QUALI-QUANTITATIVE ANALYSIS OF THE SOLID WASTES AT TAMANDARE BAY, PERNAMBUCO, BRAZIL.

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Recebido em 07/2004
Aceito em 12/2004

ABSTRACT

Coastal environments are susceptible to the accumulation of solid wastes, specially plastics, from a number of sources. The present work aimed at investigating the problem of solid wastes contamination at Tamandaré Bay, at Pernambuco's southern coast (Brazil), during February, March and April 2001. Tamandaré is a tourist beach of easy access, and intensely used during the summer months, which didn't count on beach public cleaning services at the time the sampling was conduced. Four sampling transects of 500m^2 each, from the frontal dune (including the vegetation) down to the water line at low tide, were delimited for the study. Plastic items and other petroleum products corresponded to more than 80% of the total solid wastes, similar to the situation of other beaches around the world. Among the items registered, the most frequent were related to food packaging, fisheries, domestic cleaning and personal hygiene, indicating multiple sources origin.

Key words: solid waste, coastal pollution, beach contamination

RESUMO

Análise quali-quantitativa dos resíduos sólidos na baía de Tamandaré, Pernambuco, Brasil.

Os ambientes costeiros são regiões suscetíveis ao acúmulo de resíduos sólidos principalmente plásticos, que se originam de inúmeras fontes. O presente estudo analisa a questão da contaminação por resíduos sólidos na baía de Tamandaré, litoral sul de Pernambuco, no período de fevereiro, março e abril de 2001. Tamandaré é uma praia turística, de fácil acesso, bastante freqüentada durante o verão e no período estudado não dispunha de limpeza urbana na orla. Os transectos amostrais foram em número de quatro, com área de 500m^2 cada, abrangendo desde a duna frontal (incluindo a vegetação) até próximo a linha d'água na maré baixa. Plásticos e outros derivados do petróleo corresponderam a mais de 80% do lixo total, semelhante ao que ocorre em outras praias do mundo. Desses itens os mais freqüentes estavam relacionados à alimentação, pesca, limpeza doméstica e higiene pessoal, indicando origem de múltiplas fontes.

Palavras chaves: resíduos sólidos, poluição costeira, contaminação de praias.

INTRODUCTION

Among the numerous materials in the composition of marine debris, petroleum products (plastics, rubber, polystyrene and nylon) constitute the largest fraction (ROSS *et al.*1991; GARRITY; LEVINGS, 1993; THORNTON; JACKSON, 1998; DEBROT *et al*. 1999).

The presence of solid wastes in coastal environments is directly related to a number of environmental and social factors. Among the social factors, its can be mentioned the infra-structure available, the existence of an efficient collection and adequated destination associated to recycling programs, urban drainage; educational level and living standards of the local population can be mentioned.

The life style of the western populations is the main responsible for the actual levels of environmental degradation observed. Nature shows an efficient capacity of reuse and recycling of materials, while men are efficient in the generation of non easily degradable residues, specially domestic sewage and solid wastes.

Brazil has a coast line with 7,408km of extension turned towards the Atlantic Ocean. This coastal extension creates an area of aproximately 442,000km^2 of coastal zone (both emerse and submesrse). Five of the nine largest metropolitan regions in Brazil are located on the coast. Actually, ½ of the Brazilian population lives at no more than 200km from the sea. The 70 million inhabitants of the coastal zone in Brazil generate around 56,000 tons of solid wastes per day. Only 42,000 tons are collected. From the total amount collected, 90% go to continetal landfills. Approximately half of these landfills are located near rivers, lagoons and the sea, or near ecologically important coastal environments (CNIO, 1998).

Tamandaré Municipality, southern littoral of Pernambuco State, has nearly 9 km of beaches. The beaches are knows as Carneiros, Campas and Tamandaré, from north to south. The whole stretch is protected by coastal reefs. A number of small rivers contribute to the coastal environment. The main ones are Formoso River to the north; Mamucabinhas and Una Rivers to the south (Figure 1). In the area comprised into these drainage basins there are a number of urban centers. One of them is Tamandaré, which present precarious urban infra-structure and sanitation facilities as sewage collection and treatment, solid wastes collection and adequate destination. The littoral of Tamandaré presents a higher degree of urban occupation at its northern portion, and consequently a diminished natural coastal vegetation on the dunes; the southern end is almost free from urban occupation of the beach area, favoring the presence of the natural dune vegetation. The longshore current is predominantly from south to north (Macrodiagnóstico da Zona Costeira do Brasil, 1996).

Tamandaré has a permanent population of around 17,000 inhabitants (IBGE, 2000). During the high summer season (November – February) the population can sometimes reach more than 60,000 people living in the municipality (Secretaria de Turismo de Tamandaré, pers. comm.). The incoming population include tourists from Pernambuco, other regions of the country and abroad; holiday makers who spend the whole season at hotels, rented houses or their own sea side properties and; day-visiotors who come only for using the beach, usually on Sundays.

The increased amount of people generates benefits for the local economy, but on the other hand, also potencializes already existing problems, as the generation of solid wastes and sewage.

In addition to their touristic importance, Tamandaré beaches are of high ecological and conservational relevance. They are part of two conservation units namely the continental/marine Environmental Protection Area of Guadalupe and the Marine Environmental Protection Area Costa dos Corais.

The present study aimed to quali-quantitatively investigate the solid wastes contamination on Tamandaré beach and identify the predominant types and possible sources of residues, checking

its similarity to other beaches of other parts of the world (GABRIELIDES *et al*, 1991; ROSS *et al*, 1991; WILLIAM, SIMMONS, 1997; DEBROT *et al*, 1999; DERRAIK, 2002).

MATERIAL AND METHODS

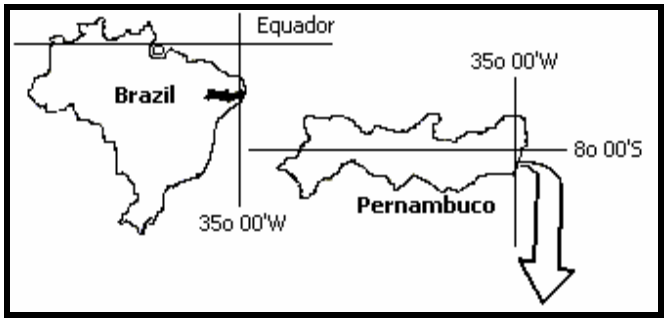
Four transects (A, B, C and D) were delimited at Tamandaré bay for samplig of the solid wastes (Figure 1). The choice of the locations was based on the different morphodynamical characteristics of the beach, the frequency and density of by beach users, the presence of vegetation and level of urban occupation. The combination of these factors is reflected in the amount of solid wastes left and accumulated on the beach. Beach users usually concentrate around areas of flatter beach profile and safer bathing conditions, easyer access and close to commercial and public services facilities (e.g. shops and showers). Transects A and B are on the southern end of the beach, little frequented by locals or visitors, where the dunes are relatively well preserved. Transects C and D have opposite characteristics, being intensely visited, especially during high summer season. Transect D has the dunes completely taken by urban occupation.

Each transect was 10m wide, from the frontal dune (including the vegetation when there was any) down to the water line at low tide. The beach, at new moon low tide, is approximatelly 50m long. Then, the total area of each transect was approximately 500m^2. Sampling took place in February, March and April 2001. These months are the end of the tourist season and also the end of the dry period. All the solid wastes, including fragments were manually collected and stored in 100L rubbish bags for posterior processing, counting and classification.

The items were counted, grouped and registerd on a table within the following categories: plastics, glass, aluminium, tin/steel, paper and wood. The 6 solid wastes categories including the 25 plastic fractions used in this work were based on Gregory (1991).

The plastic fraction (1) Botles included PET botles and other containers made of the same material. The (2) Flasks, were house cleaning products and containers of personal hygiene products as shampoos and other creams. Fraction (10) Cellophane included biscuit packs, lolly-pop wraps, crispies bags and other.

The abundance and frequency of occurrence of each category were calculated in order to determine the most expressive of them. It was also calculate the percentual of incidence of each category, the quantitative monthly variation at each transect, and the total amount accumulated during the three months of sampling.



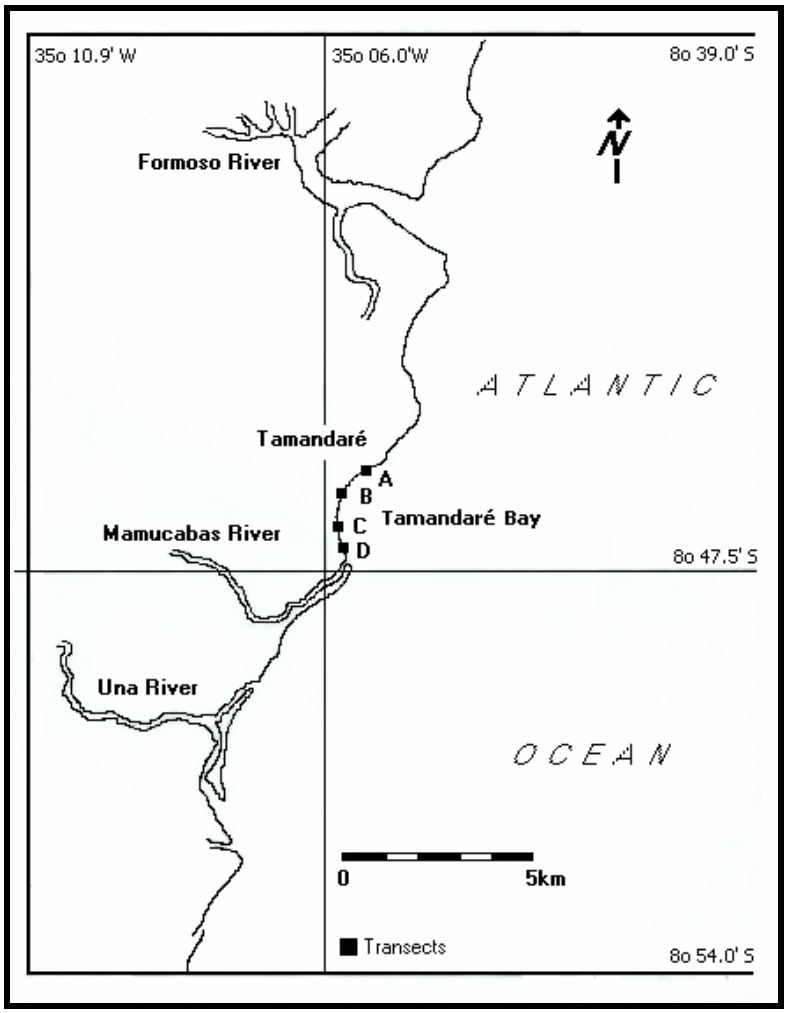


Figure 1 – Tamandaré Bay and beach in Pernambuco's southern coast, Northeastern Brazil. Study area and location of the four sampling profiles (A, B, C, D).

RESULTS AND DISCUSSION

During the three sampling months, the public cleaning services of the beach was not yet opperational in Tamandaré. This daily service was stablished only in August 2001. The solid wastes in Tamandaré Bay, independently from their origin (beach users, rivers or marine currents), showed detectable fluctuations in their accumulation rates since they were leff free to be moved around by the wind, tide and water currents. The results are shown in table 1a and 1b.

Table 1a – Number of items of plastic solid wastes per month in 2.000m^2 of beach distributed in 4 transects (A, B, C and D) perpendicular to the beach, in February, March and April 2001. The different plastic items have been classifyed into 25 fractions according to the type of plastic or petroleum hydrocarbon and respective use.

PLASTICS	February					March					April				
	A	B	C	D	**Total**	A	B	C	D	**Total**	A	B	C	D	**Total**
1. Bottles	7	23	15	7	**52**	5	6	20	2	**33**	4	8	9		**21**
2. Flasks	9	18	20	5	**52**	3	8	16	2	**29**	8	14	6	1	**29**
3. Caps/Lids	14	57	20	13	**104**	11	13	14	13	**51**	18	30	7	4	**59**
4. Buckets	1				**1**		1	2		**3**	3		1		**4**
5. Plates	1	5	3		**9**	1	2	4		**7**	2	3	1		**6**
6. Cups	20		46	7	**73**	4	1	44	1	**50**	5	23	3		**31**
7. Straws		15	8	7	**30**	3	7	7	16	**33**	2	6	8	12	**28**
8. Margerine tubs							2		5	**7**	2		1	1	**4**
9. Margerine tubs lids				2	**2**	3	2	2		**7**	1				**1**
10. Cellophane	24	43	51	30	**148**	17	19	30	20	**86**	12	24	19	11	**66**
11. Bags	18	10	27	14	**69**	5	3	15	4	**27**	1	5	6	10	**22**
12. Plastic sheets	3	18	7		**28**	2	9	17	1	**29**		11	7	6	**24**
13. Bottle top rings									4	**4**					
14. Toys / Combs		5	2	2	**9**	1	3			**4**		4			**4**
15. Fishing lines (Nylon monofilament)			1		**1**								2		**2**
16. Strips		3	1	1	**5**	4	4			**8**	3	2			**5**
17. Nylon ropes/cables	4	10	6		**20**	1	14	2	1	**18**	5	3			**8**
18. Fishing nets (Nylon monofilament)			1	1	**2**			1		**1**					
19. Light sticks	1	1	2		**4**							2			**2**
20. Rubber		1	1		**2**	2		2	2	**6**		1		1	**2**
21. Sandals/ shoes		7	1	1	**9**		1			**1**					
22. Foam		3			**3**	1			1	**2**	1	5			**6**
23. Polystyrene	20	16	34	18	**88**	7	15	5	18	**45**	6	4	6	18	**34**
24. Fragments	9	11	1	1	**22**	1	5	8	10	**24**	9	2	3		**14**
25. Others	3	3	3	3	**12**		1	1	1	**3**	3	3	1		**7**
Total	**134**	**249**	**250**	**112**	**745**	**71**	**116**	**190**	**101**	**478**	**85**	**150**	**80**	**64**	**379**

Table 1b – Number of items of solid wastes per month of other materials (glass, aluminium, tin/steel, paper and wood) in 2.000m^2 of beach distributed in 4 transects (A, B, C and D) perpendicular to the beach, in February, March and April 2001.

ITEMS	February					March					April				
	A	B	C	D	**Total**	A	B	C	D	**Total**	A	B	C	D	**Total**
GLASS															
Bottles		4	5		**9**		4	2		**6**		1	1		**2**
Lamps / Bulbs		1			**1**										
Fragments		15	9		**24**		1	3		**4**		4			**4**
Total	**0**	**20**	**14**	**0**	**34**	**0**	**5**	**5**	**0**	**10**	**0**	**5**	**1**	**0**	**6**
ALUMINIUM															
Cans															
Take-away containers		2	1	2	**5**		3			**3**		1		1	**2**
Others			2		**2**	1		1		**2**				1	**1**
Total		**2**	**3**	**2**	**7**	**1**	**3**	**1**	**0**	**5**	**0**	**1**	**0**	**2**	**3**
TIN / STEEL															
Cans			2		**2**	1	1	2		**4**				1	**1**
Drums															
Electric leads															
Caps/lids				1	**1**						1			2	**3**
Others			1		**1**						1				**1**
Total	**0**	**0**	**3**	**1**	**4**	**1**	**1**	**2**	**0**	**4**	**2**	**0**	**0**	**3**	**5**
PAPER															
Cardboard		1	3	9	**13**		2	1		**3**	1	1	4	2	**8**
Others											3				**3**
Tetra-pack		1			**1**	1	1	3		**5**					
Total	**0**	**2**	**3**	**9**	**14**	**1**	**3**	**4**	**0**	**8**	**4**	**1**	**4**	**2**	**11**
WOOD															
Pieces		9			**9**		3	1	4	**8**	1			5	**6**
Lolly pop sticks	3	5	7	8	**23**	2	6		9	**17**			4	12	**16**
Others															
Total	**3**	**14**	**7**	**8**	**32**	**2**	**9**	**1**	**13**	**25**	**1**	**0**	**4**	**17**	**22**

The accumulation of solid wastes, specially plastic packaging and polystyrene, occur preferentially in areas were there is still native vegetation where they tend to accumulate due to action of wind. Also, an acumulation at the water line, where these residues are deposited at high tide and can not be easily removed neither by natural processes or voluntary collection, can be observed. The compositional analysis of the solid wastes sampled evidences the predominace of plastic items in all four sampling transects (Table 2).

Table 2 – Monthly percentage of the plastics items in relation to other categories of litter found on Tamandaré Bay, Pernambuco, Brazil.

Category	February	March	April	Average	Standard deviation
Plastics (%)	89.1	90.2	88.9	89.4	0.6
All other categories (%)	10.9	9.8	11.1	10.6	0.6

The present data reflect a world trend (Table 3), which indicates that the highest percentage of solid waste items found on beaches around the world is made of plastic and other petroleum hydrocarbons items.

Table 3 – Percentage of plastics items in relation to the other items of litter, at Tamandaré Bay, Paernambuco, Brazil and other places of the world.

Place	Percentage (%)	Reference
Tamandaré-NE Brazil	> 80	this work
Tamandaré-NE Brazil	> 80	Araújo & Costa, 2000
Cassino-South Brazil	52	Pianowski, 1997
Curaçao	64,2	Debrot et al., 1999
Taim- South Brazil	81	Pianowski, 1997
North Sea	79	Dixon & Dixon, 1983
Mediterraneam coastline	49 – 71	Gabrielides et al., 1991
Panama (Caribbean coast)	82	Garrity & Levings, 1993
Halifax harbour - Canada	53,8	Ross et al., 1991
New Jersey - USA	42,5	Thornton & Jackson, 1998
River Taff (South Wales-UK)	82	William & Simmons, 1996
Australia	45	Whiting, 1998
St. Lucia Island (Caribbean)	82	Corbin & Singh, 1993

Even considering that each of these regions of the world have a different set of oceanographic, socio-economic, industrialization and urbanization characteristics, the values indicate a similar quali-quantitative pattern, which places this sort of solid waste as the most abundant type of marine debris.

The fact that the plastics are always indicated as the most expressive group among the categories of solid wastes found on beaches, can be justifyed by its ever increasing uses since the last 50 years, specially packaging of manufactured consumer goods. In Brazil, during the last years, the average production of solid wastes per person per day, increased from 0.5 to 1.2kg in the large urban centers. The use of food packaging increased more than 100% (Jornal do Commercio, 28/07/2002)

Due to their high fluctuability, slow degradation, easy dispersion, and ever growing production and use along the time the effects of plastics items in the marine environment are cumulative. The problems related to plastic wastes are becoming chronic and globalized, in addition to acute and regionalized (GREGORY, 1991, DERRAIK, 2002). The contamination and accumulation of solid wastes is also affecting tourist beaches, urban or remote, in a global scale and not only at the local level as it is the public perception (LAWS, 1993).

In the present study the categories plastic, wood, glass, paper, aluminium and tin/steel occurred in this order of abundance at the four sampling transects (Table 4). The abundance of the wood category, in terms of number of items is due to the large amount of lolly pop sticks left on the beach by its users.

Table 4 – Monthly quantitative variation of the solid wastes in four transects in Tamandaré Bay, Pernambuco, Brazil.

Category	February 2001	March 2001	April 2001	Total of items per category in three months	% of the items in each category in relation to the total
Plastic	745	478	379	1602	89,4
Wood	32	25	22	79	4,4
Glass	34	10	06	50	2,8
Paper	14	08	11	33	1,8
Aluminium	07	05	03	15	0,8
Tin / Steel	04	04	05	13	0,7
Total of items per month of all categories	**836**	**530**	**426**	**1792**	**100**

With the exception of plastics, the sum of all the items of the other categories corresponded to only 10.6 %, which could place them into a position of secondary importance in the solid wastes scenery in coastal and marine environments (Table 4). From these secondary categories, only glass and metals may reach levels of important concern, due to their low degradability when compared to wood and paper.

It is important to call attention to the almost complete absence of aluminium cans from fizzy drinks and beer during the sampling months. Although the consumption of these beverages is very frequently observed on the beach, the absence of the cans can be explained by the efficiency in their collection for recycling by people from the local population. Brazil has a promising market for aluminium recycling which collection step is traditionally exploited by the poorest layers of the human society.

In respect to plastics, from the 25 fractions identifyed (Table 1a), nine presented a higher frequency (cellophane, caps/lids, polystyrene, straws, bags, flasks, bottles and plastic sheets),

representing 1/3 of the fractions and 80% of the number of items (Table 5). From these nine fractions, only one is related to fisheries (polystyrene); four (bottles, cups, straws and cellophane) were related exclusivelly to food packaging; and the other could not be surely related to a specific use/source.

Table 5 – Percentage of the nine more frequent plastic fractions in relation to the total number of plastic items.

PLASTIC FRACTION	MONTHS		
	February	March	April
All 25 fractions (no. items)	745	478	379
Nine most frequent fractions (no. items)	644	383	314
Nine most frequent (no. % in relation to the total amount of plastic items)	86.4	80.1	82.8

The large incidence of plastic items related to food packaging is probably explained by the fact that this sort of residue has its origin from multiple sources as rivers, beach users, boats and ships (marine debris).

Among the five fractions of plastic items originating from fisheries, polystyrene can be highlighted by its quantity. It was actually the 3rd most frequent plastic item at the end of the three months. This fraction, without any reusable or recyclable alternative, is frequently found along the whole bay in the form of pieces of many sizes (diameters) and has its main origin at the small boats (in Portuguese *jangadas*) which use this material as a filling to improve flutuability, fishing net buoys and anchoring buoys. Since it is compact and of low density, its transport is very efficient both by wind or water. Many other coastal regions of the world also present significative amounts of polystyrene as an integral part and significant contribution of marine debris, as for instance, the coast of Panamá where this type of residue represents 31% of the items made of petroleum products identifyed (GARRITY; LEVINGS, 1993).

Although in lesser amounts in relation to polystyrene, another fisheries plastic residue which occurred were light-sticks from commercial fishing lines. These light-sticks are accidentally lost from the fishing lines and end up on beaches after suffering long range transport by the wind and ocean currents. Until recently, this item was rare on Brazilian beaches, but has become more and more common since the last four years.

The mixture of solid wastes found at coastal environments is frequently originary from a number of sources (EARLL *et al.*, 1997). Nevertheless, some items as flasks from house cleaning products (e.g. bleach), personal hygiene or sewage effluents are related exclusively to the riverine contribution. These residues, hardly the type left by beach users, suggests the inefficiency of public collection services, disposition and treatment of domestic and commercial solid wastes at the local municipalities.

Still in respect to plastics, it was possible to observe that although there was a general reduction in the total of items, from February onwards (Table 4), the same is not observed for each transect individually (A, B, C, D). It is possible to observe that for transects A and B this was not true (Table 6). The apparent reduction in the number of total items suggests a reduction of the wastes left on the beach with the end of high summer season (February to April). According to the *F* test, for 11 degrees of freedon ($p < 0.05\%$), the sampling months are similar.

Table 6 – Monthly quantitative variation of the plastic items in each transect in Tamandaré Bay, Pernambuco, Brazil.

Transect	February	March	April
A	134	71	85
B	249	116	150
C	250	190	80
D	112	101	64
Average	186.2	119.5	94.7
Standard deviation	73.5	50.5	37.9

From the four sampling transects, C and B were those which presented the largest amounts of plastic items, specially related to food packaging, this occured probably due to the contribution of the beach goers who stay preferably at these beach areas, near parking lots. The contribution of beach goers to the contamination of the beach, specially by plastics, was also observed by Pianowski (1997) at Cassino and Praia Grande beaches at Rio Grande do Sul (south Brazil) where tourism is intense and results in an elevated solid wastes production during the summer months (December-March).

Other authors also considered the weight of the sampled solid wastes on beaches (CORBIN; SINGH, 1993; THORNTON; JACKSON, 1998). In the present work it was chosen not to do so because when weighted separetelly each category produces information of little value. The weight is not related to the amount of items in each category. The parameter *number of items* is far more important to the sort of analysis done in the present work: the characterization of the sources and frequency of solid wastes contamination on beaches. Some materials, like glass and metals, have a higher weight than plastics. For example: a 1L whisky glass bottle weights the same as 11 2L PET bottles from fizzy drinks, however the aesthetic results of these two types of residue on a beach are quite different.

Another important question is the high occurrence of fragments. It is probable that a large number of fragments will occur on beaches in a mixture with sand, sometimes completely buried, difficultating its identification and quantification. This could justify the reduced amount of fragments found during the samplings in relation to the other items found still whole (Tables 1a e 1b).

The evidences suggest that plastic bottles made of polyethylene of high density are photodegradable outside the water (DIXON; DIXON, 1981).

Photodegradation is the main process to degrade plastics in the sea, since UV radiation reduces the molecular weight of the polymers and causes their desintegration/fragmentation. The photochemical process is further helped by the drying action of seasalt and wind. However, biodegradation is almost impossible due to the high molecular weight and rigidity of its structure, making impossible microbiological action on this type of substrate (WILLIAMS; SIMMONS, 1996).

If the amount of plastic items sampled in the four transects was extrapolated to the whole extension of beaches in Tamandaré Municipality (450,000m^2) there would be 41,900 items in February, 26,890 items in March and 21,300 items in April 2001. The large amount of solid wastes,

although not presenting immediate health risk for beach users and marine biota, represent a signifficant consumption of time and financial resources to be collected on a beach. However, they would also cause severe losses of revenue due to the objectable asthetic condition of the coastal environment, severely affecting tourist activities and bringing serious economic constrains to the municipality and the region. In addition, since the solid wastes were not collected, they were free to return to the bay waters and circulate among the reefs, reach the coastal currents, get lost to sea and, maybe, re-deposit on another stretch of the beach or elsewhere.

To mitigate or stop the solid wastes contamination of the studied beaches it will be paramount to invest in environmental education of the communities around and within Tamandaré; to promote consistant public solid wastes collecting services, inclusive for recycling; and to adopt controlling measures to reduce the amounts of wastes left by day-visitors, specially during summer months. It is also necessary to encourage the municipal administrations surrounding Tamandare beache to promote joint programs of collection, disposition and treatment of the urban wastes generated within the drainage basin, since there was a high proportion of wastes of clearly continental (urban) origin found at the beach (household cleaning, personal hygiene and sewage etc.). These actions would reduce the contribution of the rivers draining to the bay and consequently diminish the amount of plastic solid wastes arriving at the coastal and marine environments.

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