Life cycle energy comparison of organically-segregated MSW collection systems in city´s historic areas in Spain

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SUPPLEMENTARY MATERIAL

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Section S1. Waste collection plant

The energy consumed in the waste pneumatic collection system is due essentially to the suction and compaction waste operation from the waste collection plant.

For the energy calculation used in a waste collection plant per tonne of waste collected, the following procedure has been used:

Data average from ENVAC:

- Waste suction:
  - **S:** suction consumption: 220 kWh/h
  - **H_s:** working hours: 3,500 h/year
  - **W:** total waste collected: 6,482 t/year (value used for model calibration)
- Waste compaction
  - **C:** compaction consumption: 15 kWh/h
  - **H_c:** working hours: 1,100 h/year
  - **W:** total waste collected: 6,482 t/year

For these data, the consumption per tonne of waste collected for both processes has been estimated, obtaining the total consumption of this collection system.

1. Calculation of suction consumption

T_s: total energy consumption per year (kWh/year)

T_s = S*Hs = 770,000 kWh/year

ESW: total energy suction (kWh/t waste)

ESW = T_s/W = 119 kWh/ton waste

2. Calculation of compaction consumption

Tc: total energy consumption per year (kWh/year)

Tc = C*H_c = 16,550 kWh/year

ECW: total energy compaction (kWh/t waste)

ECW = T_c/W = 2.55 kWh/ton waste

T_e: TOTAL ENERGY CONSUMPTION IN A WASTE COLLECTION PLANT (per tonne of waste collected)

T_e = ESW + ECW = 119 + 2.55 = 121.55 kWh/t waste

Section S2. Central collection points

The number of the bins per collection point is variable depending on the company who manage it. Ros roca usually collects 3 separate waste fractions, corresponding to 3 bins per collection point, while Envac only collects 2 fractions (Ecoembes, 2011). In the model under study we have considered only one fraction at a time. Consequently, we consider one bin per collection point regardless of the number of the waste fractions that are collected.

Data provided from two soruces: Ecoembes (2011) and Medina-Díaz (2009).

- Data from Ecoembes (2011):
  - **N_b:** number of collection points per kilometre = 70 collection point/km = 70 bins/km
  - **U_b**: useful life of bin = 9 years

- **L_p:** total length of pipe line = 1 km (value used for model calibration)
- **W:** total waste collected: 6,482 t/year

➢ Data from Medina (2009):

- **W_b:** weight of one bin = 40 kg assuming that the bin is totally composed by steel.

The procedure for the calculation of the weight of bin in the system (kg) per tonne waste collected in a pneumatic waste collection system was the following:

1. Calculation of the weight of bin in the system

WT_b: weight of total bin

$WT_b = N_b * W_b * L_p$ = 70*40*1 = 2,800 kg bin

2. Calculation of the total weight of the bin per tonne of collected waste

T_b: weight of the bin per tonne of waste collected

$$\mathbf{T_b} = \frac{{}^{WT_b}/_{U_b}}{W} = \frac{{}^{2{,}800\ \text{kg bin}}/_{9\ \text{years}}}{6{,}482\ \text{t waste/year}} = \mathbf{0.0479\ kg\ bin/t\ waste}$$

Section S3. Underground pipes

Data provided by Ecoembes (2011), Medina-Díaz (2009) and Comarca de Pamplona (2007):

- **N_b:** number of collection points per km= 70 bin/km= 70 bin/km
- **U_p:** Useful life of pipes = 30 years
- **L_p:** Average pipe length per station line = 1 km

Data from Comarca de Pamplona (2007):

- **S_d:** Steel density of the pipe: 7,850 kg/m3
- **I_d:** Inner diameter: 0.498 m
- **I_r:** Inner radius: 0.249 m
- **W_t:** Wall thickness: 0.0125 m

1. Calculation of the weight of pipe in the system

M_r: major radius = I_r + W_t = 0.249 + 0.0125 = 0.262 m

O_v: outer volume = $\pi \cdot (M_r)^2 \cdot L_p = \pi \cdot (0.262\ \text{m})^2 \cdot 1000\ \text{m} = 215\ \text{m}^3$

I_v: inner volume = $\pi \cdot (I_r)^2 \cdot L_p = \pi \cdot (0.249\ \text{m})^2 \cdot 1000\ \text{m} = 195\ \text{m}^3$

P_v: pipe volume = O_v-I_v = 20 m^3

W_p: weight of pipe = P_v*S_d = 157.37 kg pipe/km

2. Calculation of the total weight of pipe per tonne of waste collected

L_p: total length of pipe line = 1 km (value used for model calibration)

W: total waste collected: 6,482 t/year

T_P: weight of pipe per tonne of waste collected

$$\mathbf{T_P} = \frac{\left(W_P \cdot L_p\right)/U_p}{W} = \frac{(157.37 \text{ kg pipe} \cdot 1 \text{ km})/30 \text{ years}}{6{,}482 \text{ t/year}} = 8.093 \cdot 10^{-4} \text{ kg pipe}/\text{t waste}$$

Knowing Tb and Tp, the total weight of stainless steel per tonne of waste collected in:

$T = T_b + T_P$ = 0.0487 kg steel/t waste

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