Energy Intensity in waste collection services

V. Sousa[1*], I. Meireles[2], J. Vaz[3], C. Dias-Ferreira[4,5]

[1]CERIS, DECivil, IST – University of Lisbon, Lisbon, 1049-001, Portugal

[2]RISCO, Department of Civil Engineering, University of Aveiro, Aveiro, Portugal

[3]Ecogestus, Lda., Figueira da Foz, Portugal

[4] Universidade Aberta, Lisboa, Portugal

[5] CERNAS, Instituto Politécnico de Coimbra, Portugal

[*]corresponding author. Tel.: +351 933 755 084 E-mail address: vitor.sousa@tecnico.ulisboa.pt

Abstract

Waste collection services optimization require balancing waste generation, waste containers capacity, waste truck capacity, circuit length and collection frequency. Since the largest resource consumption and corresponding operational costs are due to fuel consumption, the objective function to optimize a collection service is driven by the minimization of the energy intensity (energy spent per unit weight of waste collected). The present research effort reports on the energy intensity of the mixed waste collection service in Cascais Municipality.

Keywords

Waste collection; mixed waste; fuel consumption rate; collection route

1. Introduction

Municipal solid waste collection represents the largest share (from 50% to 70%) of waste management costs and fuel is a substantial expense in waste collection and transportation (Sonesson 2000; Sousa et al. 2018). Relatively large fuel consumption rates are required for waste collection and transportation, not only because heavy-duty vehicles are used, but the driving profile requires frequent stops (Nguyen and Wilson 2010).

Previous studies of rear- and side-loader garbage trucks reported fuel consumptions from 53 L/100 km

up to 235 L/100 km (Agar et al., 2007; Ivanič, 2007; Thiruvengadam et al., 2010; Sandhu et al. 2015). Bender et al. (2014) measured a fuel consumption of 79 L/100 km, from which nearly 60% was due to the compactor operation / idling. In Portugal, Teixeira et al. (2014) estimated an average fuel consumption of 3.96 L/t for mixed waste collection in the city of Porto, Portugal. There are also a number of other studies about fuel consumption rates for heavy-duty vehicles (e.g., US EPA 2002a,b; DEFRA 2005, NRC 2009).

The present contribution presents the data on fuel consumption, distance covered, duration and waste collected of the mixed waste collection routes in operation in Cascais Municipality. This reveals not only the average values, but also the variability of the fuel consumption rate in a real waste collection service within a single utility.

2. Case Study

Cascais municipality is located at approximately 30 km west of the capital of Portugal, Lisbon. Covering an area of almost 100 km^2 and with a population varying between 181 440 (in 2003) and 211 714 (in 2018) inhabitants, the average mixed solid waste collected yearly in that period was 136 000 tonnes. The average mixed waste generated was 91 290 tonnes, presenting a descending trend until 2013 and increase since then (Figure 1). This pattern is explained by changes in the waste collection service, namely the increase in the segregate collection coverage on the first years, and the economic context, in particular the 2008 world economic crisis that resulted in the public finance intervention program negotiated with ECB (European Central Bank) and IMF (International Monetary Fund) between 2011 and 2017.

The certification of the EMAC asset management system according to the ISO 55000 family of standards in 2017, the first (and only to date) on the waste collection sector and one of the few in Portugal, brought noticeable improvements in the information collected. Amongst those improvements, the amount of waste collected, the distance and the time spend per shift in each circuit started to be collected. The data on the duration, distance and waste collect per day in each mixed waste collection route is available from 01/01/2018 to 30/05/2018. The reported average fuel consumption per tonne of mixed waste collected was 4.9 L/tonne, in 2017, and 5.0 L/tonne, in 2016 (ERSAR 2018, 2017).

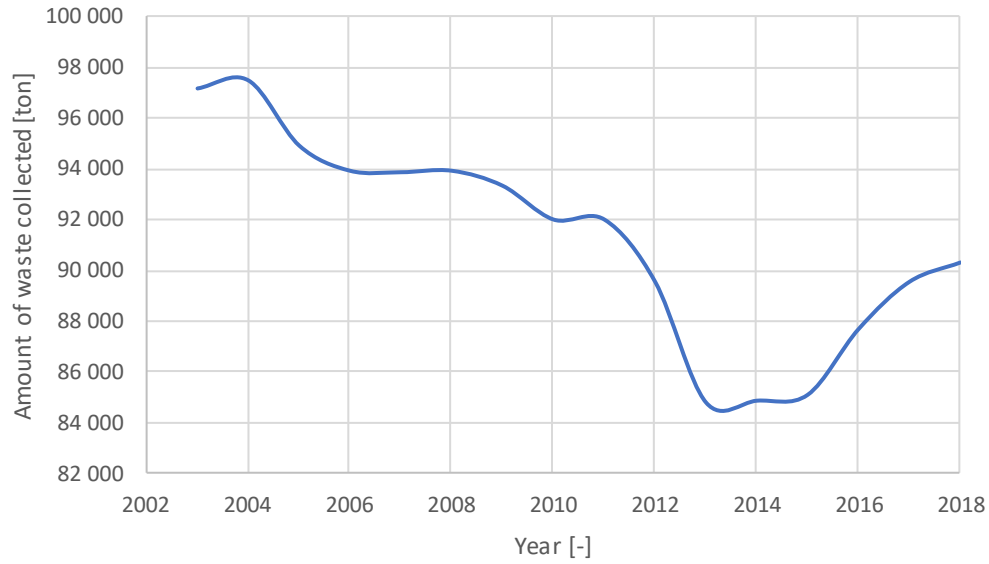

Figure 1 – Mixed waste collected in Cascais between 2003 and 2018.

Figure 2 presents the histogram of the fuel consumption rate, revealing a substantial variability when analysing all shifts in all routes in the period between 01/01/2018 and 30/05/2018. The underlying reason is the waste generation variability, creating situation were large amounts can be collected in short distances as well as requiring large distances to be travelled to collect relatively small amounts of waste.

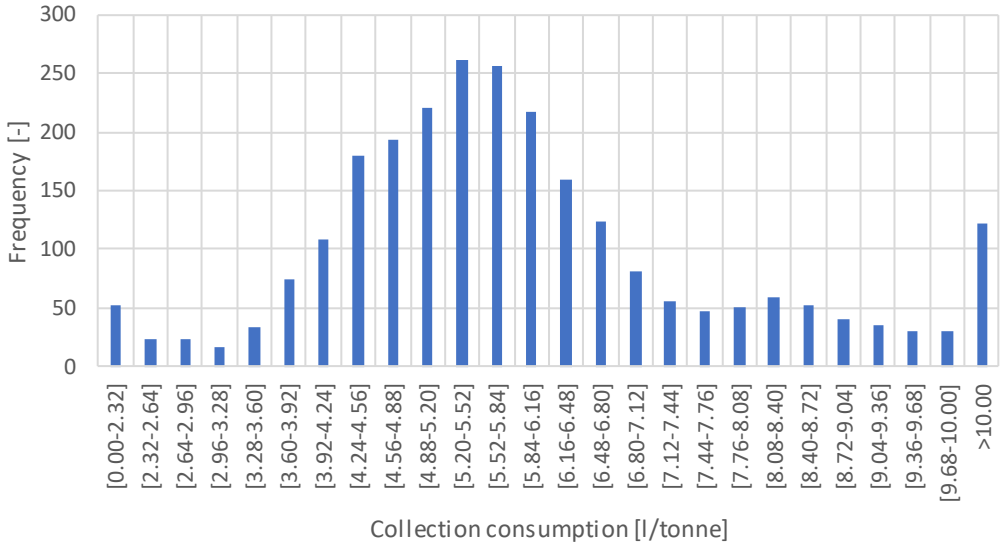

Figure 2 – Global fuel consumption rate variability.

Figure 3 and Figure 4 present the histograms of fuel consumption rates per month and weekday, respectively. The results do not show significant differences between them, revealing that the waste generation and collection patterns are relatively uniform throughout the months and days of the week. This is an indication that the variability is probably due to factors affecting waste generation globally, such as holidays, vacations or special events.

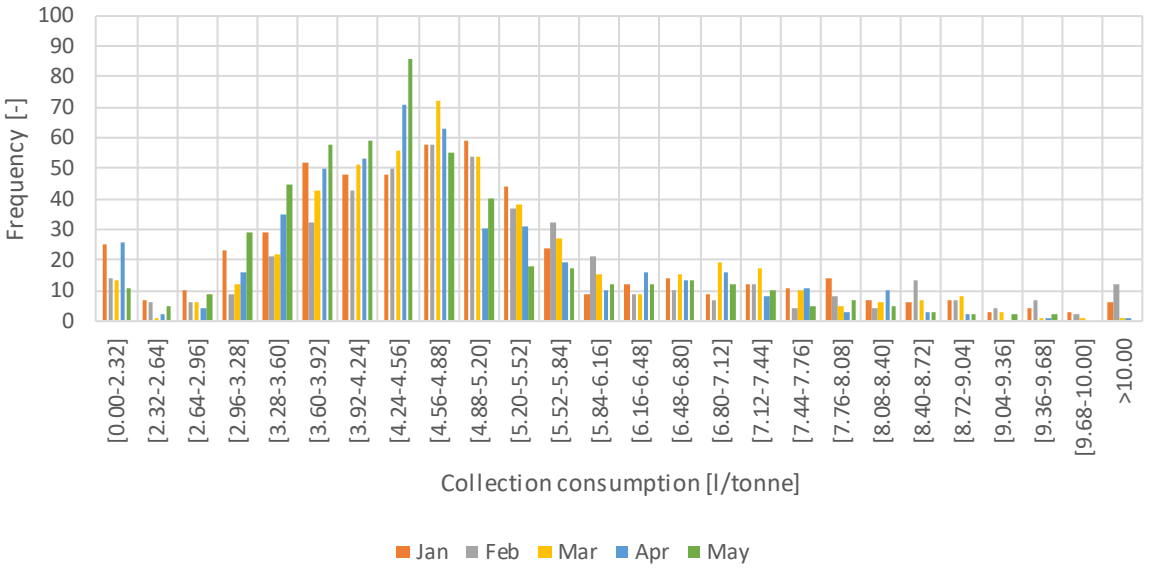

Figure 3 – Fuel consumption rate per month.

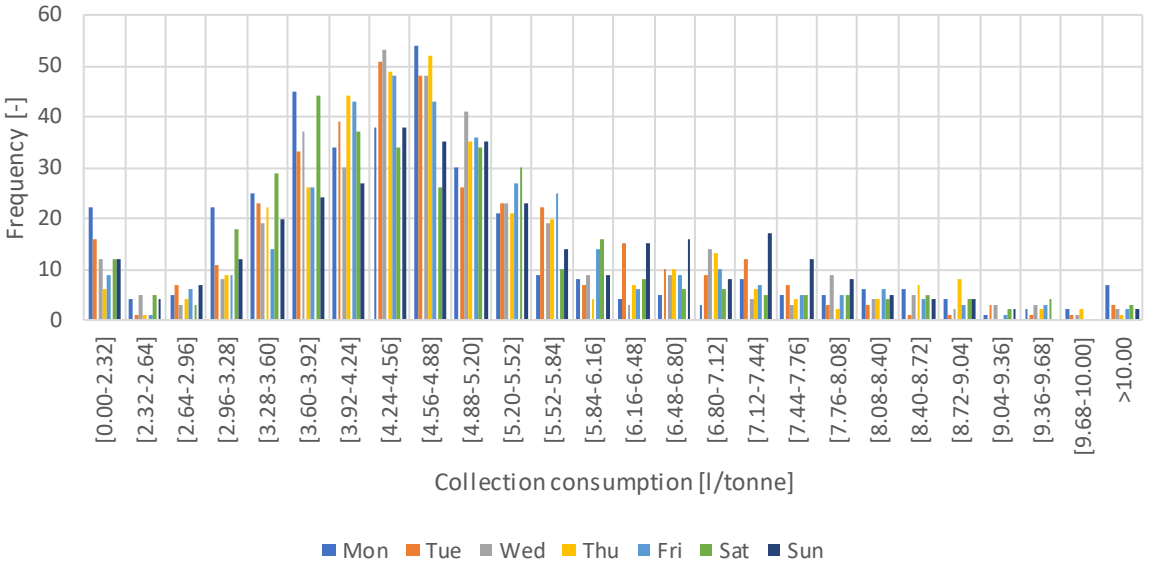

Figure 4 – Fuel consumption rate per weekday.

3. Conclusions

The fuel consumption rate per distance was estimated in 83 L/100 km, which is within the range of values published in the literature. However, considering that the goal of the waste collection service is to pick up and transport the waste, the fuels consumption rate per amount of waste is a more informative indicator. This ranged from 0.63 L/tonne to 53.59 L/tonne, with an average of 4.95 L/tonne, a median of 4.66 L/tonne and a standard deviation of 1.90 L/tonne.

Fuel consumption rates depend on the specific context in which the waste utility operates. Usually, waste collection in urban areas tend to enable the collection of larger amounts of waste in smaller distances,

but require more frequent stops. This research reveals that even within a single utility the fuel consumption rates also vary broadly depending on the waste generation pattern.

References

Agar, B.J., B.W. Baetz, and B.G. Wilson. 2007. Fuel consumption, emissions estimation, and emissions cost estimates using global positioning data. J. Air Waste Manage. Assoc. 57(3):348–54.

Bender, F.A., Bosse, T., Sawodny, O., 2014. An investigation on the fuel savings potential of hybrid hydraulic refuse collection vehicles. Waste Manag., 34(9):1577-1583.

DEFRA, 2005. Guidelines for company reporting on Greenhouse gas emissions. From Department for environment, food and rural affairs (DEFRA), UK.

Eisted, R., Larsen, A.W., Christensen, T.H., 2009. Collection, transfer and transport of waste: accounting of greenhouse gases and global warming contribution. Waste Manage. Res. 27(8):738–745.

ERSAR (2017). Relatório Anual dos Serviços de Água e Resíduos em Portugal (RASARP 2016). Edições Anuais RASARP vol. 1 & 2, Entidade Reguladora dos Serviços de Águas e Resíduos (ERSAR), Lisboa, Portugal. (in portuguese)

ERSAR (2018). Relatório Anual dos Serviços de Água e Resíduos em Portugal (RASARP 2017). Edições Anuais RASARP vol. 1 & 2, Entidade Reguladora dos Serviços de Águas e Resíduos (ERSAR), Lisboa, Portugal. (in portuguese)

Fruergaard, T., Astrup, T., Ekvall, T., 2009. Energy use and recovery in waste management and implications for accounting of greenhouse gases and global warming contributions. Waste Manage. Res. 27(8):724–737.

Ivanič, Ž. 2007. Data collection and development of New York City refuse truck duty cycle. SAE Tech. Paper 2007-01-4118. doi:10.4271/2007-01-4118

NRC, 2011. 2009 Canadian Vehicle Survey: Summary Report. Office of Energy Efficiency, Natural Resources Canada (NRC), Ottawa, Canada. http://publications.gc.ca/collections/collection_2012/rncan-nrcan/M141-18-2009-eng.pdf (accessed May 2019)

Sandhu, G.S., Frey, H.C., Bartelt-Hunt, S., Jones E. 2015. In-use activity, fuel use, and emissions of heavy-duty diesel rolloff refuse trucks, Journal of the Air & Waste Management Association, 65:(3):306-323.

Sonesson, U., 2000. Modelling of waste collection – a general approach to calculate fuel consumption and time. Waste Manage. Res. 18(2):115–123.

Sousa, V.; Dias-Ferreira, C.; Vaz, J. M.; Meireles, I. (2018). Life-cycle cost as basis to optimize waste collection in space and time: a methodology for obtaining a detailed cost breakdown structure. Waste

Manage. Res. 36(9):788-799.

Teixeira, C.A., Russo, M., Matos, C., Bentes, I., 2014. Evaluation of operational, economic, and environmental performance of mixed and selective collection of municipal solid waste: Porto case study. Waste Manag. Res. 32(12):1210-1218.

Thiruvengadam, A., Carder, D.K., Krishnamurthy, M., Gautam, M. 2010. Comparison of regulated and unregulated exhaust emissions from a fleet of multi-fuel solid resource collection vehicles. Proceedings of the ASME 2010 Internal Combustion Engine Division Fall Technical Conference, September 12–15, 139–147. San Antonio, TX: American Society of Mechanical Engineers.

US EPA, 2002a. Study of exhaust emissions from idling heavy-duty diesel trucks and commercially available idle-reducing devices. EPA420-R-02-025, United States Environmental Protection Agency (US EPA), USA.

US EPA, 2002b. Update Heavy-duty Engine emission conversion factors for MOBILE6: Analysis of BSFCs and Calculation of Heavy-Duty Engine emission conversion factors. EPA420-P-98-014, United States Environmental Protection Agency (US EPA), USA.