



The significance of solid wastes with land-based sources for a tourist beach: Pernambuco, Brazil

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Abstract. This study evaluates the significance of land-based sources of solid wastes (plastics, rubber, polystyrene and nylon), in the contamination of a tourist beach on the southern coast of Pernambuco State, NE Brazil, from July 2001 to September 2002. Four transects each covering 2,500 m² and extending from the frontal dune to the water line at low tide were sampled along a 3 km beach. Plastic items were collected and placed in categories reflecting their most likely use/source. Results showed that the most frequent items (> 90%) were food packaging (~55.2%), fisheries (~13.0%), house cleaning (~8.3%), sewage/personal hygiene (~8.0%) and general home use (~6.6%). Except for fisheries related items, the most important litter contributions came from land-based, riverine sources and beach users. A consortium of the municipalities within the watershed is proposed as the best economic and ecological approach to control, collection and disposal of these solid wastes.

Key words: plastics, beach contamination, beach user, riverine litter, solid wastes disposal.

Resumo. A significância de resíduos sólidos de origem terrestre em uma praia turística: Pernambuco, Brasil. Este estudo avaliou a significância das fontes de resíduos sólidos (plásticos, borracha, isopor e nylon) de origem terrestre, na contaminação de uma praia turística na costa sul do estado de Pernambuco, Nordeste do Brasil, de julho de 2001 até setembro de 2002. Quatro transectos (com 2500 m² cada, indo da duna frontal até a linha d'água na maré baixa) foram amostrados ao longo de 3 km da praia. Os itens plásticos foram coletados e registrados dentro de categorias de acordo com sua fonte. Os resultados demonstraram que os itens mais frequentes (>90%) foram classificados como embalagens de alimentos (~55.2%), pesca (~13.0%), limpeza doméstica (~8.3%), esgotos/higiene pessoal (~8.0%) e uso geral de casa (~6.6%) respectivamente, indicando (exceto para pesca) a grande contribuição de fontes de origem terrestre, como lixo ribeirinho e usuários da praia. Um consórcio das municipalidades dentro da bacia é proposto como a melhor alternativa econômica e ecológica para a adequada coleta e destinação dos resíduos sólidos.

Palavras Chave: plásticos, contaminação de praias, usuário de praia, lixo ribeirinho, disposição de resíduos sólidos.

Introduction

Solid wastes from petroleum products (plastics, rubber, polystyrene and nylon) commonly constitute the largest fraction to be found in accumulations of marine debris, (e.g. Derraik 2002, Kusui and Noda 2003, Santos *et al.* 2005a, Araújo and Costa 2004, 2006). Plastics have low density, slow accumulation rates but high persistency, increasing supply with time, and broad dissemination in their use (Dixon and Dixon 1981, Gregory 1999, Derraik 2002). As a

consequence, beaches are susceptible to the accumulation of solid wastes originating from ships, rivers and beach users. Contamination rates of beaches by marine debris depends on several factors including: physical characteristics, prevailing winds and currents, hydrological regime, distance from population centers and sources that can be shore or ocean-based (Ryan 1987, Corbin and Sing 1993). The presence of solid wastes at coastal environments is also related to socio-economic variables as

regional infra-structure (e.g. collection and destination of solid wastes; controlled urban drainage) and educational and/or income level of the population. The undesirable impacts of solid wastes in coastal and marine environments are widely acknowledged and include reduction of tourist income and aesthetic value, risks to human health, damage to fisheries (artisanal, recreational and commercial), maritime safety and navigation, damage to biota, entanglement and ingestion (anthropogenic debris were ingested by 65.5% of the green turtles analysed by Bugoni *et al.* (2001) in Southern Brazil), and dispersion of fouling from one place to another (Gregory 1999).

The contribution of beach users to solid wastes on beaches has been investigated in respect to its presence and quantification of the items. Few works have focused on other sources, especially land-based sources, related to sewage and rivers. It is estimated that, at a global level, up to 80% of the solid wastes found on beaches had its origin at the nearest rivers (CMIO 1999), indicating that watersheds and nearby beaches are parts of a single, unified land-ocean system. According to Earll *et al.* (1997), linking solid wastes to their sources is a key issue to effectively minimise the problem in coastal and oceanic areas. It has a direct relationship to the prevention strategy to be used in its control and solution. Brazil has an 8.5 thousand km coast-line facing the Atlantic Ocean. Half the Brazilian population lives within 200 km from the sea (CNIO 1998), and inhabitants of the coastal zone generate 56,000 tons*day⁻¹ of solid wastes. Of this amount, a total of 75% is collected and goes to landfills. Approximately half of these landfills are located near rivers, lagoons, the sea, or ecologically important coastal environments as conservation units (CNIO, 1998). The plastics fraction was chosen to be the focus of this study because it dominated (>80%) among the solid wastes categories (Araújo and Costa 2004, 2006).

The present work aimed at evaluating the significance of different sources (land-based, marine and beach users) of solid wastes (plastics, rubber, polystyrene and nylon), in the contamination of a well known and favoured tourist beach on the southern coast of Pernambuco State, NE Brazil. This has been achieved through classification of plastics into eight specific use-related categories (fisheries, food packaging and disposable utensils, hazardous, sewage and personal hygiene, domestic cleaning, beach user, general house use and others).

Tamandaré municipality has 9 km of beaches, which in addition to their tourist importance, are of considerable ecological and

conservational relevance (Maida and Ferreira 1997). The hydrographic basins in which they lie are short coastal basins which drain urban centres with no basic water supply, sewage treatment, solid wastes collection, and run-off control. There are three rivers in the study area. Tamandaré Beach (Figure 1) receives riverine influences from north (Formoso River) and south (Mamucabas and Una Rivers).

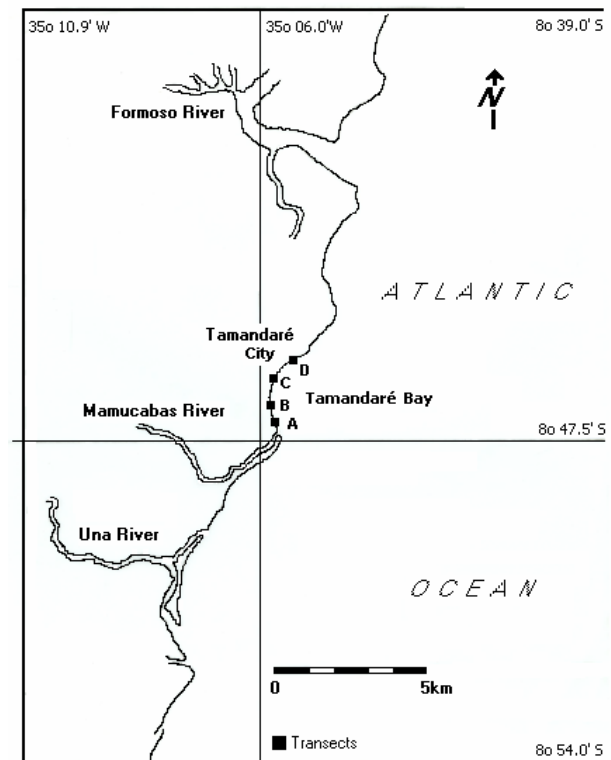


Figure 1. Map of the area and location of the sampling transects (A, B, C and D) at Tamandaré Beach, Pernambuco State, Brazil.

From dry to rainy seasons (Figure 2), the river water discharges at the coast from these rivers can increase up to three fold (<http://www.inmet.gov.br>). Formoso river is a tidal creek, having no significant freshwater discharge, except land drainage during the rainy season. Mamucabas river is short (>30 km) and crosses either agricultural or forested areas. It borders Tamandaré urban area along the southernmost inhabited areas. The Una River drains 32 urban centres along its course. It is the only proper river basin in the area, with a catchment area of 6,300 km² housing half million inhabitants, who live mainly in urban areas. When it reaches its lower course it represents an important source of coastal pollution, degradation of the biological resources and threat to the tourist activities (CPRH 2004).

Solid wastes collected by these municipalities are dumped in landfills, with significant social, sanitary and ecological

consequences. The region does not have an effective solid wastes disposal policy, recycling schemes or hazardous wastes management practices. Another important variable is the seasonality of domestic sewage and solid wastes production patterns. In the high summer season (November - March) the population in Tamandaré, increases 4.5 fold with the arrival of tourists and local beach users.

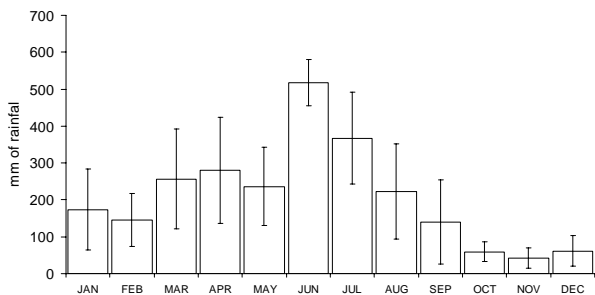


Figure 2. Average rainfall in Recife, Pernambuco (Brazil) from 2000 to 2004. Recife meteorological data are valid for a 100 km radius (<http://www.inmet.gov.br>).

Material and Methods

Four sampling transects (A, B, C, D) were established at Tamandaré Beach (Figure 1). The 4 locations had different morphological characteristics, frequency and intensity of use by beach-goers, dune and native vegetation integrity and level of urban occupation. Transects A and B are little frequented by locals or visitors, where the dunes are relatively well preserved. Transects C and D are intensely visited, especially during high summer season. Transect D has the dunes completely taken by urban occupation.

Each transect was 50 m wide ranging from the frontal dune (including the vegetation, if any) down to the water line at low tide (~2.500 m² each). Sampling took place at new moon in: September and November 2001; January, March, April, May, June, July and September 2002. The sampling months were grouped into rainy (April to July 2002) and dry seasons (September and November 2001; January and March 2002; September 2002) (Figure 2).

It was not possible to assess solid wastes accumulation or recolonization processes because Tamandaré Beach is periodically cleaned by municipal services (Araújo and Costa 2006).

Plastic items were collected and registered into eight categories related to their most likely source and/or use following Earll *et al.* (1997). These categories were: fisheries, food packaging and disposable utensils, hazardous, sewage and personal hygiene, beach user, general home use and others (Table I) and are a simplification of the “25

fractions” recognised previously (Araújo and Costa 2004, Table 1a).

The mean and standard deviation of the number of items found within each transect at Tamandaré Beach were calculated. In order to establish whether or not there were significant differences in the mean number of items in each transect between rainy and dry seasons, a t-test was applied (at 95%).

Results and Discussion

There were similar patterns in the types of the solid wastes accumulating in each of the studied beach transects. This suggests that the items found in the different areas of the beach have a common origin. Five categories were more frequent (>90%) but at different amounts at each transect. Food, fisheries, house cleaning, and sewage represented approximately 55, 13, 8 and 8% of the items, respectively. Items within the home category represented, in average, 7%, and the beach users category 5%. The hazardous items represented <1%, and the category others contributed with ~3% of the items sampled on this beach (Table II).

Although the total number of items in the rainy season is 70% of the number of items present during the dry season, there was no significant difference when comparing numbers of items in each category for each transect, between rainy and dry periods, with the exception of food packaging (Table II). In this particular case, the mean number of items is twice as much in the dry season compared to the rainy season. This is probably a response to the more intense tourist flux and use of the beach during the high summer season (November - March). Over this period the population of Tamandaré municipality increases from 17 to 60 thousand people. This suggests that these items are not solely related to beach users, but also to other sources.

It is well established that there are two main sources of solid wastes reaching the marine environment: they can be either land- or ocean-based (*e.g.* Rees and Pond 1995). Litter accumulating on Tamandaré Beach comes from all the initially predicted sources. The exclusively land-based source (river runoff represented by home, house cleaning, sewage and hazardous) was the most significant individual wastes contributor (1/4) to the study area. Fisheries is the only category which can be considered of exclusively marine origin, and contributed, in average, with 13% of the items. Food packaging was the most abundant category within all transects, at any time. However, it does not have an undisputable land-based origin. It probably has

Table I. Examples of the items which characterise each category according to their use.

Categories	Most common items
Fisheries	Nylon ropes and cables, nets, buoys, light-sticks, polystyrene, engine oil bottles.
Food packaging and disposable utensils	Biscuit packs, pop-corn and crisps packs, lollipop wraps and slush bags, PET fizzy drink bottles, mineral water bottles, lids and caps of food stuff containers, margarine tubs, straws, cups, plates and cutlery.
Hazardous	Hypodermic syringes (with and without needles), syringe needles, physiological solution flasks, medicine vials (both empty and half full), gynecological applicators, flasks of chemicals and pesticides.
Sewage and personal hygiene	Tooth brush, cotton-buds, tampon applicators, sanitary towels, condoms, disposable nappy, shampoo flasks and deodorant sticks, nail polish remover and combs.
House cleaning	Bleach flasks, general use detergents and disinfectants, liquid wax flasks, caps and lids of cleaning product containers.
Beach users	Tanning lotion and sun-screen bottles, hair bleaching solutions, flip-flops, sun glasses, training shoes.
General home use	Cooking utensils, toys, buckets, parts of electrical appliances, brushes of all sorts, sweeps; safety seals from gas bottles, pens and dummies.
Others	Items or fragments (immediately visible to the naked eye) which use-related identification was not possible.

multiple sources (beach user, riverine litter, ships). This category includes all sorts of containers used to sell, protect, transport or for food consumption, and contributed with more than ½ of the items found on Tamandaré Beach. The most frequent items were polyethylene terphalate (PET) bottles for fizzy drinks, biscuit packs, crisps bags, lollipop wraps and margarine tubs. In Brazil, due to the widely spread consumption of fizzy drinks in PET bottles over the last decade, accumulation of these and similar types of containers in the environment has become a chronic problem of difficult solution. Brazil has an efficient policy for recycling beverage aluminium cans, and this has restricted their accumulation in the natural and urban environments. The same is not true with PET bottles which are still discarded to the environment for lack of market value. This tendency has been observed by other authors (Jozwiak 2005).

Beach users contribute in part to beach contamination by solid wastes, sometimes with large amounts. Their contribution comes mainly in the plastics fraction. This has been also observed at Cassino and Praia Grande beaches, both at Rio Grande do Sul State, Southern Brazil, where the beach is used exclusively during the summer (Santos *et al.* 2005b). At the South of Brazil (~ 30° S), the climatic conditions are temperate and consequently the use of the beach is limited to a few months per year. In Pernambuco (~ 8° S), the beaches are used all year long, but more intensely during the dry season (September - March).

At transect C the largest total numbers of items were observed during the high summer season, due to its proximity to an intensely used stretch of the beach (Table II). Transect D, has no native vegetation at the dunes, and part of the backshore occupied by edifications (private property), which makes it different from the other transects. Here, the beach area adjacent to the residences is frequently cleaned by house-keepers, and daily by the tide. This may account for the lesser quantities of these items found at this transect. These are the two only notable differences in the total number of items among transects. In general, there was no spatial differences in the average number of items found in each transect. Margarine tubs are the only container type which does not have a logical connection to beach users. We consider these were essentially of domestic origin. They reach the beach through rivers, and were once observed in large numbers (650 items/500 m of beach), by the authors in an extreme event in May 2001.

Plastic debris accumulation in coastal environments commonly derived from a number of sources (Earll *et al.* 1997). However, from the five most abundant categories observed during this study, three (house cleaning, sewage, general home use) are exclusively related to riverine contribution. Williams and Simmons (1999) also found that plastics made up half of the total amount sampled at the Taff River (Wales). Feminine hygiene products alone were 22% of the wastes. Dixon and Dixon (1981) found that

Table II. Mean and standard deviation of the total number of items found at Tamandaré Beach (50 m wide transects A, B, C and D) in each use/source related category during rainy (n=4) and dry (n=5) seasons.

Categories	A		B		C		D	
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
Food packaging	26 ± 11.9	62.2 ± 60.9	35.8 ± 16.6	67.6 ± 32.9	49.3 ± 15.2	102.4 ± 28.6	26.3 ± 14.1	44.4 ± 30.8
Fisheries	7.5 ± 3.1	11.6 ± 2.5	10.8 ± 6.8	16.2 ± 10.3	17.8 ± 7.6	24.2 ± 10.5	10 ± 4.8	5.6 ± 3.3
House cleaning	6.8 ± 2.6	5.2 ± 3.3	7.8 ± 2.9	7 ± 4.4	15 ± 12.0	12.8 ± 7.2	9.5 ± 6.6	2.8 ± 3.1
Sewage/Hygiene	4.8 ± 1.7	6.2 ± 4.1	9.5 ± 2.4	6.2 ± 4.3	14.3 ± 12.0	11.2 ± 6.7	8.8 ± 8.4	3.2 ± 2.6
General home use	5.3 ± 3.3	4.4 ± 2.7	7.8 ± 6.1	8.8 ± 7.1	6 ± 3.5	12.6 ± 15.6	4.5 ± 3.1	3 ± 4.2
Beach user	3.5 ± 1.9	3.8 ± 2.3	3.3 ± 1.3	4.6 ± 1.5	8 ± 7.2	7.2 ± 2.2	3.8 ± 3.6	5.6 ± 3.9
Hazardous	0.3 ± 0.5	0.8 ± 0.8	0.5 ± 0.6	1.8 ± 1.5	1.3 ± 1.0	0.8 ± 0.8	1 ± 1.4	0.2 ± 0.4
Others	1.3 ± 1.0	1.8 ± 1.3	5.3 ± 0.5	2 ± 2.7	3 ± 3.4	4.6 ± 9.2	3 ± 0.8	2 ± 1.6

containers for sanitary and domestic cleaning products were the first and second most frequent items on western European beaches. Gregory (1999) has similarly recorded items of domestic and personal origin (cosmetics and hygiene) at isolated islands of the South Pacific. The large number of items related to house cleaning (e.g. bleach and detergent flasks), and personal hygiene (e.g. deodorant sticks and shampoo bottles), are hardly the type of residue left by beach users. This is indicative of inefficiencies of the public cleaning services in the collection and disposal of municipal solid wastes. In addition, increments in the use of disposable sanitary towels and nappies in the last decades have significantly contributed to the increase of sewage related solid wastes items in aquatic environments.

Visitors negative perceptions of solid wastes on beaches has been emphasised by Herring & House (*in* Williams and Nelson 1997) who concluded that sewage related contaminants (e.g. condoms and sanitary towels) have a greater impact than other contaminant categories. Results from the present study show similarities with observations made elsewhere. Ross *et al.* (1991) studied solid residues at Halifax Harbour (Canada) and related the residues to their sources. They found that 62% of the items had a domestic origin (e.g. plastic bags, tampon applicators, food containers, sheets and bottles). The plastic residues sampled by Williams and Simmons (1997) at the Bristol Channel (UK) were 47% of the total amount of items, and of these, 10% were related to house cleaning.

The effects of the pollution load generated at the municipalities drained by the Una River are detectable at the coastal environments down current. The prevailing long shore current is south to north (Macrodiagnóstico da Zona Costeira do Brasil, 1996). The river plume, and its contaminants, flow towards Tamandaré Beach. Solid wastes of domestic

origin (cooking oil bottles, bleach and detergent flasks, personal hygiene containers) and freshwater plant litter along the strand-line of the beach at Tamandaré Beach support this interpretation. Beaches north of Formoso River, similarly collect significant quantities of comparable contaminants, transported by the same northwards-flowing current (pers. obs.). Plastic solid wastes of low density and high floatability from the Formoso river might reach Tamandaré Beach when NE winds prevail, during the summer. The Mamucaba river represents the lesser source of solid wastes contamination to Tamandaré Beach due to its small size and very low population density.

Fisheries items were the second place in importance due to polystyrene fragments. This fraction is frequently found along the whole bay in the form of pieces of many sizes (12 to 15 cm). Its sources lie in degrading fishing net buoys, anchoring buoys and the small fishing boats which use this material as filling to improve floatation. Since it is compact and of low density, its transport is very efficient both by wind and water. Many other coastal regions of the world also accumulate significant amounts of polystyrene in marine debris. On the coast of Panamá this type of residue represents up to 31% of the items made of petroleum products identified (Garrity and Levings 1993). Light-sticks were another plastic product related to fisheries encountered Tamandaré Beach. These have come from the accidental loss of commercial fishing lines. They end up on local beaches after long-distance transport by the wind and currents. Until recently, these items were rare on Brazilian beaches, but they have become more common since 1999 with at least two recent "spill" events in the area of study.

In spite of the small number of items recorded wastes that can be related to hospital and health services were found in all Tamandaré Beach transects. In Brazil this type of waste is frequently

disposed off together with ordinary urban solid wastes. In our study this type of waste has been placed in the more general "hazardous" category. The most frequently encountered items of this type were hypodermic syringes (with and without needles) and medicine vials (empty or with their original contents). While waste residues of this type should be virtually absent from the environment they have been recorded elsewhere. Garrity and Levings (1993) found hospital wastes on 19 beaches sampled along the coast of Panama, and Ross *et al.* (1991) similarly recorded small quantities in 9 of 19 transects sampled in surveying the shoreline litter of Halifax Harbour, Canada (Ross *et al.* 1991).

Conclusions

Solid wastes management on beaches is often limited to an immediate clean-up response or operation that fails to take into consideration any preventive action. Despite cleaning, any beach can be rapidly and repeatedly fouled by newly arriving solid waste items if their sources have not been controlled. The temporary and ephemeral nature of beach cleaning, and accompanying costs to taxpayers, have forced the search for more effective management measures – ones which prevent contamination in the first place.

The region's rivers, but mainly the Una River, are a permanent and continual source of solid wastes to the coastal environments down-current (i.e. northwards) from their mouths. At least ¼ of the solid wastes deposited along Tamandré Bay have been passively imported from sources that are kilometres away. And this figure does not even consider the food-related items that can be attributed to both land-based sources and beach users, which alone represent ½ of the wastes on the beach. There exists at present a situation threatening the health of local inhabitants and tourists alike. The impact may also be to the detriment of marine biota of the Conservation Unit in which the study was conducted. Also, it could seriously compromise the possibilities of economic exploitation of the landscape and ecological services of Pernambuco's southern coast.

A possible approach could be to amalgamate the municipalities within the Tamandaré hydrographic basin into a single, unified, environmental authority. The different municipalities would then agree to accept common solid waste management policies. These could include waste reduction and recycling actions by the society and the private sector. Either way there will be need to initiate policies for regular at-source

collection and practices, as well as to identify, promote and manage transport of waste to disposal sites. In this way, significant reductions in amounts of waste entering rivers and reaching the coast should soon be apparent. Unification of municipalities around this issue, or at least adoption of a common management policy, should lead to lowering of costs in each of the present administrative units. Addressing the problems associated with beach users and tourists' waste disposal will necessitate other approaches. In the first instance identification of waste disposal and environmental contamination patterns may be required. This will need to be followed by intensive educational and advertising campaigns addressed at both adults and children, especially during the summer.

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