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COST OF RECYCLING IN ZONGULDAK CITY CENTRE

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Abstract

Solid Waste Management (SWM) has becoming a great problem for urban areas. Although directly transferring waste to landfill are is the cheapest solution, it is difficult to manage landfills due to some environmental problems. Therefore, reduction of solid wastes by means of recycling is needed. Benefits of recycling include recovery of valuable materials and volume reduction in landfill. Zonguldak Municipal and Medical Landfill Site have been operating since 2008. This facility also contains packaging wastes collection and separation plant. Nevertheless, recycling has not been started in Zonguldak city centre, except Bülent Ecevit University Farabi Campus.

In this study, we investigated the cost of waste recycling in Zonguldak city centre. Total recyclable waste amount is calculated as 16876 kg/day. We found that 247 containers are required to temporarily store recyclable waste. Total cost of waste containers is 176605 TL (46844.8 €). Yearly recyclable waste transportation cost is 273567.5 TL, which is equal to 72564.3 €. The costs of new recycling waste containers require new investment; however, transportation cost is not a new expense. We only separated the transportation cost of recycled material from transportation of total wastes.

Key words*: cost analysis, municipal solid wastes, recycling, Zonguldak*

INTRODUCTION

Increasing in population, quality of life and rapid urbanisation bring about sharply increase in solid waste generation (Guerrero et al., 2013). Solid Waste Management (SWM) has becoming a great challenge for cities in developing and underdeveloped countries. SWM includes the following steps: control of generation, collection, transportation, processing and ultimate disposal of solid wastes (Daskalopoulos et al., 1997; Armijo de Vega et al., 2008; Akinci et al., 2012; Yıldız-Geyhan et al., 2016).Improper waste collection, open dumping, uncontrolled burning or discharge into surface watercan be seen in underdeveloped countries (Berkun et al., 2005; Gamze Turan et al., 2009). Inconvenient methods of SWM result in public health issues, soil, groundwater, air pollutions, other aesthetic problemsand loss of valuable materials (Gamze Turan et al., 2009; Kanat, 2010; Erses Yay, 2015). Although directly transferring of municipal solid wastes to landfill area is the cheapest method, it will be costly in highly populated cities. Also, there exist some environmental problems arising from landfill sites like landfill gas and leachate. Therefore, volume reduction is needed and that can be achieved by means of waste recycling (Daskalopoulos et al., 1997). Separately collection of recyclable waste is another problem since it depends on several factors like social, economic, cultural and environmental (Yıldız-Geyhan et al., 2016). Troschinetz and Mihelcic (2009) mentioned that there exist 12 important issues in sustainable recycling of municipal solid waste. These are:

1. Government policy
2. Government finances
3. Waste characterisation
4. Waste collection and segregation
5. Household education
6. Household economics
7. SWM administration
8. SWM personnel education
9. SWM plan
10. Local recycled material market
11. Technological and human resources
12. Land availability

Disposal of solid waste is one of the biggest environmental problems in Turkey (Berkun et al., 2005; Tınmaz and Demir, 2006; Gamze Turan et al., 2009). According to the Waste Management Regulation (a replacement of old Solid Waste Control Regulation, 1991)

municipalities are responsible from collecting waste separately.

Moreover, construction and management of waste disposal facilities are again the responsibilities of municipalities (WMA, 2015).

A decade ago, there was not a landfill area in Zonguldak, Turkey. Municipal and medical wastes were dumping on the shoreline. In 2006, environmental impact assessment report of Zonguldak Municipal and Medical Landfill Site has been approved. Landfill has started serving in 5 November 2008. Packaging wastes collection and separation plant was constructed in March 2010. However, recyclable waste collection has not started yet in Zonguldak city centre. Only Bülent Ecevit University has been separating wastes since 2012. Placing recyclable waste containers in city centre has not been performed so far (MİMKO, 2006; ZONCEB, 2016).

In this study, we tried to find the cost of waste recycling in Zonguldak city centre.

Firstly, we investigated the composition of Zonguldak wastes via previously published literature. Next, we calculated the amount of recyclable wastes generated. After that, the required amount and costs of recycle waste containers have been found for each district of Zonguldak. Finally, recycled waste transportation costs have been calculated.

The rest of the paper is organised as follows: study area is defined in Materials and Methods part. Also, information about waste generation rates, recyclable fraction, selected waste containers and waste trucks have been given in this part.

Calculations of the required amount recyclable waste containers and the calculations of truck routes have been given in Results and Discussion section. Moreover in this part, cost calculations have been given too. Also, benefits of waste recycling in Zonguldak are discussed. In conclusion part, brief summary of this study exists.

MATERIALS AND METHODS

Study Area

Zonguldak is located in North-Eastern part of Turkey on the Black Sea shore. Zonguldak is the first city of Turkish republic and founded in 1924. City covers 3310 km^2 area. Economy mainly depends on bituminous coal mining, iron and steel production, forestry and energy sectors.

According to the results of Address Based Population Registration System, 597524 inhabitants live in the entire city. There are 108180 people in Zonguldak city centre (within the boundary of Zonguldak Municipality) in 2016. 19 districts exist in city centre (Figure 1). Names and populations of these districts are given in Table 1 (TSI, 2017).

Total area of 19 districts is 23.9 km^2.

The climate of the city is Black Sea climate, rainy and temperate in all seasons. According to the long years (1950 - 2015) meteorological records, average temperature is 13.7 °C in Zonguldak. 1216.8 mm yearly annual precipitation is recorded (TSMS, 2017).

Table 1. Populations of districts in Zonguldak city centre

District Name	2016 Population
Asma	2255
Bağlık	1282
Bahçelievler	16718
Baştarla	2133
Birlik	3899
Çaydamar	3910
Çınartepe	2768
Dilaver	1966
İnağzı	2744
İncivez	8158
Karaelmas	9102
Meşrutiyet	7784
Mithatpaşa	8360
On Temmuz	3971
Tepebaşı	13051
Terakki	11201
Yayla	1845
Yeni	3072
Yeşil	3961
Total Population	**108180**

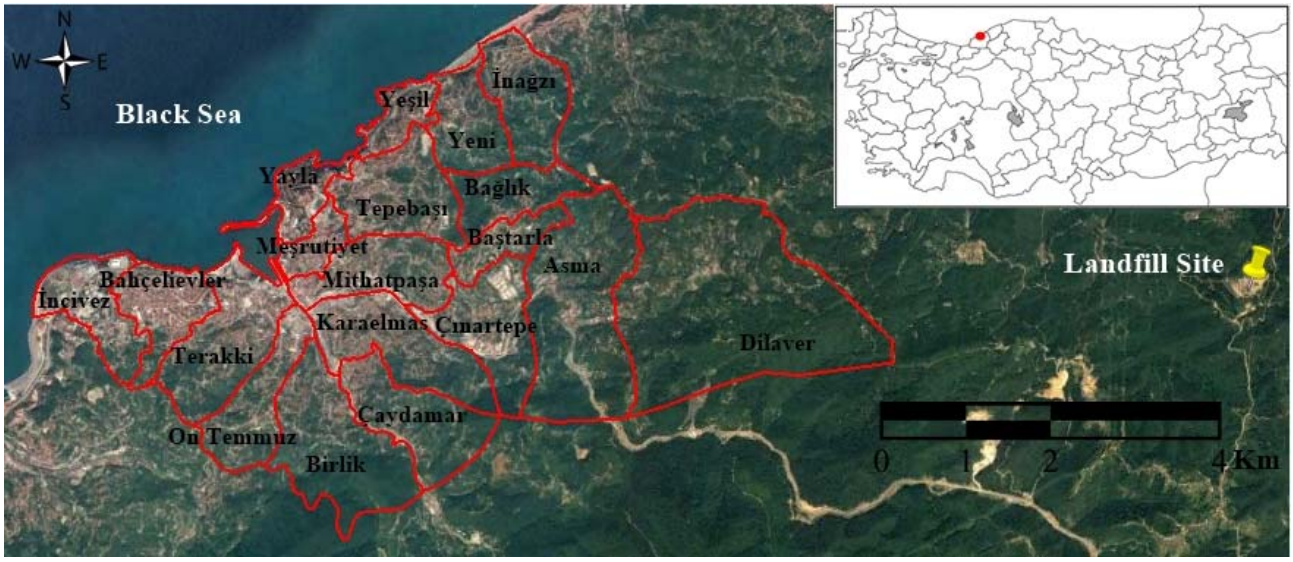

Figure 1. Zonguldak districts map and landfill site

Waste Generation and Recycling

Average municipal solid waste generation rate in Turkey is 1.15 kg/person-day according to the "Turkish Environment State Report - 2011" published by Ministry of Urbanization and Environment. Waste generation rate in the study area is 0.8 kg/person-day, which is less than country average. Waste composition is given in Table 2. Paper, plastic, glass and metal wastes can be recycled. According to the Table 2, total recyclable percentage of Zonguldak wastes are 19.5%. Metin et al., (2003) reported that nearly quarter of waste generated in Turkey is recyclable. Recyclable portion of wastes in Zonguldak is less than Turkey's average. There is no local study related with the density. Therefore, the value of recyclable wastes density is taken from another study. Lino et al., (2010) reported the density of recyclable wastes as 102.2 kg/m^3.

Table 2. Waste composition of Zonguldak

Waste composition	Percent (%)
Paper	5.0
Plastic	7.5
Glass	3.8
Metal	3.2
Textile	1.0
Organic wastes	47.0
Others	32.5

Zonguldak city centre does not have recyclable waste containers. Recyclable waste containers, shown in Figure 2, are selected to store glass, plastic, paper and metal separately at the same time. Unit price of container is 715 Turkish Liras (TL). The volume of each separate unit is 0.27 m^3 (120 × 30 × 75 cm).

Figure 2. Recyclable waste container

Zonguldak Municipal and Medical Landfill Site is located near Sofular Village, which is 18 km away from city centre (Figure 1). Landfill site covers 150000 m^2. Zonguldak Municipality has 13 waste trucks with volume of 15 m^3. If 19.5% of waste is recyclable, the same ratio of trucks is needed to transport recyclable waste. So, we decided that 3 of the trucks can be used to transfer recycled wastes with simple modifications. By this way, it is avoided to by new trucks. In order to calculate the fuel consumption cost of trucks several information are needed. "EMEP/EEA air pollutant emission

inventory guidebook 2016" states that typical fuel consumption of a heavy duty diesel vehicle is 0.24 kg/km (EEA, 2016). The density of diesel fuel is 0.87 kg/l. Finally, diesel fuel price in Zonguldak city centre is 4.66 TL/l (Opet, 2017) and 1 € is equal to 3.77 TL (24 February 2017).

RESULTS AND DISCUSSIONS

The total amount of municipal solid waste, recyclable waste amount and daily volume of recyclable waste generated in study area are calculated as follows:

Total waste amount = 108180 persons × 0.8 kg/person/day = 86544 kg/day

Recyclable waste amount = 86544 kg/day × 0.195 = 16876 kg/day

Daily volume of recyclable waste = 16876 kg/day / 102.2 kg/m^3 = 165.1 m^3/day

Daily volume of recyclable waste generated in study area is 165.1m^3/day. To determine that amount in each district, total volume is divided by districts' population and results are shown in Table 3. Among the 19 districts Bahçelievler, Tepebaşıand Terakki has highest daily recyclable waste volumes. Since recyclable waste volumes of these 3 districts are higher than the volume of a truck (15 m^3), 2 trips are required daily. The rest of the districts have less recyclable waste volumes. Therefore, recyclable wastes of two or more districts can be collectedin one trip. In previous section, it is mentioned that 3 trucks are enough for recyclable waste collection. Average distances of each district to landfill site have been roughly measured by using Google Maps. These values are represented in Table 3.
In order to calculate, the required number of containers volume of waste should be divided by container volume. However, at this point, it must be noted that recyclable waste generation amounts are different from waste to waste. Since plastic has the highest ratio in total recyclable waste (7.5/19.5 = 0.39) calculation should be done for this waste. The other waste container parts will not reach full capacity when plastic container is full. The calculation of number of container needed to hold daily recyclable waste for Asma district is shown below. Decimal result is rounded to the next integer. The rest is calculated and tabulated in Table 3 with the same manner.

Container number = 3.4m^3 × 0.39 / 0.27 m^3Container number = 4.98 → 5

According to Table 3, 247 containers are required to hold daily recyclable waste of Zonguldak city centre. The unit was 715 TL. So, the total capital cost of containers is:

Containers cost = 247 × 715 TL = 176605 TL
(Containers cost = 46844.8 €)

Table 3. Recyclable wastes

District Name	Recyclable waste volume (m^3/day)	Distance to landfill (km)	Number of containers needed
Asma	3.4	17.4	5
Bağlık	2.0	22.5	3
Bahçelievler	25.5	24.0	37
Baştarla	3.3	21.1	5
Birlik	6.0	26.1	9
Çaydamar	6.0	24.5	9
Çınartepe	4.2	19.8	7
Dilaver	3.0	18.2	5
İnağzı	4.2	26.2	7
İncivez	12.5	24.6	18
Karaelmas	13.9	22.1	21
Meşrutiyet	11.9	22.5	18
Mithatpaşa	12.8	21.2	19
On Temmuz	6.1	23.2	9
Tepebaşı	19.9	22.6	29
Terakki	17.1	23.9	25
Yayla	2.8	23.2	5
Yeni	4.7	23.6	7
Yeşil	6.0	24.8	9
Total	**165.1**		**247**

We divided study area into 3 zones for 3 trucks to minimize trip costs of trucks. First zone consists of İncivez, Bahçelievler, Terakki, On Temmuz and Birlik districts. Second zone covers Yayla, Meşrutiyet, Yeşil, Tepebaşı, Yeni, İnağzı, Bağlık and Baştarla districts. Finally, Mithatpaşa, Karaelmas, Çaydamar, Çınartepe, Asma and Dilaver fall into third zone. Total trips for each zone are shown in Table 4. Distances of each trip are again measured via Google Maps. Daily fuel consumptions of trucks are calculated

accordingly. Truck fuel cost of trip 1 in first zone is shown as an example. The rest is calculated and represented in Table 4 with the same manner.

Daily fuel consumption in Trip 1 of Zone 1:
49.2 km × 0.24 kg/km × 4.66 TL/l / 0.87 kg/l = 63.2 TL

Table 4. Trip costs

	Trips	Trip coverage	Total distance (km)	Daily fuel consumption (TL)
Zone 1	Trip 1	İncivez, Bahçelievler	49.2	63.2
	Trip 2	Bahçelievler	48.0	61.7
	Trip 3	Bahçelievler, Terakki	48.0	61.7
	Trip 4	Terakki, On Temmuz	47.8	61.4
	Trip 5	Birlik	52.2	67.1
Zone 2	Trip 1	Yayla, Meşrutiyet	46.4	59.6
	Trip 2	Yeşil, Tepebaşı	49.6	63.8
	Trip 3	Tepebaşı, Yeni	47.2	60.7
	Trip 4	İnağzi, Bağlık, Baştarla	52.4	67.4
Zone 3	Trip 1	Mithatpaşa, Karaelmas	44.2	56.8
	Trip 2	Karaelmas, Çaydamar	49.0	63.0
	Trip 3	Çaydamar, Çınartepe, Asma, Dilaver	49.0	63.0
Total trip length			**583.0**	**749.5**

Total fuel cost of all trucks is 749.5 TL/day (198.8 €/day). Yearly, 273567.5 TL will be spent on fuel consumption, which is equal to 72564.3 €. Actually, fuel cost of trucks is not a new expense. We only separated the cost of recyclable waste transport from total municipal waste transport expenditure. It is possible to reduce this expense, if recyclable waste could be sold.

CONCLUSIONS

In this study, we investigated the cost of municipal waste recycling in Zonguldak city centre.

Total recyclable waste amount is calculated as 16876 kg/day. We found that 247 containers are required to temporarily store recyclable waste. Total cost of waste containers is 176605 TL (46844.8 €). It is possible to reduce container costs by donation. For instance, Şişecam, one of the leading glass manufacturers in Turkey, has donated 12900 glass waste banks since 2011 (Şişecam Group, 2017).

Daily truck fuel cost is 749.5 TL/day (198.8 €/day) for transportation of recyclable wastes.

Recovery of valuable materials from municipal solid waste is the biggest gain of recycling. Arı and Yılmaz (2016) reported that the estimated value of recyclable items that go to waste is 1.5billion TL/year. Furthermore, recycled wastes will not consume any volume in landfill so that estimated use of landfill can be extended.

Waste recycling has not been started in Zonguldak city centre apart from Bülent Ecevit University Farabi Campus.

Recycling of municipal solid waste can be applied more easily in university campuses. Armijo de Vega et al., (2008) states that "universities have the moral and ethical obligation to act responsibly towards the environment". By performing recycling, reduction in financial costs and being an example to students can be achieved. Moreover, recyclable portion of the solid waste in university campuses is more thanthat of cities.

Armijo de Vega et al., (2008) mentioned that more than 65% of the wastes are recyclable in Campus Mexicali I of the Autonomous University of Baja California.

Developed countries give money back for return of package wastes and apply fines for throwing recyclable waste together with regular wastes. On the other hand, recycling is generally voluntary in developing countries. In order to be successful in waste recycling, public education plays an important role.

Arı and Yılmaz (2016) point out that majority of female adult population in Turkey is not working can be described as housewives, who works in home. Therefore, education of housewives on waste recycling is crucial.

There is also one final thing that should be mentioned here. Recycling alone is not the only way of sustainable SWM. Other waste management options must be considered together. For example, Erses Yay (2015) proposed an integrated system that consists of material recovery, composting, incineration and landfilling, as a sustainable way of SWM.

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REFERENCES

Akinci G., DuyusenGuven, E., Gok G., 2012. Evaluation of waste management options and resource conservation potentials according to the waste characteristics and household income: A case study in Aegean Region, Turkey. Resources, Conservation and Recycling, 58, p. 114-124.

Arı E., Yılmaz V., 2016. A proposed structural model for housewives' recycling behavior: A casestudy from Turkey. Ecological Economics, 129, p. 132-142.

Armijo de Vega C.,Benítez S. O., Barreto M. E. R., 2008. Solid waste characterization and recycling potential for a university campus. Waste Management, 28, p. S21-S26.

Berkun M., Aras E., Nemlioglu S., 2005. Disposal of solid waste in Istanbul and along the Black Sea coast of Turkey. Waste Management, 25, p. 847-855.

Daskalopoulos E., Badr O., Probert S. D., 1997. Economic and Environmental Evaluations of Waste Treatment and Disposal Technologies for Municipal Solid Waste. Applied Energy, 58 (4), p. 209-255.

EEA, European Environmental Agency, EMEP/EEA air pollutant emission inventory guidebook 2016. EEA Report No 21/2016, http://www.eea.europa.eu/publications/emep-eea-guidebook-2016, 2016

Erses Yay A. S., 2015. Application of life cycle assessment (LCA) for municipal solid waste management: a case study of Sakarya. Journal of Cleaner Production, 94, p. 284-293.

GamzeTuran N.,Çoruh S., Akdemir A., Ergun O. N., 2009. Municipal solid waste management strategies in Turkey. Waste Management, 29, p. 465-469.

Guerrero L. A., Maas G., Hogland W., 2013. Solid waste management challenges for cities in developing countries. Waste Management, 33, p. 220-232.

Kanat, G., 2010. Municipal solid-waste management in Istanbul. Waste Management, 30, p. 1737-1745.

Lino F. A. M., Bizzo W. A., da Silva E. P. Ismail K. A. R., 2010. Energy impact of waste recyclable in a Brazilian metropolitan. Resources, Conservation and Recycling, 54, p. 916-922.

MİMKO, MİMKO Engineering Construction Manufacturing Consulting & Trade. Environmental impact assessment report of Zonguldak Municipal and Medical Landfill Site, 2006

Opet, Zonguldak Fuel Prices, https://www.opet.com.tr/zonguldak-akaryakit-fiyatlari, 2017

Şişecam Group,Corporate Social Responsibility, http://www.sisecam.com.tr/en/sustainability/corporate-social-responsibility, 2017

Tınmaz E., Demir, İ., 2006. Research on solid waste management system: To improve existing situation in Çorlu Town of Turkey. Waste Management, 26, p. 307-314.

Troschinetz A. M., Mihelcic J. R. 2009. Sustainable recycling of municipal solid waste in developing countries. Waste Management, 29, p. 915-923.

TSI, Turkish Statistical Institute, Address Based Population Registration System, https://biruni.tuik.gov.tr/medas/?kn=95&locale=en, 2017

TSMS, Turkish State Meteorological Service, https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=ZONGULDAK, 2017

WMA, Waste Management Regulation, Turkish Republic Official Gazette date: 02.04.2015, number: 29314, 2015

Yıldız-Geyhan E., Yılan-Çiftçi G., Altun-Çiftçioğlu G. A., Kadırgan M. A. N., 2016. Environmental analysis of different packaging waste collection systems for Istanbul - Turkey case study. Resources, Conservation and Recycling, 107, p. 27-37.

ZONCEB, Zonguldak Special Provincial Directorate of Administration and Union of Municipality's Environment Services, http://www.zonceb.gov.tr/wp-content/uploads/2016/05/2015-YILI-FAAL%C4%B0YET-RAPORU.pdf, 2015