DOI: http://dx.doi.org/10.32571/ijct.992891 E-ISSN: 2602-277X

International Journal of Chemistry and Technology

http://dergipark.org.tr/ijct

Research Article

Evaluation of zero waste management system and Adana metropolitan municipality zero waste implementation

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Received: 8 September 2021; Revised: 15 September 2021; Accepted: 19 September 2021

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Citation: Sarı, B.; Küpeli, H. Ş.; Güney, H.; Keskinkan, O. *Int. J. Chem. Technol.* **2021**, 5 (2), 100-107.

ABSTRACT

In this study, policies and regulations about the operation of the system in the world and in Turkey regarding the necessity of transitioning to the Zero Waste Management System as a waste management system were examined and a literature review was made about the studies on this subject. In line with the information obtained, the implementation of the system in the administrative service units of Adana Metropolitan Municipality was evaluated. For this purpose, the amounts of recyclable wastes and non-recyclable wastes collected separately in the service buildings, taking into account the 12-month period, were determined. In this process, a total of 137992 kg of waste was collected. 119009 kg of these wastes were included in the urban waste collection system and sent to the integrated solid waste disposal facility, while 21983 kg was delivered to licensed companies as recyclable waste. With the transition to the Zero Waste Management System, it has been determined that the amount of waste going to the integrated solid waste disposal site has decreased by 16% in a 12-month period. In addition, as a result of the statistical studies on waste data, it was determined that the recyclable wastes and the non-recyclable wastes in the 95% confidence interval showed a statistically significant difference according to the service units ($p<0.05$).

Keywords: Solid Waste, Zero Waste, Waste Separation, Recycling, Adana Metropolitan Municipality.

Sıfır atık yönetim sistemi ve Adana büyükşehir belediyesi sıfır atık uygulamasının değerlendirilmesi

ÖZ

Bu çalışmada atık yönetim sistemi olarak Sıfır Atık Yönetim Sistemi'ne geçilmesinin gerekliliği ile ilgili Dünya'da ve Türkiye'de sistemin işleyişi hakkında politikalar, mevzuatlar incelenerek bu konuda yapılan çalışmalarla ilgili literatür taraması yapılmıştır. Elde edilen bilgiler doğrultusunda Adana Büyükşehir Belediyesine ait idari hizmet birimlerinde sistemin uygulanması değerlendirilmiştir. Bu amaçla hizmet binalarında 12 aylık dönem dikkate alınarak geri dönüştürülebilen atıklar (GDM) ile geri dönüşümü mümkün olmayan atıkların (GDMO) ayrı ayrı toplanan miktarları tespit edilmiştir. Bu süreçte toplam 137992 kg atık toplanmıştır. Bu atıkların 119009 kg'ı kentsel atık toplama sistemine dahil edilip entegre katı atık bertaraf tesisine gönderilirken, 21983 kg'ı GDM olarak lisanslı firmalara teslim edilmiştir. Sıfır Atık Yönetim Sistemine geçilmesiyle entegre katı atık bertaraf sahasına giden atık miktarının 12 aylık süreçte %16 azaldığı tespit edilmiştir. Ayrıca atık verilerine dair istatistiksel çalışmalar neticesinde %95 güven aralığında GDM ve GDMO'ların hizmet birimlerine göre istatistiksel olarak anlamlı bir farklılık gösterdiği tespit edilmiştir ($p<0.05$).

Anahtar Kelimeler: Katı Atık, Sıfır Atık, Atık Ayırma, Geri Kazanım, Adana Büyükşehir Belediyesi.

1. INTRODUCTION

The "disposable" culture, which developed with the rapid urbanization, economic and industrial developments, and the rise in living standards due to the increasing population in developing countries, has significantly changed both the waste production rate and the waste composition. However, considering the lack of

DOI: http://dx.doi.org/10.32571/ijct.992891 E-ISSN: 2602-277X

awareness in the society about waste diversity and waste separation, the inadequacy of waste collection-transport organization and the difficulties experienced in financial resources, it is becoming more and more difficult for municipalities that are responsible for waste management in cities to provide an effective and efficient service to the residents of the city.[1] Ensuring an effective, systematic and efficient waste management from the formation of the waste to its final disposal depends on the good implementation of waste management.[2] In this context, Zero Waste Management System (ZWMS), which is one of the waste management systems, which aims to prevent and reduce waste at its source, and to ensure its reuse when this is not possible, has gained great importance throughout the world.

The term zero waste was first used by Paul Palmer in the name of Zero Waste Systems Inc-ZWS, which was founded in the 1970s in Oakland, California, United States and obtains raw materials from chemicals. The meaning used today appeared for the first time in the late 1990s [3]. Over time, many countries and organizations around the world have adopted the concept of zero waste. Zero waste is a waste management approach that is based on sustainability in the world of production, pushes individuals to act responsibly in living and usage areas, thus aiming to produce as little waste as possible. Zero waste management hierarchy forms the basis of ZWMS. This hierarchy; It consists of four steps: (a) reject what you do not need and reduce your needs, (b) reuse what you consume, (c) recycle what you cannot refuse, reduce and reuse, and (d) compost/decompose the rest.[4]

When the methods used in the world for ZWMS are examined, six themes that can be applied in the life cycle stages of production and consumption systems and aiming to reduce waste generation are suggested. These six themes are; design for zero waste, smart waste control and reduction planning, smart waste collection, high-value mixed waste treatment, industrial collaboration, waste-to-source and recycling.[5]

Design for zero waste focuses on using less material for the product and easy assembly/disassembly of the product at end-of-life. To serve this purpose in the manufacturing industry, disassembly product designs and additive manufacturing technologies are being developed. Disassembly (reverse assembly) is the process of systematically separating the parts that make up a product, and the fact that the product can be disassembled makes great contributions to protecting the environment by facilitating its repair/renewal and recycling.[6] Smart waste controls consist of hardware and software solutions that analyze waste volumes, automatically sort waste, and evaluate opportunities to divert waste through waste reduction, recycling or reuse. Waste collection efficiency includes modern smart waste collection systems, smart waste bins monitored by an integrated sensor network, trucks, maps and a data management center, as well as using new technology providers including geographic information systems, data access networks, sensors and the internet of things. Mixed waste treatment refers to systems that accept mixed solid waste streams and then separate the designated recyclable materials through a combination of manual and mechanical separation. Industrial cooperation, on the other hand, has been respected in recent years as a cooperation structure where companies come together and the waste of one is the raw material for the other.[5] Industrial collaboration is a field of research that focuses on developing digital technologies that identify wastes suitable for resource matches and facilitate these exchanges between different companies in a particular area or region.[7]

In our country, ZWMS was first implemented in the Ministry of Environment and Urbanization (MEU) and the Presidential Complex and the studies on its spread to the whole country are increasingly continuing. In this context, the "Zero Waste Implementation Guide", prepared to guide the implementation of ZWMS, is available on the MEU's website. In addition, with the Zero Waste Regulation published in the Official Gazette dated 12.07.2019 and numbered 30829, the responsibilities of public/private institutions and organizations were determined. In order to implement ZWMS with a sustainable and professional approach; the roadmap, which consists of 7 stages: determining the focal point, determining the current situation, planning, needs and supply, training, implementation and evaluation, was created by the MEU.[8]

In this study, the effectiveness of ZWMS in Adana Metropolitan Municipality (AMM) scale was tried to be revealed. In this context, the ZWMS applied in AMM service units has been examined and evaluated. In the study, the wastes generated in AMM were divided into two categories as "recyclable waste (RW)" and "non-recyclable waste (NRW)". Wastes were collected at source as RW and NRW, and the waste data from each service unit was recorded. The waste data obtained were evaluated with the help of descriptive statistics, parametric test ANOVA and non-parametric test Kruskal Wallis-H. It is thought that the results of the study will contribute to the spread of ZWMS applications.

2. MATERIALS AND METHODS

2.1. AMM and Its Affiliates

AMM, selected for the study, provides services in Adana Province and 15 districts with its 24 Departments, 103 Branch Offices and 9239 personnel. AMM service buildings consist of the general administration building (historical town hall), the central building, the additional service building and various campuses located in suitable places for the needs of the city. The service units

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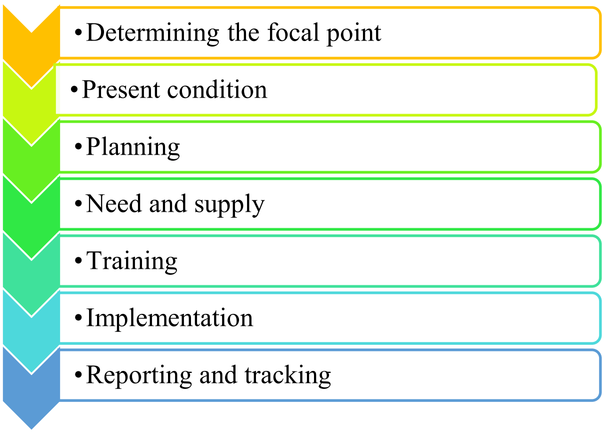
examined within the scope of the study and where ZWMS is applied are given below:

- AMM Headquarters and Additional Service Buildings
- Municipal Houses Additional Service Building
- Department of Agricultural Rural Services
- Department of Culture and Social Affairs
- Transportation Department Bus Branch Office
- Municipal Police Department
- Department of Parks and Gardens

2.2. ZWMS Review at AMM

The ZWMS, which is being implemented in AMM, has been examined roadmap covering the stages presented in Figure 1 according to Ministry of Environment and Urbanization applications, Zero Waste Regulation legislation and taking into account the relevant literature.

Figure 1. Roadmap of ZWMS[8]



2.3. Obtaining the Essential Oils mixtures Statistical Evaluation of ZVMS at AMM

SPSS 22 V. package program was used for statistical analysis of waste data. One-way analysis of variance (ANOVA) used in the study is used to compare the means of more than two groups.[9] In order to apply this analysis; data should consist of quantitative variables, distribution of data should be normal, group variances should be relatively homogeneous.[10] The distribution of data was evaluated with the Kolmogorov - Smirnov test.[11,12] Levene test was used to test the homogeneity of group variances.[13] If there is a difference between the groups in the comparison of group means, Duncan test, which is one of the multiple comparison tests, was used to determine which group had the greater effect.[14] Another test used in the study is the Kruskal-Wallis-H test. This test, which is a non-parametric test, is used when there is a problem in the assumptions of one-way analysis of variance.[15] If there is a statistically significant difference between the groups, the Bonferroni-corrected Mann Whitney-U Test, which is preferred in pairwise comparisons, was used to determine between which groups this difference was.[16]

3. RESULT AND DISCUSSION

3.1. ZWMS Review at AMM

Feasibility studies for the Zero Waste Management System started in AMM service buildings in 2018, and it was put into practice as of March 2019. In order to realize ZWMS in AMM with a sustainable and professional approach, a roadmap consisting of 7 stages was taken as a basis: focus, current situation, planning, needs and procurement, training, implementation, reporting and follow-up. In order to carry out all the work and operations related to ZWMS, the Waste Management Branch Directorate under the Environmental Protection and Control Department has been determined as the focal point. The types of wastes coming out of the administrative service units are generally paper-cardboard wastes in the current situation. After paper, the most common type of waste is plastic, glass and metal (water bottles, glass juice bottles, metal beverage bottles, etc.). There is no food leftovers because of there is no cafeteria in the service buildings. Since the personnel meets their nutritional needs from outside, there is only packaging waste of food. In addition, in the case of bringing fruit and vegetables from home, fruit peels and tea and coffee pulp are waste as a result of frequent beverage consumption in offices. There are also napkins, wet wipes, etc. in the garbage cans in the toilets. wastes are generated. The number of RW and NRW boxes to be delivered to the service units were determined by the focal point personnel, taking into account the floor plan, number of rooms and corridor lengths of each service building, as presented in Table 1.

Table 1. Binary Collection System Boxes Distributed to Service Units

Service Units	RW Box (pcs)	NRW Box (pcs)
AMM Headquarters and Additional Service Buildings	100	100
Belediye Evleri-Additional Service Building	30	30
Department of Agricultural Rural Services	6	6
Department of Culture and Social Affairs	5	5
Transportation Department Bus Branch Office	6	6
Municipal Police Department	5	5
Department of Parks and Gardens	6	6

Following the planning stage, by the staff of the Waste Management Branch (focus point) for the employees of the institution in the training hall of the AMM main

DOI: http://dx.doi.org/10.32571/ijct.992891 E-ISSN: 2602-277X

service building; training was provided on prevention of waste generation, minimizing waste if prevention is not possible, prioritizing reuse, separate collection of waste at source, recycling/recovery of waste, and project process (Figure 2).

Figure 2. Images Of The Training Phase In AMM

In the service buildings of the institution, a dual collection system has been established in the offices in accordance with the ZWMS. According to this system, RWs are collected in blue boxes and NRWs are collected in gray boxes. The filled boxes are weighed and the waste data is recorded. The wastes coming out of the blue boxes are stored in the temporary storage area determined in the service units and sent to the collection and sorting facilities from there. The wastes collected in gray boxes are included in the urban garbage collection system and delivered to the ITC (Invest Trading & Consulting AG) Solid Waste Disposal Facility, which serves under the responsibility of AMM.

Since it is not possible to create an area that will allow to collect each type of waste in separate categories in AMM service units, a dual collection system is applied in the offices. However, as can be seen in Figure 3, a "Zero Waste Corner" has been created on the ground floor of the service building, which is called the Main Building, where it can be easily reached by the staff and visitors. Boxes suitable for collecting waste were placed in eight different categories: brown for organic waste, black for non-recyclable waste, purple for bread residues, blue for paper-cardboard waste, yellow for plastic waste, green for glass waste, gray for metal waste, white for food residues. In addition, a red-colored box was placed for battery waste and implementation was started in this region. With this application, it is aimed to raise awareness of the personnel and citizens visiting the institution by drawing their attention on the subject.

Temporary storage areas have been created within the service units in order to keep the wastes safely before they are delivered to the processing facilities. The cleaning personnel perform the occupancy checks of the collection equipment, emptying and cleaning the waste bins, changing the bags according to the color scale, weighing the collected wastes, and delivering them to the temporary storage area

Figure 3. AMM Waste Collection Equipment

In order to register, document and monitor the places to apply ZWMS and to ensure the traceability of the wastes managed within the scope of the system, the Integrated

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Environmental Information System (IEIS), which is an online system created by the MEU, has been registered as AMM and service units have been added. The amount of waste collected from the buildings on a monthly basis by the Waste Management Branch is reported to the IEIS. It is possible to say that the roadmap and similar methods chosen for the implementation of ZWMS in AMM strengthen the sustainable environmental policy and support social awareness in waste management.

3.2. Calculation of Waste Amounts in Service Units Affiliated to AMM

Waste calculation results generated within the scope of ZWMS in AMM service units between October 2019 and September 2020 are given in Table 2 on a monthly basis. The working period is also included in the fight against the Covid-19 epidemic of the world and our country. Especially in March-April-May 2020, the decrease in the amount of waste and the change in the amount of waste during the period can be explained by our country's full closure, alternate and flexible working practices within the scope of the epidemic.

Table 2. Amount of Waste Collected in All Service Units by Month

Months	RW (kg)	NRW (kg)	Total (kg)	Recovery rate (%)
October 2019	1735	10130	11865	14.60
November 2019	1228	9110	10338	11.88
December 2019	1620	9791	11411	14.20
January 2020	1550	10500	12050	13.58
February 2020	1525	10220	11745	13.00
March 2020	1185	7925	9110	13.00
April 2020	1520	7590	9110	16.70
May 2020	1480	9422	10902	13.58
June 2020	2950	10256	13206	22.40
July 2020	2015	10920	12935	15.58
August 2020	3070	10235	13305	23.07
September 2020	2105	9910	12015	17.52
Total	21983	116009	137992	16

The recovery rates of wastes in the selected period are given in Figure 4. As seen in Figure 4, the highest recovery rate is in August with 23.07%, followed by June with 22.40%.

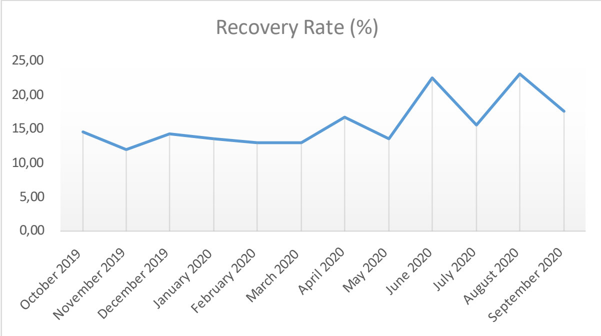

Figure 4. Monthly Waste Recovery Rates in All Service Units Applying ZWMS

Erdur (2019) reported that the amount of recyclable waste removed from the garbage with the implementation of the ZWMS project in the administrative service buildings of Süleymanpaşa Municipality was 18.04% in the first month of the project, while it was 27.03% in the twelfth month.[17] With ZWMS, it was stated that by learning which materials should not be thrown away, a decrease in the amount of waste and an increase in recyclable wastes were observed with the formation of zero waste awareness in the personnel. In general, fluctuations are observed in the recovery rates of the service units obtained in this study (Figure 4). The reason for this is the fact that the staff has been transferred to a rotating/flexible working system in order to protect the health of the employees of the institution in many service units, with the Covid-19 virus epidemic appearing in our country for the first time on March 11, 2020, and as a result, the number of daily working people has decreased. In addition, it has been evaluated that factors such as the increase in the use of disposable materials such as masks due to the change in habits during the epidemic period, the increase in the use of napkins and wet wipes in the garbage cans in the toilets, along with the increase in the habit of hand washing, caused fluctuations in the amount of waste and recycling rates.

3.3. Statistical Evaluation of Waste Data

Descriptive statistics on waste data from AMM service units are presented in Table 3. According to Table 3, while the average RW collected in all service units during a year is 1831.92 kg, the average NRW is 9667.42 kg. The Kolmogorov-Smirnov test and Levene test results of the collected waste data are given in Table 4. According to Table 4, it was observed that the RW data did not conform to the normal distribution at the 95% confidence interval ($p<0.05$) and their variances were not homogeneous ($p<0.05$). It was observed that the NRW data conformed to the normal distribution at the 95% confidence interval ($p>0.05$) and their variances were homogeneous ($p>0.05$).

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Table 3. Descriptive Statistics on Waste Data in AMM Service Units

Descriptive Statistics	RW (kg)	NRW (kg)
N	12	12
Mean	1831.92	9667.42
Standard error of mean	176.74	291.89
Median	1585.00	10020.00
Mode	1185.00**	7590.00**
Standard deviation	612.25	1011.15
Variance	374853.17	1022437.35
Minimum	1185.00	7590.00
Maximum	3070.00	10920.00

**: Multiple modes are available. The smallest value is shown.

Table 4. Kolmogorov- Smirnov Test and Levene Test Results of Waste Types

Tests	Type of Waste	Test Statistics	p
Kolmogorov- Smirnov	RW	0.22	0.00*
	NRW	0.08	0.20
Levene	RW	12.43	0.00*
	NRW	2.18	0.06

*: $p<0.05$

ANOVA test was used because NRW data provided the assumptions of normality and homogeneity of variances, and Kruskal-Wallis-H test was applied because RW data did not provide assumptions. Obtained results are given in Table 5. According to Table 5, NRWs and RWs show a statistically significant difference in 95% confidence interval according to service units ($p<0.05$). According to the Duncan test result applied to the NRW data to find out which service unit or units these differences originate from, it was seen that this difference was mostly in the Central Building and Additional Service Buildings. The result of the Mann-Whitney U test with Bonferroni correction applied to the RW data is given graphically in Figure 5. In Figure 5, the differences between service units are shown in orange. Considering the average rank of the service units, it is seen that the 1st service unit, called the Central Building and Additional Service Buildings, has higher RW than the other service units.

Table 5. ANOVA and Kruskal-Wallis-H test results

Tests	Test Statistics	p
NRW - ANOVA	12.57	0.00*
RW - Kruskal-Wallis-H	49.18	0.00*

In this study, the wastes from the service units of AMM were evaluated in 2 separate categories as RW and NRW, while Ayeleru et al. collected daily and weekly wastes specific to the city and classified them into 9 different categories as paper and cardboard, glass, metal, plastic, textiles, organics, construction and demolition, special care waste, and other wastes. [18]

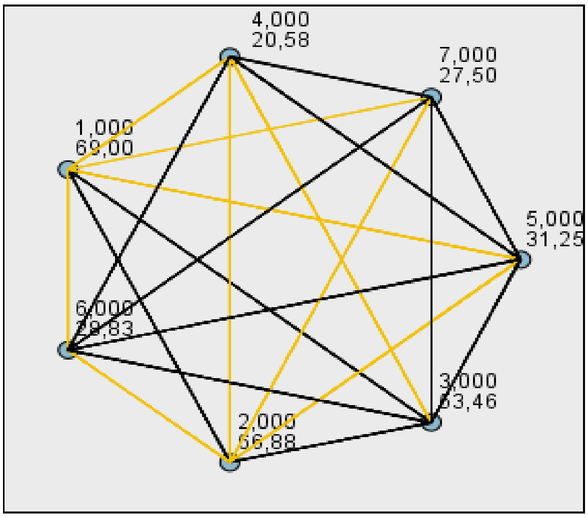

Figure 5. Differences of RW by Service Units

In the study, one-way analysis of variance (ANOVA), which was also used in this study, was used to control whether the wastes showed statistical differences according to summer and winter seasons. Since it is a city-specific study, Minitab Version 17 was used to evaluate whether the differences between waste data according to population, employment and number of households based on historical data covering summer and winter months are significant. As a result of the studies, it has been calculated that the highest waste composition among the daily collected wastes is plastic waste, which is 28% in summer and 26% in winter. Similarly, it was determined that organic wastes constitute the highest waste composition among the weekly collected wastes, with 28% in summer and 29% in winter, and it was argued that the difference between the wastes generated in the two seasons was not statistically significant ($p>0.05$). The common aim of both studies is to evaluate the appropriate ZWMS model by analyzing the information on waste data with statistical analysis methods.

4. CONCLUSION

With increasing pressure on limited natural resources, it is clear that governing bodies around the world are increasingly interested in models, frameworks and approaches to sustainable development. Adoption of ZWMS in waste management has become a necessity rather than a choice for the transition to a low-carbon and less polluting economy, where emerging models such as circular economy principles are adopted in environmental management, which can alleviate increasing waste volumes. In this context, when the ZWMS applied in AMM Administrative Service Buildings is examined; It has been observed that waste management is carried out within the framework of the Zero Waste Management Regulation legislation provisions and within the scope of a certain hierarchy.[19]

DOI: http://dx.doi.org/10.32571/ijct.992891 E-ISSN: 2602-277X

As a result of the statistical studies, it has been determined that the Central Building and Additional Service Buildings have higher RWs than other service units. In the institutional sense, with the ZWMS application, it has been determined that the recovery target of the RWs in the waste is achieved here at best. It is thought that the fact that posters and information brochures about zero waste are used more widely in the Headquarters and Additional Service Buildings and that the personnel in this unit participate in zero waste trainings are effective in this situation. 119009 kg of the 137992 kg waste collected during the study was included in the urban waste collection system and sent to the integrated solid waste disposal facility, while 21983 kg was delivered to licensed companies as recyclable waste. Thus, it was possible to achieve an average recovery rate of 16% for the 12-month period. It is thought that this rate of gain obtained in the first year of the AMM ZWMS application will increase with the full adoption of the application by the institution and the awareness of the employees.

ACKNOWLEDGEMENTS

This study was produced from the master thesis of Çukurova University, Institute of Natural and Applied Sciences, Department of Environmental Engineering, No. 5896.

Conflict of interests

I declares that there is no a conflict of interest with any person, institute, company, etc.

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