which deal directly with the main dealers so securing higher prices. Combined with modifications to existing structures (some of which involve major infrastructure changes such as new landfill sites) dramatic improvements to SWM could be achieved (see Table 1).

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Composition, distribution and waste management of Playa Grande, the most important touristic beach of Mar del Plata city, Argentina

Beach debris, defined as solid waste materials of anthropogenic origin discarded at sea or reaching the sea through other ways, is one of the most highly visible expressions of human impact on the marine environment.

Beaches across the planet accumulate marine debris and this phenomenon has been widely documented on many beaches in different countries (Claereboudt, 2004). Even though beach debris is a worldwide problem, it has been little studied in South America. In Argentina, until the present there have been no intensive studies on distribution, composition and sources of beach debris in touristic beaches from Argentina. Being this crucial a information for urban waste management and beach cleaning purposes, our goal is to evaluate the abundance, sources and distribution of superficial and buried beach debris of Playa Grande, the most important recreational beach of Mar del Plata city, Argentina.

Materials and methods

Our study was performed in the coast of Mar del Plata city (38°00 S, 57°33W), the most populated and oldest marine coastal city of Argentina, that holds more than half a million inhabitants, but receives between 2 and 3 million tourists during the summer season (December–March).

An intensive sampling was carried out in Playa Grande in May 2010, after the summer. Playa Grande is one of the longest beaches in Mar del Plata city (500 m long and 150 m wide) and probably the most impacted beach by tourism during the summer season. Moreover, this beach has no periodic cleaning system, thus becoming a beach model for the study of contamination by solid waste.

Five transect lines, parallel to the coast, of 400 m length each were sampled. Each of them corresponds to five different beach levels separated by 25 m (Level 0, 25, 50, 75 and 100 m), from the high tide line (line 0) to the upper levels of the beach. In each transect line two different methodologies were carried out: superficial debris collections transect (SDCT) in order to evaluate superficial debris, and buried debris collections transect (BDCT) to obtain buried debris through sieving techniques. SDCT consisted in walked debris collection, recording visible (surfacing and partially buried) debris all along each transect. BDCT was performed in 4 of the 5 beach levels (25, 50, 75 and 100 m) using a beach rake 100 cm width, with a metal sieve 1 cm mesh size that collected buried debris up to 10–15 cm in the sandy sediment. Sediment from level 0 was not sieved because of the moisted sand condition at this level. In each BDCT 30 sediment sub samples (5×1 m), homogeneously distributed along each transect, were sieved, representing 37% of the total transect superficial.

Beach debris was collected in plastic bags in order to be to later separated and weighed (1 g precision) in the laboratory. Debris was classified into different categories (plastics, paper, wood, organics, metal, glass and cigarette butts) and in terms of sources of origin packaging (PACK), coastal and recreation activities (CRA), from masonry activities (MA) and from fishing and navigation activities (FNA).

Frequency of Occurrence (FO%: percentage of lines/transects in which a debris type/source occurred) and Numerical Abundance (NA%: percentage of number of each debris type/source from all beach debris found) were determined for type and source of debris. Moreover the mean contamination was calculated (items.m-1, number of items by linear meters) to SDCT methods (Claereboudt, 2004). Distribution of the absolute number of each type of debris was evaluated using log-linear models, computed by the maximum likelihood ratio Chi-square statistic.

Results

In our survey we collected a total of 2863 items and 37.32 kg of beach debris. The most abundant (NA%) solid waste were cigarette butts and plastics (hard plastic fragments, beverage bottles, bottle cups, toys, disposables, etc.). The most frequent (FO%) debris were cigarette butts and paper in almost all transect sampled (Table 1). Following the global tendencies, plastics are one of the dominant beach debris of Mar del Plata (Argentina) (Laist, 1987). Previous

Table 1
General beach debris composition from Mar del Plata (Argentina) and comparative between two methods, superficial and buried: *n*, absolute number; NA %, numerical abundance; FO %, frequency of occurrence.

	n	FO (%)	NA (%)		*n*	FO (%)	NA (%)		*n*	FO (%)	NA (%)
Total debris				Superficial debris collections transect				Buried debris collections transect			
Plastic	635	70.00	22.18	Plastic	542	100.00	29.14	Plastic	93	40.00	5.02
Paper	221	90.00	7.72	Paper	141	100.00	7.58	Paper	80	80.00	4.30
Wood	225	60	7,87	Wood	112	80	6.02	Wood	113	40.00	6.09
Metal	46	70.00	1.62	Metal	33	100.00	1.77	Metal	13	40.00	0.72
Organic	36	50.00	1.27	Organic	23	60.00	1.24	Organic	13	40.00	0.72
Cigarette butts	1691	90.00	59.04	Cigarette butts	151	100.00	8.12	Cigarette butts	1540	80.00	82.80
Glass	9	20.00	0.30	Glass	2	20.00	0.11	Glass	7	20.00	0.36

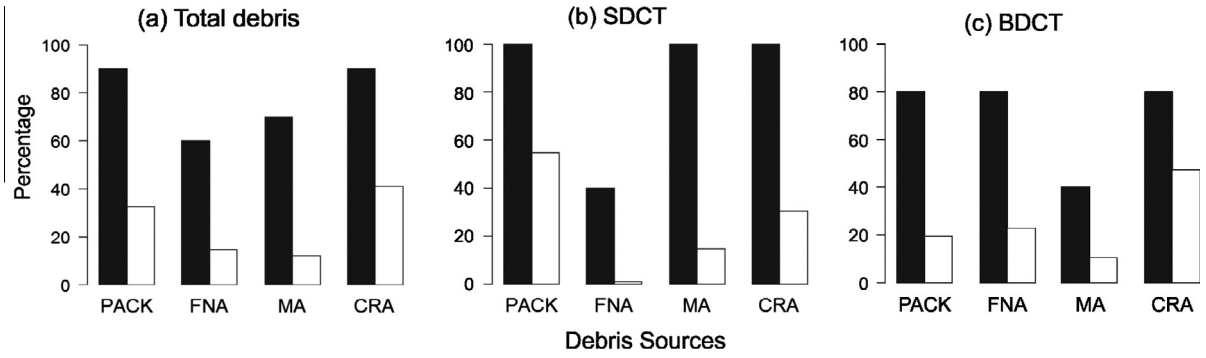

Fig. 1. Frequency of occurrence (FO%, black bars) and numerical abundance (NA%, white bars) of debris sources found in Playa Grande for total debris (a), surface debris, SDCT (b) and buried debris, BDTC (c). PACK, packaging; FNA, fishing and navigation activities; MA, masonry activities; CRA, coastal and recreation activities.

studies showed that between 50% and 80% of waste in the ocean is composed by plastics (Laist, 1987). Other abundant and frequent types of beach debris found in the study area were cigarette butts whose high abundance could also be related to its resistance and easy accumulation in beaches.

Papers, woods, metals, organics and fragment of glasses were other types of beach debris found in our study in low values of abundance (Table 1), but very common in other beaches studies around the world (Claereboudt, 2004).

Superficial debris collection transect (SDCT) concentrates 35% (1004 items) of total beach debris abundance whereas 65% (1859 items) corresponds to buried debris collection transect (BDCT) (Table 1).

Regarding the sources of origin, debris derived from packaging (PACK) and debris from coastal and recreation activities (CRA) were the most abundant and frequent (Fig. 1a), besides that, debris from fishing and nautical activities (FNA) were particularly abundant in BDCT methods (Fig. 1c). Both items PACK and CRA were probably the consequence of population increase in coastal cities as Mar del Plata, exceeding 2 million of tourists during summer season and a permanent source of solid urban waste in the rest of the year.

The impact of solid waste to marine animals is primarily mechanical due to ingestion and/or entanglement in synthetic ropes, lines or drift nets (Denuncio et al., 2011; Laist, 1987). In this sense, packaging waste (PACK) deserves a particular analysis because of its effect on marine organism as turtles and marine mammals. This material can be confused by turtles as prey items (Laist, 1987), or could act as playing attractions in the case of marine mammals (Denuncio et al., 2011).

Besides the consequences on marine organisms, beach debris carried out serious problems to humans activities. On the Argentine coast, fishing activities is affected by marine debris entangled in fishing nets; also clogging problems were detected in the Power Stations from Necochea city, south of Mar del Plata, because of plastic bags accumulation in the intake filters.

Beaches of Mar del Plata showed low solid waste contamination in comparison with other beaches around the world (Claereboudt, 2004). Considering only superficial debris of the five studied transect lines, the mean contamination was 0.51 items.m-1, with a maximun in level 0 (1.34 items.m-1) and a minimum in level 25 (0.09 items.m-1). Our results represent lower values compared with other beach studies such as those carried out in Curaçao Island, with 60 items.m-1; Jamaica, with 19 items.m-1 and St. Lucia, with 11.2 items.m-1, in the Caribbean (Claereboudt, 2004).

The solid waste of Playa Grande beach, Mar del Plata, was heterogeneously distributed. Log-linear models revealed highly significant associations between the type of beach debris and beach levels (distance to the high tide line) and method (superficial and buried debris), which explains that both sediment depth and distance to the lower tide affect the distribution of each type of debris (Associations – likelihood ratio – between levels, $p < 0.01$).

The absolute number (n) of beach debris shows spatial segregation of debris categories in each transect line (considering SDCT and BDCT added). Transect line 0 had great abundance of plastics, but is lower in the other levels (Table 1). The others transect lines were dominated by cigarette butts with the exception of line 50 that showed the lowest abundance of beach debris (Table 1). Also, the relationship of absolute number between plastics and cigarette butts in SDCT method was 3:1 whereas in BDCT method was 1:16 (Table 1). Those results suggest that the high tide line and the nearby zone are important areas of debris accumulation although few studies on beach debris analyze its spatial distribution. Claereboudt (2004) found similar pattern of debris distribution in beaches of the Oman Gulf (Asia), where the contamination level reaches a maximum at 8 m from tide line, decreasing in the middle zone of the beach.

Final remarks

Most of the previous studies on beach debris around the world describes exclusively superficial beach debris. In the present study, besides the description, abundance and composition of superficial beach debris, we also evaluated the composition, abundance and distribution of the buried debris in the sediment, using sieve techniques. These methods revealed two important conclusions: (1) there is an important retention of beach debris hidden in the sediments that it was never considered in beach debris descriptions; (2), superficial and deeper zones of the beach were contaminated by different types of solid wastes.

Moreover, our study provides a baseline of the knowledge on beach debris in Mar del Plata city. Beach debris can be prevented and controlled through educational programs, regulations and specific legislation in order to reduce solid waste on beaches.

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