of 529.4 billion tons (46.5%).

Nuclear energy is also an important source. Its first applications after World War II took place mainly in military. Later, civilian applications were allowed, and the first nuclear power plant was launched in Russia in 1954 [Jezierski 2005]. Since then, nuclear power has developed rapidly. Further power plants generating electricity for civil purposes were built. Figure 3 presents the number of nuclear reactors operating in December 2017. In total, 448 reactors operated at that time in the world.

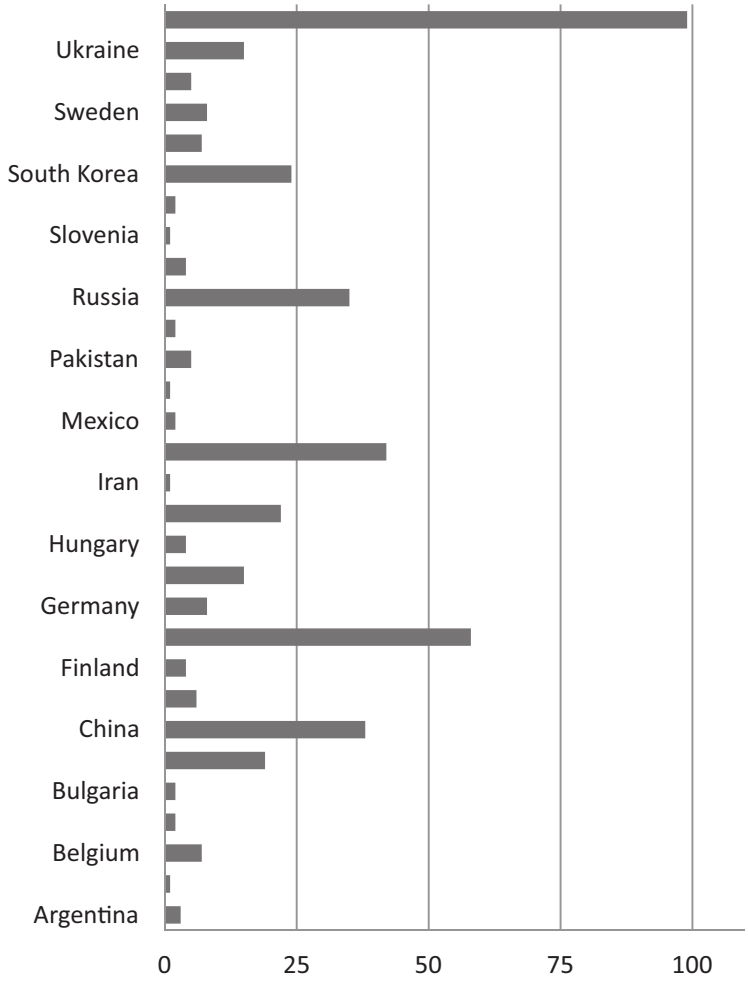

Figure 3. Number of nuclear reactors in the world by country
Rysunek 3. Liczba reaktorów jądrowych na świecie według krajów
Source: [IAEA, PRIS 2018].

The last source discussed is renewable energy, which comes from natural, repetitive processes of nature. The following types can be distinguished: water, sea currents, waves and tides, wind, solar, biomass, geothermal. So far, biomass has been the most important in the European Union. It is widely available and can be used in direct combustion processes (e.g. wood, straw, sewage sludge), processed into liquid fuels (e.g. rapeseed oil esters, alcohol) or gas (e.g. agricultural biogas, biogas from sewage treatment plants, gas landfill). However, the biomass share is decreasing. Solar and wind energy are becoming more and more important, their consumption in several years has increased 20-fold and 6-fold (Table 2), respectively [Gradziuk 2017].

Table 2. Structure of renewable energy sources in the world in 1965–2016 [%]
Tabela 2. Struktura odnawialnych źródeł energii na świecie w latach 1965–2016 [%]

Energy source	Years						
	1965	1975	1985	1995	2005	2015	2016
Traditional biofuels	90.83	86.94	83.84	82.28	78.62	66.79	65.18
Waterenergy	9.12	12.89	15.74	16.67	19.01	23.46	23.83
Solar energy	0	0	0.01	0.01	0.03	1.54	1.97
Wind energy	0	0	0.01	0.05	0.68	4.98	5.68
Other renewable sources (modern biofuels, geothermal energy, wave and tidal energy)	0.05	0.16	0.4	0.99	1.66	3.22	3.33

Source: own study based on [Ritchie and Roser 2016].

It is believed that energy from renewable sources is an alternative to energy from fossil fuels because its production does not involve the depletion of limited resources of energy resources. Therefore, firstly, it does not pollute the environment, and secondly, at least in theory, its sources are inexhaustible. Energy from renewable sources is gaining importance due to:

- continuous increase in human demand for energy due to both the increase in the human population and economic development;
- the gradual depletion of traditional energy resources, i.e. crude oil, coal and natural gas, which causes the need to look for alternative methods of obtaining energy;
- increased concern for the natural environment and the related need to reduce greenhouse gas emissions from the combustion of fossil fuels and other pollutants.

Today, renewable energy is mainly used in four sectors: for electricity production (e.g. wind, solar, hydro), in heating (e.g. geothermal energy), in transport (e.g. fuel cells) and as an energy source in areas deprived of other energy infrastructure for various reasons.

Norway is the only country in the world where the share of renewable energy consumption in the total structure of primary energy consumption is over 50% (Table 3).

Table 3. Countries with the largest share of renewable energy consumption in the total structure of primary energy consumption in 2016
Tabela 3. Kraje o największym udziale zużycia energii odnawialnej w ogólnej strukturze zużycia energii pierwotnej w 2016 r.

No.	Country	Share (%)
1.	Norway	67.86
2.	New Zealand	38.87
3.	Sweden	38.72
4.	Brasil	35.57
5.	Austria	32.53
6.	Switzerland	32.47
7.	Canada	29.43
8.	Portugal	28.08
9.	Columbia	27.05
10.	Finland	25.56

Source: [BP 2017].

Only in six countries of the world this ratio was above 30%. It is worth noting that among the leaders in renewable energy are three Scandinavian countries.

Conclusions

Energy resources have an impact on economic processes in the modern world. Their role and importance for the economy are decisive. Every type of human economic activity requires the use of energy. Agriculture, industry, production of goods or provision of services cannot function without energy, in particular from crude oil, natural gas and coal. Planet Earth without hydrocarbons would face a disaster. The challenge for humanity is therefore proper management of resources of these raw materials, which are exhaustible and unevenly distributed in the world. Several countries have over 80% of the world's reserves (in the case of coal, 10 countries with the largest deposits have 93% of the global reserves). This arrangement of energy potentials causes other countries and societies to depend on resource monopolists. Modern civilization is more than ever a "slave of energy", in particular those countries that have energy resources.

Extraction of energy resources and their processing is invasive for the natural environment. The increase in the concentration of pollutants in the atmosphere as an effect of fuel combustion and the technological processes of many industries and transport disturbs the balance of energy exchange between Earth and space. This causes a rise in global temperature, and consequently melting glaciers and rising sea levels, ozone layer reduction, acid rain, smog, drought and other anomalies. Pollution with gases and dust as a result of energy production causes a disturbance in the proportion of natural air composition, harming human life and health and adversely affecting the development of plants and animals. The energy sector is responsible for almost 70% of global anthropogenic greenhouse gas emissions, which is a significant problem of ecological security and global air pollution. One of the directions limiting this negative impact is the development of energy based on renewable sources. Alternative fuels and the energy transformation towards a low-carbon economy based on civic energy (distributed, renewable energy sources) can be the future of energy. Europe is a prominent region in this respect, in particular Scandinavian countries. In Norway, the share of renewable energy consumption in the total structure of primary energy consumption is almost 70%, in Sweden 38%, and in Finland 25%.

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Ecologistics as an integral element of the sustainable development of farms in Poland

Ekologistyka jako integralny element zrównoważonego rozwoju gospodarstw rolnych w Polsce

Abstract. In the era of growing competitiveness and searching for ways to better use the available resources, their optimal use in Polish farms becomes the direction that determines their activities. The changing market and legal environment forces Polish farmers to look for new solutions. The law also dictates the methods of achieving the development of these entities. One of the basic trends indicated in the law is the development of all Polish entities based on the assumptions contained in the concept of sustainable development. Therefore, it seems reasonable to implement logistic and ecologistic strategies on Polish farms. The article presents the basic issues related to the implementation of ecologistic concepts in Polish farms and the factors determining their development. The article presents the current state of awareness in Polish farms related to the implementation of sustainable development in these entities based on logistic and ecologistic tools.

Key words: ecologistic, sustainable development, Polish farms, waste

Synopsis. W dobie rosnącej konkurencyjności i poszukiwania sposobów lepszego wykorzystania dostępnych zasobów, ich optymalne wykorzystanie w polskich gospodarstwach staje się kierunkiem determinującym ich działania. Zmieniający się rynek i otoczenie prawne wymuszają na polskich rolnikach poszukiwanie nowych rozwiązań. Prawo dyktuje również sposoby osiągania rozwoju podmiotów rolniczych. Jednym z podstawowych trendów wskazanych w prawie jest rozwój na podstawie założeń zawartych w koncepcji zrównoważonego rozwoju. Zasadne wydaje się wdrażanie strategii logistycznych i ekologicznych w polskich gospodarstwach. W artykule przedstawiono podstawowe zagadnienia związane z wdrażaniem koncepcji ekologicznych w polskich gospodarstwach rolnych oraz czynniki warunkujące ich rozwój. Przedstawiono również aktualny stan świadomości polskich gospodarstw rolnych w zakresie wdrażania zrównoważonego rozwoju na podstawie narzędzi logistycznych i ekologicznych.

Słowa kluczowe: ekologistyka, zrównoważony rozwój, polskie gospodarstwa, odpady

Introduction

The turn of the 20th and 21st century is clearly associated with the statement that one of the basic factors influencing the achievement of revenues by enterprises is logistics with all its tools supporting management, flow of raw materials and related information [Ficoń 2001]. Moreover, the first two decades of the 21st century showed that the ever-growing competition on all markets means that also agricultural enterprises have to pay much more attention to processes directly related to logistics. We are talking here, among others about: procurement, distribution, transport and storage [Kuboń 2008].

It should be noted, however, that modern logistic concepts that comprehensively served supply chains consisting of farms, despite the changes taking place on the markets, still do not play a leading role in planning the strategy of Polish farms. This is due to the fact that the overwhelming majority of farmers in Poland conduct their production based on conventional supply and distribution systems. Their systems are made up of a group of independent wholesalers, retailers and brokers. This means that in most cases these entities function as independent links which are only loosely related to the logistic food chain. Due to this state of affairs, these farms have a limited ability to control the physical flow of raw materials and final products, which has been illustrated by the Figure 1 [Wajszczuk 2001, Kuboń 2008].

The Figure 1 illustrates a typical model of an integrated logistic chain with a non-integrated food chain. It should be emphasized that the lack of integration of Polish farms

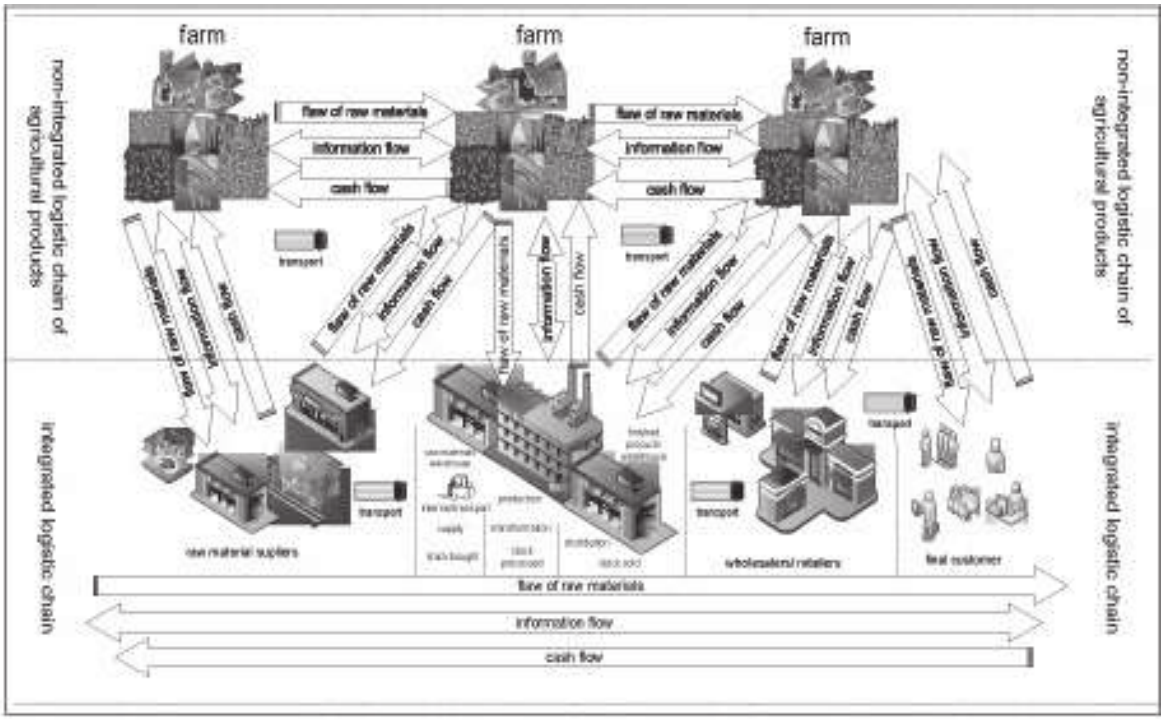

Figure 1. Integrated logistic chain in connection with a non-integrated food logistic chain
Rysunek 1. Zintegrowany łańcuch logistyczny w połączeniu z niezintegrowanym łańcuchem logistycznym żywności

Source: own study based on [Andrzejczyk 2012b].

is the most common barrier to their development. This means that all actions should be taken to integrate Polish farms into integrated logistic chains in order to increase their competitiveness both on the domestic and international markets.

Currently, in Poland, about 60% of the total area of the country is used by farms, which, while conducting their basic activities, have a significant impact on the condition of the natural environment. Everyone knows that a Polish farmer produces food, but not everyone is aware that apart from food production, they are responsible for maintaining the cleanliness of the environment and its natural and landscape values for the next generations [Grabczyńska 2018].

The generation of waste is an inevitable consequence of the functioning of any society, both in the area of residence and in the place of professional activity, it also applies to rural areas. The dynamic economic development of Poland in recent years has contributed to an increase in the amount of waste generated in macrological systems operating at the level of Polish communes, and thus at the micrological level in the form of farms [Andrzejczyk 2012a]. Therefore, taking protective measures in rural areas for the benefit of the natural environment becomes a necessity, which results both from the newly emerging legal regulations in this area, but above all is an expression of the basic relationship that takes place between the farmer and the natural environment [Grabczyńska 2018].

Each economic development is accompanied by the improvement of micrological systems. A particular development of these systems can be seen on the example of Polish farms, which, using new technical and organizational solutions, together with the implementation of logistic concepts and the improvement of logistic processes taking place on these farms, achieve the assumed economic growth, thus changing the shape of Polish farms [Andrzejczyk 2012a].

Each farm in Poland uses the natural resources of the environment, influencing them both positively and negatively. It is believed that the positive effects of farming activities are expressed in the sustainable shaping of the rural landscape, including construction, checkered fields and open water, and in the protection of the traditional management system with extensive grasslands and wetlands with a variety of flora and fauna. It should be noted that on the other side there is agricultural activity which poses a potential threat to the environment contributing to its degradation [Grabczyńska 2018].

Due to the above, it seems necessary to use ecological tools in Polish farms. Ecological logistics, also known as recycling logistics [Andrzejczyk 2009], consists in managing the processes of moving damaged, incorrectly delivered, used, redundant products, classified as surplus stock and used disposable packaging. This management aims to recover as much as possible materials that are no longer needed, and then to reuse them in production or logistics processes, while minimizing the amount of waste that goes to the landfill. [Andrzejczyk 2012b]. It should be emphasized here that both the development of logistics itself at the turn of the 20th and 21st century, as well as the IT revolution that accompanied this development, also caused a change in the approach to the subject of waste. Today, waste that is the result of production is no longer treated only as an unnecessary element that needs to be disposed of. It often turns out that what is waste in one farm may be the starting material for the production of finished products elsewhere in another [Andrzejczyk 2012a].

This study is a starting point for the next article, which will compare the described ecologistic systems related to the functioning of Polish farms in the aspect of the competitiveness of the Polish agricultural sector.

Purpose and method of research

The aim of the article is to identify the level of implementation of the concept of sustainable development of Polish farms based on the available ecologistic tools. The article was prepared on the basis of an analysis of formal and legal documents and normative acts in force in the described area. The article uses the method of a critical literature review in the field of the definition of sustainable development, along with the available ecological tools and the possibilities of using these tools in Polish farms. In addition, the method of graphic modeling was used, with the help of which examples of models of logistic chain connections in the aspect of the functioning of Polish farms were indicated. Additionally, the survey method was used, which was carried out among Polish farms with an acreage from 1 to 100 hectares, located in Lower Silesia and in the Opolskie and Wielkopolskie Voivodeships. The aim of the survey was also to find out about the potential willingness of respondents to cooperate in the field of sending used packaging to appropriate points for processing and re-use. The conducted research was of a pilot nature. The sample was purposefully selected. The characteristics of the sample and the sampling method do not provide grounds for generalizing the results to all farms in Poland. However, on their basis, it is possible to make assumptions about the trends and awareness of Polish farmers regarding the use of ecology on their farms. The obtained results may also be an inspiration for further, in-depth research in this area.

Ecologistics as an element of the development of Polish farms

In the Action Program of the Ministry of Agriculture and Rural Development for 2015−2019, measures were outlined to increase the profitability and equalize the standard of living of Polish farming families and other rural residents compared to urban residents. This objective was to be achieved through the implementation of the activities resulting from the Program in such a way that they would ensure the security and food sovereignty of the country for Poles. Based on the above-mentioned assumptions, the Polish government took care of a stable situation in basic agricultural markets by improving economic processes in the food chain, as well as sustainable development of rural areas and effective land management. The above assumptions are reflected in the Strategy for Responsible Development of Polish Villages until 2020 with a perspective until 2030, as well as in other strategic documents prepared by the Ministry of Agriculture [Jurgiel 2018].

The Ministry of Agriculture takes a similar position in the discussion on the future Common Agricultural Policy (CAP) of the European Union, emphasizing that future measures under the European Union's CAP should be defined in such a way that will help improve the stability of farms and provide them with a constant level of income. It should also be noted that practically all member states notice the importance of farms for the existence of the entire economic community. This translates into the creation of the

future European Union budget, which assumes that the common agricultural policy of the European Union should remain a strong and properly financed European Union policy, especially in the face of growing challenges around the world related to the instability of agricultural markets, demographic changes, food security and limited natural resources, and recently also crises caused by epidemiological threats [Jurgiel 2018].

Therefore, it is extremely important to use logistic solutions more widely, both in production processes and in the so-called reverse logistics. This is due to the need to plan logistic processes in Polish farms in such a way that will allow these economic entities to survive [Andrzejczyk 2009]. Today, it is not enough for Polish farmers to be a loosely connected link in the logistics chain that supplies its products to recipients (Figure 1), because in the situation of uncertainty of demand and supply in the consumer goods market, it requires domestic economic entities to deal with such phenomena as: lack of recipients of agricultural produce, lack of labor, low prices for the offered products, rising prices for energy and labor, and recently frequent droughts. This presents farmers with the need to make choices that are economically difficult to make. Often a Polish farmer is faced with the choice of the profitability of running a production activity. In addition, the beginning of the 21st century imposed new requirements on farmers for environmental protection. All this means that Polish farms have to look for solutions that will keep agricultural production profitable. In connection with the above, it is worth asking the question: where and how is agricultural production located in the areas of logistics tools?

Answering the question above, it should be clearly emphasized that in each farm there are typical logistic processes, such as: transport, production, storage. Importantly, in the case of transport, storage and production in agriculture, attention should be paid to a completely different approach to these issues in a farm and in agribusiness enterprises, and even more so in a typical production enterprise. On the farm, activities related to transport and storage are often performed. A typical farmer, however, does not distinguish these activities, usually focusing on the production itself and its technology. On the other hand, in the case of agribusiness enterprises, there is considerable variation in seasonality, the type of required means of transport, the storage used, and the storage period. Manufacturing companies, however, carefully analyze all the processes taking place in it and in its environment. Therefore, when analyzing transport and storage, each type of enterprise should be considered separately. It should also be emphasized that often production companies distinguish between individual costs, while farms do not isolate given logistic processes, treating the costs of transport and storage as the costs of obtaining raw materials and production [Rokicki and Wicki 2010].

At the end of the 20th century, the ever-growing environmental problems resulting from the expansive human activity were noticed in the social, economic and ethical dimensions. Combined with the growing awareness of the society in this regard, at the beginning of the 21st century, in the management of enterprises, including Polish farms, an increasing influence of concepts aimed at solving these problems is observed. Undoubtedly, one of them is the strategy of sustainable development [World Commission on Environment and Development 1987]. The scope of all pro-ecological activities promoted in this concept has been extended to include social aspects in another concept, called corporate social responsibility, in which, inter alia, reference was made to human rights, with particular emphasis on preserving the principles of economic development

based on respect for natural resources in such a way that future generations would have access to it [Robinson 2004].

It should be remembered that the development of Polish farms is strongly related to the development of the regions in which these farms are located. This means that the development of these regions should also be based on respect for the natural environment, which is reflected in the so-called eco-development also called sustainable development. The socio-economic structure of the population living in a given area is of great importance for the development of the region. Sustainable development in this case means conducting all economic activities in harmony with the natural environment, so as not to cause irreversible changes in nature that destroy the ecosystem. In a situation where the operation of agricultural holdings requires interference with the natural environment, the resulting environmental degradation should be minimal, and the related losses should be ecologically acceptable and economically and socially justified. To sum up, the sustainable development of regions, therefore, of Polish farms, should be based on the dependencies between such areas as society − economy − environment, which was illustrated by Figure 2 [Andrzejczyk 2009].

As we can read from the Figure 2, the development of each entity should be based on three pillars that take into account the needs of continuous process improvement, social needs and economic resources. This state of affairs means that when planning the development of Polish farms, we have to deal with a wide range of various scientific fields. It should be noted here that the area that binds these areas is undoubtedly logistics, by means of which we integrate many different types of economic processes. It is possible

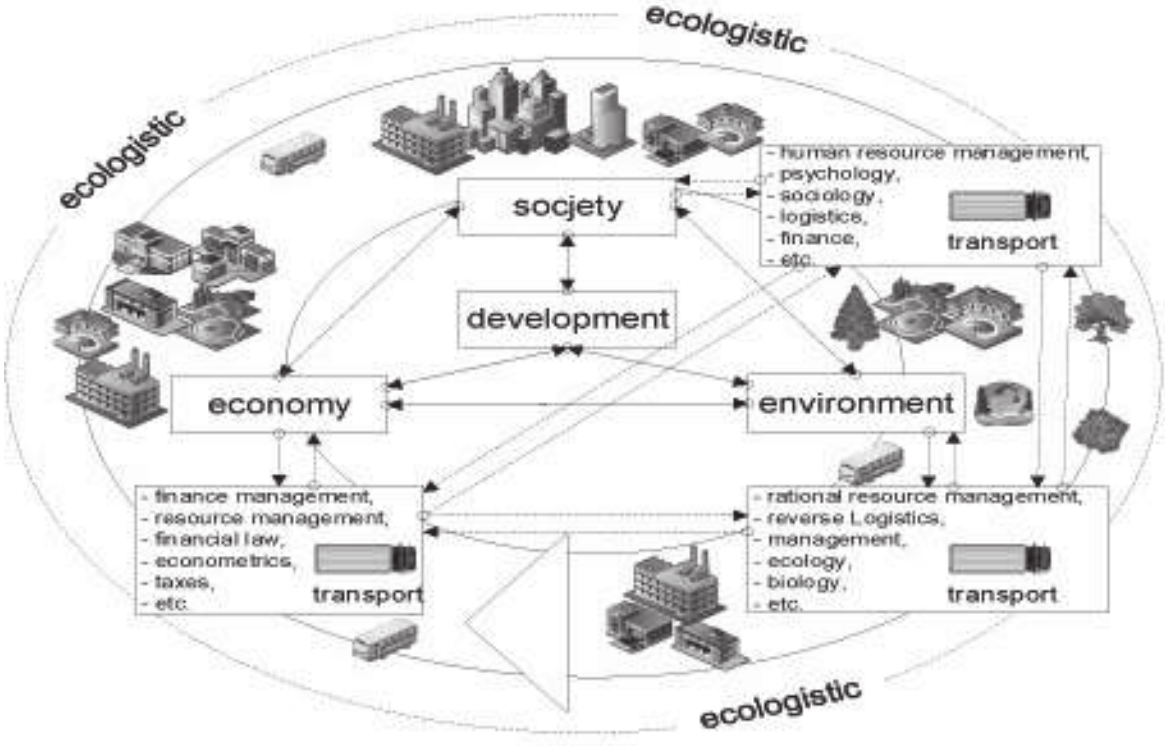

Figure 2. Interdisciplinarity of sustainable development
Rysunek 2. Interdyscyplinarność zrównoważonego rozwoju
Source: [Andrzejczyk 2020].

because logisticians pay attention to many aspects related to the proper management of resources, taking care to meet, for example, the 7W principle, also known as the 7R principle, that is: right product, right quantity, right condition, right place, right time, right customer, right price.

It should be clearly emphasized that one of the first concepts in which the search for pro-ecological solutions was started are precisely logistics concepts in which logistics processes were discussed, and more precisely, transport, later production, warehouse processes, etc. Over the years, pro-ecological activities in logistics have been extended to the pro-social sphere. Ultimately, the common scope of these activities was defined as logistics social responsibility [Carter and Jennings 2002].

The logistics social responsibility concept is a young concept whose scope is constantly developing. New issues are constantly being included, e.g. of an ethical nature, working conditions, philanthropic attitudes, waste, etc. [Carter and Jennings 2002]. Therefore, many research centers, domestic and foreign, make many attempts to develop comprehensive methods of assessing the implementation of this concept, both in enterprises and entire supply chains. The attempts to develop such a method so far are of a more general nature and do not exhaust all the possibilities of this concept [Murphy and Poist 2002]. Both the foreign and Polish literature on the subject clearly lack research results showing the degree of logistics sustainability according to the indicated concept at the level of specific industries, not to mention the application of this concept in Polish farms [Murphy and Poist 2002, Andrzejczyk 2009].

The problem above can be solved by the application of the concept of ecologistics, otherwise known as recycling logistics. It is based on managing the processes of moving products: damaged, incorrectly delivered, used, redundant, classified as excess inventory and used disposable packaging. It should be emphasized that this management aims at the highest possible level of recovery of products/materials that are theoretically unnecessary, and in the next stage − their reuse in both production and logistics processes. What is extremely important, this task is carried out with the maximum minimization of the amount of new waste. Currently, when designing logistics and production flows, it is also planned to recover resources after the end of the product life. The current trends are aimed at closing the circulation of the raw material into a closed circuit. It is assumed that products that end their useful life will be completely eliminated from the landfill. This applies to both the entire used object and its parts [Andrzejczyk et al. 2020].

"The basic model of ecologistics is the ecologistic supply chain (Figure 3), in which reverse logistics is an extremely important element, with its help it is possible to rationally and effectively recover all kinds of waste. The primary goal of recovering unwanted raw materials is to subject them to treatments that minimize their negative impact on the environment. It should be noted that products that were once considered waste are now a source of raw materials." [Andrzejczyk et al. 2020]. In the case of Polish farms, for example, heaps of stones collected from the field, which are now sold as building blocks of all kinds of ponds, constitute a valuable source of resources that were a problem in the past, and today in many cases are an object for which more and more customers are competing. Another example of products that were previously considered mainly waste are animal by-products, which are now used in many cases as materials for the production of modern and efficient fertilizers.

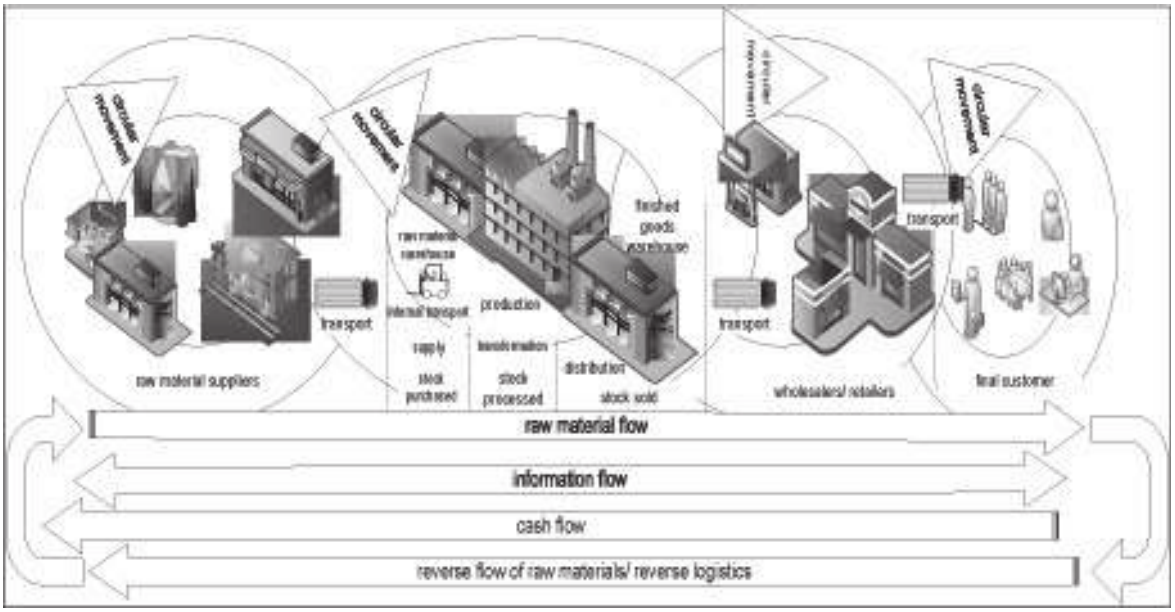

Figure 3. Model of the logistics chain
Rysunek 3. Model łańcucha logistycznego
Source: [Andrzejczyk 2020].

Ecologistics and sustainable development of farms in Poland – the as-is

As already mentioned, the purpose of this article is to define the current level of knowledge in Polish farms on the application of the concept of ecologistics in the process of development of these entities. In order to achieve the intended goal, in selected groups of farms, research was carried out on a sample of 100 farms located in southern Poland. The research was aimed at determining the current potential of using logistic concepts and their related ones, with particular emphasis on ecologistic concepts. Based on the logistic concepts presented above, the adopted objective of the study, related to the positioning of ecology in the integrated logistic chains of agricultural products produced on Polish farms, was carried out using the method of analysis and criticism of the literature and logical inference based on the obtained results of research conducted on a sample of Polish farms agricultural areas, which were divided according to the size of the cultivated land (Figure 4). The largest group of the researched farms were farms managing from 5 to 10 hectares, then farms with an area of 10 to 20 hectares, both these groups accounted for almost 50% of the respondents.

It should be noted that among the farmers who were tested, as many as 45% believe that they do not use any logistic tools in managing their farm. Even more farms do not use the tools available in the ecologistic concept (Figures 5 and 6).

On the basis of the conducted research, it can be observed that large farms much more often use logistic and ecologistic solutions than smaller ones (Tables 1 and 2). This state of affairs is most often due to the fact that small farms are most often family projects passed on from the great-grandfather, along with all the benefits of livestock. Therefore, such farms do not develop while remaining in stagnation. In the case of large farms, continuous develop-

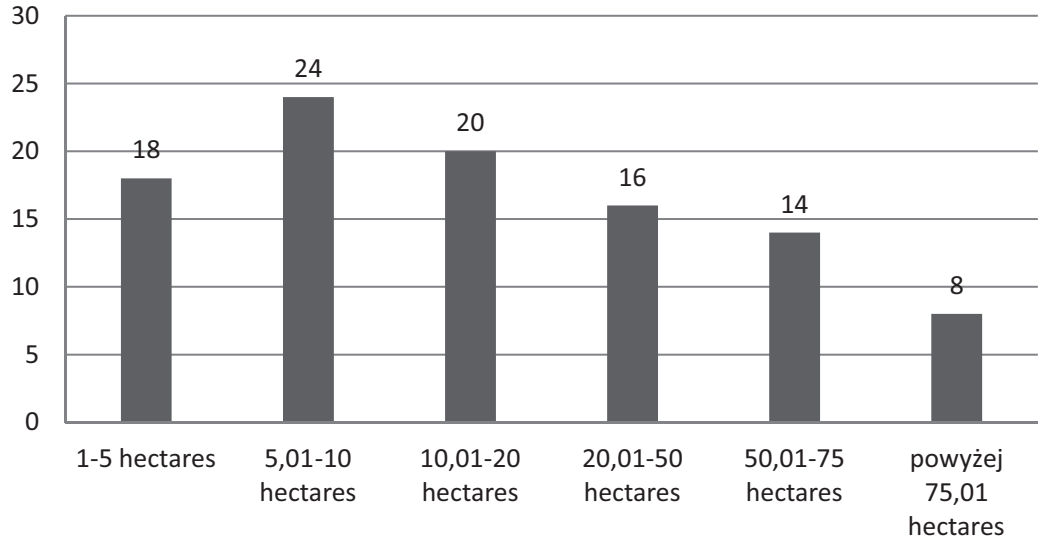

Figure 4. Size of the researched farms
Rysunek 4. Wielkość badanych gospodarstw
Source: own study.

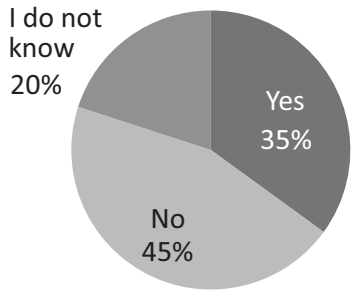

Figure 5. Share of farms where logistic tools are used
Rysunek 5. Udział gospodarstw, w których używane są narzędzia logistyczne
Source: own study.

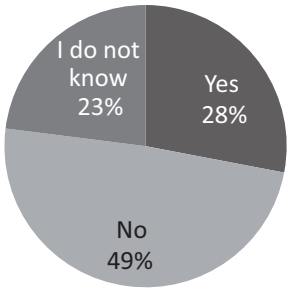

Figure 6. Share of farms where ecologistic tools are used
Rysunek 6. Udział gospodarstw, w których stosowane są narzędzia ekologiczne
Source: own study.

Table 1. Share of farms where logistic tools are used [%]
Tabela 1. Udział gospodarstw, w których używane są narzędzia logistyczne [%]

Does your farm use logistic tools?	Farm size [hectares]					
	1−5	5,01−10	10,01−20	20,01−50	50,01−75	more than 75,01
Yes	4	5	6	7	8	5
No	8	14	10	7	4	2
I do not know	6	5	4	2	2	1
Total	18	24	20	16	14	8

Source: own study.

Table 2. Share of farms where ecologistic tools are used [%]
Tabela 3. Udział gospodarstw, w których stosowane są narzędzia ekologiczne [%]

Does your farm use ecologistic tools?	Farm size [hectares]					
	1−5	5,01−10	10,01−20	20,01−50	50,01−75	more than 75,01
Yes	2	5	7	5	6	3
No	10	12	11	7	6	3
I do not know	6	7	2	4	2	2
Total	18	24	20	16	14	8

Source: own study.

ment can be observed. These entities, in order to survive on the market, must transform into the type of organization that must be adapted to the integrated supply chain.

When analyzing the above tables, it can also be noticed that Polish farms are not very eager to look at ecology and while the tools of logistics itself are already used, those that allow to protect the natural environment to a much lesser extent. Which will be even more visible in the results presented below.

From the obtained results, one can draw a conclusion that the majority of Polish farms have been developing in the last 10 years (Figure 7). Unfortunately, most of the surveyed entities do not apply the sustainable development strategy (Figure 8). Which coincides with the fact that a Polish farmer uses logistic tools, but not necessarily ecologistic ones.

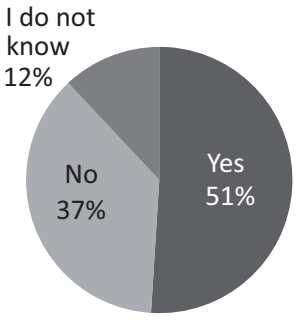

Figure 7. Share of farms which recorded development in the last 10 years
Rysunek 7. Udział gospodarstw, które odnotowały rozwój w ostatnich 10 latach
Source: own study.

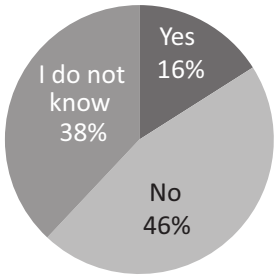

Figure 8. Share of farms in which the concept of sustainable development is applied
Rysunek 8. Udział gospodarstw, w których stosowana jest koncepcja zrównoważonego rozwoju
Source: own study.

From Tables 3 and 4 it can be concluded that Polish farms are developing. Unfortunately, almost 40% of them report problems in this respect, and 12% are unable to identify themselves (Table 3). This state of affairs results from the constantly changing market environment of these farms. Farmers are also not helped by the legal system, which somehow forces them to apply the concept of sustainable development, and as can be read from Table 4, the Polish farmer does not readily use it, because only 16% of Polish farms use this strategy.

Table. 3. Share of farms which recorded development in the last 10 years [%]
Tabela 3. Udział gospodarstw, które odnotowały rozwój w ostatnich 10 latach [%]

Has your farm been developing in the last 10 years?	Farm size [hectares]					
	1−5	5,01−10	10,01−20	20,01−50	50,01−75	more than 75,01
Yes	9	12	10	9	7	4
No	7	9	5	6	6	4
I do not know	2	3	5	1	1	0
Total	18	24	20	16	14	8

Source: own study.

Table 4. Share of farms where the concept of sustainable development is applied [%]
Tabela 4. Udział gospodarstw, w których stosowana jest koncepcja zrównoważonego rozwoju [%]

Is your farm developing based on the concept of sustainable development?	Farm size [hectares]					
	1−5	5,01−10	10,01−20	20,01−50	50,01−75	more than 75,01
Yes	1	3	5	2	3	2
No	10	12	10	5	5	4
I do not know	7	9	5	9	6	2
Total	18	24	20	16	14	8

Source: own study.

To the question about the farm generate municipal waste, half of the respondents answered affirmative (Figure 9). On the basis of the interviews conducted, it can also be concluded that Polish farmers distinguish between municipal waste and industrial and hazardous waste. Farmers are also aware that among the products they produce, they have also those that should be classified as hazardous waste (Figure 10).

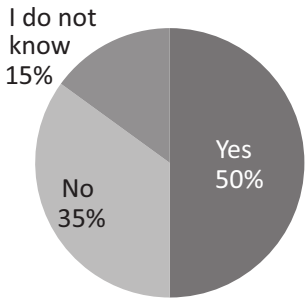

Figure 9. Share of farms producing municipal waste
Rysunek 9. Udział gospodarstw wytwarzających odpady komunalne
Source: own study.

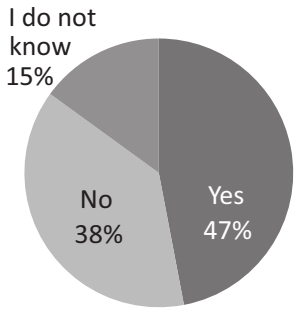

Figure 10. Share of farms producing hazardous waste
Rysunek 10. Udział gospodarstw wytwarzających odpady niebezpieczne
Source: own study.

What is extremely important, the number of farmers who are aware of the harmfulness of the produced waste is still growing (Tables 5 and 6). It can also be noticed that they do not avoid issues related to it, which is reflected in their interest and exploration of the topic in this regard. Only 15% of the surveyed people showed complete ignorance of the subject. It should be noted here that the larger the farm, the greater the knowledge of issues related to the area in question.

Table. 5. Share of farms generating municipal waste [%]
Tabela 5. Udział gospodarstw wytwarzających odpady komunalne [%]

Does your farm produce municipal waste?	Farm size [hectars]					
	1−5	5,01−10	10,01−20	20,01−50	50,01−75	more than 75,01
Yes	10	11	11	8	5	5
No	7	9	8	4	5	2
I do not know	1	4	1	4	4	1
Total	18	24	20	16	14	8

Source: own study.

Table. 6. Share of farms producing hazardous waste [%]
Tabela 6. Udział gospodarstw wytwarzających odpady niebezpieczne [%]

Does your farm produce hazardous waste?	Farm size [hectars]					
	1−5	5,01−10	10,01−20	20,01−50	50,01−75	more than 75,01
Yes	5	8	10	6	10	8
No	7	13	8	6	4	0
I do not know	6	3	2	4	0	0
Total	18	24	20	16	14	8

Source: own study.

Pursuant to the amendment to the Act on Waste, farmers who farm over 75 hectares of agricultural land are subject to mandatory entry in the BDO (waste database), i.e. the Product and Packaging Database and Waste Management. If the farmer produces other waste and the waste company collects the above-mentioned packaging waste directly from the farm, he is obliged to keep records of waste on an ongoing basis. In connection with the above, farmers were asked whether their farms are subject to the necessity to obtain an entry in the BDO register and whether they know the criteria that oblige them to obtain such an entry. To the great surprise of the respondents, despite the freshness of the introduced regulations, most of the surveyed farmers know the requirements in this regard (Figures 11 and 12.). In the entire survey, only 17% of farmers do not know whether they must be registered in the above-mentioned system, and 13% do not know the related criteria at all.

It should be emphasized that despite the fact that the regulations on BDO entered into force on August 13, 2019, Polish farmers show high awareness of this issue (Tables 7 and 8). This state of affairs may result from the fact that non-compliance with these stand-

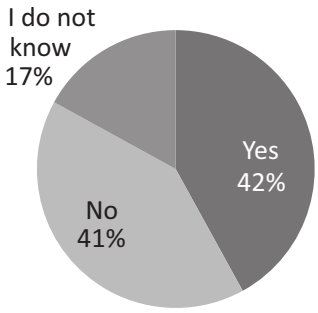

Figure 11. Share of farms requiring an entry in the BDO register
Rysunek 11. Udział gospodarstw wymagających wpisu do rejestru BDO
Source: own study.

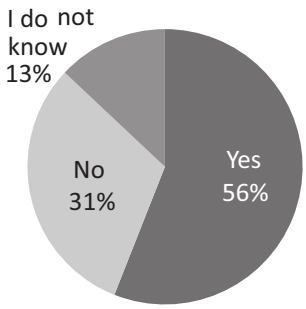

Figure 12. Share of farms with known criteria for the necessity to obtain an entry in the BDO register
Rysunek 12. Udział gospodarstw o znanych kryteriach konieczności uzyskania wpisu do rejestru BDO
Source: own study.

ards may result in high penalties, as anyone who runs a business without the required entry in the BDO Register may be subject to an administrative fine of PLN 5000 to PLN 1,000,000 [Obwieszczenie Marszałka Sejmu...]. However, the amount of possible fines is not a sufficient argument for some farmers. This is especially true for small entities that are not yet trained to analyze changes in the law that directly affect them.

Table. 7. Share of farms requiring an entry in the BDO register [%]
Tabela 7. Udział gospodarstw wymagających wpisu do rejestru BDO [%]

Is it necessary to obtain an entry in the BDO register (Database on products and packaging) in your farm?	Farm size [hectares]					
	1−5	5,01−10	10,01−20	20,01−50	50,01−75	more than 75,01
Yes	3	6	8	9	9	7
No	9	13	9	5	4	1
I do not know	6	5	3	2	1	0
Total	18	24	20	16	14	8

Source: own study.

Table. 8. Share of farms with known criteria for the necessity to be entered in the BDO register [%]
Tabela 8. Udział gospodarstw o znanych kryteriach konieczności uzyskania wpisu do rejestru BDO [%]

Do you know the criteria that require an entry in the BDO register (Database on products and packaging)?	Farm size [hectares]					
	1−5	5,01−10	10,01−20	20,01−50	50,01−75	more than 75,01
Yes	9	13	9	9	9	7
No	7	6	8	5	4	1
I do not know	2	5	3	2	1	0
Total	18	24	20	16	14	8

Source: own study.

Therefore, the question arises how do Polish farmers deal with waste? Therefore, the authors of the study asked Polish farmers what they do with the waste that occurs in each of them. We are talking about fertilizer bags. The obtained results show that only 31% of farmers hand over this waste to the appropriate recipient (Table 9).

Table 9. Manners of handling fertilizer bags in Polish farms [%]
Tabela 9. Sposoby obchodzenia się z workami nawozowymi w polskich gospodarstwach [%]

Which of the following methods of handling fertilizer bags are used on your farm?	Farm size [hectars]						Total
	1−5	5,01−10	10,01−20	20,01−50	50,01−75	more than 75,01	
Delivery to special farm waste collection points	1	3	6	7	8	6	31
Disposal in municipal containers for mixed waste	3	5	4	4	2	1	19
Use as packaging in trade with individual recipients of agricultural produce	4	8	5	3	2	1	23
Re-use in field work	2	3	2	0	2	0	9
Burying in the ground	2	1	0	0	0	0	3
Burning	6	4	3	2	0	0	15
Total	18	24	20	16	14	8	100

Source: own study.

The rest of the activities are against the legal standards and the principles of sustainable development. For example, it should be stated that 15% of farmers explicitly admit to burning this type of waste, and 3% to burying it in the ground. A large group of farmers are those who throw fertilizer bags into mixed municipal waste. This state of affairs generates further questions regarding, for example, issues related to other waste, e.g. what happens to used tires for agricultural machinery, or what happens to containers for plant protection products?

Summary and conclusions

The paper presents the results of a pilot study assessing the degree of application of the logistics strategy in selected Polish farms in terms of the concept of sustainable development with an emphasis on the ecologistic concept. Based on the conducted analyzes of the literature and surveys conducted in one hundred different types of farms, it can be concluded that Polish farmers are interested in the use of logistic concepts and less in the use of ecologistic tools, and even less in typical strategies related to the sustainable development of these entities. This state of affairs occurs despite the fact that these strategies are closely related. It should be emphasized that the level of logistics in Polish farms is in a phase of slow implementation. This process may be accelerated by the changes taking place in Polish legislation. However, a much greater stimulus determining Polish farmers' willingness to use ecologistic tools, and thus create their development with concepts

taking into account sustainable development, will be the dynamically changing market on which Polish farms operate, which will autonomously force a change in the strategy in farm management. Because their recipients will set new requirements both in terms of individual main processes carried out on the farm, and in social, economic and, above all, ecological dimensions. It should be emphasized here that the Polish farmer is slowly noticing that the way he conducts his agricultural activity is changing. Today, the winner is the farmer who has access to information and modern technologies that will enable him to integrate into the logistic chain.

Not without significance is the ever-growing pressure of society to increase the safety of the flow of food products in the supply chain. This is related to, for example, new epidemiological threats that force agricultural entities to maintain transparency, and this in turn will force the implementation of the principles of logistics, ecologistics and sustainable development to an ever greater extent. Based on the above, it can be concluded that even small farms should assume the independent implementation of the above-mentioned ones in their development strategies. However, in a situation where they are not able to cope with it on their own, they will have to form groups that will cope with it. Thus, becoming responsible suppliers of products for both large enterprises and individual consumers.

Considering the analysis of the literature on the subject and the results obtained on the basis of questionnaire surveys of Polish farms, it can be concluded that the aim of the presented article has been achieved. It can be inferred that although many Polish farms still do not use logistic tools in creating their development, and thus do not implement the concept of sustainable development of these farms, there are many entities among Polish farms that know and use the indicated tools in their strategies that are also based on sustainable development. It can also be noticed that farms run by the younger generation are more willing to use modern farm management solutions. Young farmers see the need to integrate their chains with global sales networks and are aware of the dwindling natural resources. Polish farmers experience it, for example, in the form of a lack of access to an adequate amount of water as a result of the prevailing droughts. Therefore, they have to adapt to the type of production that will take this into account. It seems logical that the development of Polish farms will require the use of logistic and ecologistic tools, and this translates into the need for a wider use of the concept of sustainable development in this sector.

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Selected methods of location logistic distribution centers in food supply chains

Wybrane metody lokalizacji logistycznych centrów dystrybucyjnych w łańcuchach dostaw żywności

Abstract. The paper presents method of selecting the location of a logistics distribution center in food supply chains. This selected method examines the problem of choosing a location in terms of total costs or the factor of space, more precisely − distance. The paper presents the possibility of using method. For this purpose, a short review of the literature is presented, then at the end of the article, the possibility of using method to solve the problem is shown.

Key words: food supply chain, location, logistic center

Synopsis. W pracy przedstawiono jedną z wielu prezentowanych w literaturze przedmiotu metodę wyboru lokalizacji logistycznego centrum dystrybucyjnego w łańcuchach dostaw żywności. Metoda ta rozpatruje problem wyboru lokalizacji w aspekcie kosztów całkowitych lub czynnika przestrzeni, a dokładniej – odległości. W pracy przedstawiono możliwość zastosowania tej metody. W tym celu przedstawiono krótki przegląd literatury, następnie na końcu artykułu pokazano możliwość zastosowania metody do rozwiązania problemu.

Słowa kluczowe: łańcuch dostaw żywności, lokalizacja, centrum logistyczne

Introduction

The agri-food supply chain concept was first proposed by scholars in the agricultural economics and management discipline [Salin 1998, Mardsen et al. 2000, Manzini and Accorsi 2013]. The commonly used terms to describe this idea include agricultural supply chain, agricultural value chain, food supply chain, and food value chain. The food supply chain is composed of a wide diversity of products and companies which operate in different markets and sell a variety of food products [Vlajic et al. 2012, van der Vorst 2000]. It combines activities whose primary purpose is to ensure buyer satisfaction and profit to enterprises participating in the flow of products and services from the sphere of primary agricultural production (farmer) to the consumer (Figure 1). All sectors, which belongs and create the food supply chain, are important from the economically point of

view [Yu and Nagurney 2013]. There is many interactions between this sectors, purchasers and suppliers appear in every link in the food supply chain [Bukeviciute et al. 2009, Nicholson et al. 2011].

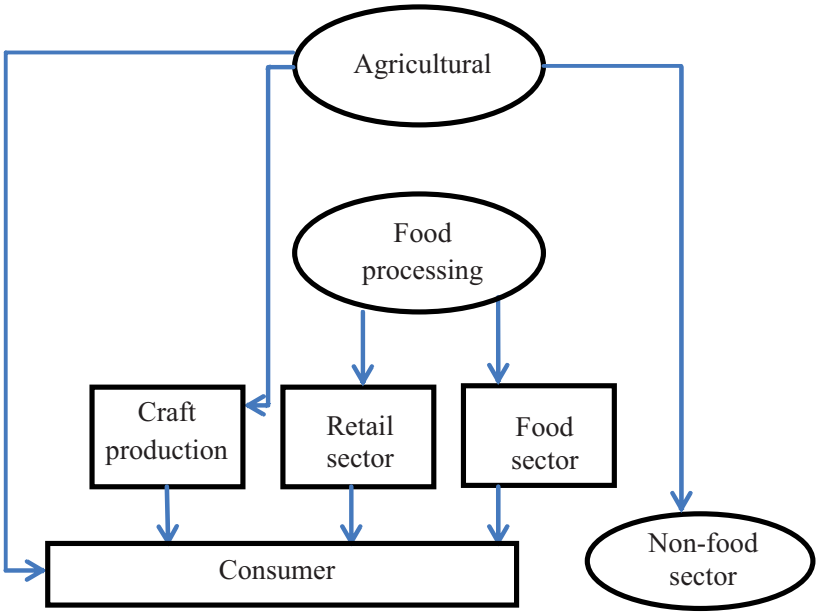

Figure 1. Schematic representation of the food supply chain
Rysunek 1. Schemat łańcucha dostaw żywności
Source: [Bukeviciute et al. 2009].

The emergence of distribution centers and logistics centers in recent years has become a common phenomenon resulting from the ongoing global economic processes. They replace in their assumption the existing warehouse retailers, as well as in the version of manufacturers of warehouses of finished products [Ahumada and Villalobos 2009, Kozierska 2016]. As a result, distribution centers are important in the place of distribution where there is a greater number of participants (both from the side and the recipients). In logistics terminology, there are various definitions of a logistics center, which have their source in attempts at classification, their regulation, distribution, and logistics distribution center [Frechner 2010]. Logistics distribution center, defined in the literature as "a center dealing with the coordination of logistics services and transport over short and long distances, ensuring an integrated transport connection with the flow of information between producers, distributors and consumers, and a control system" [Abt 1996]. In Anglo-Saxon literature, the concept of a distribution center is defined as an object, often smaller than the company's central warehouse, used for the temporary storage of goods and their distribution, often referred to as a distribution warehouse [Viale 1996, Opara 2003].

The problem of location is usually considered in many aspects, and the most common methods of assessment are used to solve it. The selection criteria include:
– labor costs in the regions where facilities are located,
– storage and transport costs,
– required order fulfillment time (service level),

– existing infrastructure (roads, railways, inland waterways, airports),
– distance from procurement markets and customers,
– local taxes and regional development incentives.
– the ability to identify the types of cargo transported.

For the purposes of this work, the distribution center is understood as a spatial object with an organization and infrastructure appropriate for it, so that it allows the economic entity to store, service operations on goods and coordinate transport in order to meet the needs, in the shortest time and at the service cost [van der Vosrt et al. 2009, Grabański 2015].

The analysis of the literature shows that different criteria are used to select the locations of nodal points in the network, and the authors often postulate simultaneous rest in many of the criteria. These approaches are defined as multi-criteria or multi-faceted. In multi-criteria approaches, they are mentioned as the main regulation deciding on the selection of logistics locations [Jezusek and Widera 2001, Wasiak 2004].

Methodology[1]

The literature on the subject presents many methods allowing to determine the location of a logistic distribution center [Liu 1999, Nozick and Turnquist 2001, Kuo 2011, Mousavi et al. 2015, Hu et al. 2020]. The center of gravity method is widely described in the literature on the subject [Zhongyi 2005, Zhang et al. 2009, Ying 2014] . It can be used to define the strategic location of a single logistic facility. This method is especially useful when planning a logistics network, when it is necessary to decide on the location of a production plant, warehouse or store. This method uses the location of individual sending and receiving points in the form of geographic coordinates and the volume of supply and demand at individual points in the network. Optimization in this method consists in determining the location of the facility that will minimize the costs of transporting raw materials, semi-finished products or goods to the facility and exporting finished goods from the facility. The center of gravity method is used when there are many suppliers and many sales markets. The main parameter to be optimized for the center of gravity model is distance. This method does not use the real distance and the most commonly used distance measures are formulas [Kuczyńska and Ziółkowski 2001]:

$$d_{ij}^{p} = \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2}$$

where:
$A_i(x_i, y_i)$, $A_j(x_j, y_j)$ – points R^2.

Usually, the real distance between the points is not less than the distance determined by the taxicab distance and not shorter than the distance determined by the Euclidean

[1] Based on: [Kauf and Tłuczak 2016].

metric [Sherali and Tuncbilek 1992, Goncalves et al. 2014, You et al. 2019]. The differences in the interpretation of both metrics are shown in Figure 2.

It is assumed that the coordinates of location of A_i suppliers (x_{iA}, y_{iA}) and B_j recipients (x_{jB}, y_{jB}), the volumes of deliveries a_i and the demand b_j represented by suppliers and recipients, are known. In addition, it is assumed that the unit, calculated cost of transport to the k_A warehouse and from the warehouse to k_B points of sale will be known.

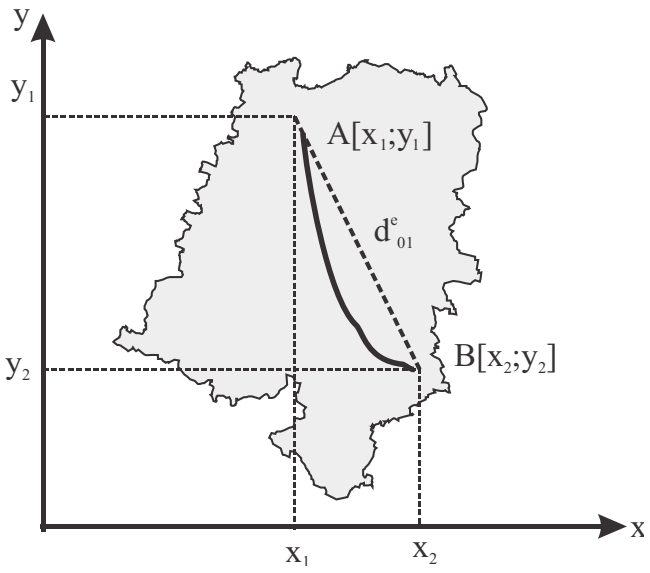

Figure 2. Euclidean, rectangular and real distances A(x_1, y_1), B(x_2, y_2).
Rysunek 2. Odległości euklidesowa, prostokątna i rzeczywista między punktami A(x_1, y_1), B(x_2, y_2).
Source: [Kauf and Tłuczak 2016].

The issue under consideration is based on the minimization of the travel cost function, which is given by the formula:

$$K = \sum_{i=1}^{m} a_i k_i^a d_{i0} + \sum_{j=1}^{n} b_j k_j^b dj_{i0}$$

Looking for a solution to the above optimization task, one should find the coordinates of the location of the distribution center according to the formulas:

$$\overline{x}_0 = \frac{\sum_{i=1}^{m} a_i k_i^A x_i^A + \sum_{j=1}^{n} b_j k_j^B x_j^B}{\sum_{i=1}^{m} a_i k_i^A + \sum_{j=1}^{n} b_j k_j^B}$$

$$x_0 = \frac{237909.84}{12174} = 19.54 \quad \text{and} \quad y_0 = \frac{644756.62}{12174} = 52.96$$

When determining the coordinates of the position of the balanced center of gravity, the calculation of the corrective indicators:

$$x_0 = \frac{\sum_{i=1}^{m} \frac{a_i k_i^A x_i^A}{d_i^A} + \sum_{j=1}^{n} \frac{b_j k_j^B x_j^B}{d_j^B}}{\sum_{i=1}^{m} \frac{a_i k_i^A}{d_i^A} + \sum_{j=1}^{n} \frac{b_j k_j^B}{d_j^B}}$$

$$y_0 = \frac{\sum_{i=1}^{m} \frac{a_i k_i^A y_i^A}{d_i^A} + \sum_{j=1}^{n} \frac{b_j k_j^B y_j^B}{d_j^B}}{\sum_{i=1}^{m} \frac{a_i k_i^A}{d_i^A} + \sum_{j=1}^{n} \frac{b_j k_j^B}{d_j^B}}$$

Example of use of the gravity method

For easier understanding of the procedure for determining the location of the distribution center, we will use an example. We are looking for a location for a distribution center serving the participants (suppliers and recipients) of the food supply chain from all over Poland. We assume that the center cooperates with three suppliers and two recipients. Data needed for calculations: coordinates of recipients and suppliers, size and cost of transport are presented in Table 1. Tables 2−5 show the calculations needed to find the location of the distribution center.

Table 1. Data for the location of the logistics center
Tabela 1. Dane do lokalizacji centrum logistycznego

Suppliers and Recipients	Coordinates		Shipment size (number of pallets)	Unit cost of transport [PLN]
	x_i	y_i		
Supplier A_1	16.17	54.19	520	5.2
Supplier A_2	23.16	53.13	580	5.9
Supplier A_3	19.03	54.03	350	4.8
Recipient B_1	17.03	51.1	480	4.6
Recipient B_2	21.00	52.23	400	5.4

Source: own study.

The given coordinates identify the selected places where the hypothetical suppliers and recipients are. The calculations needed to determine the center of gravity are presented in Table 2, on the basis of which we have that:

$$x_0 = \frac{237909.84}{12174} = 19.54 \quad \text{and} \quad y_0 = \frac{644756.62}{12174} = 52.96$$

Table 2. Setting the center of gravity
Tabela 2. Wyznaczanie środka ciężkości

Suppliers and recipients	Coordinates		Shipment size (number of pallets)	Unit cost of transport [PLN]	Transportation cost	Values	Values
	x_i	y_i			$a_ik_i;\ b_jk_j$	$x_ia_ik_i;\ x_jb_jk_j$	$y_ia_ik_i;\ y_jb_jk_j$
Supplier A_1	16.17	54.19	520	5,2	2 704	43723,68	146529,76
Supplier A_2	23.16	53.13	580	5,9	3 422	79253,52	181810,86
Supplier A_3	19.03	54.03	350	4,8	1 680	31970,4	90770,4
Recipient B_1	17.03	51.1	480	4,6	2 208	37602,24	112828,8
Recipient B_2	21	52.23	400	5,4	2 160	45360	112816,8
Sum					12 174	237909.84	644756.62

Source: own study.

Based on the data, transport costs can be determined for individual suppliers and recipients. The total cost of transport from suppliers, through the distribution center, to recipients is PLN 34,515.52 (Table 3).

Table 3. Calculation of freight costs
Tabela 3. Obliczanie kosztów przewozu

Suppliers and recipients	Coordinates		Shipment size (number of pallets)	Transportation cost	Distances of suppliers and recipients from the center of gravity	Values
	x_i	y_i	$a_i;\ b_j$	$a_ik_i;\ b_jk_j$	$d_i;\ d_j$	$a_ik_id_i;\ b_jk_jd_j$
Supplier A_1	16.17	50.47	450	2 704.00	3.59	9 705,06
Supplier A_2	19.04	49.5	600	3 422.00	3.62	12 392,62
Supplier A_3	18.44	51.36	200	1 680.00	1.18	1 990,44
Recipient B_1	17.29	50.52	700	2 208.00	3.13	6 904,59
Recipient B_2	18.34	51.13	550	2 160.00	1.63	3 522,81
Center of gravity	17.77	50.47		Sum		34 515.52

Source: own study.

The determined coordinates x_0, y_0 will be used in order to determine the corrected coordinates $\overline{x}_0$, $\overline{y}_0$, which will allow for a new location of the distribution center, and this location will reduce transport costs (Table 4):

$$\overline{x}_0 = \frac{1008878.81}{5146.77} = 19.60 \quad \text{and} \quad \overline{y}_0 = \frac{272897.41}{5146.77} = 53.02$$

In the next step, the distance of individual suppliers and customers from the center of gravity should be determined (Table 4).

On the basis of the determined distances and transport costs, it was possible to determine the corrected coordinates of the center of gravity and total cost (Table 5).

The corrected coordinates determined in this way allow for the determination of a new, lower transport cost of: PLN 33,123.15 (Table 5).

Table 4. Determination of the corrected center of gravity
Tabela 4. Wyznaczanie skorygowanego punktu ciężkości

Suppliers and recipients	Distances of suppliers and recipients from the center of gravity	Transpo--rtation cost	Values	Values	Values $\frac{a_i k_i x_i}{d_i}$ $\frac{b_j k_j x_j}{d_j}$	Values $\frac{a_i k_i y_i}{d_i}$ $\frac{b_j k_j y_j}{d_j}$	Values $\frac{a_i k_i}{d_i}$ $\frac{b_j k_j}{d_j}$
	d_i; d_j	$a_i k_i$; $b_j k_j$	$x_i a_i k_i$; $x_j b_j k_j$	$y_i a_i k_i$; $y_j b_j k_j$			
Supplier A_1	3.59	2 704	43 723.68	146 529.76	12 182.19	40 825.77	753.38
Supplier A_2	3.62	3 422	79 253.52	181 810.86	21 884.44	50 203.82	944.92
Supplier A_3	1.18	1 680	31 970.4	90 770.40	26 984.10	76 613.29	1 417.98
Recipient B_1	3.13	2 208	37 602.24	112 828.80	12 024.72	36 081.21	706.09
Recipient B_2	1.63	2 160	45 360	112 816.80	27 812.36	69 173.32	1 324.40
Sum					100 887.81	272 897.41	5 146.77

Source: own study.

Table 5. Calculation of freight costs for a corrected center of gravity
Tabela 5. Obliczanie kosztów przewou dla korygowanego środka ciężkości

Suppliers and recipients	Coordinates		Shipment size (number of pallets)	Transpo--rtation cost	Distances of suppliers and recipients from the center of gravity	Values
	x_i	y_i	a_i; b_j	$a_i k_i$; $b_j k_j$	d_i; d_j	$a_i k_i d_i$; $b_j k_j d_j$
Supplier A_1	16.17	54.19	450	2 704.00	3.63	7 830.26
Supplier A_2	23.16	53.13	600	3 422.00	3.56	8 969.82
Supplier A_3	19.03	54.03	200	1 680.00	1.16	880.21
Recipient B_1	17.03	51.10	700	2 208.00	3.21	11 465.21
Recipient B_2	21.00	52.23	550	2 160.00	1.61	3 977.65
Center of gravity	19.60	53.02		Sum		33 123.15

Source: own study.

It should be in mind that the designated coordinates may indicate a place where there will be no infrastructure allowing for the construction of a distribution center. Therefore, the designated coordinates can be treated as an introduction to further search for the best location of logistic distribution centers in food supply chains.

The suggested location of the company's own distribution point, obtained as a result of applying the center of gravity method, should be carefully analyzed. Identifying the location using this method is only the beginning of the proper analysis of the location conditions for your own distribution point.

Summary

Determining the approximate transport costs for the analyzed variants is an element supporting the decision to choose the best location for the distribution center. This is the most important element, the correctness of estimating these costs may significantly affect the final decision. It is possible to determine the cost of transport by simulating the distribution using historical data for the analyzed variants.

The proposed location of the distribution point for the surveyed suppliers and recipients, obtained as a result of applying the center of gravity method, requires a thorough analysis. Determining the location using this method is only the beginning of the proper analysis of the location conditions of your own distribution point. You should carefully check regional and local factors that will have a significant impact on decision making.

An important element is to identify additional location factors that will affect the decision-making. They largely depend on the preparation of the decision maker and the analyst's knowledge. If the decision-maker is unable to specify the factors to be followed when selecting a location, a substantively prepared analyst should indicate factors that may have a significant impact on the location of the distribution center.

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Implementation of return logistics rules in waste management by municipalities

Wdrożenie zasad logistyki zwrotnej w gospodarce odpadami przez gminy

Abstract. The article presents the need to implement the principles of return logistics in municipal waste management, which in Poland is implemented by municipalities as local government bodies. Municipalities have had a statutory obligation since 2012 to develop waste management systems. According to specialists in logistics, municipal waste management systems should meet the requirements of logistics systems. For example, in terms of logistics, the waste management system in Warsaw was evaluated.

Key words: municipal waste, waste management, logistics systems, circular economy

Synopsis. W artykule przedstawiono potrzebę wdrożenia zasad logistyki zwrotu w gospodarce odpadami komunalnymi, która w Polsce realizowana jest przez gminy jako organy samorządu terytorialnego. Gminy mają od 2012 roku ustawowy obowiązek opracowania systemów gospodarowania odpadami. Według ocen specjalistów z zakresu logistyki gminne systemy gospodarowania odpadami powinny spełniać wymagania systemów logistycznych. Przykładowo, w aspekcie logistycznym został oceniony system gospodarki odpadami w Warszawie.

Słowa kluczowe: odpady komunalne, gospodarka odpadami, systemy logistyczne, gospodarka o obiegu zamkniętym

Introduction

According to the amended regulations on waste management, the municipal authorities in Poland are obliged to manage the waste because the municipalities became their owners [Ustawa z dnia 1 lipca 2011 r…]. New waste management policy required by the European Union directives was introduced by the Waste Act in late 2012, which began to apply in 2013 [Ustawa z dnia 14 grudnia 2012 r…]. Waste management regulations speci-

fied in the law are aimed at protect human life and health and protect the environment in accordance with the principles of sustainable development. In detail, the regulations include sections such as prevention of waste generation, reduction of waste production, elimination of negative impact of landfills and processing plants on the environment, and preparation of waste for reuse or utilization.

According to the latest European Union directives related to functioning of the whole economy in close circulation, Poland must achieve 50% of waste recovery by 2020. In addition, the European Union rules stipulate that waste should be processed on its area, so e.g. composting should be done in waste collection areas. Taking into account currently required the priority of recycling, municipalities should accomplish two goals: organizing a well-functioning waste reception system and ensuring an adequate level of waste recovery [Buclet 2010, OECD 2015].

New tasks as results of European Union regulations are the challenge for these municipalities that invested in waste incineration plants [Bril and Rydygier 2016].

According to logistics specialists waste management, in order to achieve efficiency and effectiveness, should be supported by logistical solutions [Żygadło 1999, Szoltysik 2009]. New ways to manage waste can be found in the new branch of logistics called return or reverse logistics. In the literature of the subject, the return logistics is also known by the name waste logistics, recycling logistics, recovery logistics as well as eco-logistics [Szoltysik 2009]. The purpose of waste logistics is to find the most convenient organizational and cost solutions for transport, storage, processing and waste disposal. Waste logistics supports all waste management processes (including full and damaged products recognized by their disposers as a waste) and information related to waste flows from places of origin (appearance in the logistics system) to the place of destination where the waste is treated for reuse, recovery (repair or recycling) or proper disposal and long-term storage [Żygadło 1999, Christian et al. 2003, Pichtel 2014].

The Waste Act, amended in 2012, requires every municipality, which in Poland is the local self-government administration authority, to develop a waste management system [Ustawa z dnia 14 grudnia 2012 r…]. Authors of this article decided to investigate whether municipal waste management systems are logistics systems. Therefore, the purpose of this work is to examine waste management systems developed by municipalities in terms of compliance with the principles of logistics systems. As an example, the waste management system developed by the city of Warsaw was examined.

Methodology of research

As the research material, authors of this article took a waste management system in force in Warsaw, the capital city of Poland. The operation of the system was examined, including the implementation of planned activities and the founded construction of new investments. The analysis of the established waste managing system is carried out on the basis of the expert knowledge of the authors of the article and their experience of working in local governments. The study consisted of comparison the existing plan with the waste logistics system promoted in the literature. Then the implementation of an approved waste management system is examined. The examination of the implementation covered

the period from 2012 to 2020. The implementation of planned activities and investments was followed. It has been shown that many of the significant intended activities have not been carried out in the assumed time, and important investments in waste utilization plants have not been implemented to this day.

Logistics waste management systems

The logistics waste management system should take into account functional areas including waste generation, transport to processing facilities where waste is stored, recycled or neutralized, as well as current general and local regulations [Żygadło 1999, Bril and Rydygier 2017].

External conditions constituting restrictions on the functioning of the logistic waste management system include:

- quantity, composition, and location of waste,
- degree of regularity and dynamics of waste generation,
- principles of environmental protection,
- spatial and urban factors such as the structure and configuration of the settlement network of the region, the location of processing facilities, transport routes, spatial structure of economic activity,
- general standards, as well as local and regional requirements for acceptable environmental pollutants.

Internal conditions are closely related to the technological aspect of transport, storage and processing of waste and include:

- way of collecting waste,
- location and size of objects,
- waste transport routes and appropriate means of transport.

In a static model, the description of the system operation concerns a specific time point and a dynamic model takes into account changes in input parameters over time. Therefore, the dynamic model should take into account:

- frequency of waste generation,
- possibility of stepwise localization of objects,
- restrictions on the capacity of objects,
- possibility of launching new waste recycling processes,
- location of places available to build new objects.

The developed logistics waste management system should contain guidelines for future development as well as planned emergency procedures.

Warsaw waste management system

Warsaw, the Capital City, is the largest city of Poland, located in the central-eastern part of the country, on the Vistula River. Warsaw is a municipality with province rights. Warsaw municipal waste management system was established in a document entitled "Waste Management Plan for the Capital City Warsaw for the years 2008−2011, taking into account the years 2012−2015" [Fajfer et al. 2008]. Due to the dates, it looks like

the waste management system was created before the statutory obligation to develop it and was extended to 2012−2015. The plan includes basic data on the morphology of the waste, the number of inhabitants and the nature of the buildings. Morphological analysis presented in the examined document showed that municipal waste mainly includes organic components (vegetable, kitchen remnants, and animals), paper and cardboard, plastics, glass, metals, minerals, ash fraction, hazardous waste. In the stream of municipal waste there are also components requiring separate treatment, i.e. large-scale waste and waste from the renovation of houses and flats. Warsaw occupies a total area of 617 km^2, inhabited by 1.7 million people. There are also 500,000 people not registered in Warsaw. In the structure of Warsaw residential areas (habitable, industrial and other built-up areas, also undeveloped and recreational areas) are predominant. A significant part of the city area also occupies farmland, over 15,000 hectares, but their surface is decreasing. The remaining part includes grassland (over 3000 hectares). Warsaw is divided into 18 districts (from 2002) having the status of auxiliary self-government units (Figure 1). The largest district constituting 15.4% of the city's total area is Wawer District, then Białołęka (14.1%), Ursynów (8.5%), Wilanów (7.1%), Mokotów (6.9%), Bielany (6.3%), Włochy (5.5%), Bemowo (4.8%), Targówek (4.7%), Wesoła (4.4%), Praga Południe (4.3%), Wola (3.7%), Rembertów (3.7%), Śródmieście, i.e. Central District (3.0%), Praga Północ (2.2%), Ochota (1.9%), Ursus (1.8%) and Żoliborz (1.6%).

To realize waste management in Warsaw the following types of activities are listed:

1. Organization the system of selective waste collection through:
   - collection by the way 'at source' and 'containers set in the neighborhood',
   - district points of voluntary waste collection,
   - mobile points of waste collection.
2. Investments:
   - material recovery facilities for selective waste collection:
     - construction of eight district points of voluntary waste collection,
     - construction of two systems for the sorting of selective waste materials with a capacity of 20,000 Mg/year with the possibility of expansion to 30,000 Mg/ /year; In addition, there will be existing sorts of raw material waste belonging to private entrepreneurs,
     - construction of green waste composting plant with a capacity of 20,000 Mg/ /year,
     - construction of an anaerobic plant for biodegradable waste (a capacity 10,000 Mg/year),
     - construction of an installation for the dismantling of large-scale waste, including partially used electrical equipment with a target capacity of about 10,000 Mg/year,
     - construction of a plant to process the waste generated in home renovations with a capacity of 8,000 Mg/year;
   - installations for the disposal of waste mixed with the recovery of heat and electricity:
     - modernization and extension of the existing municipal waste utilization and incineration plant for operation of the right bank of Warsaw (Municipal Solid

Waste Disposal Plant) and the agglomeration with the target capacity of 312,000 Mg/year,

- undertaking activities aimed at the construction of a second waste disposal facility for operation of the left bank of Warsaw and the agglomeration of 390,000 Mg/year (taking into account the forecasts of the amount of generated waste by 2025 and the possibility of servicing the surrounding municipalities);

– storage facilities:

- construction of a non-hazardous and inert waste landfill with a capacity of 400,000 Mg in 2009, 300,000 Mg in 2011 and then around 190,000 Mg in 2013. The amount of landfill waste will be reduced due to the requirement to reduce the amount of biodegradable waste directed to the landfill and from 8 January 2013 to meet the criteria for the acceptance of waste for disposal at the landfill of that type.

3. Education: different means and forms of teaching the inhabitants how to handle waste properly.

The Warsaw waste management system can be presented on the Figure 1.

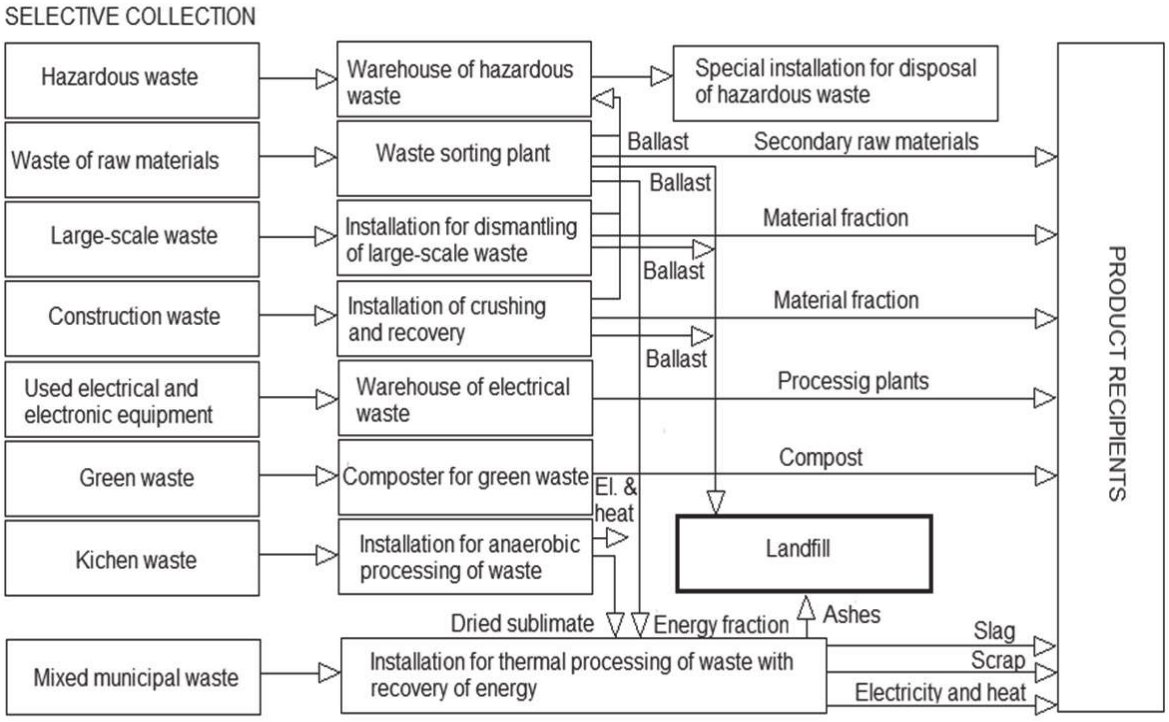

Figure 1. Scheme of waste management system in Warsaw

Rysunek 1. Schemat systemu gospodarowania odpadami w Warszawie

Source: own material on the basis of the [Fajfer et al. 2008].

Functioning of the system:

1. The mixed municipal waste will be directed to the thermal treatment of waste with the recovery of heat and electricity.
2. The system of selective collection and recovery of waste will be expanded:

- selective collection will cover the following types of waste: packaging waste, paper and cardboard waste, plastics waste, metals, hazardous waste, large-scale waste, construction waste, green waste, biodegradable kitchen waste (restaurants, hotels, canteens) and waste electrical and electronic equipment;
- selected raw material waste will be collected 'at source' from single family housing, and from multi-family housing by means of 'neighboring containers' and in district points of voluntary waste collection and then directed to the waste sorting plant,
- household waste and other biodegradable waste will be collected selectively 'at source' in single family and low multi-family housing;
- green waste from green areas will be selectively collected 'a source' and through district points of voluntary waste collection;
- selectively collected biodegradable waste will be composted in green waste composters and fermented in methanization plants;
- hazardous waste will be collected at district points of selective waste collection and in specially designated areas (e.g. pharmacies, schools, shopping centers, etc.); in addition, companies authorized to receive municipal waste, according to the regulations are obliged to receive, among others. Selectively collected hazardous waste by landlords;
- hazardous waste will be disposed of in specialized facilities dealing with the disposal of hazardous waste outside the capital city of Warsaw;
- large-scale waste will be collected as part of a temporary collection and in selective waste collection districts; in addition, companies authorized to receive municipal waste pursuant to the regulations are obliged to collect selectively collected large-scale waste by landlords;
- large-scale waste will be recycled in special dismantling installations;
- waste from repairs and demolition shall be taken in the district points of selective waste accumulation and recovered in the debris processing plant; in addition, companies authorized to receive municipal waste are obliged to collect waste from demolition;
- ballast waste from the sorting plant for packaging and raw material waste will be disposed in the waste thermal treatment plant and to the landfill depending on the type of waste.

Results

Waste Management Plan in Capital City of Warsaw was evaluated by the authors of this paper first in 2015 at the end of the period of validity [Bril et al. 2015]. No new document of the nature of the previous plan covering 2015 was developed. The city authorities planned to update the waste management system as part of the creation of the new "Environmental Protection Program for the Capital City of Warsaw for 2017–2020 with a view to 2023". In this purpose, a cycle of debates under the name EcoWarsaw was organized as meetings of inhabitants with experts and officials. However, as a result of these activities, no document updating the previous plan has been developed. It seems

that the reason for such behavior of the Warsaw authorities was the failure to implement the assumed investment plans. Useful information instructions for residents are published on the municipal portal includes up-to-date communications, legal documents specifying the system framework, form templates for making declarations, answers to frequently asked questions, useful tips, for example how to properly segregate waste, or how to set up a composter.

Regarding the planned system described in the Waste Management Plan in Warsaw, authors of this paper find that it contains logistic-oriented system features, as the specification of external determinants and internal conditions, the forecast of waste generation and required investments.

Evaluation of functioning system was made on the basis of ongoing implementation, comments of self-government activists, guidelines of the Ministry of Environmental Protection and opinions of residents as well as of the changes enforced by the new legislation in response to European Union Circular Economy Directives. Accurate studies of the course in the years 2012–2020 have shown that from the beginning the system was incorrectly implemented.

The main defects in the functioning of the system are:

1. Wild dumps.

Despite the obligation to export and segregate waste to municipalities, rubbish in the initial phase of the system‘s implementation was still being dumped in the forest and into illegal landfills. The reason for littering the surrounding woods was that many people successfully avoided fees, such as keeping the number of homeowners and not reporting their homes. Wild dumps were a scourge beyond control by administrative methods, because to be effective one had to catch the perpetrator on the spot. It wasn‘t until 2020 that the government, through amendments to regulations, supported municipal activities aimed at eliminating illegal garbage dumps and the shadow economy. From 1st January 2020, every waste disposal company registered in the Waste Database must keep electronic records of its operations.

2. Inadequate selective waste collection infrastructure.

The city has long failed to fulfill its obligation to create voluntary waste segregation points. Access to information on hazardous waste collection sites or large-scale disposals was difficult. Due to the permanent monitoring by the local press journalists, the Mayor Hall organized two points of selective waste collection in October 2015: one on the left bank of the Vistula River (Wilanów Districts) and second on the right bank (Białołęka District). In addition, mobile collection points were organized. It consists in the fact that from mid-October 2015 on Wednesdays and Saturdays special cars are on the streets of Warsaw and they stand after 1.5 hours in a designated place in each district. Compared to plans, the implementation of selective waste collection took too long.

3. Lack of economic aspect in educational campaigns.

Long preparing of the principles of waste segregation delayed the placement of properly labeled waste containers in the streets, which was only done in mid-2014. Waste were divided into three groups: dry waste (in red containers), glass (in green containers) and mixed waste (in black containers). After three years of application of the three-fraction segregation method, since 1 July 2017 Ministry of Environmental Protection has introduced a unified waste selection rules. Now, waste must be collected in four containers of

different colors: glass (green containers), paper, including cardboard (blue), biodegradable waste with special consideration of bio-waste such as kitchen waste (brown), metals and plastics (yellow). For mixed waste there are intended black containers. Despite the statutory provisions in Warsaw, containers for a new waste segregation have not been set up. This delayed the educational campaign explaining to inhabitants the new waste segregation. In January 2019, an educational campaign was launched with the use of large advertisements hung at public transport stops and on the walls of the metro station. Unfortunately, it was not possible to introduce new segregation rules in all districts, because the periods of acquiring waste collection companies were extended. The educational campaign had to be extended. In February 2020 posters appeared in the subway and at the stops, and in March 2020 even billboards. The idea of current action is different in 2019 because a specific type of waste is selected with information about where to throw it away. However, there is no action to mobilize residents to reduce waste production. The campaign to promote the reduction of garbage production is very desirable, but it must also have a financial incentive. Meanwhile, the flat-rate fee system is not such an incentive. The new segregation rules related to the circular economy have resulted in an increase in costs, which translated into an increase in fees for the waste disposal. Therefore, the residents received further waste segregation instructional actions as the authorities' expenses not for help but for restructuring.

4. Investment delays.

The construction of new waste treatment plants is necessary because existing plants use outdated technology requiring long storage of waste before they can be re-used. The municipal waste recovery and disposal system is based on the following main facilities Radiowo Composting Plant. Composting plant at 'Marywilska' Street at the Bialoleka District was not approved for waste treatment in 2006. Municipal Solid Waste Disposal Plant and Municipal Waste Landfill are located in Lubna locality in the municipality of the town of Gora Kalwaria. In total, the waste is exported to 19 landfills (public and private), up to 44 waste recovery plants and to the Municipal Waste Disposal Plant (incineration plant). Long-term waste discharges the odor nuisance for local residents. Before the elections in Warsaw in November 2014, the city authorities had promised to transfer the waste disposal plant from the Radiowo in Bielany District to the nearby town of Zielonka. After the election, the new authorities of Warsaw decided to expand the municipal waste treatment facility on the right side of the Vistula River on at the Targówek District. This plant handles around 40,000 tons of rubbish a year, and after the extension, it is expected to convert over 300,000 tons. The factory has been operating since 2000 as a waste incineration plant. This incinerator was obsolete at the time of launch, because the city government had opted for a cheaper old 80s technology. Today the plant uses about 10% of municipal waste, which is about 70 thousand tons per year. In December 2015, the Warsaw Council decided that the expansion of the incinerator, which would remove up to 320,000 tons of rubbish a year, would be financed by the town hall. Municipal City Cleaning Company (called MPO) is able to finance the investment financially as the European Investment Bank had already awarded over PLN 560 million. Commercial credit has been negotiated too. In addition, the MPO was seeking around PLN 600 million from European Union funds to refinance loans. In 2019 the tender for the construction of the incineration plant has been annulled because the MPO was misled by the Chinese tender winner. The new

tender will be settled in mid-2020. The expansion of the incineration plant will begin in 2021, and its completion is expected after 36 months, i.e. around 2024.

5. Inconvenience of landfills for local residents.

The landfill in Radiowo was liquidated in 2017 as a result of the decision of the Administrative Court in Warsaw after a six years battle of Association Czyste Radiowo, but it is still a source of odor, now as a result of green waste storage. Residents say that not only branches or cut grass are transported to the landfill, but also plastic or potato peelers, in plastic bags. Currently the residents have no clout, because the Warsaw authorities do not want to close the disposal of green waste. After that, residents will be exposed to nuisance for a long time because the liquidation of a closed landfill is at least a 30-year process, and it is still degassed all the time.

6. Large increase in fees for waste exports.

Pursuant to the resolution of the City Council of December 12 last year, from 1 March 2020 in Warsaw new rates of waste collection fees are charged. A fixed monthly amount for the collection of segregated waste from a single-family house is PLN 94, and from an apartment in a block of flats or a tenement house – PLN 65. In the event of unsorted waste, the fees will double. These are large increases, which are criticized by residents. Until now, a mixed method was used, depending on the class of households: one person residing in a single-family house paid PLN 30 per month for collecting segregated waste, two people – PLN 45, and three and more – PLN 60. In the case of a flat in a single-family house, the fees were PLN 15, 23 and 30 respectively. Similarly, in multi-flat real estate, e.g. in apartment blocks and tenement houses, the lowest rate was paid by one-person households. The rate for one person to collect segregated garbage is PLN 10, two people –PLN 19, three – PLN 28, and four and more – PLN 37. In the event of unsorted waste, 20% added the amount indicated. Currently, changes in rates are the most severe for those living on their own premises. Their fees will increase by up to 600%. The smallest difference will be felt by multi-person households. The fee for waste disposal in Warsaw has not changed since 2013, and labor, energy and fuel costs increased during this time. The method of calculating fees was changed before the vote, the payment was abandoned on the area of the apartment, and a system flat-rate was introduced for all apartments. Residents do not see the sense of waste segregation into five fractions. The waste collection fee is also influenced by the fact that the city does not invest in modern waste treatment plants and this is a serious drawback.

Conclusions

A thorough analysis of the elaborated plan of Warsaw waste management system has shown that the developed plan meets the requirements of the logistics systems. External determinants and internal conditions have been correctly listed. The functional areas including waste generation and transport to processing plants have been correct showed. The need for new investments was justified. It can be concluded that the developed system has the features of a dynamic model.

Unfortunately, there were undesirable delays and omissions in implementation. It should be emphasized that waste management operates on the basis of free market princi-

ples; therefore municipalities cannot predict many additional factors. A serious omission in the implementation of the assumed plan is the lack of a modern waste incineration plant. This drawback has a negative impact on many other aspects of waste management, and also increases the cost of maintaining the system: economic and social.

It should be pointed that a transformation the economy into a closed circuit is a major change for municipalities which requires a financial help from the state. Currently, two issues are burdensome for residents: waste segregation and waste collection fees. These are matters related to each other because they affect the differentiation of fees. According to the city authorities, the reasons for the increase in waste collection costs are the new five-fraction segregation system, energy price increases (by 67%), rising labor and minimum wage costs (by 25%), reduced rates for companies such as restaurants, shops and shopping centers; and the lack of financial responsibility on the part of producers of plastic packaging, e.g. plastic bottles. The city also includes the reasons for the increase in collection costs: withdrawal of companies from the recycling market, decrease in the prices of raw materials on the market, the cost of obtaining, sorting and cleaning them is several times higher than the purchase prices. Costs increased due to imports of raw material waste from abroad and a dramatic increase of 1100% environmental fee for gases or dust released into the air and placement of waste at the landfill. This rate until the end of 2017 was PLN 24.15, while in 2020 the rates increased up to PLN 270 per ton. No allowances are provided for those residents who reduce waste production. However, the local government is also responsible for the large increase in costs in waste collection. The choice of the method of billing was adopted by a resolution of the City Council for quickly without public consultation and comparison of the results of simulations of the operation of different options. In fact, the Warsaw City Council will now consider replacing the flat-rate scheme with linking charges to water consumption. The situation of mutual blaming local and central authorities for the rising costs of waste disposal is highly undesirable.

The conclusion summarizing this work is the statement that the development of a correct logistics system without systematic and planned implementation of the assumed activities leads to chaos in ad hoc decisions, which has a negative impact on the quality of life of residents.

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Reverse logistics as an important element of the functioning of households in Poland – assessment of the facts

Logistyka zwrotna jako ważny element funkcjonowania gospodarstw domowych w Polsce – ocena stanu faktycznego

Abstract. In the era of growing consumerism, the generation of various types of waste has become a standard from which it is difficult to break free. This, combined with the ever faster shrinkage of natural resources, forces us to search for effective ways of recovering used and unwanted resources from Polish households. This state of affairs becomes a direction that determines activities for a large number of entities operating within various logistic chains. The changing market and legal environment forces producers, but also Polish farms to look for savings, which in turn translates into a more rational policy of these entities. In connection with the above, Polish families are also changing their approach to the issues related to the waste generated within them. Therefore, it seems reasonable to implement logistic strategies in Polish farms related to the optimal use of resources, including those that are no longer needed. The article examines the level of awareness in Polish households on issues related to waste recovery and the knowledge of basic issues related to the implementation of ecologistic concepts in households.

Key words: reverse logistics, Polish households, waste, reverse logistics chain, pro-ecological awareness

Synopsis. W dobie narastającego konsumpcjonizmu wytwarzanie różnego rodzaju odpadów stało się trudnym do wyeliminowania zjawiskiem. Trudność ta, w połączeniu z coraz szybszym kurczeniem się zasobów naturalnych, zmusza do poszukiwania skutecznych sposobów odzyskiwania zużytych i niechcianych zasobów, co dotyczy również polskich gospodarstw domowych. Taki stan rzeczy staje się kierunkiem determinującym działania dużej liczby podmiotów działających w różnych łańcuchach logistycznych. Zmieniający się rynek i otoczenie prawne zmusza producentów, ale także polskie gospodarstwa, do poszukiwania oszczędności, co z kolei przekłada się na bardziej racjonalną politykę tych podmiotów. W związku z powyższym polskie rodziny zmieniają także podejście do kwestii związanych z wytwarzanymi odpadami. Dlatego zasadne wydaje się wdrażanie strategii logistycznych w polskich gospodarstwach rolnych, związanych z optymalnym wykorzystaniem zasobów. Artykuł analizuje poziom świadomości polskich gospodarstw

domowych w zakresie zagadnień związanych z odzyskiem odpadów oraz znajomość podstawowych zagadnień związanych z wdrażaniem koncepcji ekologicznych gospodarstwach domowych.

Słowa kluczowe: logistyka zwrotna, polskie gospodarstwa domowe, odpady, łańcuch logistyki zwrotnej, świadomość proekologiczna

Introduction

For many years now, one of the basic objects of interest in modern logistics is a systemic approach to effectively solving problems related to waste management. Entrepreneurs and scientists are constantly looking for new ways to minimize the loss of all kinds of resources. In connection with the above, the so-called Reverse logistics, which in its area of interest covers all management processes related to the flows of waste and related information from the places where they arise to the places of their proper destination [Budzik-Nowodzińska 2013]. It should be noted that the indicated area has definitions that are ambiguous in their message, having both common features and those that differentiate them. The correct definition of the indicated area should start with the explanation of the slogan ecologistics, which was created by combining two terms: ecology and logistics. Ecology studies the interrelationships between the natural environment and living organisms. Importantly, waste is also of interest to ecology. In this respect, it is particularly important to determine the negative impact of individual wastes on the condition of the natural environment. However, under the slogan logistics, it has an interdisciplinary character, and therefore has many definitions. Simply put, logistics should be seen as an integrated flow system of material flows in the form of raw materials, finished products and waste. What is extremely important, these streams are usually accompanied by the flow of information, which serves to optimize the transformation of physical goods.

Ecologistics, also known as recycling logistics, consists in managing the processes of moving damaged, incorrectly delivered, used, redundant products, classified as excess inventory and used disposable packaging. This management aims to recover materials that are no longer needed as much as possible, and then to reuse them in production or logistics processes, while minimizing the amount of waste that goes to the landfill [Andrzejczyk 2012b].

In its structure, recovery logistics includes the process of planning, implementing and controlling the effective and economically effective flow of raw materials, semi-finished products and finished products along with the related information flows from the place of consumption to the place of origin, for the purpose of recovery or proper management [Rogers and Tibben-Lembke 1998]. The definition of reverse logistics is almost the same as the definition of reverse logistics, otherwise known as reverse logistics.

Reverse Logistics covers all operations related to the reuse of end-of-life products and materials. Reverse logistics is a process that consists in moving end-of-life goods from the place of withdrawal to the place of reprocessing in order to obtain a specific added value or in the absence of such a possibility of proper disposal [Srivastava 2008].

The last term that should be defined is recycling (recirculation), which means taking measures to reuse waste as a starting material, or as a secondary raw material in industrial processes. According to the legal definition in Poland given in the Waste Act, recycling is understood as "recovery in which waste is reprocessed into products, materials or substances used for the original purpose or other purposes; this includes the reprocessing of organic material (organic recycling) but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling [Obwieszczenie Marszałka…, Ustawa z dnia 14 maja 2020 r…].

Note that the topic of reverse logistics in Poland seems to be still relevant because in the country an increase in the amount of waste generated in Polish households can be observed. According to the data of the Central Statistical Office, a statistical Pole produces/produces annually 325 kilograms of municipal waste. It should be noted that despite the increase in the amount of generated waste, we are still not leaders in this field. Poles are still below the European average in the area of waste generation. In 2018, the production of 12,485 thouseand tonnes of municipal waste was recorded. This means an increase in production by 4.3% compared to the previous year. There was also an increase in the amount of municipal waste generated per capita from 311 kilograms in 2017 to 325 kilograms in 2018 [GUS 2020].

The largest amount of waste in Poland per capita, as much as 394 kilograms, was recorded in 2018 in the Dolnośląskie Voivodeship. This result was significantly influenced by the largest city in the region, Wrocław, which generated 531 kilograms of municipal waste per capita. On the other hand, the lowest value in the discussed scope was achieved in the Świętokrzyskie Voivodeship, where only 201 kilograms of municipal waste per capita was generated during one year [GUS 2020].

Compared to other European Union countries, Poland is much less efficient in terms of waste production than other member states. Based on the data from 2017, it can be clearly read that the average amount of municipal waste generated per capita of the European Union in 2017 was 486 kilograms, which is 161 kilograms more than the Polish processing capacity. Most of the waste was generated by countries that are characterized by high prosperity, among others, such countries as: Denmark – 781 kilograms, Germany – 633 kilograms, Luxembourg – 607 kilograms. It should also be emphasized that, apart from the countries mentioned above, also countries with a lower development potential struggle with overproduction of waste. These are, for example, countries with a large volume of tourists, including: Cyprus – 637 kilograms and Malta – 604 kilograms [Eurostat 2020].

It should be noted that not only European Union countries generate large amounts of waste. Countries outside the European Union are also struggling with the same problem. Large amounts of municipal waste were generated, among others, by: Norway – 748 kilograms, Switzerland – 704 kilograms, Iceland – 656 kilograms per capita. In connection with the above, it can be concluded that Poland has one of the lowest indicators related to waste generation per capita among European countries [Eurostat 2020]. Which does not mean that, as a country, it deals with waste in the manner desired by its socio-economic and economic environment.

In accordance with the assumptions of the European Union's policy in the field of waste management, each country within the intra-community structures should maximize

the use of all kinds of resources, while minimizing their waste. Therefore, in 2017, 30% of the total amount of municipal waste generated in the European Union subjected to material recycling, 29% thermally neutralized, 23% neutralized by landfilling, 17% composted. Despite the fact that the problem of municipal waste is an issue that requires an appropriate solution, it should be noted that Polish pro-ecological awareness, both in the society and among its authorities, is still growing. Still, all Poles have a lot of catching up to do in this respect [Andrzejczyk 2009].

Analyzing 2018, only 26% of waste was recycled in Poland, and as much as 42% was landfilled. This means that 7.1 million tonnes of municipal waste collected in 2018 was allocated for recovery. The 3.3 million tonnes (26%) of which was designed for recycling, 2.8 million tonnes (23%) for thermal transformation with energy recovery, 1.0 was directed to biological processing processes (compositing or fermantation) million tonnes (8%) [GUS 2020]. In 2018, a total of 5.4 million tonnes were directed to the disposal processes, of which 5.2 million tonnes (approx. 42% of municipal waste generated) were designated for landfilling, and the remaining 0.2 million tonnes (approx. 2% of production) for disposal by incineration without energy recovery.

Comparing the above, it can be seen that the amount of municipal waste collected selectively in Poland is growing year by year. In 2005, separate collection accounted for only 3% of the collected municipal waste (295,000 tonnes) [Andrzejczyk 2009], while in 2018, over 3.6 million tonnes were collected selectively, which was 29% generated municipal waste [GUS 2020]. Therefore, it seems important to examine the influence of households on the functioning of reverse logistics and what determines pro-ecological behavior in these entities.

Therefore, the main aim of the article is to examine the level of awareness in the field of the production and recovery of waste generated in Polish households, as well as the level of households' awareness of the use of ecology in them. An additional aim of the presented article is to identify the phenomenon related to the lack of pro-ecological attitudes in Polish households and the reasons for this.

The article was created on the basis of an analysis of formal and legal documents, a critical review of the literature on the subject and normative acts in force in the described area, as well as on the basis of observations and surveys carried out in Polish households, divided into households living in rural, urban and urban-rural areas.

Households' place in the logistics reverse chain

In Poland, in 2018, the amount of waste collected separately was 94 kilograms per capita. Mixed municipal waste dominates among the waste generated. In 2018, their quantity was 8.9 million tonnes, i.e. 71% all generated municipal waste. In 2018, in Polish cities, 106 kilograms per capita were selectively collected, while in rural areas 76 kilograms per capita [GUS 2020]. When analyzing the data from the Central Statistical Office, it can be clearly stated that Poles segregate waste more and more willingly every year. It manifests itself in the growing set of segregated products. Table 1 presents the basic data on separate collection of municipal waste in 2017–2018. Based on the table below, it is noted that the amount of separately collected waste is growing for each group included in it.

Despite the fact that in Poland less municipal waste is generated per capita than in most European countries, it should be noted that in Poland it is still at a low level.

Table 1. Amount of separately collected municipal waste in 2017–2018
Tabela 1. Wielkość zbieranego selektywnie odpadu komunalnego w latach 2017–2018

Type of waste	Amount of waste collected per capita [kilograms]		Increase [%]
	2017	2018	
Biodegradable waste	23	26	88,46
Mixed packaging waste	14	15	93,33
Bulky waste	11	14	78,57
Glass	12	13	92,31
Plastics	8	9	88,89
Paper and cardboard	6	7	85,71

Source: own study based on [GUS 2020].

According to the data of the Central Statistical Office, in 2019 the amount of municipal waste obtained in relation to the previous year increased by 2%. In 2019, on average, 332 kilograms of collected waste per capita was collected. It means that in the previous year the average Pole generated 7 kilograms more waste than in the previous year. What is extremely important, in 2019 12.8 million tonnes of municipal waste was collected, which means an increase by 2.1% compared to 2018. Of which 10.8 million tonnes of waste were collected from households, which constituted 84.5% of all municipal waste generated in Poland [GUS 2020].

In 2019, there were 2190 separate collection points for municipal waste in Poland. The municipal waste collection service was provided by 1352 enterprises. Despite the growing environmental awareness in Poland, at the end of 2019, there were still 278 municipal landfills in operation in the country, the total area of which was almost 1700 hectares. The positive in this respect is the fact that over 92% of them are equipped with degassing installations, as a result of which it was possible to burn gas in these landfills in the amount of about 91,153 thousand megajoules of thermal energy and approx. 112,914 thousand kilowatt-hours of electricity. In accordance with the assumptions of the waste policy, 16 landfills with a total area of approximately 52.8 hectares were closed in Poland in 2019. Which still does not exhaust the assumptions of this policy [GUS 2020].

The formation of the so-called wild landfills raises much concern. In 2019, 11,371 illegal landfills were liquidated in Poland, of which approx. 26,000 were collected in total tonnes of municipal waste. At the beginning of 2020, the existence of nearly 2,000 illegal dumps has already been recorded [GUS 2020].

The reallocation of resources contained in municipal waste requires the coordination of many areas. In the processes carried out in households, as well as in enterprises, not only desired products are created, but also those that the inhabitants of these households do not want, they are waste. Importantly, waste is divided into various types and fractions. Most of the waste generated by households is municipal waste. Which does not mean that municipal waste constitutes 100% of the waste generated by these entities, because Polish households also produce hazardous waste, electronic waste, and animal waste. Nevertheless, municipal waste constitutes the overwhelming majority [Andrzejczyk 2012a].

According to the authors, the basic social unit which is the family can be compared to a system consisting of many subsystems, which can be ideally described using the model illustrated, which presents the basic subsystems functioning in typical Polish households. Their construction can also be compared to the construction of models functioning within economic entities, but also logistic subsystems functioning within the state administration (Figure 1) [Andrzejczyk 2012b].

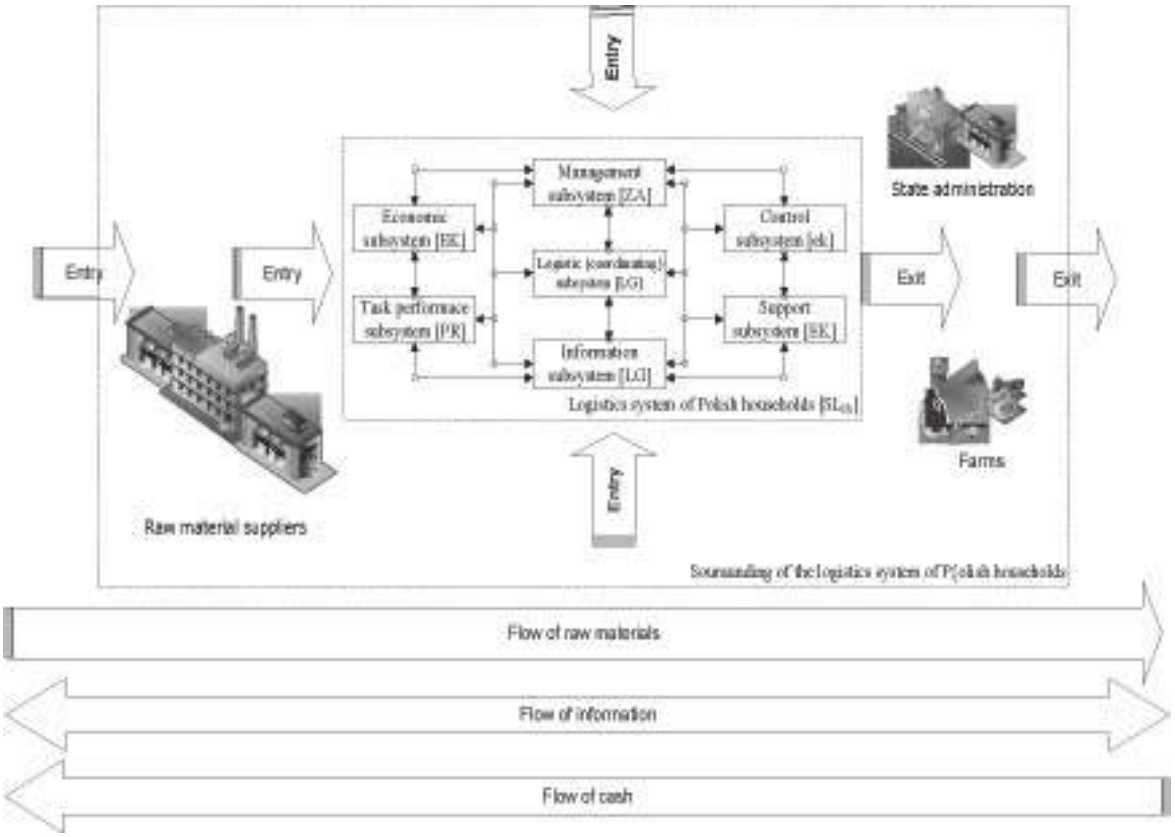

Fig. 1 Logistic chain in the aspect of household functioning
Rys. 1 Łańcuch logistyczny w aspekcie funkcjonowania gospodarstw domowych
Source: own study.

Logistic processes take place in every family, as in every commune, town, village or enterprise. This means that each of the above-mentioned entities manages various types of flows. This, on the other hand, indicates that it can be assumed that households perform logistic process management. Which, in turn, generates the crystallization of subsystems, including logistics, from the abovementioned farms. Going further between the individual subsystems, there are many relationships that are often very complex and require the cooperation of many people and entities. Therefore, more and more often one can find expressions that indicate that in order to be able to efficiently manage the whole family at all, a systemic approach becomes necessary, which in turn leads to the formation of an often informal logistics subsystem. Such a system, thanks to the coordination of physi-

cal and information flows, it facilitates the efficient functioning of the system created by households [Andrzejczyk 2012b].

This means that also households in most cases function as independent links, which are only loosely linked to logistic chains. Due to this state of affairs, households as individual entities have a limited ability to control the physical flow of raw materials and final products [Kuboń 2008, Wajszczuk 2001]. Nevertheless, consumption often depends on these farms, and this translates into production volume. The 21st century is clearly associated with the statement that one of the basic factors influencing the achievement of revenues by enterprises is logistics with all its management tools, flow of raw materials and related information [Ficoń 2001]. The same applies to modern families, which in the era of constantly emerging crises are forced to seek optimal benefits. The search for them is not necessarily related to the need to gain an advantage over the neighbor, but to the need to maintain a certain life status.

From Figure 1 it can be concluded that the logistic subsystem of households has a lot to do with the functioning of economic entities. It has a subsystem of management, information flow and raw materials. Each household is connected with its surroundings in the form of other families, enterprises and public administration facilities. The relations between the aforementioned units depend on the efficiency of logistic chains. Due to the above, it seems necessary to use logistic tools to optimize these tasks.

While observing the situation of Polish households, the cost of living has been increasing recently. Therefore, these entities are running out of funds. The protracted corona virus pandemic is not improving the situation. In addition, public administration bodies forced to tighten their belts, constantly increase fees in the form of various tributes. Such levies include fees related to the disposal of municipal waste. These fees are charged according to different criteria and have different rates. What is extremely important, they also depend on the method of waste collection, and in particular on whether they are segregated or not. As can be concluded, the level of obtained waste in a selective manner seems at least unsatisfactory. So the question arises: how to achieve a situation in which the issues related to waste collection would be as effective as possible for both the entities collecting this waste and their producers?

When talking about efficiency, one should start with the correct definition of the indicated concept. The dominant concept in management theory is the concept of organizational effectiveness, also known as the effectiveness of the system, which is understood as the company's ability to adapt to changes in the environment on an ongoing basis and to use its resources productively to achieve the planned goals [Szymańska 2010].

The above-mentioned approach, in conjunction with the use of ecological tools, may have a positive effect in Polish households, which may translate into effective achievement of the goals indicated by Polish households. "Ecologistics is also known as recycling logistics, otherwise also reverse logistics" [Andrzejczyk 2009]. Ecological logistics, also known as recycling logistics, consists in managing the processes of moving damaged, incorrectly delivered, used, redundant products, classified as excess inventories and used disposable packaging. This management aims to recover materials that are no longer needed as much as possible, and then to reuse them in production or logistic processes, while minimizing the amount of waste that goes to the landfill [Sadowski 2009].

Functioning of Polish households and ecological awareness – state assessment

When analyzing the statistics related to municipal waste in Poland, one can get the wrong impression that it is good. This is due to the fact that we produce less waste than most European countries. Unfortunately, the collected waste, unlike the countries of the European Union, in most cases is unsorted, and what is worse, the collected waste is sent to landfills instead of reprocessing, thus occupying unproductive space, often polluting the natural environment, while making life difficult for Polish households, for example by generating an unbearable odor. This situation is reflected in the statistics of the Central Statistical Office, which states that the collected municipal waste in 2019 was directed to the following processes [GUS data, 2020]:

- Recovery – 7087.0 thousand tonnes (55.6%), including:
  - recycling – 3192.1 thousand tonnes (25.0%),
  - biological processing processes (composting or fermentation) – 1153.2 thousand tonnes (9.0%),
  - thermal transformation with energy recovery – 2741.8 thousand tonnes (21.5%).
- Disposal of 5665.7 thousand tonnes (44.4%), including:
  - thermal transformation without energy recovery – 178.6 thousand tonnes (1.4%),
  - storage – 5487.2 thousand tonnes (43.0%).

Therefore, the question arises why as much as 43% of municipal waste was landfilled. Why are these resources unused and what prevents their reuse. Therefore, research was carried out in Polish households on issues related to the discussed topic. The study included 100 families from such provinces as: Dolnośląskie, Wielkopolskie, Śląskie and Opolskie. The research was conducted in the period from 31 August to 20 September 2020. A questionnaire and an interview questionnaire was used in the study. Based on the collected results, an analysis was carried out on the basis of which the following study was prepared.

As already mentioned, the purpose of this article is to determine the current level of knowledge in Polish households on the application of the concept of ecology in the process of efficient resource management of these entities. The research aimed to determine the current potential of using logistic concepts and related concepts, with particular emphasis on ecological concepts. Based on the logistic concepts presented above, the adopted objective is to examine the level of awareness of production and recovery of waste generated in Polish households, as well as the level of these households' awareness of the use of ecologistics by them. The goal was achieved using the method of analysis and criticism of the literature and logical inference based on the results of research carried out on a sample of Polish households, which were divided according to the criterion of place of residence in terms of urban and rural area, as well as the type of building inhabited and the type of ownership of a residential facility (Figures 2 and 3.). The Figures 2 and 3 show the basic dependencies related to the functioning of Polish households. It is about the way of living and the form of ownership. Detached houses dominate in rural areas, while in cities, apartments whose owners form housing communities and cooperatives predominate. These creations support the owners in keeping the buildings in proper condition. It should be noted that a large proportion of flats in urban areas is rented. These flats are also part of housing communities or cooperatives.

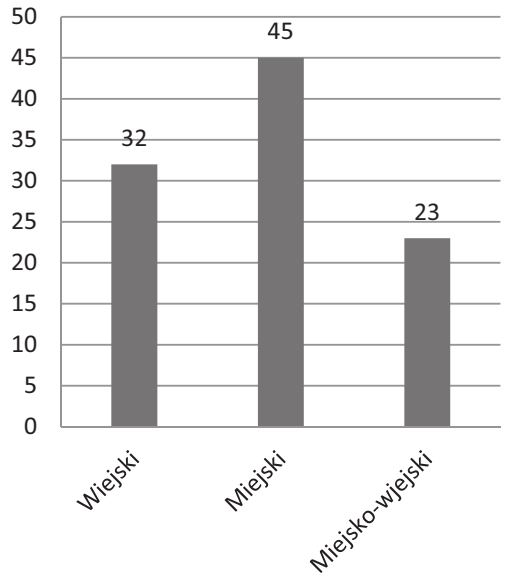

Figure 2. Area where households are located

Rysunek 2. Obszar w których gospodarstwa domowe mają swoją siedzibę

Source: own study.

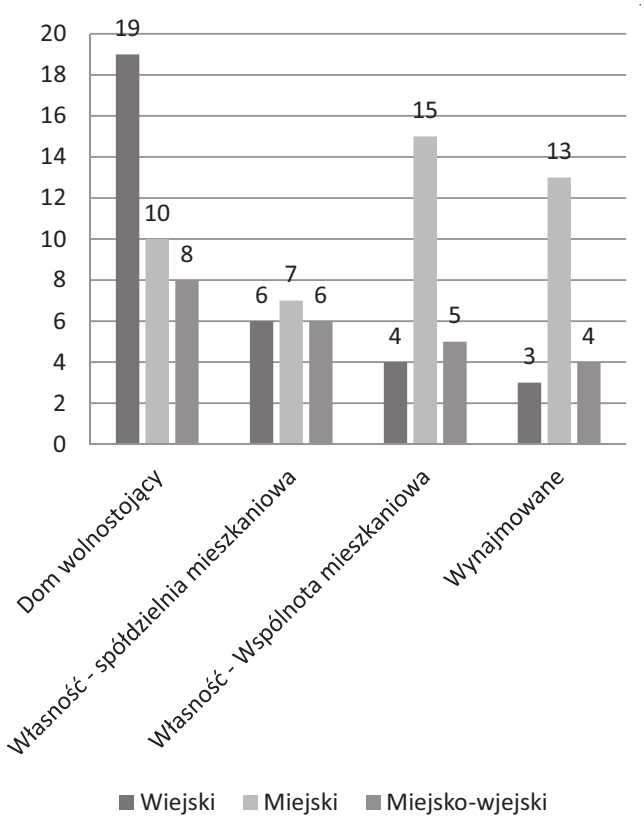

Figure 3. Type of house/flat ownership and related interdepencies

Rysunek 3. Rodzaj własności domu/mieszkania oraz współzależności z tym związane

Source: own study.

It should be noted that among the Polish households that were surveyed, as many as 52% believe that they do not use any logistic tools in managing their farms. Even more households do not use the tools available in the ecological concept (cf. Figure 4 of Figure 5). During the research, the authors checked the general awareness of ecologistics. The aim of the study was to determine whether households have knowledge of these issues at all. The entire study should be treated as a pilot and as the beginning of further research on the possibility of implementing the indicated concepts in Polish households.

On the basis of the conducted research and interviews, it can be observed that urban households much more often use logistic and ecologistic solutions than those based in the countryside (see Table 2 and 3). This situation is most often due to the fact that small urban households have better access to education, both at the post-primary and tertiary level. These households also interact with facilities that have a well-developed logistics infrastructure, which is often difficult in the countryside.

Moreover, a large proportion of the respondents, who had no knowledge of ecologistics before the survey, showed great interest in the surveyed areas, asking what both concepts were all about.

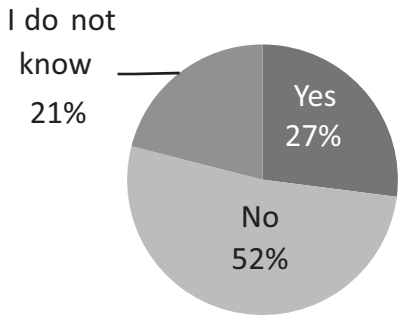

Figure 4. Share of households using logistic tools
Rysunek 4. Udział gospodarstw domowych, w których stosuje się narzędzia logistyczne
Źródło: own study.

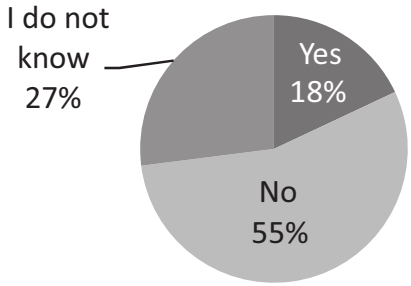

Fig. 5. Share of households using ekologistic tools.
Rys. 5. Udział gospodarstw domowych, w których stosuje się narzędzia ekologistyczne
Source: own study.

Table 2. Share of households using logistic tools [%]
Tabela 2. Udział gospodarstw domowych, w których stosuje się narzędzia logistyczne [%]

Do you use logistic tools in your household?	Area of residence in which the surveyed households are located			
	rural	urban	urban and rural	total
Yes	6	15	6	27
No	17	22	13	52
I do not know	9	8	4	21
Total	32	45	23	100

Source: own study.

Table 3. Share of households using ecologistic tools [%]
Tabela 3. Udział gospodarstw domowych, w których stosuje się narzędzia ekologistyczne [%]

Do you use ecologistic tools in your household?	Area of residence in which the surveyed households are located			
	rural	urban	urban and rural	total
Yes	4	10	4	18
No	18	24	13	55
I do not know	10	11	6	27
Total	32	45	23	100

Source: own study.

Analyzing the tables above, it can also be noticed that Polish households are not very keen on looking at ecology and while the tools of logistics itself are already used, those that allow to protect the natural environment to a much lesser extent. This will be even more visible in the results presented below. This situation results from low awareness, both in terms of logistics and ecologistics. Additionally, some of the respondents do not correctly recognize the keywords in the surveyed area, it is particularly visible in rural areas.

To the question asked: does the household generate municipal waste? almost half of the respondents answered yes (Figure 6). Based on the interviews conducted, it can also be concluded that Poles distinguish municipal waste from other waste, they are also aware that among the products they produce, they have also those that should be classified as non-municipal waste, including hazardous waste (Figure 7).

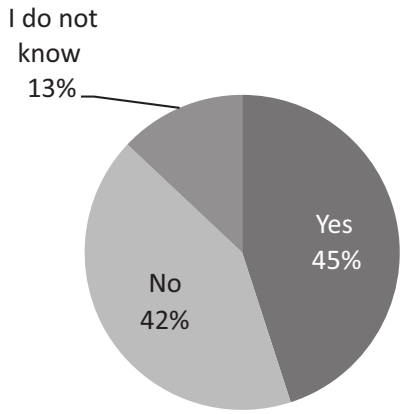

Figure 6. Share of agricultural households producing municipal waste
Rysunek 6. Udział gospodarstw domowych, w których powstają odpady komunalne
Source: own study.

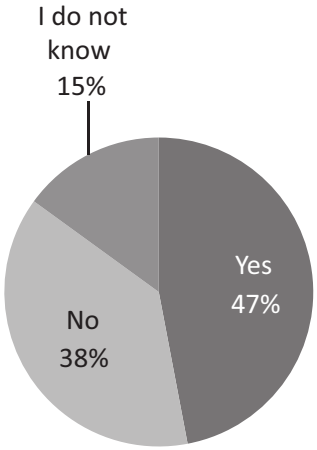

Figure 7. Share of households generating non-municipal waste, including hazardous waste
Rysunek 6. Udział gospodarstw domowych, w których powstają odpady komunalne
Source: own study.

Based on the Figures 6 and 7 and Tables 4 and 5, it can be noticed that Polish households do not avoid the related issues, as less than 15% of the respondents were completely unfamiliar with the subject. It should be noted here that the larger the farm, the greater the knowledge of issues related to the area in question.

Table 4. Share of households generating municipal waste [%]
Tabela 4. Udział gospodarstw domowych, w których powstają odpady komunalne[%]

Does your household generate municipal waste?	Area of residence in which the surveyed households are located			
	rural	urban	urban and rural	total
Yes	10	25	10	45
No	18	14	10	42
I do not know	4	6	3	13
Total	32	45	23	100

Source: own study.

Analyzing the data from the table above, one can assume that many Polish households do not generate municipal waste. In fact, such a situation does not occur, because practically everyone produces municipal waste. In connection with the received responses, the respondents were asked why they did not produce municipal waste. It turns out that many of them assumed that they do not produce the indicated type of waste because they define this type of waste simply as waste without specifying their qualifications. Such a situation

is particularly visible in rural areas. In addition, it turned out that in rural areas, despite the prohibitions and the risk of penalties, there is still the phenomenon of burning waste in stoves or on the property. Interestingly, there is still consent to such behavior. Of course, these are not the only reasons for this, as there are individual cases of waste removal and disposal in prohibited places, e.g. in forests.

Table 5. Share of farm households generating hazardous waste [%]
Tabela 5. Udział gospodarstw domowych, w których powstają odpady niebezpieczne [%]

Does your household generate waste other than municipal waste, including hazardous waste?	Area of residence in which the surveyed households are located			
	rural	urban	urban and rural	total
Yes	7	8	8	23
No	19	33	10	67
I do not know	6	4	5	15
Total	32	45	23	100

Source: own study.

What is extremely important, the number of households with selective waste collection is nearly 70% (Figure 8), unfortunately only 30% of households that comply with all the related rules (Figure 9).

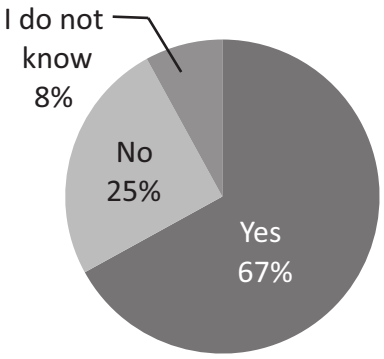

Figure 8. Share of households with selective municipal waste collection
Rysunek 8. Udział gospodarstw domowych, w których prowadzi się selektywną zbiórkę odpadów komunalnych
Source: own study.

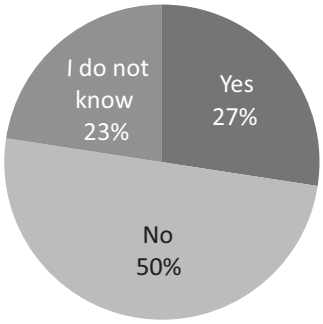

Figure 9. Share of households respecting the principles of selective municipal waste collection
Rysunek 9. Udział gospodarstw domowych, w których przestrzega się zasad selektywnej zbiórki odpadów komunalnych
Source: own study.

The range of harmfulness of the produced waste is still growing (Tables 5 and 6). It can also be noticed that in urban areas there are many more irregularities with separate waste collection than in rural areas 9 (Tables 6 and 7).

It should be emphasized that despite the fact that there are relevant regulations on waste collection and European Union directives, Polish households do not comply with

Table 6. Share of households with selective municipal waste collection [%]
Tabela 6. Udział gospodarstw domowych, w których prowadzi się selektywną zbiórkę odpadów komunalnych [%]

Is separate waste collection carried out in your household?	Area of residence in which the surveyed households are located			
	rural	urban	urban and rural	total
Yes	20	32	15	67
No	10	10	5	25
I do not know	2	3	3	8
Total	32	45	23	100

Source: own study.

Table 7. Share of households respecting the principles of selective municipal waste collection [%]
Tabela 7. Udział gospodarstw domowych, w których przestrzega się zasad selektywnej zbiórki odpadów komunalnych [%]

Does your household comply with all the rules related to separate waste collection?	Area of residence in which the surveyed households are located			
	rural	urban	urban and rural	total
Yes	3	6	8	17
No	9	13	9	31
I do not know	6	5	3	14
Total	18	24	20	62

Source: own study.

the related standards in a proper manner. Importantly, some respondents avoided answering this question, especially inhabitants of urban areas. This situation may be due to the fact that non-compliance with these standards is not subject to high penalties, and the collection of municipal waste is usually not much more expensive than selective waste. The lack of adequate motivation is particularly evident in the case of households that are interdependent on all types of housing associations and housing cooperatives. This is due to the fact that in the case of members of communities and cooperatives, it is very difficult to detect cases of non-segregation of waste, which makes it difficult to impose a fine on people who do not segregate waste. On the other hand, households living in detached houses are easy to trace and it is much easier to prove the fact of non-compliance with the principles of selective waste collection, therefore the imposition of penalties for offenses in this respect is much simpler (Tables 8 and 9).

In addition, many respondents pointed to the lack of time to conduct selective collection of municipal waste, which, combined with the lack of motivation and the general claim that this system does not work properly, means that selective waste management simply does not work, which is confirmed, for example, in the view of overfilled containers with waste and the lack of appropriate waste selection. This, in turn, translates into a malfunction of reverse logistics both at the micro and macro level.

Table 8. Share of households respecting the principles of separate collection of municipal waste according to the apartment/house ownership criterion [%]

Tabela 8. Udział gospodarstw domowych, w których przestrzega się zasad selektywnej zbiórki odpadów komunalnych według kryterium własności mieszkania/domu [%]

Does your household comply with all the rules related to separate waste collection?	Type of ownership of the house/flat and the related interdependencies in the field of selective municipal waste collection				
	detached house	ownership – housing association	ownership – housng cooperative	rented	total
Yes	25	3	7	5	40
No	6	15	15	10	46
I do not know	6	1	2	5	14
Total	37	19	24	20	100

Source: own study.

Table 9. Reasons for non-compliance with the principles of separate collection of municipal waste according to the flat/house ownership criterion [%]

Tabela 9. Przyczyny nie przestrzegania zasad selektywnej zbiórki odpadów komunalnych według kryterium własności mieszkania/domu [%]

Why the rules of municipal waste management are not respected in the household	Type of ownership of the house/flat and the related interdependencies in the field of selective municipal waste collection				
	detached house	ownership – household association	ownership – household cooperatives	rented	total
Too little motivation	4	2	6	7	19
Too low penalties for not following the rules	4	1	4	4	13
There is no adequate system of selective collection of municipal waste	8	8	5	3	24
Wrong location of selective waste collection points	6	3	2	0	11
The inefficiency of the selective waste collection system	4	1	2	0	7
Lack of time	11	4	5	6	26
Total	37	19	24	20	100

Source: own study.

Summary

The paper presents the results of a pilot study assessing the level of awareness of the inhabitants of Polish households on the level of application of ecologistics concepts in these households in terms of the concept of waste collection and recycling.

Based on the literature analyzes and surveys conducted in one hundred different types of households, it can be concluded that Polish families show interest in the use of logistic concepts and less use of ecologistic tools.

Based on the empirical research conducted, it is clearly visible that the inhabitants of Polish households with selective waste collection constitute the majority of the surveyed respondents. The percentage of such people is almost 70% (Figure 8). What is worrying, however, is the number of households that follow all the related rules, as it is only 30% of the answers (Figure 9). Such a situation, according to the respondents, results from: lack of time to conduct separate waste collection (26 responses), lack of an appropriate system of separate collection of municipal waste (24 responses), insufficient motivation (19 responses), too low penalties for non-compliance (13 responses). Of course, there are other reasons as well. Nevertheless, those mentioned above clearly indicate the causes of low social awareness related to the ecological conduct of everyday life.

Therefore, it is not surprising that among the Polish households that were surveyed, as many as 52% believe that they do not use any logistic tools in managing their farms. Even more households do not use the tools available in the ecologistic concept as much as 55%. This situation is confirmed by the large number of farms that use logistic (27%) and ecologistic (18%) tools. Which, in turn, translates into a low level of recycling and recovery of waste in Poland, which for recovery amounts to 7,087.0 thousand tonnes (55.6%), of which recycling accounts for only 3 192.1 thousand tonnes (25.0%) [GUS 2020].

In connection with the above, it should be emphasized that the level of logistics implementation in Polish households is in the initial stage. This process may be accelerated by the changes taking place in Polish legislation. However, a much greater stimulus determining Polish households more willing to use ecological tools will be the dynamically changing market with which Polish households are directly related and the situation related to the corona virus, which will autonomously force a change in the management strategy of these farms. In addition, the environment of the entities in question will pose more and more new challenges. It should be emphasized here that Polish farms will be forced to look for savings, thus they will have to minimize the waste of their resources and maximize their use. Today, every Polish family has unlimited access to resources and information, through the use of modern technologies that will enable the optimal and effective integration of Polish households with the logistics chain.

Not without significance is the ever-growing pressure of society to increase the security of future generations, which manifests itself in the rationalization of production and the flow of products in the supply chain. This is related to, for example, new epidemiological threats that force entities to remain transparent, and this in turn will force the implementation of principles consistent with ecologistic and sustainable development. Based on the above, it can be concluded that even households should assume the implementation of the aforementioned logistic concepts in their activities. Thus, becoming responsible recipients of products both from large enterprises and small entities. This means that a single consumer, who is a component of the household, becomes an integral part of the supply chains, which affects its functioning both in terms of purchasing goods and their withdrawal from the market through the logistic feedback chain.

Summing up, on the basis of the literature review and the observations and surveys carried out, it can be clearly stated that in Poland the level of social awareness in the field of ecology is still at a low level. There is a lack of effective systems motivating the inhabitants of Polish households to comply with the principles that create pro-ecological attitudes. It can also be stated that the surveyed inhabitants make little use of logistic and

ecologistic tools in terms of ecology. This is due to many reasons, the basic one is the lack of time and low motivation as well as the lack of appropriate legal sanctions, for example in the form of administrative penalties. In connection with the above, it is necessary to consider developing an appropriate logistic concept that will create an appropriate pro-ecological basis in the society. IT tools that will allow households to become active participants in logistics chains may prove extremely helpful in this regard. Perhaps it will be possible thanks to the so-called industrial revolution 4.0. The answer to this question will be the subject of further consideration.

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Waste management in Poland versus the circular economy

Gospodarowanie odpadami w Polsce w warunkach gospodarki w obiegu zamkniętym

Abstract. The authors of the article examined the municipal waste management system in Poland in terms of the impact of European Union directives introducing a circular economy in the European Union countries. When assessing the functioning of the system, the social factor was taken into account, as municipal waste management has a significant impact on social life. For example, increasing costs of waste management, resulting in high increases in fees for garbage collection, cause opposition from residents. Lack of funds for the implementation of waste management tasks by municipalities may result in failure to comply with the obligatory recycling levels, which may result in imposing fines on the municipalities. In addition, recycling rates may not be met due to the coronavirus epidemy. It should be emphasized that, just as the introduction of municipal responsibility for waste management in 2012 was equated to a revolution called commonly the "junk revolution", the conversion of the entire economy to a closed loop is an extremely difficult challenge for municipalities, as neglect of waste management may result in an ecological disaster.

Key words: municipal waste, waste management, circular economy

Synopsis. Autorzy artykułu zbadali system gospodarowania odpadami komunalnymi w Polsce pod kątem wpływu dyrektyw unijnych wprowadzających w krajach Unii Europejskiej gospodarkę w obiegu zamkniętym. Przy ocenie funkcjonowania systemu wzięto pod uwagę czynnik społeczny, gdyż gospodarka odpadami komunalnymi ma znaczący wpływ na życie społeczne. Przykładowo, wzrastające koszty gospodarowania odpadami skutkujące wysokimi podwyżkami opłat za wywóz śmieci powodują sprzeciw mieszkańców. Brak funduszy na realizację przez gminy zadań w zakresie gospodarowania odpadami może skutkować niezachowaniem obowiązkowych poziomów recyklingu, co grozi nałożeniem kar pieniężnych na gminy. Ponadto, poziomy recyklingu mogą zostać niezachowane z powodu epidemii koronawirusa. Należy podkreślić, że tak jak wprowadzenie odpowiedzialności gmin za gospodarowanie odpadami w 2012 roku było przyrównywane do rewolu-

cji, nazwanej powszechnie „rewolucją śmieciową", to przestawienie całości gospodarki na obieg zamknięty stanowi wyjątkowo trudne wyzwanie dla gmin, gdyż zaniedbania w zakresie gospodarki odpadami grożą katastrofą ekologiczną.

Słowa kluczowe: odpady komunalne, gospodarowanie odpadami, gospodarka w obiegu zamkniętym

Introduction

The recent transition of the European Union economy to a closed circuit model has resulted in significant changes in waste management. In the new conditions a waste recycling has become the priority, while other ways of waste utilization like storage and incineration have been reduced. According to the European Union directives, Poland should achieve 50% of waste recovery by 2020. In Poland, since 2012, municipalities are obliged to manage waste [Ustawa z dnia 14 grudnia 2012 r…]. Municipalities represent the local government territorial authority at the lowest level. In large cities, the municipality also includes second-level local government, i.e. district authority. In new conditions in the field of waste management defined by European Union directives, municipalities should pursue two objectives: implement a well-functioning waste collection system and ensure an appropriate level of recycling [Pichtel 2014, OECD 2015]. Taking into account changes in waste management resulting from the transition of the economy to a closed circuit creates a real challenge for municipalities, especially for those that have invested in waste incineration plants. Municipal waste management is the current research area of the authors of this article. The research is being conducted in cooperation with various academic research centers such as the University of Technology and Humanities in Radom, or the Kielce University of Technology. The results of this cooperation were presented at international scientific conferences on logistics, transport systems and transport safety organized by the Transport Committee of the Polish Academy of Sciences in Szczyrk, Poland [Bril et al. 2017] and at national scientific conferences like for example Symposium on Science –Technology – Management organized by the Saint Cross University of Technology in Kielce, Poland [Bril and Rydygier 2016]. The research concerned the use of return logistics rules in the development of municipal waste management systems [Bril and Rydygier 2017]. The research presented in this article fits in the lines of research conducted in Polish research centers in the field of economics on various aspects of municipal waste management, such as, for example, research on the impact of the principles of sustainable development [Maśloch 2014], opinions of residents [Lorek 2015]. On the other hand, the impact of the circular economy is investigated in a technical aspect [Smol et al. 2019], and the authors of this article also took into account the social perception of changes in municipal waste management.

Method of research

The presented article is an analysis of the functioning of the national waste management system based on the expert knowledge of the authors. The authors of this article undertook to assess the situation of waste management in Poland using their knowledge

in the field of return logistics as well as experience in activities in government administration and authorities. Municipal waste management is a specific waste management issue which is closely linked to the social aspect and has a direct impact on the lives of residents. The authors of the article thoroughly examined all legal acts and documents concerning the functioning of the municipal waste management system in Poland: parliament acts, government regulations, announcements of high state offices or acts of local law. The opinions of local government activists, non-governmental organizations, press studies and the position of the inhabitants were also taken into account. As the conducted analysis concerns the aspect of functioning of the municipal waste management system in the conditions of the circular economy, the period 2017–2020 was taken into account. In 2017, the regulation of the Minister of the Environment from 29 December 2016, on the detailed method of selective collection of selected waste fractions came into force [Rozporządzenie Ministra…].

Influence of European Union circular economy on a waste management

European Union directives on the development of circular economy (also called a closed-loop economy) according to which recycling is to be a promise in waste utilization and storage and incineration have been significantly reduced. Waste incineration with heat and electricity production is allowed. These directives order by 2025, at least 55% municipal waste is to be recycled, in 2030 − up to 60%, and in 2035 already 65%. By 2030, only 10% municipal waste will be able to end up in landfills. Earlier, various methods of waste utilization, such as storage, incineration and recycling, were permitted by law [Ustawa z dnia 1 lipca 2011 r…]. In connection with the promotion of sustainable development of the economy in the world, recycling was recommended to recover secondary raw materials [Zygadlo 1999, Christian at al. 2003, Buclet 2010]. The transfer of economy in European Union countries to a closed cycle also changes the functioning of the packaging industry. The limited liability of packaging manufacturers has been promoted up to now, and now the government is introducing the producer's total responsibility for packaging.

In case of a closed economy cycle in urban agglomerations are only allowed the waste incinerations with energy recovery. These activities are part of the search for ways to replace conventional sources with others. Energetically, 1 ton of coal corresponds to 2––3 tons of municipal waste. At the same time, in a sense, waste that is once processed into energy disappears because the energy obtained is used to produce many other products from which energy can also be produced.

In 1 July 2017, in connection with new European Union directives, the Ministry of the Environment has introduced a unified waste selection rule [Rozporządzenie Ministra…]. Waste must to be collected in four containers of different colors: glass packaging (green), paper including cardboard (blue), biodegradable waste with special consideration of biowaste such as kitchen waste (brown) and metals together with plastic (yellow). The mixed waste is collected in black containers. Earlier the waste was segregated, but each commune could use its own segregation system. In Warsaw the segregation covered three groups of waste: dry waste (red containers), glass (green containers) and mixed waste (black containers).

It should be noted that the new waste segregation rules corresponding to the European Union directives preferring recycling depend on the good will of the residents. However, if the residents persistently fail to comply with the segregation rules, they will be punished with a doubling of the waste collection fee. Much in this regard depends on the public's awareness of environmental protection. Listed below are directions for changes in waste management due to a closed-loop economy.

Recycling of hazardous waste

Interest in the recycling of hazardous waste is growing, as it is the way to implement the circular economy. Hazardous waste requires the application of very strict rules, regulated by law, regarding their storage, transport, utilization or recycling. Hazardous waste includes fuels, glycols, paints, glues, industrial ashes, catalysts, solvents, pickling acids and alkalis, or used oils. They are usually disposed of and could be recovered [LaGreda et al. 2010]. For example, the product resulting from the processing of solvents can be used in the paint industry and for the production of plastics. The same is true for glycols used in refrigeration, which can be distilled and reused. Some substances contained in hazardous waste mean that they cannot be recycled. However, their number is gradually decreasing. A good example is the use of metals contained in hazardous waste in catalysts from the food and chemical industries, or in galvanic sludges and in lithium-ion batteries.

Circulation of packagings

In view of the growing amount of municipal waste, actions to reduce their production are important. Because packaging accounts for almost half of municipal waste, municipalities are demanding that producers of packaged goods also invest in the waste management system. As a result, this will reduce drastically rising prices for collecting waste from residents. Manufacturers set the condition: if they were to take over responsibility for bottles, containers, bags or boxes in which they pack their goods, then they would also like to take full responsibility for the collection and management of this waste financed from product fees. There would also be deposits for returnable packaging. However, local government officials believe that they will then have trouble achieving adequate levels of recycling imposed by the European Union. The producer's responsibility for the collection and management of waste is called extended producer responsibility. The implemented concept of extended producer responsibility should lead to a reduction in the amount of packaging waste produced from plastics that cannot be recycled today. It is also possible that some of today's known packaging will be withdrawn from the market, because the burden of being unable to meet recycling obligations will be so high that they will force companies to look for alternative solutions. Another element is the standardization of returnable packaging specified by standards under pain of penalties for marketing non-standard packaging. Municipalities believe that the implementation of extended producer responsibility must involve a product fee paid by the producers. It would ultimately cover the costs associated with the operation and development of the recovery and recycling organization and the selective collection of packaging waste.

The Ministry of Climate, former Ministry of Environment, is working on the new regulations on the extended producer responsibility. The designed system is essentially based on two mechanisms – fees and deposit.

The fees mechanism includes two types of fees by the manufacturer:

- a first fee paid only for marketed packaged products intended for households, which will then be paid to marshal offices,
- a second charge that will apply in practice to all other packaging products that will be marketed and which will be paid to the organization of extended producer responsibility.

The deposit mechanism will apply to selected types of packaging.

In practice, it will be the creation of a completely new system that will be aimed at starting the functioning of a new, green order in the field of environmental protection. Unfortunately, the new regulations were not implemented either in the summer or in the fall. In October 2020, the Ministry of Climate announced that the new provisions on extended producer responsibility will not enter into force until 1 January 2022. From that date, packaging producers will participate in the costs of waste management. The new act will implement the European Union directive on waste, packaging and packaging waste into Polish law. According to the new law, producers of e.g. products in packaging are to finance the collection and management of packaging waste at a much higher level than is currently the case. The fees charged to packaging manufacturers will be determined by the regulator's office. According to the assumptions of the Ministry of Climate, this office is to be established at the Institute of Environmental Protection, which is responsible, inter alia, for maintaining a waste database. The fees are to be collected per ton of packaging placed on the market and will depend, among others, on what they consist of (plastic, metal, paper or glass) and whether they are easier to manage (the fees will be lower, the more environmentally friendly a given product is, i.e. the more recyclable). The production of PET bottles with heat-shrinkable foil will certainly not be profitable. It will also be more expensive to pay for tetrapacks, which consist of several materials and are more difficult to recycle. However, with regard to the deposit system, which includes, for example, purchase points for packaging from buyers, the Ministry of Climate still develops rules in talks with entrepreneurs. Funds obtained from the application of extended producer responsibility will be able to flow to local governments to co-finance waste collection and treatment systems.

Environmental awareness of society

Educational campaigns carried out by municipalities focus on explaining the principles of waste segregation, while there is no explanation as to why waste should be segregated, there is also no teaching on how to produce less garbage, i.e., there are no elements of raising awareness. To explain how to operate in a circular economy, a broad social educational campaign is needed at government level, also for cost reasons. In addition, to the transfer of knowledge, it is necessary to create a fashion for eco-products, the message should focus on the fact that the product from recovery is trendy, at the top and cheaper than a similar one made from raw material not yet processed. To be effective, a campaign to raise environmental awareness must include television, and messages should take advertising time.

Municipalities obliged to run educational campaigns are limited our education actions only to propagating waste segregation instructions. Large cities have more opportunities here than small municipalities. And so, in Warsaw, from February 2020, the second educational campaign is already underway. The first outpaced the real placement of appropriate containers due to protracted tenders for waste collection companies. In addition, it was criticized for the excessive artistic expression of the posters at the expense of their content. Now the educational campaign has to be extended. Posters have not only appeared in the subway and at the bus and tram stops, but also billboards have been used. Leaflets informing about how to properly segregate waste were propagated through post boxes and were also placed in garbage cans and arbors (Figure 1). The current action is completely different from the one carried out in 2019. The idea is that a specific type of waste is selected with information about where to throw it away (Figure 2). The educational campaign only concerns instructions on how to segregate waste, and it does not explain why segregation is necessary. Also it does not promote the principles of closed-circuit economy and does not promote the reduction of waste production by household.

Figure 1. Information leaflets on waste segregation
Rysunek 1. Ulotki informacyjne o segregacji odpadów
Source: private material, photo by E. Rydygier.

Figure 2. Poster at a bus stop
Rysunek 2. Plakat na przystanku
Source: private material, photo by E. Rydygier.

In big cities various pro-ecological actions are also organized by non-governmental organizations with the help of local commune authorities consisting in rewarding people who select waste. One of these actions is the setup the recycling machines in several places in Warsaw (Figure 3).

The recycling machine is similar to a parcel machine, but instead of issuing parcels, it accepts PET bottles, glass bottles and cans. First, the user must download the Eco Wallet application, create an account in it, and after receiving the QR code, scan it in the recycling machine. Points are awarded for each raw material thrown into the recycling machine, which can later be converted into discounts for coffee or tickets to the cinema 'Multikino' and to two Warsaw theaters.

Together 'Coca-Cola' and the 'Our Earth' Foundation are responsible for the project. By funding recyclers, 'Coca-Cola' as a great carbonated beverage producer that generates tons of garbage, wants to encourage people to recycle them. However, this does not replace the producer's responsibility for the production of waste wrapped from bottles used by customers. Customers would prefer to receive money for bottles thrown in to recycling machines.

Figure 3. Recycling machine near the Warsaw City Hall
Rysunek 3. Butelkomat niedaleko warszawskiego ratusza
Source: private material, photo by E. Rydygier.

It is commendable to the attitude of artists who have engaged in promoting recycling by designing furniture or clothing from recycled materials and even by creating works of art from waste. For example, the workers of the scrap metal warehouse in Pruszków, the city near Warsaw, are created steel-cast sculptures showing various vehicles and characters from science-fiction films. The local municipal authorities opened the special pavilion for these sculptures as the Gallery of Steel Figures. Schools are organized trips to this museum for pupils. The Gallery also organizes exhibitions in various Polish cities (Figure 4).

Figure 4. Exhibition of steel figures at the Palace of Culture and Science in Warsaw
Rysunek 4. Wystawa figur stalowych w Pałacu Kultury i Nauki w Warszawie
Source: advertising materials of the Gallery of Steel Figures.

Fees for waste disposal

The transition of the economies of the European Union countries has a closed cycle, resulting in an increase in fees for garbage collection. Pursuant to the act on maintaining cleanliness and order in municipalities, municipal authorities set the amount of fees for waste disposal. Inefficient waste management in Poland causes that waste collection fees are constantly increasing. An increase of garbage disposal fees is inevitable as waste treatment costs are currently underestimated. So far, relatively low rates for garbage did not take into account the real costs of their export and disposal. Meanwhile, the amount of waste produced is constantly increasing. Non-segregating people will usually pay twice as much as segregating ones. The current increase in fees for garbage collection results not only from earlier underestimation of costs, but also, among others from rising fuel and electricity prices. More expensive electricity means higher costs of transport as well as storage or combustion of waste. In 2019, electricity prices did not rise, although they should have been because they were frozen by a special government bill. In 2020, due to the increase in the costs of waste management (as a result of new rules of waste segregation and due to new obligations imposed on waste processing installations, such as: video surveillance, financial security of claims, regulation of legal titles to real estate, fire safety requirements), municipalities introduced high increases in fees for waste disposal. In accordance with the provisions of the Act on maintain of cleanliness and order in municipalities [Ustawa z dnia 1 lipca 2011 r…], self-government authorities cannot set arbitrarily high fees for waste collection. To determine the maximum rates of fees for municipal waste management, the average monthly disposable income per capita in the previous year is of key importance. It is announced by the president of the Central Statistical Office. On 31 March 2020, an average monthly disposable income of 1 person in total for the previous year in the amount of PLN 1819 was announced [Obwieszczenie

Prezesa...]. The maximum rate for waste can be 2% of disposable income. This means that currently residents cannot pay more than PLN 36.38 for collecting segregated waste. In the absence of segregation, the highest rate is PLN 145.52. If the method of calculating the amount of water consumed is used, the maximum rate is PLN 12.7 per cubic meter, whereas when the fee is calculated on the basis of the premises, a resident may pay a maximum of PLN 1.46 per square meter. The highest fee possible when charging it from the household is PLN 101.86. For example in Warsaw, from 1 March 2020, new rules for calculating fees have been adopted by the City Council. On 12 December 2019, the Council of the Capital City of Warsaw has decided to introduce new rates for municipal waste management in Warsaw [Uchwała nr XXIV/676/2019…]. It was agreed that the fees for waste collection will be calculated on a flat-rate basis both for family housing and for multi-family housing. A fixed monthly amount for the collection of segregated waste from a single-family house is PLN 94, and from an apartment in a block of flats or a tenement house − PLN 65. In the event of unsorted waste, the fees will double. These are large increases, which are criticized by residents. Until now, a mixed method was used, depending on the class of households: one person residing in a single-family house paid PLN 30 per month for collecting segregated waste, for two persons − PLN 45, for three and more persons − PLN 60. In the case of a flat in a single-family house, the fees were PLN 15, 23 and 30 respectively. Similarly, in multi-flat real estate, in apartment blocks and tenement houses, the lowest rate was paid by one-person households. The rate for one person to collect segregated garbage is PLN 10, for two persons − PLN 19, for three persons − PLN 28, for four and more persons − PLN 37. In the event of unsorted waste, 20% added the amount indicated. Currently, changes in rates are the most severe for those living on their own premises. Their fees will increase by up to 600%. The fee for waste disposal in Warsaw has not changed since 2013, and labor, energy and fuel costs increased during this time. The Warsaw authorities blame the government for the need for increases, but they could nevertheless be better prepared to introduce them. The method of calculating fees was changed before the vote, the payment was abandoned on the area of the apartment, and a flat rate was introduced for all apartments. Residents do not see the sense of waste segregation, and since waste has to be divided into five fractions, segregation has declined. The waste collection fee is also influenced by the fact that the city does not invest in modern waste treatment plants. Real estate used for non-residential purposes is to be excluded: shopping malls, hotels, etc. Other rates will be developed for them. In December 2019, the town hall wanted to link the fees for garbage collection with the area of apartments. It would also mean increases, especially for lonely and elderly people who occupy large flats from which children moved out. At the last minute before voting, majority club councilors pushed the fee with a flat rate for flats (PLN 65) and single-family houses (PLN 94). Currently, companies using real estate for non-residential purposes pay abnormally low rates for municipal waste management, because this is blocked by law. In view of the residents' permanent objection to the flat-rate fee, during the session on 15 October 2020 Council of the Capital City Warsaw adopted a resolution on new rules for calculating fees for waste management, which will apply from 1 December 2020. The Council of the Capital City of Warsaw decided to introduce a solution other than the flat-rate one, which is provided for in the regulations, i.e. the calculation of the fee depends on the amount of water used. The monthly fee for single-family houses,

multi-family flats and for mixed properties will be calculated according to the formula: PLN 12.73 per cubic meter. The fee will be calculated on the basis of the average water consumption for the next six months of the last year. If the property does not have a water meter or it is not connected to the water supply system or there is no data on water consumption for the period of six consecutive months, we will calculate the fee according to the formula: inhabited property: number of inhabitants × 4 per cubic meter of water × × PLN 12.73, while mixed, uninhabited property (e.g. a delicatessen in a tenement house, a beauty salon in a multi-family block): water consumption standards according to the annex to the resolution of the Council of Warsaw of 12 December 2019 on the method of calculating the fee for waste management and multiplied by PLN 12.73. Both in the case of multi-family and single-family properties, residents will not pay for irretrievably used water, i.e. water used for watering the garden. It will be deducted and will not affect the amount of the waste fees. The fee for summer houses or other recreational and holiday properties will be PLN 181.90 per year. The resolution adopted by the Warsaw Council is criticized by councilors from the opposition club, according to them, the rate per cubic meter should be at least four times lower. They believe that the Warsaw authorities want to save the waste budget by increasing the fees, and so far they have done little on waste management, for example, the extension of the waste incineration plant in the Targówek district has not been completed. Residents perceive the new regulation in fees as a drastic increase, especially severe for families, because on average one person a month would pay approx. PLN 50, two − PLN 100, but a family of four − PLN 200.

Impact of coronavirus epidemic on the waste management

Because of the coronavirus epidemic, there is a fear of a "junk crisis". Today, the municipal industry is the third, after health and uniformed services, front line in the war with corona virus. Many sorting plants, especially the less modern ones, which depend on employees and not machines separating waste into individual fractions, may cease operations. Employees of waste companies may be forced to quarantine, and may refuse to work for fear of exposure to the virus. On the other hand, residents in panic before infection may not stick to waste segregation. Negligence in waste segregation and recycling may result in municipalities failing to comply with the levels of recycling required by regulations (50% this year), which entails millions of penalties. Added to this is the increase in waste collection fees. With ever-increasing costs, waste industry companies may give up contracts or fail because there will be no jobs that would guarantee profitability. The fewer companies, the more difficult it is to manage litter, which in turn translates into increased fees. To avoid such a black scenario, on April 7, 2020 the Minister of Climate and the Chief Sanitary Inspector developed guidelines on the management of waste generated during the occurrence of SARS-CoV-2 coronavirus infection and incidence of COVID-19 disease caused by it. These guidelines are intended for municipalities, people in isolation, healthy persons in quarantine, entities dealing with waste collection and management, and for persons using preventive measures such as gloves or masks at work or during shopping.

According to the guidelines, waste generated by healthy people, e.g. masks and gloves used to minimize the risk of coronavirus infection and spread, including in the workplace, and public transport, or during shopping, should be thrown into a container or mixed waste bag. Waste generated, among others caution is required in places of insulation. Municipalities should provide bags in a specific color or marked with a symbol (e.g. the inscription C) in order to uniquely identify waste, ensure collection at no less than every seven days of marked bags, organize appropriate transport directly to the municipal waste disposal installation of marked bags or designated by the municipality places for the collection of municipal waste from insulated households and to ensure disinfection of reusable containers and means of transporting waste transporting waste from households or persons from groups C.

Waste collection and recycling companies should store selectively collected waste for nine days before sending it for processing. Waste in specially marked bags taken from persons in isolation or quarantine should not be processed with the participation of sorting persons. In the absence of technical processing capabilities only on fully automated lines without human intervention, this waste should be sent directly for disposal (thermal transformation or direct storage is recommended preferably in landfills with an active degassing installation). The guidelines recommend that employees use personal protective equipment, i.e. glasses or visors, masks, gloves and work clothes.

Conclusions

Municipalities in Poland need state support. When passing the waste management to municipalities, the legislator did not expect such deep changes in the functioning of the economy in the European Union. The transfer of the European Union economy to a closed cycle changes the paradigm of dealing with pollution and caring for environmental protection. This matter will not be dealt with by ministerial ordinances. There is a need to change the environmental awareness of the society, but also specific state actions supporting the industry related to waste recycling, which requires special funds. Without this state aid, the municipalities do not carry out the waste management tasks imposed on them. The conflict between municipal and central authorities is already visible today, for example in the area of waste collection charges. A comprehensive reform of all aspects of the system is needed, especially in terms of financial support of investments in recycling, reduction of fees for waste collection, introduction of total producer responsibility for packaging as well as more effective public education, including regarding waste segregation.

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The impact of waste quality on a sustainable waste management model

Wpływu jakości odpadów na zrównoważony model gospodarki odpadami

Abstract. The growing interest of enterprises in development in the directions of the concept of sustainable development or corporate social responsibility somehow forced market participants to be more flexible in their actions. Entities from the waste industry must quickly adapt to changing, dynamic realities in order to maintain an appropriate position on the market. The aim and subject of the publication is to present the impact of waste quality on the construction of a sustainable waste management model. The quality of waste determines whether a given waste processing product meets the expectations and standards of the final recipient, as well as the costs of its final management or recycling. The article also presents waste in the light of the applicable national and European Union regulations as well as sustainable development in the aspect of industrial waste management.

Key words: sustainable development, waste management model, waste

Synopsis. Wzrost zainteresowania przedsiębiorstw rozwojem w kierunkach koncepcji zrównoważonego rozwoju czy społecznej odpowiedzialności biznesu niejako wymusiły na uczestnikach rynku większą elastyczność w działaniu. Podmioty branży odpadowej muszą bardzo szybko dostosować się do zmiennych i dynamicznych realiów, chcąc utrzymać odpowiednią pozycję na rynku. Celem i przedmiotem publikacji jest przedstawienie wpływu jakości odpadów na budowę zrównoważonego modelu gospodarki odpadami. Jakość odpadów decyduje o tym, czy dany wyrób z przetwarzania odpadów spełnia oczekiwania i normy odbiorcy końcowego, a także o kosztach jego ostatecznego zagospodarowania czy recyklingu. W artykule także przedstawiono odpad w świetle obowiązujących przepisów krajowych i unijnych oraz rozwój zrównoważony w aspekcie gospodarki odpadami przemysłowymi.

Słowa kluczowe: zrównoważony rozwój , model gospodarki odpadami, odpady

Introduction

The growing interest of enterprises in the development of the concept of sustainable development or corporate social responsibility somehow forced market participants to be more flexible in their actions. This situation only confirmed that the main task of modern

management is to observe the business environment and search for answers to emerging questions and problems [Nogalski 2008]. Waste industry entities had to adapt very quickly to the changing, dynamic realities in order to maintain an appropriate position on the market. It turned out to be important to create the image and value of the company through the time criterion – the speed of action on the existing situations, cooperative and network connections. A single installation will not manage all waste from a given producer and will not be able to react quickly enough. With such defined cooperation, there are much greater opportunities to create cooperation while starting the waste processing process at the producer's.

When analysing the currently available publications related to waste management, one can notice a clear interest in the issues of municipal waste management with particular emphasis on packaging waste and, to a much lesser extent, broadly understood post-mining waste. Such a state of affairs may result from the pressure of the European Union and pro-ecological organizations in the last decade to reduce the amount of municipal waste deposited, reduce the consumption of natural resources and increase the use of secondary raw materials.

All these activities are related to the growing consumption and use of plastic packaging in almost every area of the economy. The legal basis for the functioning of the European Union and domestic waste market is also focused on municipal waste, treating post-production waste extremely superficially.

The aim and subject of the publication is to present the impact of waste quality on the construction of a sustainable waste management model. The quality of the waste in the model also determines the costs that their producer must incur when transferring the waste to the final installation and what costs will be incurred by the installation during the treatment process. The quality of waste determines whether a given waste processing product meets the expectations and standards of the final recipient, as well as the costs of its final management or recycling. The article focuses on sustainable development in terms of industrial waste management and analyses waste in the light of the applicable national and European Union regulations. The research method used in the publication is the analysis of existing data and literary criticism. The literature, netography and statistical data show that industrial waste management can be an effective management system that allows to achieve high-quality final products obtained from processed post-production waste by means of marginal installations and allows enterprises to function in a circular economy. However, you should be aware of both its advantages and disadvantages.

Waste in the light of applicable national and European Union regulations

Waste, understood as all useless and thrown things or substances, both in European and national regulations, does not have a single general definition. It should be noted that we are dealing with a number of wastes that are defined depending on many factors and criteria classifying them as waste. European and national legislation is identical in this respect due to the implementation of European Union regulations into national legislation.

The basic definition of waste in European regulations was included in the Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives in Article 3 [Directive 2008/98/EC…] and defines waste as "any substance or object which the holder discards or intends or is required to discard". Also included is the definition of hazardous waste, meaning waste showing at least one of the hazardous properties listed in Annex III to the Directive. These properties include materials and substances: explosive, oxidizing, highly flammable, flammable, irritating, harmful, toxic, carcinogenic, corrosive, infectious, harmful to reproduction, mutagenic, waste which in contact with water, air or acid releases toxic or highly toxic gases, sensitizing, ecotoxic, waste which, after disposal, can by any means yield another substance, for example in the form of a leachate, which has at least one of the characteristics listed above.

Bio-waste was defined as "biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail outlets and comparable waste from food processing plants". Municipal waste should also be mentioned, the definition of which was developed for statistical purposes by Eurostat and the Organization for Economic Co-operation and Development in order to harmonize the data provided by the Member States. Municipal waste is defined as "household waste and waste from other sources, such as retail, administration, education, healthcare, housing and catering services and other services and activities, similar in nature and composition to household waste".

As stated above, in terms of the definition and conception of waste, national regulations are in line with community regulations. Regardless of the adjective describing the type of waste (liquid, industrial, etc.), one should focus, as Jerzmański [2013] notes, on the basic definition of waste, which is based on three actions of the waste producer – disposal, intention to dispose of and the obligation to dispose of the waste. Therefore, we can talk about a cause-and-effect relationship that occurs in deliberate and planned waste management. With such a definition of waste, in principle, everything or substance that the user has at his disposal at a given moment will be waste at an indefinite time. However, the decision about the situation in which an item or substance will change its status to waste is made by the so-called producer of this waste [Radecki 2008]. However, in the literature on the subject, one can find many doubts as to whether the mere fact of disposing of an item or substance by a waste producer, for example in the production process, actually gives it the status of waste.

The end-of-waste regulation has been implemented into national legislation on the basis of Article 6 of Directive 2008/98/EC of the European Parliament and of the Council. Poland did not make use of the possibility of taking a national decision on the possibility of determining criteria whether certain waste may cease to be waste as a result of technical regulations, administrative regulations or voluntary agreements [Mazurek 2019]. The implemented provision was included in Article 14 of the Waste Act of 2012 [Ustawa z dnia 14 grudnia 2012 r…]. Certain types of waste cease to be waste if, as a result of their recovery, including recycling, they meet the following conditions:

– the object or substance is used for specific purposes;
– there is a market or demand for such items or substances;

– the given object or substance meets the technical requirements for use for specific purposes and meets the requirements set out in the regulations and standards applicable to the product;
– the use of the object or substance does not lead to negative effects on life, health or the environment.

By recovery referred to in Art. 1.3 clause 1 point 14 of the Waste Act should be understood as any process the main result of which is that the waste serves a useful purpose by replacing other materials that would otherwise be used to perform a given function, or as a result of which the waste is prepared to perform such a function in a given plant or in the economy in general. However, in Art. 3 clause 1 point 23 of the Act on waste, one of the types of recovery is recycling, which is understood as recovery, where waste is reprocessed into products, materials or substances used for the original purpose or other purposes.

Sustainable development in terms of industrial waste management

The present concept of sustainable development was popularized by the Brundtland Commission (World Commission on Environment and Development), which in its report presented this definition: "sustainable development is development that meets the needs of the present without endangering the possibility of meeting the needs of future generations" [Misztal 2017]. However, in order for the concept of sustainable development to exist more broadly in the production dimension, manufacturing plants must adapt to it.

In terms of waste management, sustainable development is perhaps the most desirable and visible activity from all sectors of the economy. Both the applicable legal regulations and the efforts of global organizations to take measures to reduce the generation of waste and any harmful emissions while maintaining the natural environment in its present shape, force the shaping of systems based on three balancing pillars: social, economic and environmental development [Biegańska and Ciuła 2011]. Social and economic development can be assessed through the prism of the amount of waste, both municipal and packaging waste. All waste is considered a source of pollution, and when stored it is dangerous to soil, water and air.

Properly prepared, processed and recovered waste can be a valuable source of raw materials. Sustainable development of waste management is primarily waste management without the need to landfill it, with maximum recovery of input materials. This is particularly evident in the management of industrial waste. The activities of the industry are interfering more and more deeply with the waste policy of production companies, not limiting their role only to waste recipients. More and more often, the waste producer expects as much waste as possible to be recycled, and the recipient takes steps to enable this process. The joint cooperation is aimed at optimizing the waste management process from the place of production, through sorting, logistic preparation, to final management. This approach allows for the development of methods and schemes of action that take into account pro-environmental processes. The responsibility of the waste producer for its management gives another tool to supervise the waste management process, taking into account all environmental standards. It also eliminates to a large extent unfair practices of waste recipients, which contributes to the observance and improvement of environmental protection standards.

A properly designed waste management system allows to reduce both emissions related to transport, limits energy consumption to the necessary amounts supporting the process of waste disposal from the plant, but also allows to increase the amount of waste intended for recycling. Properly prepared waste, transferred to the terminal installation, allows to disable one or more processes related to waste preparation for further processing. This allows for further reductions in emissions and resource consumption for the purposes of own operation and/or the recovery of materials for further processing, including in the form of raw materials.

Assumptions and construction of a waste management model

Shifting the waste processing process involves the producer of the waste to be jointly responsible for its quality, thus giving a real impact on the costs borne by the producer for waste management. The problem is both the delivered waste and the end product for each type of installation. Reclassification of the final product, price change for processed waste and raw materials, returns or inclusions deducted from the product weight result in a decrease in both the effectiveness of the entire waste processing system and the profitability of individual types of installations [Szweda 2017].

Each of the installations is characterized by a certain specificity of operation, whether it be the types of processed waste or the final product produced, which will have a different recipient. It also includes the waste processing technology of a given installation as well as the technological and production line. Installations also differ in terms of recipients or the number of deliveries and production capacity specified in the environmental permit, but for each installation, one of the most important performance indicators is the number of widely understood complaints [Rosik-Dulewska 2020].

Complaints may relate to virtually any aspect of the processed waste. Each processed waste may be subject to a complaint, as well as untimely deliveries. The waste management model must take into account those factors that are directly responsible for the elimination of existing non-conformities and have an impact on the costs of the entire process. At the same time, it should be borne in mind that not all changes, although they will bring measurable benefits to each of the participants in the industrial waste management system process, will be acceptable to everyone.

In accordance with the currently operating industrial waste management system, waste is transferred to terminal installations that prepare it for further management. To simplify the model, an intermediate element in the form of waste transport logistics has been omitted due to the fact that it has no significant impact on the quality of waste [Frąś 2017]. The waste is transported both by end installations and external carriers. The external carrier, on the basis of European Union (CMR convention) and national regulations, is responsible for the entrusted cargo and in the event of its damage as a result of improper securing, transportation, storage, e.g. in modal transport, it covers any damage due to the quality of the delivered waste [Gil and Ignaciuk 2014].

Only the producer has a direct impact on the quality of the waste, the recipient, who determines the quality requirements for the received products, and the terminal installation that determines the parameters of the received waste, have an indirect impact. However, it is not always possible to check whether a given batch of waste meets the assumed

requirements. Therefore, it is important that waste producers incur costs related to the transferred waste that do not meet the established criteria, on the same basis as terminal installations.

The industrial waste management model was built on the assumption that there is a correlation between the quality of the delivered waste, regardless of its type, and the quality of the final product obtained. For this purpose, two additional quality groups were designated:

- waste requiring cleaning and better, constituting the sum of waste requiring cleaning and clean,
- contaminated and better waste constituting the sum of contaminated waste, requiring cleaning and clean waste.

In the next stages in building the model, the Pearson's linear correlation can be used and the following data can be adopted:

$$y = \frac{\sum i(x - \vec{x}) \cdot (p - \vec{p})}{\sqrt{\sum (x - \vec{x})^2} \cdot \sqrt{\sum (p - \vec{p})^2}}$$

- input – share of received waste of a certain quality, average number of complaints (x, p),
- initial – correlation coefficient of the number of complaints to the share of waste of a certain quality (y).

Using the Pearson's linear correlation, we obtain an analysis of the results in three intervals

- result close to 0 – no correlation, changing one of the tested data does not change the other,
- result close to –1 – negative correlation, a change in one value from the tested data causes an opposite change in the other (e.g. increasing the value of x causes a decrease in the value of p),
- result close to +1 – positive correlation, a change in the value of one of the data causes the same change in the other (e.g. increasing the value of x increases the value of p).

As the absolute value of the coefficient increases, the strength of the correlation increases (the data is more related). So the closer to the value of –1 or 1, the more we can assume that changing one data will change the other.

Table 1 Correlation coefficients for individual waste quality groups
Tabela 1 Współczynniki korelacji dla poszczególnych grup jakościowych odpadów

	Waste unsuitable for processing	Waste very heavily conta--minated	Conta--minated waste	Waste that requires cleaning	Clean waste	Waste that needs cleaning and better	Waste polluted and better	
Y	from –1 to +1	from –1 to +1	from –1 to +1	from –1 to +1	from –1 to +1	from –1 to +1	from –1 to +1	Average number of complaints

Source: own study.

Summary and conclusions

This paper presents a theoretical model of waste management, which does not cover the entire industrial waste management system, but focuses on its most important element – waste quality. The quality of the waste determines the extent to which a given waste will be utilized, and to what extent it will be stored in a landfill. Therefore, quality has a direct impact on the achieved recycling and recovery levels. The quality of the waste also determines the costs that must be borne by the producer when transferring the waste to the final installation and what costs will be incurred by the installation during the treatment process. The quality of waste determines whether a given waste treatment product meets the expectations and standards of the final recipient, as well as the costs of its final management or recycling.

The effectiveness of industrial waste management depends on both legal regulations and solutions implemented by individual installations. As shown in the model, the quality aspect of the delivered waste is extremely important. In the current waste management system, only a few waste or groups of waste have a normative classification, which is the same as determining the class and quality of a given waste. One example of such standardization will be the classification of scrap and waste paper.

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