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Review Article

Waste classification and separation practices from Türkiye and selected countries of the world

Kemal ULUSOY[1], Neslihan DOĞAN-SAĞLAMTİMUR[1,*], Paulina Magdalena SEKUŁA[2], Andrzej STERNIK[2]

[1]Department of Environmental Engineering, Niğde Ömer Halisdemir University, Niğde, 51240, Türkiye
[2]The Faculty of Engineering, University of Southern Denmark (SDU), Campusvej 55 DK-5230 Odense, Denmark

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ABSTRACT

Waste is an integral part of our lives. It is a fundamental by-product of human activities. Waste is divided into several groups, including medical, hazardous, municipal, biodegradable, industrial, and inert waste. Both the waste producer and its owners have many obligations imposed upon them by the appropriate standards and laws in force in each country. Waste classification and segregation have many benefits, including less environmental pollution; improved living conditions for plants, animals, and humans, and the ability to obtain better raw materials for recycling through segregation. In this study, waste classification and separation systems are assessed. Waste classification method that considers the source, basic composition, and physical, chemical, and biological properties of the waste. Manual, mechanical, and optical systems were used to separate the waste. Nowadays, smart waste classification and segregation systems are being developed for automation. They separate mixed waste effectively. It is a very modern and efficient method that requires less work to function properly than basic waste classification and segregation methods. It is also a faster, more professional method that avoids incorrect sorting of waste. It can be called a future-oriented way of waste disposal and should gradually be introduced into our civilization. Examples of this technology include smart bins, automatic bottle vending machines, and automatic segregation/sorting. Solving the waste classification and separation problem is one of the issues that need special attention in the coming years. The constant development of technology related to this topic is a staple of the circular economy.

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INTRODUCTION

It is natural that by performing many activities, man creates superfluous substances and objects that he wants to get rid of. The concept of waste is very broad because of its diversity. Among other things, we distinguish municipal waste, hazardous waste, biodegradable waste, and industrial waste. Each type of waste needs a suitable treatment system. The problem of waste and how to manage

***Corresponding author.**
*E-mail address: neslihandogansaglamtimur@gmail.com

it has been known to mankind for a long time. However, in ancient times, it received much less attention than in modern times. It is inseparable from human development and the acquired ability to transform and produce goods from readily available raw materials. In the past, humans have created waste that could be completely absorbed by the environment. This was due to limited raw material processing skills. In other words, man did not transform the acquired materials, using them only to satisfy his basic needs. Thus, it did not disturb the natural circulation of matter in nature. Unfortunately, with the development of the human species and technology, this trend has changed. The man was able to produce much more processed products that satisfied not only elementary but also secondary needs. The amount of waste produced increased every year, but the most rapid increase occurred in the 16th century when the industrial revolution began. They assumed a series of economic, social, and technological changes that were initiated in England and Scotland. Until then, human work was mostly manual labour, resulting in limited production of basic materials. The revolution was characterized by the mechanization of production, in which manual labour was replaced by machines. This greatly accelerated the production of goods. People began to produce new materials, from which more diverse waste began to be produced. During this period, vacant landfills began to appear (due to excess waste). Over the past few years, urban migration has been on the rise, further exacerbating this problem. This was related to a better standard of living in urban agglomerations compared to rural areas. There were many more well-paid jobs in the cities. Centres were established in cities to meet the needs of people at that time, which intensified the migration of people using them. All these elements were the reason for the increase in the production of by-products that were difficult to manage [1].

Nowadays, we observe a constant upward trend in waste production, whose effective storage and management are becoming frequent problems. Increasing environmental problems and a global character have led countries to take serious steps both locally and globally. Also, the gradual decrease and rapid consumption of natural resources have made the concept of sustainability popular, and it has made the concept of environmental development widespread, considering that the balance between development and the environment should be maintained. For this reason, the concept of effective waste management began to be developed. Its aim is to reduce the negative impact of this waste on the environment. A significant part of the discussed waste management concerns solid municipal waste, which is generated because of the activities of many areas, including industry, households, and trade. Proper waste management practices vary by country and region (rural and urban). Differentiation also implies individual handling of waste from the industrial or residential sectors. In this study, the evaluation of solid waste has been handled with a systematic approach, and the concept of solid waste management has been developed by accepting that it is an issue that needs to be managed. It has become essential to use the developing technology for the collection, transportation, and disposal of solid wastes. One of the first steps required for the technology to be integrated into the system is correct classification, followed by separation and various disposal processes [2]. Observing the efforts of different countries in the activities carried out within the framework of waste management, one gets the impression that the performance of these processes is not uniform. The key issue is intervening in education on proper waste sorting/segregation as well as further treatment measures [3]. The biggest responsibility in this matter lies with the people. Solid waste management, which can vary according to the level of development and socio-political characteristics of societies, will no longer be an issue with measures taken at the individual level and conscious steps taken jointly. In this study, waste management practices in Türkiye and selected countries around the world are discussed.

TRADITIONAL WASTE CLASSIFICATION AND SEPARATION APPROACHES

Waste classification and separation are two of the most important issues in waste management. It is also a fundamental part of sustainability. Both activities are closely related and enrich each other. Classification enables proper waste sorting, and, as a result, proper waste segregation, collection, and disposal. Proper waste management is possible only through the correct classification and segregation of waste. The way these treatments are carried out depends on the country of occurrence and its characteristics. These are often deeply different systems that have been built on a common elemental pattern. To better understand the concepts of classification and segregation, in the following section, these basic schemes will be shown and presented.

Classification of Waste

Waste segregation is a particularly important part of waste management. This system facilitates other processes related to waste treatment. Wastes with similar or identical characteristics could be listed using reliable classification. The potential for waste treatment and recovery is very favorable. Therefore, the selection of waste classification criteria is necessary. The classification of waste is based on its origin, physical and chemical properties, toxicity, physical state, degree of danger to the environment and people, adequacy, and treatment [4]. Different properties must be considered for each waste classification criterion. For example, when classifying waste by toxicity, special attention should be paid to the content of the most hazardous component, which determines the carcinogenic potential of the waste, the degree of hazard, and water, soil, and atmosphere pollution or flammability [5]. Waste classification rules are set forth in the relevant legal acts in force in unions of countries, for example, in the European Union (EU) or

only in a certain country. Legal acts enacted individually by a country can vary from country to country.

In Türkiye, waste management is one of the main issues addressed by the Ministry of Environment, Urbanisation, and Climate Change (MoEUCC). Against this backdrop, announced the "National Action Plan on Waste Management to 2023" in 2016, which assesses the situation of waste management in the country, analyzes the waste management mechanism, and sets the country's waste management targets in the short term. Waste management has become an ever-evolving field and has become the raw material market for Türkiye. According to the report "Management of Municipal Waste in Turkey" published by the MoEUCC in 2016, landfills, and recycling facilities have increased from 15 to 82 and from 46 to 1226, respectively, compared to 2003 and 2016 [6]. Domestic, construction, and industrial waste are at the top of the waste bracket in Türkiye. Hazardous waste is incinerated at different facilities. İZAYDAŞ, Petkim, Tüpraş, Erdemir, and cement plants have the necessary permits and licenses to meet their energy needs in this way. In Türkiye, waste is sorted by code, like in many other countries. In Poland, there are 20 waste groups and waste classifications. The Waste Transport Table, formerly known as the National Waste Transport Form and completed online through the Integrated Environmental Information System, can dispose of its waste with the condition that the Ministry be notified of the waste codes of the carrier and the disposer. For example, the code for paper and cardboard packaging is 15 01 01 [7].

In Poland, the classification of waste is carried out in accordance with the applicable waste catalogue. Waste is divided into groups, subgroups, and types, and it is also specified which waste is hazardous. For this reason, each waste has its own six-digit code, in which the first two digits indicate its group -the source of waste- the next two subgroups -the component or process from which the waste is generated- and the last two digits -the type- the chemical composition of the waste. Hazardous waste is additionally marked with an asterisk "*" There are twenty waste groups and many subgroups and types. For example, the leaves have the code 200201 because they can be included in the group of municipal waste together with the selectively collected fractions (20), the subgroup of garden and park waste-02, and the type of biodegradable waste-01 [8]. Another example can be found in Australia, where the classification of waste is slightly different. In Australia, the national waste classification system is based on two foundations: waste streams and waste depots. The most frequently mentioned source sectors in this country are municipal solid waste (MSW), commercial and industrial (C&I) waste and construction and demolition (C&D) waste. However, detailed rules for the classification of trash are set by the governments of each of Australia's jurisdictions; in some jurisdictions, waste from various materials is classified strictly. For example, "fly ash" waste in Victoria, Queensland, and Western Australia is considered hazardous waste, while in South Australia it is not [9, 10]. In Japan, the classification of waste begins with its division into household waste and business activity waste. Household waste includes waste that can be incinerated or recycled at the end of its life cycle as well as waste that must be managed individually (non-combustible, toxic, or oversized). The Japanese government pays great attention to recycling, including in this group such items as paper, clothing, plastic bottles, cans, and bottles. This is a commonly used classification in developed countries. The difference is that Japan has created a separate category for recycled waste, which is white food trays. In the case of the second branch (business wastes), the process consists of the correct classification of waste generated in industrial activities. There are cases where part of the by-product can be classified and treated as household waste, but most of the waste is treated as industrial waste [11].

Separation of Waste

Waste separation is another basic and important element in the waste management system. Separation is the activity of placing specific types of waste in appropriate containers. After proper classification, waste is separated according to the material from which it was created. The waste segregation process most often takes place in the places where waste is generated, that is, in households or production companies [12].

The waste segregation system is not yet fully implemented in Türkiye. Many local authorities still collect mixed waste. However, with the zero-waste approach, improvements are made in the selective collection of waste, especially in public institutions and agencies, supermarkets, and various social facilities. All public institutions and agencies have been trained and recycling bins have been installed. The Zero Waste Project, which started being implemented in 2017, generated 16.5 million tons of paper and cardboard, 4.1 million tons of plastic, 1.7 million tons of glass, 0.4 million tons of metal, and 1.5 million tons of organic and other recyclable waste, for a total of approximately 24.2 million tons. Recyclable waste is brought into the economy. Furthermore, this project increased the recovery rate from 13% in 2017 to 22.4% by August 2021. It is hoped that by the end of 2023, this rate will have risen to 35%. Another practice considered part of waste reduction in Türkiye is the pricing of plastic bags, which aims to reduce plastic waste. With the decision taken in 2019, the use of plastic bags has decreased by 75%, and the formation of 354000 tons of plastic waste originating from plastic bags has been prevented. Because of the decision taken, the import of plastic raw materials required to produce plastic bags was reduced; approximately 2.44 billion Turkish Lira (TL) was saved, and 14640 tons of greenhouse gas emissions were prevented [13]. Many universities are still establishing waste collection centres today. As one of Türkiye's most important universities, Middle East Technical University (METU) which is an international research university with

around 27000 students and one of Türkiye's largest campuses, encompassing 4500 hectares, is highly appreciated for its solid waste management system. Bahçelioğlu's study includes the evaluation of the effectiveness of existing solid waste management strategies by various methods (survey, etc.) starting from waste generation. According to the study's findings, the daily average solid waste production factor on METU campus is 0.40 kg/day/person, with the total amount of waste produced ranging between 5.8 and 10.3 tons/day/weekly. It has also been stated that the total recyclable waste collected is 13% of the total waste [14]. Recycling facilities and/or businesses acquire waste-derived raw materials through a variety of partnerships with regional governments. The city has integrated waste separation boxes, waste oil collecting boxes, waste accumulators, and battery stations so that they can be used as raw materials in specific locations. According to the system created by Kepez Municipality in Antalya, a waste oil collection vehicle picks up used motor oil from specific locations on specific days and times. Once more, several information technologies (IT) firms (including Turkcell, a digital operator in Türkiye) coordinate programs for the segregated collection and recycling of electronic waste. Several foundations (including the Turkish Educational Volunteers Foundation (TEGV) and Turkcell Partnership) have stated that they accept electronic waste in terms of separate collection and evaluation and that they contribute to the circular economy. They also stated that the money they will make from this will be used to fund scholarships for students [15]. Reimbursement systems, which reward consumers for loading coupons or cards from waste bottles, are becoming more common thanks to the collaboration of environmental and software firms. It has been determined that training is necessary for the systems to be implemented successfully. As a result, new environmental-related courses were introduced to the curriculum. The separate collection of waste, particularly zero waste, has been the subject of short videos, public service announcements (PSAs), and numerous advertisements [16]. A sustainable waste management system and circular economy practices require that recyclable waste be collected separately at the source and that the recycling process be carried out in a planned manner. Separate collection of waste at the source, public participation in the zero-waste process, and raising awareness is essential for the success of this process.

The form of waste segregation at the source of its generation is also known as "selective waste collection" and forms the first element of a well-organized waste management system. Selective waste collection consists of collecting it individually from each property. For example, the selective collection of municipal waste (Figure 1) mainly involves the collection of recyclable materials such as metal, glass, plastic, or paper. This method of collecting waste has many advantages. These include, first, a smaller amount of waste sent to landfills; a collection of waste distinguished by the subsequent technology of their treatment; or the possibility

Figure 1. Selective collection of municipal waste [19].

of obtaining clean secondary raw materials. It is also worth noting that the reprocessing of secondary raw materials is much more beneficial than production using primary raw materials; it has a positive effect on the environment by reducing pollution and decreasing energy expenditure. Various types of (dedicated) containers, litter bins, and bags are used for selective collection of waste at the source. Another way of sorting waste is secondary sorting, which takes place in disposal plants. Both methods of waste segregation are used in Poland [17, 18].

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The segregation technology prepares waste for reuse and contributes to the possibility of recovering individual raw materials with the indicated degree of purity, which is why it is an extremely important process. Many countries around the world pay special attention to this element of waste management. In this case, it is worth looking at the inhabitants of Germany. Germany is a country that is an innovator in waste segregation in Europe due to its

high consumption and high living standard. When waste became a big problem there, interventions began. The principle of the three Rs (reduce, reuse and recycle) has started. The focus was primarily on the segregation of communal trash and its proper management. Initial sorting of household waste has become the most important. Special containers for waste batteries or electronic equipment were also implemented and installed in easily accessible places (e.g., supermarkets). The problem of bottles has also been solved; appropriate vending machines for accepting bottles have been designed and installed (Figure 2). Therefore, the user has the option of returning the previously paid deposit in the coupon. The coupon could be used for shopping, donated to charity, or exchanged for money. Also, each raw material intended for recycling is marked with an appropriate label to make the proper classification easier. This is an important point because, for example, if it were necessary to distinguish packaging made of polypropylene, polyethene, polystyrene, or polyvinyl chloride, there would be a problem because they are quite similar. The focus was also on the educational issue, and from an early age, efforts were made to inculcate the idea of proper trash segregation. Each of these steps helped reduce the massive amount of garbage. The basis for solving this problem was the improvement of waste segregation systems [20]. In Japan, the segregation of waste is analogous to the generally accepted pattern, i.e., the person or entity producing the waste is obliged to separate it properly and take it to the designated place. In the city of Utsunomiya (Japan), each resident has a list of the days when their garbage is collected from the common waste collection station. It is the resident`s duty to carefully select the generated waste and collect it in the household, awaiting the day when they can hand it over for further disposal. The Japanese pay a lot of attention to ensuring that the collected waste is properly prepared for the next processing stage. Residents must clean their garbage, shred it, and dry it to facilitate their further journey. Utsunomiya city government documents provide a detailed description of waste handling. We can, among other things, find information about household appliances that must be recycled. These include air conditioners, TVs, freezers, washing machines, etc. When getting rid of one of the above-mentioned devices, it is the owner's responsibility to pay the recycling fee and the pick-up service charge. A similar method of handling occurs with oversized waste, where the owner of the waste pays a fee for the excess kilograms of waste generated [11].

Figure 2. Vending machines for accepting bottles [21].

SMART WASTE CLASSIFICATION AND SEPARATION APPROACHES

Due to the economic development models adopted, the phenomenon of more people migrating to cities, and the different codes of conduct in different countries, waste management is a major problem to be solved. The most common waste treatment method is the manual method, which requires the use of workers. People who sort and store garbage can get many diseases due to the harmful substances contained in it. In addition, employees face many accidents that can seriously affect their health. These are automated systems that perform the sorting and segregation of mixed waste and, unlike previous methods, are more efficient and take less time to perform these operations. Technological development has enabled the creation of intelligent waste classification and segregation systems. These systems are more advantageous than existing methods and systems due to the following features:

- Make the sorting and separation process faster and more professional,
- Be healtier in terms of human health,
- Eliminate occupational health and safety problems associated with waste segregation,
- High discriminant performance,
- Recover lost time in sorting mixed waste,
- Preventing errors in waste sorting,
- Cheaper and with less environmental risk.

A smart sorting and separation system can be used to automatically sort waste, reduce human intervention, and prevent infection and contamination. It has a lower risk of error than traditional waste sorting and grading systems. It's a much faster system that works by limiting or eliminating human activity.

There are some smart waste applications and practices in Türkiye. In Manisa Akhisar Municipality, the amount of waste could be monitored from the centre with the smart container system. Thanks to the related system, the route can be redetermined, and unnecessary fuel consumption is prevented. In addition, regular monitoring of the container occupancy rate ensures the elimination of odour and visual pollution elements that may occur. It is stated that 4500 waste containers are included in the system within the scope of the smart waste collection system [22]. Muğla Bodrum Municipality has made some improvements to its waste management plan within the scope of the zero-waste

project. Container and vehicle tracking systems and the Clean City Tracking System have started to be implemented using Radio Frequency Identification Technology (RFID). Development activities in related systems are still ongoing [23]. The underground garbage container application was implemented by İstanbul Başakşehir Municipality. Within the scope of the zero-waste project, the smart garbage collection and sorting mechanisms, which have been implemented because of the efforts to make waste management more efficient and at the same time reduce the carbon footprint, are used by the Başakşehir Municipality. Thanks to the smart garbage collection system prepared using the RFID system, just like in Akhisar and Bodrum municipalities, preventing unnecessary fuel consumption and protecting the environment and public health are among the main objectives [24]. Antalya Muratpaşa Municipality uses LED screens to display the occupancy rate of garbage containers to users as part of smart waste management. In addition, the system obtains the electrical energy it needs from solar panels within the scope of renewable energy [25]. Nevşehir Municipality implemented a smart container system, mobile tracking system, route arrangements, and vehicle tracking system applications based on data in 2016. In cooperation with the Evreka firm and the municipality, it is stated that monitoring and follow-ups are carried out in 350 active containers, and because of the application, a decrease of 24% is experienced in the distances covered by the vehicles. In addition, it is reported that 15% of fuel savings were recorded [26].

A well-known and increasingly popular example is the previously mentioned reverse vending machines (RVM). These are automatic machines where people can recycle empty bottles, cans, and beverage containers. In return, the machine returns a receipt with which the owner can go to the point to collect the previously paid cash deposit, which is added to each recyclable bottle. RVM is a multifunctional device. When returning an empty bottle, the machine starts scanning the item, recognizing its size and material, and checking whether the bottle is empty. The bottles that will be approved by the machine are properly classified and segregated. Recyclable items are rapidly mechanically converted to provide size reduction, thereby increasing machine capacity. The converted items are sorted into appropriate containers that will be delivered to recycling companies. The system is widely used around the world, e.g., in Denmark. It is a country that is a leader in the effectiveness of the implemented solution. Over 92% of all purchased bottles are recycled using, e.g., RVM, which enables each person to contribute to improving the environment [27].

Another example is the Danish company “DON’T WASTE IT”, which introduced an innovative improvement to garbage collection during large events. Their product is a universal lid for a trash can that is properly marked and has specially measured openings for the collection of appropriate garbage. “Waste Top” fits commonly used containers with a capacity of 240 L. This eliminates the need to purchase dedicated containers, allowing you to make the necessary changes based on the amount of waste in each bin. Proper sorting of waste at the source increases the probability of avoiding errors in further parts of waste management and affects the construction of a closed circuit [28].

The other example comes from Norway and concerns an automated industrial waste sorting plant made by Bjorstaddalen in cooperation with Zen Robotics. The facility is in the municipality of Skien. A robotic station using artificial intelligence could carry out an independent waste sorting process with a capacity of 150000 tons per year [29].

Sweden is also actively implementing innovative measures that have a positive impact on more efficient waste management. In Alingsås Municipality, the concept of smart waste bins was presented, which were programmed to communicate and rely solely on solar energy. Thrown garbage is automatically compressed by the device. Smart bins communicate the current level of garbage filling. This facilitates the work of the municipality, adapting the way of emptying the bins to their real needs. By analyzing the degree of basket filling, it is possible to determine which locations the number of containers should be increased, and which should be reduced [30].

Smart waste classification and separation is a new concept with high potential for further development in the future. Nevertheless, it will not completely solve the problem of waste segregation and classification if the society is not sufficiently educated on the proper handling of waste.

CONCLUSION

Inadequate infrastructure, increased costs, the use of landfills because of local and regional agreements, and the implementation of joint decisions between districts and municipalities regardless of waste characterization are the issues that need to be improved in waste management. It is possible to increase waste recovery rates with the development and improvement of waste separation technologies, process selection based on waste characterization, and necessary infrastructure investments. In this context, any improvement that will reduce costs will be the key to local and regional development within the scope of waste management. Implementation of the "polluter pays principle" in industrial solid waste management and providing incentives and payment facilities within the reward system to companies that make clean production or contribute to recycling will be beneficial to waste management, especially for Organized Industrial Zones.

Waste management practices are various due to their diversity. Among other things, there is a distinction between municipal waste, biodegradable waste, and industrial waste. The problem of waste and how to manage it has been known to mankind for a long time. However, nowadays this problem has become significantly worse due to a steady increase in waste production and improper waste management. For this reason, the concept of effective waste management began to develop. It is primarily concerned

with the waste classification and segregation. This makes it possible to effectively pursue the introduction of a circular economy, which should replace its traditional model. Waste classification and separation offer many benefits, including reducing environmental pollution and improving the living conditions of plants, animals, and people, as well as obtaining better raw materials for recycling. Waste classification methods consider the source, basic composition, and physical, chemical, and biological properties of the waste. Manual, mechanical, and optical systems are used to separate waste. Smart waste classification and segregation systems are currently developed. These systems are automated. They separate and classify mixed waste efficiently. They are very modern and effective methods that require less work to function properly than traditional waste sorting and segregation methods. They are also faster and more professional methods of preventing incorrect waste segregation. This is what could be called a forward-looking way to dispose of waste and should gradually be introduced into our civilization. It is a way to effectively solve global waste problems facing humanity related to the state of the environment and thus maintain an appropriate level of economic growth.

DATA AVABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

AUTHOR'S CONTRIBUTION

Conceptualization, N.D.-S.; investigation, K.U, N.D.-S., P.M.S, A.S.; methodology, K.U, P.M.S, A.S.; writing-original draft, K.U, N.D.-S., P.M.S, A.S.. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] E. Amasuomo, and J. Baird, "The concept of waste and waste management," Journal of Management and Sustainability, Vol. 6(4), pp. 88–96, 2016. [CrossRef]

[2] J. Zalewska, "Waste management system in Poland-current state and directions of improvement," Economics and Organization of Logistics, Vol. 4(1), pp. 103–113, 2019.

[3] P. Smolnik, "Nature and importance of municipal waste," Scientific Journals of the Częstochowa University of Technology Management, Vol. 10, pp. 69–75, 2013.

[4] W. Czekała, A. Lewicki and D. Janczak, "Problems concerning organic waste classification," Review of Environmental Protection Law, Vol. 3, pp. 117–128, 2014.

[5] C. Rosik-Dulewska, "Basics of waste management," Warsaw, Poland: Polish Scientific Publishers PWN; 2022.

[6] U. Korkmaz, "CMS Turkey: Waste management in Turkey," https://balkangreenenergynews.com/cms-turkey-waste-management-in-turkey/ Accessed on Feb 20, 2023.

[7] Mevzuat, "Atık kodu belirleme hiyerarşisi ve atık kodu açıklamaları," https://www.mevzuat.gov.tr/mevzuatmetin/yonetmelik/7.5.20644-Ek.docx Accessed on Feb 20, 2023. [Turkish]

[8] Regulation of the Minister of Climate of January 2, 2020 in the Waste Catalog (Journal of Laws 2020 Item 10). https://www.sejm.gov Accessed on Sep 05, 2023.

[9] T. Rajaratnam, and G. Lamb, "Waste classifications in Australia. a comparison of waste classifications in the australian waste database with current jurisdictional classifications," Hyder Consulting Pty Ltd., 2011.

[10] Australian Government Productivity Commission, "Waste Management," Report no. 38, Canberra, 2006.

[11] Utsunomiya, "City of Utsunomiya," https://www.city.utsunomiya.tochigi.jp Accessed on Feb 20, 2023. [Chinese]

[12] M. Markiewicz-Patalon, "Legal and organizational aspects of the management plastic waste in Poland," 6th EurAsia Waste Management Symposium, Vol. 11(6), pp. 45–51, 2018.

[13] 2022 Yılı Cumhurbaşkanlığı Yıllık Programı, "Türkiye Cumhuriyeti Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı," Resmi Gazete (Sayı: 31639 Mükerrer). [Turkish]

[14] E. Bahçelioğlu, E. S. Buğdaycı, N. B. Doğan, N. Şimşek, S. Ö. Kaya, and E. Alp, "Integrated solid waste management strategy of a large campus: A comprehensive study on METU campus, Turkey," Journal of Cleaner Production, Volume 265, Article 121715, 2020. [CrossRef]

[15] Turkcell, "Eğitime dönüştür," https://www.turkcell.com.tr/egitime-donustur Accessed on Feb 20, 2023. [Turkish]

[16] Zero Waste, "Zero waste TV," http://zerowaste.gov.tr/en/zero-waste-tv Accessed on Feb 20, 2023. [Turkish]

[17] B. Bień, and J. D. Bień, "Legal Collection and selective collection of municipal waste in communes," Engineering and Environmental Protection, Vol. 13(3), pp. 173–183, 2010.

[18] L. Kłos, "Municipal waste management-The challenge of the XXI century," Scientific Journals of the University of Szczecin, Studies and Works of the Faculty of Economics and Management, Vol. 28, pp. 131–143, 2012.

[19] Signet, "The signetbranding," website. http://www.signetbranding.com/ Accessed on Feb 20, 2023.

[20] S. Lizęga, "Selected issues of segregation and utilization of municipal waste," Acta Agrophysica, Vol. 73, pp. 231–241, 2002.

[21] Green Diary, "The greendiary, http://www.greendiary.com/ Accessed on Feb 20, 2023.

[22] Akhisar Municipality, "Akhisar'da akıllı atık toplama devri başladı,"https://www.akhisar.bel.tr/haber/akhisar-da-akilli-atik-toplama-devri-basladi Accessed on Feb 20, 2023. [Turkish]

[23] Bodrum Municipality, "Akıllı atık toplama yönetim sistemi geliştiriliyor," https://bodrum.bel.tr/haber.php?id=9042/AKILLI_ATIK_TOPLAMA_YONETIM_SISTEMI_GELISTIRILIYOR Accessed on Feb 20, 2023. [Turkish]

[24] Başakşehir Municipality, "Akıllı çöp toplama sistemi," https://www.basaksehir.bel.tr/akilli-cop-toplama-sistemi#:~:text=Ba%C5%9Fak%C5%9Fehir%20Belediyesi%2C%20daha%20temiz%20ve,tespit%20edilerek%20arac%C4%B1n%20rotas%C4%B1n%C4%B1n%20belirleniyor Accessed on Feb 20, 2023. [Turkish]

[25] Muratpaşa Municipality, "Akıllı konteynerler," https://muratpasa-bld.gov.tr/haber/5618/akilli-konteynerler Accessed on Jan 19, 2023. [Turkish]

[26] eBelediye, "Nevşehir Belediyesi evreka ile maliyetlerini yarı yarıya düşürdü," https://www.ebelediye.info/haberler/nevsehir-belediyesi-evreka-ile-maliyetlerini-yari-yariya-dusurdu Accessed on Feb 20, 2023. [Turkish]

[27] Danish Return System, "Danish return system," https://danskretursystem.dk Accessed on Feb 20, 2023. [Danish]

[28] Don't Waste It, "Don't waste it," https://dont-waste-it.dk (accessed 20 February 2023)

[29] Recycling Inside, "Norway's first aI-powered robotic sorting station for industrial waste. https://recyclinginside.com/recycling-technology/separation-and-sorting-technology/norways-first-ai-powered-robotic-sorting-station-for-industrial-waste/ Accessed on Feb 20, 2023.

[30] Bigbelly, "Smart trash cans saving the environment in Alingsås, Sweden," https://blog.bigbelly.com/smart-trash-cans-saving-the-environment-in-alings%C3%A5s-sweden Accessed on Feb 20, 2023.