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Beach cleaning costs

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ABSTRACT

Based on the data collection of manual beach cleaning, this article measures and compares the efficiency and productivity of workers from private and public companies in nine municipalities in the Gulf of Cadiz (southwest Spain) and from the Ministry of the Environment, from 2010 to 2012. Taking into account the characteristics of the beaches, using the Clean Coast Index (CCI) and calculated cleaning parameters, as well as introducing the scientific use of €/kg, gave results which can provide guidelines for management practices that improve efficiency in the collection of litter per worker. In Chipiona the lowest efficiency and production results were found, in the high and middle seasons. La Linea de la Concepción and Chiclana, using public contractors, were the most efficient. Private contractors showed 50% efficiency, with the exception of San Fernando in the high season. In the case of Ministry of Environment (MoE) contractors, these had the highest efficiency in all of the seasons, with the highest degree of cleanliness. Among the results, an average value of 27.6 kg of litter collected per hour was found, per person and an average value of € 1/kg for private and public contractors. The highest litter collection rate, with a "moderately clean" degree of cleanliness, was found for operators working for private contractors in San Fernando. The cleaning costs of some municipalities are much higher than the average. With the adjustment of certain parameters, the methodology presented in this article can be applied to beaches elsewhere.

1. Introduction

Human settlements and the uncontrolled growth of tourism can produce negative impacts on the environment and sustainability of coastal areas. The generation of large amounts of beach litter is one of the biggest problems for countries with high levels of use in their littoral (Gabrielides et al., 1991; Galgani et al., 2013). Part of this solid waste originates from the local rivers, but the vast majority of marine litter comes from land-based sources. However, in the summer months, beach users are the main cause of waste (de Araújo and Costa, 2006). The importance of studying local sources of waste in litter management has already been underlined by Ariza et al. (2008).

Williams et al. (2016), mention that beach cleaning is essential to ensure that there is no litter on the beaches. This is required but is expensive for local government administrations. In their study, these authors showed the differences in the litter content on specific beaches around Cadiz, Spain were due to the visitor use, cleaning operations, the morphodynamic beach state, its closeness to a river or tidal creek mouth and the level of marine exposure. The distribution of litter on the various sites was found to be due to the beach cleaning operations.

Beaches with frequent cleaning are generally "relatively acceptable." Botero et al. (2017), stated that beaches in Cuba with better litter management obtained "excellent" cleanliness scores. For tourists, cleanliness is one of their five primary concerns and is thus an important element in beach quality awards (Williams and Micallef, 2009; Zielinski et al., 2019). A study conducted in Cape Peninsula, South Africa, recorded that 85% of locals and tourists would abstain from visiting a beach with more than two items of litter per metre. Around the world, cleanliness is the main factor that influences an individual's choice of beach (Ballance et al., 2000; Zielinski et al., 2019). In general, worldwide, the cleanest beaches are those that have international tourists. Beaches used more by locals, often have lower levels of cleanliness; factors such as the distance of the beach from urban areas may be of relevance (Botero et al., 2017; Mestanza et al., 2019). The negative

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aesthetic impact of anthropogenic litter is important in determining whether people return to a particular beach (Ballance et al., 2000). Similarly, the small amount of oil frequently found on certain beaches is another factor which affects the perception of beach users (Carmona et al., 2012).

Several studies have been carried out which evaluate the management of waste in an effort to improve beach cleanliness. These examine waste distribution, the types of waste found on specific beaches (associated with the beach characteristics), waste collection and its transport to waste treatment facilities and waste processing (Edyvane et al., 2004; Munari et al., 2016; Portman and Brennan, 2017; Rovira, 2006; Watkins and Ten Brink, 2017; Williams et al., 2016). In addition, studies evaluating the economic investment in litter collection have been carried out (Mouat et al., 2010; Ryan and Jewitt, 1996).

In these studies, generally, the amount of litter on beaches is measured in terms of its density, i.e. the number of items per m^2 (e.g. Williams et al., 2016; Watts et al., 2017; Vlachogianni et al., 2018) or as the number of items m^{-1} min^{-1} $person^{-1}$ (per metre per minute per person) (Bowman et al., 1998; Nelms et al., 2017; Ryan et al., 2014). However, when the size of litter items varies significantly (e.g. from a cigarette butt to a food container), it is more useful to record the weight of the litter (Marlin, 2011). Thus, weight measurements are used in this methodology (OSPAR, 2010). From an economic perspective, although some data regarding cleaning costs per km of beach exist (Mouat et al., 2010), relatively little importance has been attached to the cost of each kilogram of litter collected from the beach until now.

Beach cleaning plans usually stipulate that the foreman is responsible for requesting the number of workers required to clean the beaches, and this is done based on the foreman's experience, the season and the use of the beach (Siliceo, 2004). However, a study of manual beach cleaning should include indicators that allow decision makers to better estimate resources and thus improve the production efficiency of different organizations in order to reduce cleaning costs. The term "efficiency" measures the degree of achievement of an objective proposed by an entity. The objective of efficiency in the labour sector is to improve the quality of public services. Improved services can be more cost efficient or can be a source of increased revenue. Efficiency is measured by comparing current production with expected production (Rueda, 2011).

According to a report on tourism in the European Union (EU) (Blanke et al., 2009), Spain is one of the most popular countries. Currently, tourism generates 11% of Spanish GDP, with 70 million people visiting the coasts of Spain every year. Additionally, more than 50% of the Spanish population lives in coastal areas.

Article 225 of the current Spanish Shore Act (BOE, 2013) states that municipalities must ensure good conditions of cleanliness, hygiene and health on beaches and in public bathing places. Beach cleaning must be carried out with the frequency and schedules necessary to adequately provide these services. Williams et al. (2016) mention that most beaches in the province of Cadiz have heavy tourist and recreational use throughout the year, depending on weather conditions. So, regardless of the season and tourist demand on each beach, the municipalities carry out cleaning throughout the entire year (although with different frequencies depending on the season). However, due to lack of funds, the municipalities usually give priority to cleaning the most urban beaches and those that are most used.

For both municipalities and the Spanish Ministry of Environment (MoE), it is important to have acceptable conditions regarding litter in order to offer attractive services to beach users. For this reason, the procedure of manual cleaning of beaches carried out by the MoE and 9 municipalities in the province of Cadiz is presented here. The local authorities hire public and private workers to clean 33 beaches throughout the year, in three different times, denoted as touristic high, medium and low seasons. Production records were collected to evaluate the efficiency between these seasons with the parameter expressed in kg per hour and worker. The calculated production parameters were expressed in tons/year, tons/season, tons/team and month, tons/km, kg/day and worker and kg/m^2. Regarding production costs, the parameters were expressed in €/kg and €/km. The characteristics of the beaches, such as the degree of occupation, explain the sources that generate the litter in each municipality. Complementary to this work, the cleanliness of Cadiz beaches was assessed using the Clean Coast Index (CCI) (Alkalay et al., 2007), the purpose of which is to measure beach cleanliness and the success of the "Clean Coast" program and thus motivate the authorities to clean their beaches. This program includes components such as the routine cleaning of the coast by local authorities. The index has been used in numerous studies, since it accurately represents the degree of beach cleanliness (e.g. Laglbauer et al., 2014; Munari et al., 2016; Portman and Brennan, 2017; Terzi and Seyhan, 2017; Vlachogianni et al., 2018). In this paper the CCI was used to measure the quality of the cleaning work. These factors were cross-referenced to propose management practices with the objective of reducing beach cleaning costs in these municipalities, season by season.

1.1. The coastal municipalities of the province of Cadiz

The coastline of Cadiz, in southern Spain, is 260 km long, most of it on the on the Atlantic, western, side, the rest facing the Mediterranean Sea, on the east, Fig. 1 (Gomez-Pina et al., 2007). The province of Cadiz has 17 coastal municipalities, from Sanlucar de Barrameda, at the mouth of the river Guadalquivir, to the town of San Roque, on the Mediterranean Sea, close to the Strait of Gibraltar. The Atlantic area, is mesomareal, with an approximate tidal range of 1.20–3.30 m (Roman-Sierra et al., 2011), whereas the Mediterranean coast is micromareal. Both areas have stretches of highly urbanized coast and beaches with a high level of use throughout the year. The distribution of beach litter on the Cadiz coastline can be found in Williams et al. (2016).

Data on beach cleaning processes was received from 9 municipalities: Chipiona (Chi), Rota (Rot), San Fernando (SaF), Chiclana de la Frontera (ChF), Conil de la Frontera (CoF), Barbate (Bar), Algeciras (Alg), San Roque (SaR) and La Línea de la Concepción (LiC) (Fig. 1) and were key to this research. In this study, 33 beaches within these municipalities were examined. 14 beaches were cleaned by the MoE and 19 by the municipalities. The beaches characteristics are shown in Table 1.

2. Methodology

2.1. Manual beach cleaning procedure

In this study only the litter hand collected by the operators was considered. Litter from cleaning containers and that collected by mechanical cleaning was not taken into account. In the websites of the coastal municipalities their Cleaning Plans and the procedures of the cleaning tasks are explained, (AytSanRoque, 2010; Siliceo, 2004).

The "number of workers" refers to the people employed for the cleaning. Manual beach cleaning is carried out by 4 workers, supervised by a foreman (teams of 5 members). Normally, they use plastic bags to collect the litter, with an average weight of between 10 and 20 kg, when full. Boots and gloves are the personal protection equipment used. Some municipalities also use tongs, a hoop and a hook with each plastic bag to facilitate the litter collection. The workers walk along the beaches, collecting the larger elements (Fig. 2), assisted by a driver, with a light pick-up truck which takes the collected litter to the litter dump (Cadiz City Hall, 2018).

The number of teams contracted to perform manual beach cleaning in each municipality depends on the tourist season: high, medium or low. In the medium and high seasons more workers are needed than in low season (LIMASA, 2017). Generally, high season is from June 15th to September 15th, medium season is from March 18th to June 14th and low season from October 13th to April 6th (DPEAR, 2016). However, the data from the municipalities does not always adhere to these dates.

Each employee works 7.5 h per day, for 22 days a month. For the MoE, each team costs about 20,000 € per month (including salaries, the

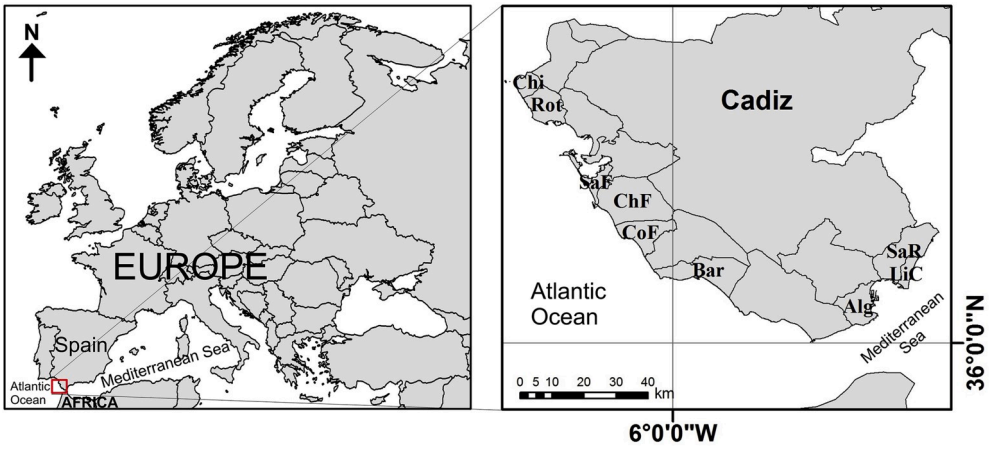

Fig. 1. Location of study area.

Table 1
Beach characteristics in the coastal municipalities examined (modified from TC (2019) and MITECO (2019)).

Municipality	Total beach length (m)	% beach cleaned by municipality	Beach width (m)	Characteristics of beaches cleaned by municipalities	Characteristics of beaches cleaned by MoE
Chipiona	14,000	42.9	100.3	a, c	g
Rota	16,000	46.9	76.4	a, c, d, j, k,	e, h
San Fernando	4270	56.2	85.1	d	g
Chiclana	7130	99.6	50.2	b	e
Conil	14,600	41.8	85.9	b, c, d, l	g, i
Barbate	22,000	54.8	100.7	a, l	f, g, i
Algeciras	5530	86.8	121.6	a, b, j	h
San Roque	12,000	58.3	101.6	b, d, k	g, h
La Linea	10,250	43.9	106.5	a, c	e, g, h

Characteristics (degree of occupation/degree of urbanization): a = high/urban, b = high/semi-urban, c = medium/urban, d = medium/semi-urban, e = medium/isolated, f = medium/rustic, g = low/semi-urban, h = low/isolated, i = low/rustic, j = −/urban, k = −/semi-urban and l = high/-. The letters from j to l, have only one factor assigned.

pick-up van, the driver and transport). This data is homogenized for the municipalities, using constant prices, to make comparisons between the seasons, which are reference prices that prevail on a given date, without the effects of inflation (Fonseca et al., 2017; Jorgenson and Griliches, 1967). The length and the average width of the beach was used to calculate the area cleared by the operators, shown in Table 1. The amount of litter recovered was taken into account.

The amount of beach litter collected is reported to the corresponding office by the foreman, to keep track of any "noticeable incidence" or unusual accumulation of waste on the beach. The foreman is thus responsible for requesting more staff to perform the cleaning tasks when necessary, and also according to the season (AytRota, 2019).

2.2. Data from ministry of the environment campaigns

The MoE provided daily records for 3 years (2010–2012) for the high, medium and low seasons; the number of litter bags, their total weight and the number of people working in beach cleaning were counted. The length of beach cleared by the MoE was given as general data to calculate the amount of litter and costs per kilometre.

After the collection process, the litter is separated into recyclable and non-recyclable waste. The non-recyclable waste is transported to the nearest dump in each municipality. The recyclable waste is taken to transfer stations before being transported to the closest recycling plant (e.g. the Southern Europe Environmental Complex or the Miramundo Waste Treatment and Composting Plant).

2.3. Data from the municipalities

In order to obtain beach cleaning data from the municipal authorities, the administrator responsible for beach cleaning in each municipal government was interviewed. The foremen were also interviewed to check details of procedures and schedules. Through the interviews, the amount of litter reported daily by the foreman was accessed. Table 2 shows the type of data collected, as well as the calculations made to obtain the production and litter costs for high, medium and low seasons. Using this data, a comparison was made between the efficiency the workers in the municipalities and the MoE workers.

Litter was also recorded in kg or tons, per month or year, and kg or tons per team per month. The cleaning costs per kilometre and per year were also determined. The litter densities were obtained by dividing the amount of litter collected by the dimensions of the beaches evaluated.

2.4. Classification of beaches assigned for cleaning by MoE and municipalities

Isolated or rustic beaches, with a medium or low level of occupation (characteristics from letter "e" to "i" of Table 1), and with complicated access due to their morphology (cliffs, coves, etc.), or beaches far from any urbanization are cleaned by the MoE. Otherwise, the municipalities clean the urban or semi-urban beaches in their area (letters "a-d" and "j-l" of Table 1); those with a high level of occupation and easy access (Fig. 3). The beach morphology data was obtained from official website photographs (MITECO, 2019; TC, 2019).

The characteristics of the beaches assessed in each municipality (total beach length, degree of occupation, degree of urbanization) were taken from the Office of Tourism and Ministry for the Ecological Transition website (formerly the Ministry of Environment, MoE) (Table 1). The degree of occupation is the percentage of the total area of the beaches occupied by businesses with an official permit, in line with the

Fig. 2. Human and material resources used during manual beach cleaning operations.

Coastal Management Plan. The rates of occupation are set out in the Spanish Coastal Law, depending on the type of beach (urban, natural, etc.). To calculate the degree of urbanization, the municipality must make its evaluation known to the regional government to determine its rate of occupation. An urban beach is close to the urban core and usually has a promenade. Semi-urban beaches are backed by forest areas or large dune fields, and are close to a settlement. Natural beaches are in areas far from an urban core, in forest areas, dunes or areas with a small population (DPEAR, 2016).

The percentage of beach cleaned per municipality was estimated through measurements made from satellite images in Google Earth.

2.5. Efficiency

To estimate the efficiency of the workers, the production of high and medium seasons were compared to that of the low season. Various studies have compared production between periods in order to calculate efficiency (Fare et al., 1994; Goto and Tsutsui, 1998; Odeck, 2008, 2007). Production is understood as the amount of litter collected by cleaning workers. The parameter of kg per hour per worker was used as the production value. The efficiency estimate was calculated with equation (1), where *Efficiency* is the quotient of the division between *P1* production achieved (high and medium seasons) and *P2* is the expected production (low season), expressed as a percentage. The percentage of the productivity increase was also calculated.

$$Efficiency = \left(\frac{P1}{P2}\right) * 100 \quad (1)$$

2.6. Degree of cleanliness

The degree of beach cleanliness was assessed after the workers finished their tasks, using the Clean Coast Index (CCI) (Alkalay et al., 2007). This index was used to assess the service quality, to assign a value to the conditions of the beaches after being cleaned and to gauge beach user satisfaction (Parasuraman et al., 1985). The CCI classification was obtained using the density of litter (kg/m^2) for each season and was used to determine the workers' performance.

CCI=CM * K, where CM is the density of litter per m^2 and K is a constant equal to 20. The coefficient 20 was inserted for statistical reasons to obtain the following classification. The value 0–2 indicates a very clean beach, 2–5 clean, 5–10 moderately clean, 10–20 dirty and >20 extremely dirty. The CCI ranges obtained in this work are within those of Alkalay et al. (2007). The assessment was performed on foot, for a 100 m stretch on every beach.

3. Results

This section presents and discusses the efficiency of MoE (state)

Table 2
Data template obtained from interviews with workers from the MoE and Municipalities.

Name of the Municipality:						
Organizations: MoE/Municipal workers/Private contractors						
Tourism Season			High[a]	Medium[b]	Low[c]	Total
Length of the beaches	Km	(0)				
Months		(1)				
Number of teams		(2)				
Number of workers		(3) = (2) · 5				
Cost of the team	€/month	(4)	20,000	20,000	20,000	
Collected litter	kg/season	(5)				
	kg/month/team	(6)= (5)/(1)/(2)				
	kg/day/team	(7)= (6)/30				
	kg/day/person	(8)= (7)/5				
Cost	€/season	(9) = (1) · (2) · (4)				
	€/kg	(9)/(5)				
	€/km	(9)/(0)				
Degree of cleanliness	CCI[d]					

[a] June 15 to September 15 (MoE). Variable duration for municipalities from 2 to 5 months.
[b] March 18 to June 14 (MoE). Variable duration for municipalities from 3 to 7 months.
[c] October 13 to April 6 (MoE). Variable duration for municipalities from 3 to 8 months.
[d] Clean Coast Index (according to Alkalay et al. (2007)).

workers versus that of the municipalities (public and private contractors). Table 3 and Table 4 show data of beach litter production per season. Data concerning the characteristics of beach occupation and urbanization in each municipality and their grade of cleanliness are also described. Later, this data is compared with beach cleaning costs in other countries. Finally, some suggestions are given for improving the efficiency of beach cleaning.

3.1. MoE efficiency

Fig. 4, shows a graph with production data, per teams and per month. The production and the number of teams was higher for the high and medium seasons. The greatest production of litter (245 tons) was in the high season of 2010 using 4 cleaning teams. The beach-cleaning teams collected more litter in the summer (20.4 tons of litter per team per month) than in the rest of the year (8 tons of litter per team per month).

As can be seen in Table 3, there was a substantial decrease in the litter collected from 2010 to 2012, with 245 tons in 2010, to 78 tons in 2011 and 55 tons in 2012 in high season. The same occurred for the medium and low seasons, dropping from 112 to 60 tons and from 219 to 46 tons, respectively. These figures correspond to a period of budgetary restraint associated with the economic crisis in Spain (Rocha and Aragon, 2012). The number of cleaning teams was reduced from 4 in 2010 to 2 in 2011 and only 1 in 2012 for the high season. Similarly, in the other periods of the year the number of teams was cut from 2 to zero for the medium and low seasons.

From the previous results, and taking into account the costs already mentioned of 20,000 € per team per month, the following values were determined (Table 5):

- The cost of collecting beach litter varies between 0.98 and 2.61 €/kg, with an average value of 1.34 €/kg. The standard deviation from the mean was less for the MoE collectors than for the municipalities.
- A beach-cleaning team, composed of 4 operators and a foreman, collects a maximum of 20 tons per month, a minimum of 13 and an average of 17 tons (Table 5). These estimates correspond to the summers of 2010, 2011 and 2012. For the medium seasons, the maximum was of 20 and the minimum 19 tons per team per month with an average of 19.5. For the low seasons there was a maximum of 18, a minimum of 8 and an average of 13.

Fig. 3. Beach classification. a) Cliff with difficult access, b) Natural beach (cover) with difficult access and c) Urban beach.

Table 3
Litter production data for the MoE. Data for the three seasons.

Season	Year or period	Tons per season	Teams	Estimated costs per season (€)	Tons per team and month	Kg per day and worker	Kg per hour and worker	Cost (€/kg)	Cost (€/km)	Density of litter (kg/m^2)
High	2010	245	4	240,000	20.4	185.6	24.7	0.98	28,504	0.38
	2011	78	2	120,000	13.0	118.2	15.8	1.54	14,252	0.19
	2012	55	1	60,000	18.3	166.7	22.2	1.09	7126	0.10
Medium	2011	112	2	120,000	18.7	169.7	22.6	1.07	14,252	0.19
	2012	60	1	60,000	20.0	181.8	24.2	1.00	7126	0.10
Low	2010–2011	219	2	240,000	18.3	165.9	22.1	1.10	57,007	0.38
	2011–2012	46	1	120,000	7.7	69.7	9.3	2.61	28,504	0.19
				Average	16.6	151.1	20.1	1.3	22,396	0.20
				St deviation	4.6	42.1	5.6	0.6	17,661	0.10

Table 4
Litter production data for the nine municipalities for the three seasons.

a)

HIGH SEASON

Municipality	Tons per season	Teams	Estimated costs per season (€)	Tons per team and month	Kg per day and worker	Kg per hour and worker	Tons of litter per kilometre of beach	Cost (€/kg)	Cost (€/km)	Density of litter (kg/m^2)
Chi	420.0	9.0	720,000	11.7	106.1	14.1	70.2	1.7	120,401	0.7
Rot	911.2	13.0	780,000	23.4	212.4	28.3	122.3	0.9	104,698	1.6
SaF	183.8	1.0	70,000	52.5	477.3	63.6	76.6	0.4	29,167	0.9
ChF	269.0	5.0	200,000	26.9	244.2	32.6	35.1	0.7	26,144	0.7
CoF	157.5	2.0	120,000	26.3	238.6	31.8	25.8	0.8	19,640	0.3
Bar	480.0	6.0	480,000	20.0	181.8	24.2	40.3	1.0	40,268	0.4
Alg	827.1	6.5	650,000	25.4	231.4	30.8	170.2	0.8	**133,745**	1.4
SaR	518.4	4.5	360,000	28.8	261.8	34.9	111.7	0.7	77,586	1.1
LiC	300.0	5.0	400,000	15.0	136.4	18.2	42.6	1.3	56,818	0.4
			Average	25.5	232.2	31.0	77.2	0.9	67,607	1.0
			St deviation	11.6	105.6	14.1	48.6	0.4	43,299	0.5

b)

MEDIUM SEASON

Municipality	Tons per season	Teams	Estimated costs per season (€)	Tons per team and month	Kg per day and worker	Kg per hour and worker	Tons of litter per kilometre of beach	Cost (€/kg)	Cost (€/km)	Density of litter (kg/m^2)
Chi	233.3	4	400,000	11.7	106.1	14.1	39.0	2.9	66,890	0.3
Rot	356.0	5	300,000	23.7	215.8	28.8	47.8	0.8	40,268	0.6
SaF	245.0	1	240,000	81.7	742.4	24.7	102.1	1.0	100,000	1.4
ChF	940.2	5	700,000	26.9	244.2	32.6	122.9	1.7	91,503	0.7
CoF	67.5	1	60,000	22.5	204.5	27.3	11.0	0.9	**9820**	0.1
LiC	171.9	2	200,000	17.2	156.3	20.8	24.4	1.9	28,409	0.2
			Average	30.6	278.2	37.1	57.9	1.5	56,148	1
			St deviation	25.6	232.6	31.0	44.6	0.8	35,934	0.5

c)

LOW SEASON

Municipality	Tons per season	Teams	Estimated costs per season (€)	Tons per team and month	Kg per day and worker	Kg per hour and worker	Tons of litter per kilometre of beach	Cost (€/kg)	Cost (€/km)	Density of litter (kg/m^2)
Chi	70.0	1.0	60,000	23.3	212.1	28.3	11.7	0.9	10,033	0.2
Rot	284.8	2.0	24,0000	23.7	215.7	28.8	38.2	1.7	32,215	0.3
SaF	100.0	0.5	55,000	36.4	330.6	44.1	41.7	1.0	22,917	0.3
ChF	161.2	2.0	120,000	26.9	244.2	32.6	21.1	0.7	15,686	0.3
CoF	135.0	0.5	60,000	45.0	409.1	54.5	22.1	0.9	**9820**	0.1
Bar	384.0	2.5	400,000	19.2	174.5	23.3	32.2	2.8	33,557	0.2
Alg	361.9	2.0	280,000	25.9	235.0	31.3	74.5	1.8	57,613	0.4
SaR	518.4	1.5	240,000	43.2	392.7	52.4	111.7	1.2	51,724	0.6
LiC	65.6	1.5	90,000	14.6	132.6	17.7	9.3	1.4	12,784	0.1
			Average	28.7	260.7	34.8	40.3	1.4	27,372	0.3
			St deviation	10.5	95.8	12.8	33.2	0.6	17,844	0.1

- The rate of litter collection ranges in high season from 16 to 24 kg per hour per worker, with an average of 21, that is 118–186 kg per day per worker (Table 5). For the medium season, litter collection is 23–24 kg per hour per worker (167–182 kg per day per worker). In low season the figures were 9–22 kg per hour per worker, (68–166 kg per day and worker).
- The production of MoE teams (20 tons of litter/team/month) was below the average value of every municipality.
- 48 km was the total beach length for the MoE with costs of 22,395.7 €/km (Table 3).
- The degree of cleanliness was “very clean” (index: 0 to 1) for the MoE.

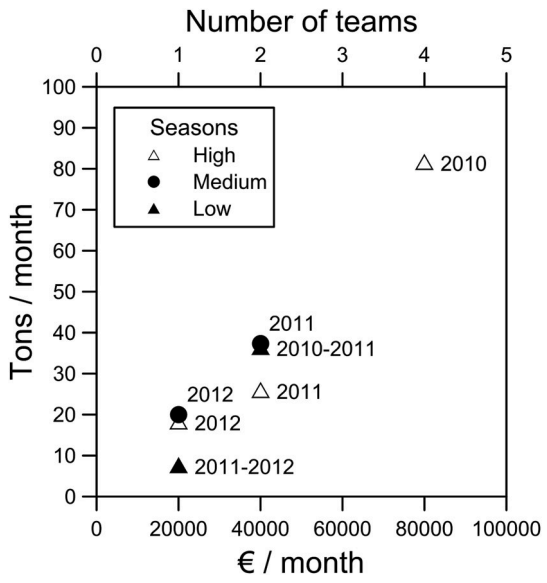

Fig. 4. Litter production per MoE team per month for all seasons.

- For the high and medium seasons, the efficiency of the workers (kg per hour) was greater than 100%. The productivity increase was 12% in 2010, 70% in 2011 and 139% in 2012 for the high season. The medium season showed a production increase of 2% in 2011 and 60% in 2012 (Fig. 5).

3.2. Municipality efficiency

Fig. 6 shows monthly input (costs per team) for the nine municipalities, which is used to generate the output (litter production) in tons per month. The graph shows production in the (a) high, (b) medium and (c) low seasons. The amount of litter collected in the high and medium season is greater than that of the low season, corresponding to the number of teams hired, as shown in Table 4.

The high and medium seasons are more symmetrical in the distribution of values compared to the low season, highlighting that the variability in the length of this season (from 3 to 8 months). The mean densities for the high and medium seasons were 0.7 and 0.45 kg/m^2, respectively. Fig. 8 shows that the upper and lower limits were different between seasons.

Public contractors are responsible for cleaning the sandy beaches at Chipiona, which are classified as having high/urban and medium/urban occupations (Table 1). Chipiona is a fishing and recreational port and is one of the 4 municipalities with the lowest beach length cleaned by the municipality. Its beaches have an average beach width of 100 m. Efficiency in Chipiona was 50% (Fig. 7) in the high and medium seasons. A greater number of teams was hired for the high and medium seasons (9 and 4 teams, respectively), compared to only 1 team for the low season, which recorded twice the production in the same work time, 23.3 tons/team/month. Chipiona had the lowest litter production in the medium season (14.1 kg per hour and worker). It had low litter densities (0.7 kg/m^2 for high season, 0.3 kg/m^2 for medium season and 0.2 kg/m^2 for the low season) with average costs of € 0.9/kg for the low season, € 2.9/kg for the medium season (the highest value for all the seasons) and € 1.7/kg for the high season.

Rota is one of the most important coastal towns, with large numbers of tourists (Williams et al., 2016). It has a small river mouth (TC, 2019) and a fishing and recreational port. Van Paassen (2010) mentions that approximately 5000 tons of waste per year reach the sea from the rivers. It has sandy beaches with the following beach occupation characteristics: high/urban, medium/urban, medium/semi-urban, -/urban and -/semi-urban (Table 1). Rota is the municipality that has the most litter per year (1552 tons), with densities of 1.6, 0.6 and 0.3 kg/m^2 for the high, medium and low seasons, respectively (Fig. 9 and Table 4). The high season density is the greatest of all the seasons and for all the municipalities. It has the third longest beach length cleaned by public contractors and the greatest number of beach cleaning teams: 13 teams in the high season, 5 in medium and 2 in low season. It is also the second narrowest average beach width (76 m). This municipality maintains 28 kg/h/worker for the three seasons. Efficiency was 98 and 100% (Fig. 7) for the high and medium seasons, because they met the production rates expected. Costs were 1.7, 0.8 and 0.9 €/kg for the low, medium and high seasons.

San Fernando has beaches with medium/semi-urban occupation. Williams et al. (2016), assess the beaches of this municipality as dissipative and protected, with litter originating from transported, floating items. This municipality collected least litter per year (529 tons/year), with low litter densities (0.9, 1.4 and 0.3 kg/m^2) and costs of 0.4 €/kg for the high season and 1 €/kg for the medium and low seasons. In the high season, San Fernando maximized production to 63 kg per hour and worker; the highest production recorded for all seasons, with the lowest costs (€ 0.4/kg). In the medium season: 24.7 kg per hour/worker and a cost of € 1/kg and in the low season 44.1 kg per hour/worker with a cost of € 1/kg. San Fernando has the shortest beach, with an average width of

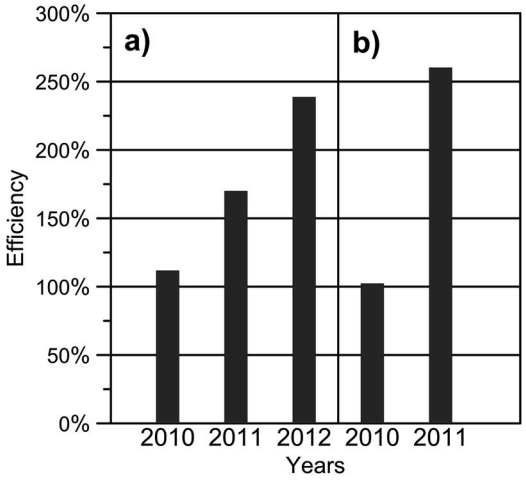

Fig. 5. Efficiency of MoE workers in a) high season and b) medium season 2010–2012.

Table 5
Comparison of rates of litter collected, cost in € per kilogram and degree of cleanliness (abbreviations are used for Maximum, Minimum and Average).

	Tons per team and month			Kg per day and worker			Kg per hour and worker			Cost €/kg			Degree of Cleanliness
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	CCI
Municipalities with a public contractor	25	12[b]	20	167	80[b]	133	21	10[b]	17	1.60[b]	0.79	0.99	1-6 Clean
Municipalities with a private contractor	53[a]	23	38	353[a]	153	253	44[a]	19	32	0.88	0.38[a]	0.63	6-9 Moderately clean
Ministry of Environment	20	13	17	136	87	111	18	11	15	1.34	0.98	1.03	0-1 Very clean

[a] These values correspond to San Fernando.
[b] Corresponding to Chipiona.

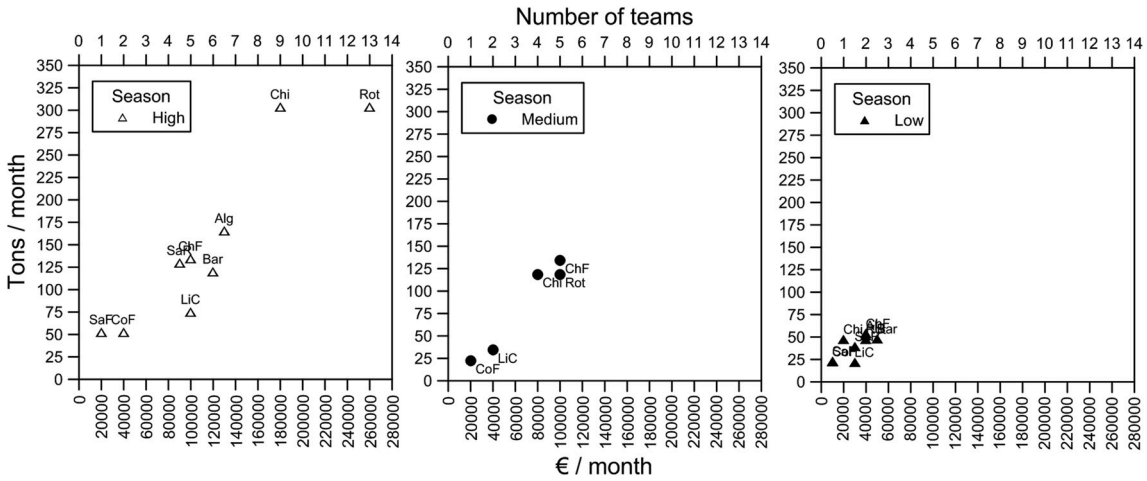

Fig. 6. Litter production per teams per month for municipalities.

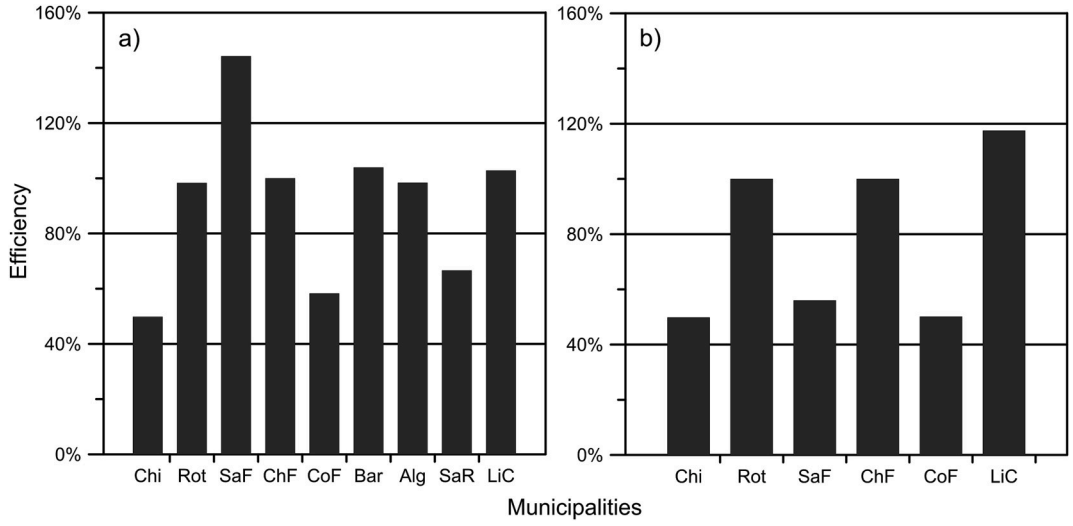

Fig. 7. Efficiency for the municipality teams in a) high season and b) medium season.

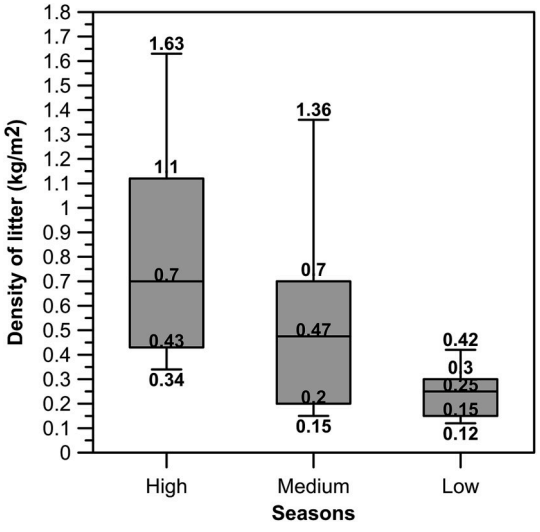

Fig. 8. Distribution of litter density on the beaches for each season. Each box represents the range of values, using half of the density data for each season. The line inside the box is the median.

85 m, cleaned by private contractors. It has one of the lowest number of beach-cleaning teams registered for all the seasons (only 0.5 teams). For the medium and high seasons only 1 team was contracted (Table 4). Efficiency was greater than 100% (Fig. 7) in the high season, increasing the amount of litter collected by 44%. Efficiency was 56% in the medium season.

Chiclana, has a fishing and recreational port and sandy beaches with high/semi-urban degrees of occupation. It has the third lowest beach length cleaned by public contractors, with 2 beach-cleaning teams in the low season and 5 teams in the high and medium seasons. The average beach width (50 m) is the narrowest registered. This municipality showed densities of 0.7 kg/m^2 for the medium and high seasons and 0.3 kg/m^2 for the low season. Costs were 0.7, 1.7 and 0.7 €/kg for the low, medium and high seasons, respectively. Chiclana showed an efficiency of 100% (Fig. 7) in the high and medium seasons, when each worker registered the same production per hour as in the low season (32.6 kg per hour/worker).

Conil has sandy beaches of medium/semi-urban occupation, high/semi-urban, medium/urban and high/-. It is the municipality using private contractors with most beach length cleaned and has an 86 m average beach width. It had 0.5 teams for the low season, 1 for the medium season and 2 for the high season. Conil has the second least amount of litter collected (360 tons/year), along with Barbate. Its

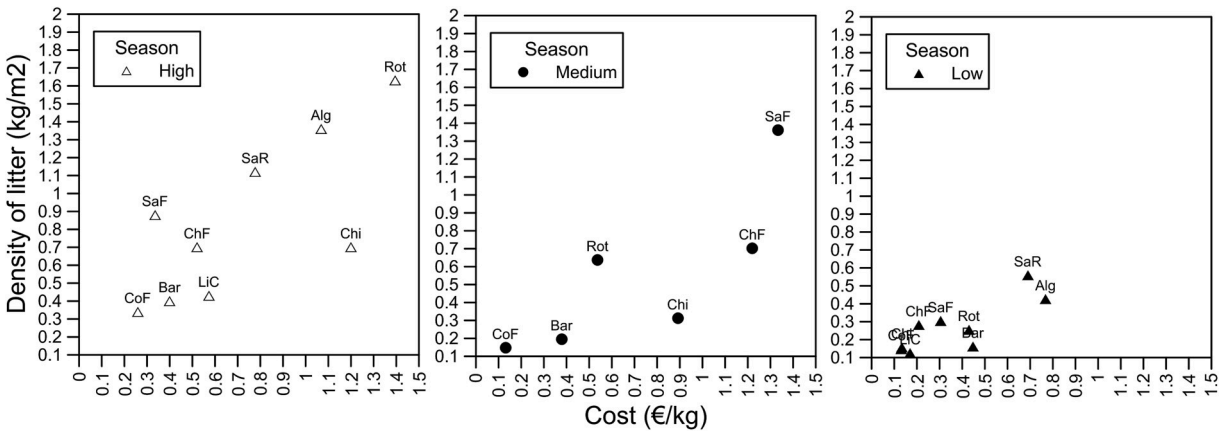

Fig. 9. Density of litter vs cost per season.

densities were 0.3 for the high season and 0.1 for the medium and low seasons, with € 0.8/kg for the high season and € 0.9/kg for the medium and low seasons. Efficiency was 58% for the high season and 50% for the medium season (Fig. 7).

Barbate, with 6 public contractor cleaning teams for the high season and 2.5 for the low season, has beaches described as high/urban and high/- (Table 1). It is the municipality that cleans the longest beach length, with an average beach width of 101 m. The efficiency of Barbate in the high season was greater than 100%, with a 4% growth in productivity (Fig. 7). No data were recorded for the medium season. Barbate showed densities of 0.4 kg/m^2 for the high season and 0.2 kg/m^2 for the low season. Costs were 1 and 2.8 €/kg for the high and low seasons, respectively; the highest costs registered by any municipality in the low season.

Algeciras, has an industrial port and a town (Barragán, 1989), and sandy beaches with a high degree of occupation (urban, semi-urban and -/urban) (Table 1). 6.5 beach-cleaning teams (public contractors) were responsible for cleaning in the high season. In the low season, two teams were hired. Some of its beaches are pocket beaches, whose morphology contributes to the accumulation of litter (Williams et al., 2016). It has the widest average beach width (122 m). Efficiency was 98% for the high season (Fig. 7), with no data available for the medium season. Recorded litter densities were 1.4 and 0.4 kg/m^2 for the high and low seasons. Costs were 0.8 and 1.8 €/kg for the high and low seasons.

San Roque uses public contractors to clean beaches with high/semi-urban, medium/semi-urban and -/semi-urban occupations (Table 1). It has a recreational port, 12 km of beach length, an average beach width of 102 m and litter concentrations of below average. San Roque hired 4.5 teams for the high season and 1.5 teams for the low season. This municipality showed an efficiency of 66% (Fig. 7) for the high season. For the medium season, there were no records. Litter densities were 1.1 and 0.6 kg/m^2 for the high and low seasons. Costs were € 0.7 and € 1.2/kg for the high and low seasons.

In La Linea, beaches have high/urban and medium/urban occupations (Table 1). It a fishing port and a commercial port (Port, 2019), with the second lowest amount of litter collected per year (537.5 tons/year). It has the fourth lowest beach length, an average beach width of 106 m, and used five beach-cleaning teams (public contractors) for the high season, two for the medium season and 1.5 for the low season. Efficiency in La Linea was calculated to be over 100% (Fig. 7) in high and medium seasons, with a growth of 3% and 18% in productivity, respectively. This municipality showed densities of 0.4, 0.2 and 0.1 for the high, medium and low seasons; the lowest recorded waste density for the low season. Average litter costs were 1.3, 1.9 and € 1.4/kg for the high, medium and low seasons.

For the high season San Fernando, Chiclana, Barbate and La Linea showed the highest efficiencies, by improving the expected low season production per hour per worker. These municipalities all increased their percentage production per hour and worker, with the exception of Chiclana, which collected the same amount of litter in both seasons, with 2 teams in the low season and 5 in the high season. San Fernando greatly improved its production, by 44% in the high season; from a collection of 44.1 kg/h/worker with 0.5 teams in the low season to 63.6 kg/h/worker with 1 team in the high season. Barbate increased by 4% from 23.3 kg/h/worker with 2.5 teams to 24.2 kg/h/worker with 6 teams and La Línea by 3% from 17.7 kg/h/worker with 1.5 teams to 18.2 kg/h/worker with 5 teams. Chipiona was the municipality with the lowest efficiency in the high season; despite hiring more teams (9) only half of the expected production in the low season was obtained (14.1 kg/h/worker, compared to 28.3 kg/h/worker).

In the medium season the efficiency in La Linea was over 100%, with a 17% increase in production, going from 17.7 with 1.5 teams in the low season to 20.8 kg/h/worker with two teams. For the medium season, expected production efficiency in Rota and Chiclana was 100%. Both municipalities maintained production in both seasons; 28.8 and 32.6 kg/h/worker. However, these municipalities increased the number of teams used from 2 to 5.

In annual terms, Rota and Chiclana collected the greatest amounts of beach litter, 19%, 17% of the total, respectively. In third place, Algeciras recorded 14% of the total of the litter collected, which could be due to the large number of merchant ships generating a lot of waste (Horsman, 1982). According to Matthews (1975), the amount of waste from a merchant ship is 0.8 kg/person/day, with approximately 660,000 tons of litter deposited in the Mediterranean per year coming from the East. In 2016, 28,913 ships were registered by the Port Maritime Traffic Service (Algeciras Port, 2019). These three municipalities and San Roque, removed one million kilograms of beach litter per year. On the other hand, some municipalities that collected least litter are San Fernando and Conil (Fig. 6); the only municipalities that contract private companies to clean their beaches.

Regarding costs, Chipiona, Barbate and La Línea had the highest average costs per kilogram of litter (Table 4). The Barbate beach is the longest of all the municipalities. These three municipalities had five or more public teams. Chipiona, with an average cost of 1.80 €/kg for all seasons, had considerably higher costs. It was also the municipality with the highest percentage of high/urban beach occupation (75%) (Table 1), with many tourists, requiring the most frequent beach cleaning operations.

Average values of € 0.99/kg and 0.63 €/kg were estimated for the municipalities which used a public contractor and a private contractor, respectively. From Table 5, the following is noted:

- A municipal beach-cleaning team collects an average of 20 tons per month when the contractor is a public company, but with great

variability (12–25 tons/month). This means 17 kg of litter per hour per worker, very similar to the rate of the MoE (16 kg/h). According to Williams et al. (2016), the surveys carried out on the beaches of Cadiz, show that the main types of litter found were, in descending order, plastic bottles/containers, plastic bags, metal containers, tetra-packs, glass bottles/bottles and PVC containers. Similarly, Watts et al. (2017) report that litter on beaches in Cornwall (UK) was mainly pieces of plastic, while Strafella et al. (2015) state that plastic was the most common type of rubbish, in terms of weight, on beaches on the northern and central Adriatic Sea.

- Private contractors almost doubled the amount of litter collected: 38 tons/month and 32 kg/h per worker. However, the higher efficiency and the lower costs of private companies is offset by a lower degree of beach cleanliness, "clean" for the municipalities with public contractors (CCI values 1–6) and only "moderately clean" for the private contractors (CCI values 6–9).

3.3. Costs compared with other countries

The only data found concerning the cost of litter collection per kilogram in other countries, is in a technical report from the Netherlands. This records beach cleaning costs of an average 1.4 €/kg, ranging from 0.5 to 3.2 €/kg (ECORYS, 2012). Although the average value obtained for Cadiz, in this work, is below that of the Dutch, it is within the range. This can be attributed to local climatic conditions and perhaps the lower salaries of the Spanish workers.

From Doomen et al. (2009), based on data provided by municipalities in the Netherlands, the following is highlighted:

- It is estimated that 1 to 2 workers are needed per day to manually clean a kilometre of beach. One municipality has 14 workers in low season and 24 in high season to clean a 12 km long beach. Between 115 m (Rota) in the high season and 2.4 km (Conil) of beach in the low season was being cleaned per operator in Cadiz (data calculated from Tables 1 and 4).
- In was mentioned that beach-cleaning wages are 25 € per hour, with 4 h worked per day. In the province of Cadiz a similar cost of 24 € per hour per person was estimated, including material resources.
- The amount of litter that a municipality collects varies between 100 and 1100 tons per year. In the case of Cadiz, litter collection by municipality was in the range of 360 (Conil) to 1552 (Rota) tons per year.

A non-exhaustive list of cost comparisons between countries is summarized in Table 6. Cleaning costs range from 9820 €/km (Conil, for medium and low seasons) to 133,745 €/km (Algeciras, for the high season). Both values are highlighted in bold in Table 4.

As can be seen in Table 6, there are two kinds of values registered. Some are less than 1000 €/km, which correspond to unique events of cleanliness. On the other hand, the cost for periodic cleaning ranges from 12,050 to 96,150 €/km while the average cleaning cost for beaches in the Gulf of Cadiz is 50,376 €/km. This variability is due to the frequency of cleaning and personnel costs.

3.4. Management considerations

In Spain, over 35% of the population lives on a 5 km coastline strip (Benavente González et al., 2009). Cadiz has one of the highest population densities in Europe (~11,000 per km^2) (Alves et al., 2014). Since the early 1960s, the coast of the Gulf of Cadiz has been transformed, with highly developed coastal stretches. The economy of Cadiz is strongly dependent on tourism, mainly in high season, so beach cleaning is essential in order to maintain the GDP.

From the analysis of manual beach cleaning carried out by the MoE and the municipalities it was possible to identify the causes of higher litter collection costs. The following suggestions were then made:

Table 6
Compilation of cleaning costs per kilometre of beach.

Researches	Study area	Cost (€)	Length (km)	Cost (€/km)
Ryan and Jewitt (1996)	South Africa	338,000	712	475
Mouat et al. (2010)	Netherlands and Belgium	$11.0 \cdot 10^6$	340	32,350
Mouat et al. (2010)	Netherlands (Scheveningen/ Kijkduin)	$1.25 \cdot 10^6$	13	96,150
Mouat et al. (2010)	Denmark	6702	18	372
Mouat et al. (2010)	Ireland	89,950–102,800	8	12,050
Mouat et al. (2010)	Portugal (2 municipalities)	318,170	15	21,200
Mouat et al. (2010)	Spain	655,518	12	54,650
Mouat et al. (2010)	Sweden	64,114	157	408

- Very high cleaning costs were detected in some municipalities. The MoE should provide training courses, at least for the foremen, to improve cleaning efficiency. Ahmed et al. (2010) and Siliceo (2004), mention that worker training is an elementary factor to improve production efficiency. Training must be given to both public and private workers. The results of efficiency, productivity and CCI suggest that the municipalities of Chiclana, Rota, Algeciras and San Roque should assess the training process that their employees undertake, since in addition to having an efficiency of less than 100%, they obtained the lowest CCI for public contractors.
- The relationship of litter densities (kg/m^2), surface (m^2), period (hours) and expected production (kg/hour/worker) allowed a recalculation of the number of teams needed in the municipalities with less than 100% efficiency in the high and medium seasons (Table 7). For example: the litter density of Chipiona, 0.7 kg/m^2 for the high season, was multiplied by the surface (600,000 m^2), giving a production of 420,000 kg per season. The period of 660 h (4 months for the high season, multiplied by 22 days and 7.5 h), is divided by the production 420,000 kg to give 636.36 kg/h. So, with 4.5 teams, there is an expected production of 28.3 kg/h/worker and, as the number of worker by team is 5, then the cleaning rate is 141.5 kg/h.
- Table 7 shows that the savings on resources were from € 10,000 to € 360,000 for the high season, while for the medium season were from € 30,000 to € 200,000. As can be seen, the costs per kilogram of litter decreased when the number of teams were adjusted. Therefore, it is concluded that where density of litter is greater and the production is higher, then the cost is lower.
- When comparing the beach occupation characteristics with the litter collection costs, it was seen that the lower costs were for beach lengths of 4–7.3 km per cleaning team, while the higher costs were for lengths of 1.5–4 km per team. The team numbers proposed in Table 7, mean that the lengths assigned to each team double, for all municipalities.
- Manual beach cleaning management should include taking measures to educate beach users.
- Historical records of litter collection by seasons should be consulted in order to assign the number of teams necessary for high seasons, since in several cases it would not have been necessary to hire so many teams to achieve the expected production.
- In the case of Spain, no action has been taken against authorities when cleaning tasks have not been carried out with the appropriate frequency. However, in order to apply some pressure, the CCI can be a useful tool to evaluate the achievements of the "clean coast" programs.

Table 7
Number of team proposed for theses municipalities.

Season	Municipality	Number of teams recalculated	Number of teams hired	Savings on resources per season	Costs recalculated (€/kg)	Previously estimated costs (€/kg)
High	Chipiona	4.5	9.0	360,000	0.9	1.7
	Rota	12.8	13.0	12,000	0.8	0.9
	Conil	1.5	2.0	30,000	0.6	0.8
	Algeciras	6.4	6.5	10,000	0.8	0.8
	San Roque	3.0	4.5	120,000	0.5	0.7
Medium	Chipiona	2.0	4.0	200,000	0.9	2.9
	Conil	0.5	1.0	30,000	0.4	0.9

Note: These numbers of teams were calculated for the municipalities with less than 100% efficiency.

To apply the methods used here to other areas, it is important to consider the dimensions of the beach walked by the cleaning operators and the approximate densities of litter recorded during the seasons of interest. With these data it is possible to calculate the quantities in kg or tons of litter per season. It is also necessary to have economic information, such as the investment costs per team. The technical report from the Netherlands, details the costs for transport, material, salaries of operators, etc., while, in this work, team costs refers to these elements (20,000 euros) as a total cost, thus facilitating cost analysis. As mentioned earlier, to compare costs between seasons, it is necessary to use constant prices for the cleaning teams. This allows comparisons to be made between the production values for different years. It will also be necessary to obtain the data of the working days (duration of the working day in hours and working days per month).

With the above data, it is possible to implement the methodology elsewhere, and to obtain the parameters for comparing beach cleaning such as: kg per hour and worker and euros per kilogram, and, from this, the efficiency. Where a country has variation of salaries in its territory, the costs for cleaning beaches (costs per team) would reflect this (Arango-Thomas et al., 2018; Huesca-Reynoso and Rodríguez Pérez, 2008; Pontieux and Concialdi, 2001). That is, the cost per team in this zone could be generalized.

Decision making would include calculating how many cleaning teams are needed to remove the amounts of litter recorded per season on the beaches in question. Being able to consult long term cleaning data of beaches, makes it possible to compare the data internationally. Since it is difficult to make comparisons between countries, it would be possible to build reliable international standardized databases.

In order to improve efficiency it is necessary to study the cleaning processes and distinguish how the tasks are being performed; factors such as:

- If the workers clean the entire beach.
- That the amount of litter reported is only that collected by hand.
- How the foreman determines the number of operators needed in medium and high seasons.

To strengthen education programs, the cleaning costs could be made public on the official websites of the municipalities.

The implementation of these points would be the responsibility of the authorities involved (e.g. municipalities and environmental ministries). If interested parties work in the same direction, they can improve the decision-making in cleaning their beaches. With this information it is possible to optimize the use of financial (e.g. more litter containers) and human resources for cleaning and, then assess whether awareness campaigns are needed. Since cleaning is only a remedy for the problem, while environmental education has a more proactive approach with long-term effects (Benavente González et al., 2009).

Previous research also reported that only about 30% of beach litter was recovered during these operations (Mouat et al., 2010). Therefore, this information allow the identification of the litter sources and point to actions which would reduce this. In the case of municipalities with commercial or industrial ports such as Algeciras, the municipality should ensure rules are kept, such as Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), which prohibits plastic dumping and limits waste discharge, according to the location of vessels and their distance from the shore (Julian, 2014).

The frequency of beach cleaning is very important for tourism. Ballance et al. (2000) mentions that a drop in beach cleaning standards could reduce tourism revenues by up to 52%. Potts and Hastings (2011) also mention that litter can affect ecosystems, and cause a decrease in ecosystem services. Thus, if the authorities do not carry out the cleaning frequency enough, litter accumulation would have serious economic and environmental repercussions. It is important to remove beach litter before it is transported into the sea (Williams and Micallef, 2009).

Finally, if the CCI was applied to each beach, before and after beach cleaning, the procedures carried out by the various operators could be evaluated. Additionally, research should be done on the training given to public and private contractors in order to make suggestions to improve their efficiency.

3.5. Research limitations

The shortage of data and difficulty in obtaining it, due to the acquired from those responsible, meant that some elements needed to gain more precise results were not available.

- As the results of the manual beach cleaning were only available at municipal and MoE level, the average width is that for all the beaches in each municipality, while the width of each beach is very variable. Having data for each individual beach would allow for better analysis taking into consideration the amounts of litter with respect to the types of beaches: urban, semi-urban, natural, rustic, etc.
- No precise information was found on the number of visitors to each beach per season. This would have offered a correlation with the amount of litter on each beach.
- The data are very specific for the province of Cadiz and for the 2010–2012 study period. However, if comparisons were made according to the characteristics of the beach (degree of occupancy and morphology), the data could be applied elsewhere.
- This work used the average width of the beaches for each municipality, not for each beach. Therefore, the densities per m^2 are inaccurate. This error may be less when applying the method for individual beaches.
- The CCI was only applied after cleaning. By applying it before and after the cleaning tasks, a comparison of the litter densities could be made which would improve the accuracy of the efficiency data per worker.

4. Discussion

This main objective of this work is to offer proposals regarding manual cleaning tasks on beaches to managers. The proposals aim to reduce the human and economic resources needed by municipalities for collecting beach litter. Authorities following this methodology could

better estimate the resources associated with a given production (e.g. the number of teams hired per season, according to the density of litter and costs presented). The interviews conducted for this research, gave a large amount of accurate data, which can also be applied with reference to beach certification, such as Blue Flag (Botero and Hurtado, 2009). In other words, the data could be used as a tool to improve beach facilities and environmental quality.

The methodology described here can be applied anywhere, with the adjustment of some parameters: initial costs per team and month, including local salaries, transport and driver, the number of cleaning teams, the weight of the litter collected and beach characteristics, such as degree of use and dimensions. Only the study by Doomen et al. (2009) expresses the costs of litter in €/kg, while the present work offers associated data of densities of litter and cleaning teams. The costs per kilo are affected by the amount of litter and the number of teams hired and costs per team. Only ECORYS (2012) and Doomen et al. (2009), offer detailed descriptions of the costs of beach cleaning in municipalities in the Netherlands. However, these studies did not associate the beach characteristics of occupation and the morphology, which are essential to understand the sources of litter and the variability of beach cleaning costs. An improvement to this methodology would be to apply established methods to calculate the expected production per worker for each season (Ahmed et al., 2010).

Efficiency in beach cleaning refers to the degree to which the expected production in the established period is met, despite reducing resources in the seasons that have less litter. In the case of the municipalities of Cadiz, it is proposed to reduce costs by a recalculation of the number of teams required for each season. Despite hiring a greater number of teams for the high season, the various municipalities, did not reach the production targets for the low season, hiring fewer teams. Some municipalities, such as Chipiona, Rota, Conil, Algeciras and San Roque hired 4.5 more teams than necessary to meet the expected production in the high and medium seasons.

The CCI evaluation in this work is used as an indicator of the quality of the cleaning service used and to evaluate efficiency and productivity. Attention should be focused on municipalities, such as Chipiona, Rota and San Roque, which, in addition to having an efficiency of less than 100%, with public workers, showed only a "clean" degree of cleanliness.

Manual cleaning of beaches must be very precise and ecological (no sand or shells taken). Since it involves taking small particles of litter, precision and results depend on the skill and interest of the worker; a laborious and time consuming task. Training and supervision must be adequate to achieve good results.

5. Conclusions

A methodology has been developed to estimate the efficiency of manual beach cleaning workers in high, medium and low tourist seasons on the beaches in the Gulf of Cadiz (Spain). Beach litter was collected manually by teams from the Ministry of Environment (MoE) and from public and private companies working for nine municipalities. The amounts of litter generated in the municipalities was assessed using data, such as the degree of occupancy of the beaches and the CCI. By associating the production and cost parameters, it was possible to offer suggestions to achieve better process management, reduce monetary costs and improve the amounts of litter collected.

Chiclana and La Linea showed an efficiency greater than or equal to 100% in the high and medium seasons, compared to the low season. However, only La Linea had an increase in its productivity (3 and 18%).

To calculate the density and the number of beach-cleaning teams, the dimensions of the beach were used to explain the variability of litter costs for the municipalities and the MoE. Chipiona, La Línea and Barbate, had the highest litter costs per kilogram, with several cleaning teams associated with shorter beach lengths. Conil and San Fernando, had the lowest costs, with fewer beach-cleaning teams working on longer beach lengths. The weight of litter collected expressed as kilos per year, m^2 and team, indicated municipalities, such as Rota, Algeciras, Chiclana, Chipiona and San Roque that collected a lot of litter and must also be efficient, as they maintain a high degree of cleanliness on the beaches throughout the year.

The highest costs of litter collection per kilogram was 2.9 €/kg, which is 70% more expensive than the average of the municipalities (0.99 €/kg) or the average MoE cost (1.03 €/kg). The average weights of litter per hour/per worker were 14–63 kg, for the municipalities, and 9–25 kg for MoE. The average cost for cleaning Cadiz beaches is 50,376 €/km, within the range given for other countries (12,050 to 96,150 €/km).

Given that beach cleaning is carried out using public funds, and that the budget for this often much less than that given to many other activities carried out by municipalities, the findings of this work are important. Making these costs public may help to change the mindset of the people who use these beaches and should also pinpoint actions which could reduce litter generated at both local and distant sources.

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Declaration of competing interest

None.

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