

MUNICIPAL SOLID WASTE UNIT PRODUCTION RATES AND ESTIMATION OF THE REQUIRED NUMBER OF WASTE STORAGE CONTAINERS IN THE MUNICIPALITY OF ATHENS

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ABSTRACT

The Municipality of Athens (M.A.) currently comprises 7 municipal districts, 7 waste collection districts (WCD) and approximately 5800 residential blocks. Solid waste is collected daily on a 7 days per week basis. The M.A. comprises approximately 119 waste collection sub-districts (herein referred to as 'collection programs' or simply 'programs'). Each 'program' consists of a number of adjacent residential blocks, whilst certain special programs include only central streets in Athens (e.g. Aharnon, Patision) or the commercial center of Athens. During the past years, each waste collection vehicle has been making 2 daily trips to the final disposal site in the Attica region, in Liosia. The above scheme is the basis on which daily collection of municipal solid waste (MSW) in the M.A. takes place. The actual residents at each residential block in Athens were based on the 2001 census. The coding of the National Statistical Agency was initially used and adjusted to the residential blocks' coding used by the M.A. The residential blocks included in each collection program were precisely identified. Average unit waste production rates (UPRs) were estimated for each collection program using:

- vehicle net weights data for February and July 2002 at the central Liosia landfill
- actual population for each residential block in Athens (2001 census) and
- number of residential blocks at each collection program

The number of waste storage containers (WSC) at each residential block was estimated by accounting for a 1,1 m³ container volume, a 80% fill ratio and a 95 kg m⁻³ uncompacted waste density. As a result of the above, UPRs and the required number of WSC were estimated for each residential block, each collection program, each WCD and for the M.A. as a whole.

Sunday has the smallest production of MSW during a week, whilst Tuesday is the day with the largest amount of MSW produced within a week. The average production rate for the M.A. was estimated to be 3,8 kg cap⁻¹ d⁻¹, ranging from 1,3 kg cap⁻¹ d⁻¹ (for district 6) to 8,9 kg cap⁻¹ d⁻¹ (for district 1). The relatively large UPR recorded for district 1 is attributed to the increased number of commercial stores (center of Athens) and due to the relatively small recorded actual population, since few apartment buildings exist in the center of Athens. The total number of waste storage containers required in the M.A. is approximately 16660, whilst the existing number is approximately 14580.

KEYWORDS: Municipal solid waste, collection, unit production rate, waste storage containers.

1. INTRODUCTION

The Municipality of Athens (M.A) comprises 7 municipal districts and approximately 5800 residential blocks of various dimensions. Solid waste is collected daily on a 7 days per week basis. Waste collection is based on 7 waste collection districts (WCD), the boundaries of which do not currently coincide with the boundaries of the 7 municipal districts. The seven (7) WCD comprise approximately 119 waste collection sub-districts (herein referred to as 'collection programs' or simply 'programs'). Each 'collection program' has designated boundaries and therefore consists of a certain number of adjacent residential blocks. A few programs include central streets in Athens (e.g. Aharnon, Patision) or certain areas in the commercial center of Athens.

Up until recently, the M.A. owned approximately 70 waste collection vehicles, of which 15 press type 13 m³ vehicles, 51 mill type 13 m³ vehicles, 2 press type 20 m³ vehicles, 3 mill type 8 m³ vehicles, 1 press type 8 m³ vehicles, 14 5 tn open trucks and various other vehicles and containers (press containers, street sweepers, container cleaning vehicles etc.). Various new vehicles were purchased prior to summer 2004 due to the Olympic Games in Athens. Currently, the (old and new) principal waste collection vehicles in operation in the M.A. are as follows:

- 80 press and mill type 13 m³ vehicles
- 10 press and mill type 8 m³ vehicles ¹
- 20 press type 4 m³ vehicles
- 5 press type 20 m³ vehicles

All 4 m³ vehicles have no regular waste collection routes and operate mostly as 'emergency' collection vehicles. The 20 m³ vehicles have been recently functioning as 'small' transfer stations, without a specific collection route, occasionally used in waste collection at the centre of Athens. The 13 m³ collection vehicles are the principal waste collection vehicles in the M.A.

During the past years, each waste collection vehicle was scheduled to collect all waste produced within each 'collection program' by realizing 2 daily trips to the final waste disposal site in Liosia. The same vehicle would be also often used to collect wastes from an adjacent waste collection program, therefore making, on average, 4 trips to the landfill on a daily basis. Experience showed that 2 trips per program were adequate to collect all wastes within a program throughout the year, whilst the vehicle at its second trip to the landfill would often be partially full.

Approximately 14500 (temporary) waste storage containers (WSC) exist in the M.A. currently. The bins had been placed in the past based on experience and observations of the waste collection vehicle operators. No specific methodology had been used to calculate and site the WSC in M.A. Therefore, it was rendered necessary to develop a methodology to estimate the theoretically required number of WCS in each residential block in Athens. This methodology is presented in this article.

2. METHODOLOGY

2.1 Variations of daily waste production

Average daily values for up to 98 collection programs were plotted separately for February '02 and July '02 (Figure 1). Figure 1 shows that Wednesdays are regularly the days within a week with the lowest solid waste production, followed by Thursdays during February. In addition, Saturdays were the days with the largest MSW production in February. During July, Tuesdays were the days with the largest waste production, whilst Wednesdays were also the days with the lowest MSW production. In both months, a slight decrease in waste amounts was observed steadily from Saturday to Wednesday and an increase later on up until Saturday. A relatively high production of MSW is observed during the week of 8th to 14th of July 2002, which cannot be explained due to the relatively small size of primary data.

¹ All newly purchased

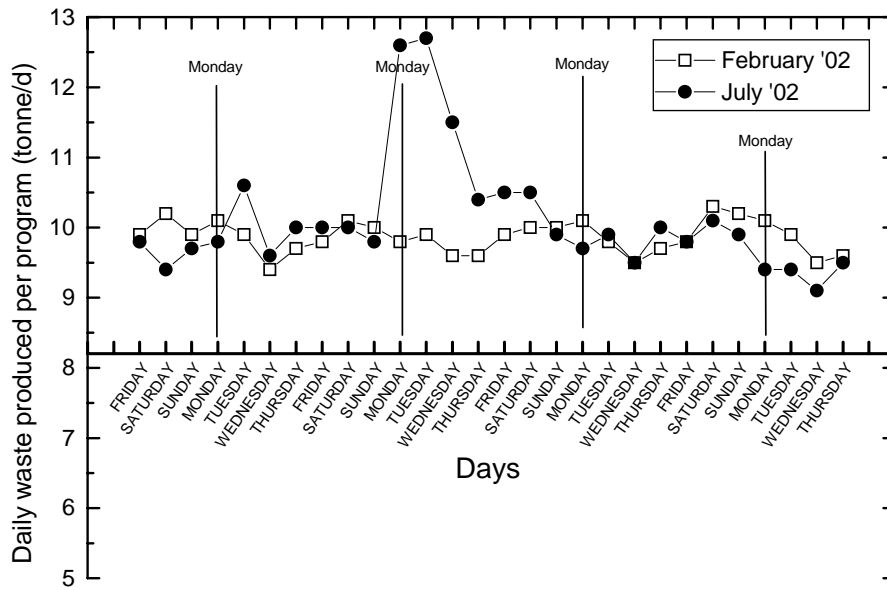


Figure 1. Variations of average daily waste produced during February '02 and July '02 (the range of number of programs accounted for in the analysis during each day is 42 to 98 for February '02 and 10 to 83 for July '02)

2.2 Average unit production rates (UPRs)

As part of the methodology presented here, the UPR for each collection program was calculated based on the following steps:

1. The permanent and actual population of each residential block in the M.A. was recorded according to the 2001 census (source: National Statistics Agency)
2. Due to differences in the coding of residential blocks as used by the M.A. and the National Statistics Agency, maps were used to identify same residential blocks under the 2 different codings. The differently coded residential blocks were finally matched for each collection program.
3. Daily waste weights of each collection program for February and July 2002 were recorded. It is noted that the most recent waste vehicle weighing in Liosia was performed during 2002. These 2 months were selected to study seasonal variations during the year. Only the weights from programs at which vehicles were weighed during both daily trips to the landfill were accounted for. In several cases, weighing took place only during the first trip of the vehicle to the landfill, and not during the 2nd, and thus these 'half' weights were apparently not accounted for. Final daily tonnage used during calculation resulted from averaging approximately 60 daily values for each program separately.
4. The total actual population per collection program was estimated by adding the actual population for each residential block in each collection program.
5. The total program waste tonnage (in kg d^{-1}), as estimated in step 3, was divided by the total program population in step 4. The UPR for each program was expressed in $\text{kg cap}^{-1} \text{d}^{-1}$. It was assumed that no significant differences in population between the year 2001 (census year) and 2002 exist. All residential blocks in each collection program were assigned the same UPR estimated for the program.

The total MSW daily amount produced in the M.A. in year 2002 is included in Table 1. It is noted that the total daily amount for both months does not include 5 additional special programs (dedicated only to hospitals and institutes) and 2 regular programs for which no data existed.

Table 1. Amounts of MSW produced per collection program in 2002

	February 2002	July 2002
Number of programs accounted for in the analysis	111	110
Total daily amount (t d ⁻¹) in the M.A.	1090	1110
Average daily amount per program (t d ⁻¹)	9,84 ± 13%	10,1 ± 19%
Range of daily amounts (t d ⁻¹) per program *	7,3-13,5	7,1-14,4

*: range based on averaged daily MSW produced from each program without including the 7 programs to hospitals, other institutes and to central Athens.

The UPRs for each collection district are included in Table 2. The relatively large UPRs recorded for districts 1 and 3 are probably due to the increased commercial activity and the relatively small number of apartment buildings, and therefore registered actual population, in these districts. Therefore, it can be stated that programs with UPRs higher than 2,0 kg cap⁻¹ d⁻¹ indicate increased commercial activity and thus increased amounts of commercial wastes as opposed to household wastes. According to Table 2, MSW produced in districts 4,5,6,7 are expected to be predominantly of household origin, whilst wastes in districts 1 and 3 of commercial origin.

Table 2. Average UPRs at each WCD in the Municipality of Athens (kg cap⁻¹ day⁻¹)

	Number of programs ¹	Range of UPRs (kg cap ⁻¹ d ⁻¹)	Average UPR (kg cap ⁻¹ d ⁻¹)
WCD 1	28	1,2-93	8,9 ± 209% ²
WCD 2	16	1,1-6,9	1,9 ± 81%
WCD 3	9	1,1-28,3	5,1 ± 183%
WCD 4	12	1,0-2,4	1,6 ± 27%
WCD 5	12	0,9-3,7	1,5 ± 51%
WCD 6	17	1,0-1,7	1,3 ± 15%
WCD 7	16	0,9-3,0	1,5 ± 34%
Mun. of Athens	110	0,9-93	3,8 ± 273%

¹: does not include 9 waste collection programs, namely programs 1600 & 6500, 2 central programs and 5 programs dedicated to various institutes, such as hospitals, since these programs do not belong to a specific WCD

²: Coefficient of variation (standard deviation divided by the average value)

It is interesting to note that the lowest UPRs never fall below 0,9 kg cap⁻¹ d⁻¹ – a value near suggested typical urban MSW unit production rates for Greece [1]. The average UPR for the M.A. as a whole is **3,8 kg cap⁻¹ d⁻¹** and shows a rather wide variation as indicated by the relatively high coefficient of variation (273%).

2.3 Number of waste storage containers

Following steps 1 to 5 presented above, the following additional steps were used to estimate the number of WSC 2008 (design year).

- The amount of wastes (in kg d⁻¹) produced from each residential block was calculated as the product of its recorded actual population (2001 census) and the assigned UPR calculated in step 5.
- A 2% population increase for the 2008 design year was assumed. No increase in UPR was assumed.
- The numbers of WSC for each residential block was calculated by using a 95 kg m⁻³ waste density, close to the low range value for uncompacted commingled MSW [2] [3], a 1,1 m³ WSC volume and a 80% filling ratio. An integer number of WSCs was apparently calculated for each residential block in M.A.

The number of WSC calculated for each residential block was compared to the existing number of WSC. The results are included in Table 3.

Table 3. Existing and required number of WSC in the Municipality of Athens

	Existing containers	Calculated number of required containers	Excess number of containers	Container shortage	Additional WSC requirements
Waste collection district 1	2871	4093		1222	
Waste collection district 2	1958	2328		370	
Waste collection district 3	1402	1314	88		
Waste collection district 4	1664	1899		235	
Waste collection district 5	1602	1795		193	
Waste collection district 6	2546	2474	72		
Waste collection district 7	2187	2413		226	
Program 6500 (Patision St)	200	200		0	
Program 1600 (Aharon St)	153	146	7		
Mun. of Athens	14583	16662	167	2246	2079

As seen in Table 3, approximately 12% of the existing WSC are required additionally. Transfer of WSC from one district to another is also necessary. Only in municipal districts 3 and 6 there is an excess of the existing WSC compared to the theoretically required ones. The excess number of containers can be simply transferred to collection programs with a container shortage. It is interesting to note that district 1 (centre of Athens) requires approximately 1220 additional WSC. However, it is almost impossible to site such an additional number of WSC in these commercial and touristic sites, such as the center of Athens, due to limited available space. This may partly explain the present shortage of bins in various central areas of district 1.

Currently, WSC are being relocated in waste districts 4 and 6, according to the results of this study. In addition, the boundaries of the 7 waste districts are being restructured to precisely coincide to the boundaries of the municipal districts. In addition, all waste collection programs are being redesigned according to the findings of this study.

3. CONCLUSIONS

- Each waste collection program produces approximately 10 tonne of MSW daily.
- The lowest amount of MSW during the week is produced on Wednesday, whilst Saturday is the day with the highest amount of produced wastes during the week.
- The average production rate in the M.A. is $3,8 \text{ kg cap}^{-1} \text{ d}^{-1}$, ranging from $0,9 \text{ kg cap}^{-1} \text{ d}^{-1}$ to $93 \text{ kg cap}^{-1} \text{ d}^{-1}$.
- The relatively high UPR are found in districts 1 and 3, with increased commercial activity and low number of households.
- There is an overall shortage of approximately 2080 waste storage containers in the Municipality of Athens.

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