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Monitoring of Plastic Waste on the Beaches of Grand-Bassam, Ivory Coast

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Abstract:- The presence of plastic waste is increasingly evident on the beaches of Grand-Bassam, a UNESCO World Heritage Site. This state of affairs calls for diagnostic studies. Thus, the objective of this study was to monitor plastic waste on the beaches of Grand-Bassam according to the four (04) climatic seasons of the area. To this end, three (03) sites were defined on the coast of Grand-Bassam for the monitoring of this plastic waste. Subsequently, from March 2022 to October 2022, eight (08) sampling campaigns including two (02) per season, were conducted on a transect of 25 meters from each site. The results of the surveys on the beaches of Grand-Bassam indicate that the quantities of plastic waste vary from 2.67 kg (Site 2, Long Dry Season) to 9.8 kg (Site 3, Short Dry Season) for a transect of 25 meters. It appears that the composition of these plastics is largely dominated by polypropylene (PP) with 33.35% and low density polyethylene (LDPE) with 23.43% of the total quantity of plastic waste collected on the three (03) sites. The results of the test of variability (discriminant analysis) and statistical analysis (ANOVA test) indicate variability from one range to another and from one season to another.

Keywords:- *Waste, Grand-Bassam, beach, plastic, quantification, variability.*

I. INTRODUCTION

The extreme versatility, lightness and strength of plastics, combined with their affordability and ease of maintenance, make them a popular material for manufacturers and consumers (Adjalo, 2015; SEAS, 2021). Plastic has gradually become essential in all sectors including food; agriculture; construction; transportation (Traoré, 2018; Plasticseurope, 2019). However, this surge in plastic consumption has a cost for the environment (SEAS, 2021). Indeed, every minute it is the equivalent of a garbage truck of plastic waste that is dumped into the oceans (Ter and Perez, 2018; Anthony, 2019). As a result, fishing and tourism are disrupted and ecosystems and biodiversity continue to be threatened (Sarasamma *et al.*, 2020). In Côte d'Ivoire, plastic waste production was estimated at 437,476 tons in 2010 and will reach 613,200 tons in 2025 in the absence of an effective management strategy (UEMOA, 2013). Given the magnitude of the challenges of plastic pollution, particularly in the oceans, the Ivorian authorities have adopted strategies to manage and reduce these plastics through the Ministry of Environment and Sustainable Development, the Ministry of Hydraulics, Sanitation and Hygiene and the Ministry of Health, Hygiene and Universal Health Coverage. Thus, the decree number 2013-327 of May 22, 2013 banning the production, import, marketing, possession and use of plastic bags in Côte d'Ivoire is part of these strategies. The said decree in accordance with its article 3, aims at fighting against plastic pollution and promoting public health. However, this decree has proved difficult to apply, because of economic interests. Also, with regard to the specific case of the Ivorian coastline, one of the measures aimed at preserving coastal areas in Côte d'Ivoire is law number 378 of June 02, 2017 on the development, protection and integrated management of the Ivorian coastline. Despite the efforts made by state authorities, Ivorian beaches continue to be crowded with waste including plastic materials whose control escapes the control of public authorities. Grand-Bassam, a coastal town located in the southeast of Côte d'Ivoire, has beaches that unfortunately do not escape this situation (BNETD-DUDT, 2017). Indeed, visitors are constantly coming to Grand-Bassam because of its beautiful beaches and resorts built along its coastline. The latter leave considerable quantities of plastic materials on the beaches. The latter leave considerable quantities of plastic materials on the beaches. However, in the current context, the efficient management of plastic waste on the beaches depends on public policy choices, organizational choices, technological means, but also on a prior and precise knowledge in quantitative and qualitative terms of these plastic materials. In order to find solutions that are accepted by all stakeholders and to better sensitize citizens, this research proposes to monitor plastic waste on the beaches of Grand-Bassam according to climatic seasons.

II. MATERIAL AND METHODS

A. Site selection criteria

This study was conducted in Grand-Bassam, a city located in the southeast of Côte d'Ivoire, in the Comoé district, more precisely in the South Comoé region whose capital is Aboisso (Rakotomamon and Gandreau, 2015). A historic city with colonial architecture, Grand-Bassam has been a UNESCO World Heritage Site since 2012 (Koutoua and Kouakou, 2019). The city of Grand-Bassam is located 43.5 Km from Abidjan, the economic capital of Côte d'Ivoire between latitudes 5°12.000'N and 5°16.800'N and longitudes 3°40.800'W and 3°50.40'W (Fig. 1). The climate

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of the area is of the transitional equatorial type with four (4) well-marked seasons. In addition, the Grand-Bassam area is drained by the Comoé River and the Ebrié and Ouladine lagoons. Mangroves are concentrated around these lagoons thus ensuring several roles of ecological importance.

B. Site selection criteria

The criteria for selecting sites are free access to the beach and year-round accessibility by the team involved in the various plastic waste collection campaigns. Ideally, the site should not be a place where other collections are made. However, the areas chosen are touristy and heavily used by the public year-round. The length of time that these sites are not cleaned prior to the survey is known. In addition, the plastic waste survey is not expected to have any impact on protected or endangered species or sensitive coastal vegetation. On this basis, three (3) sites named S1, S2 and S3 were defined on the Grand-Bassam coastline (Fig. 1 and Plate 1). The first site (S1) is located at the beach of Saint-Cyr hotel (photo A). The second site (S2) is located at the beach of the South Star (photo B) and the third site (S3) is located at the beach of the fishermen village (photos C and D).

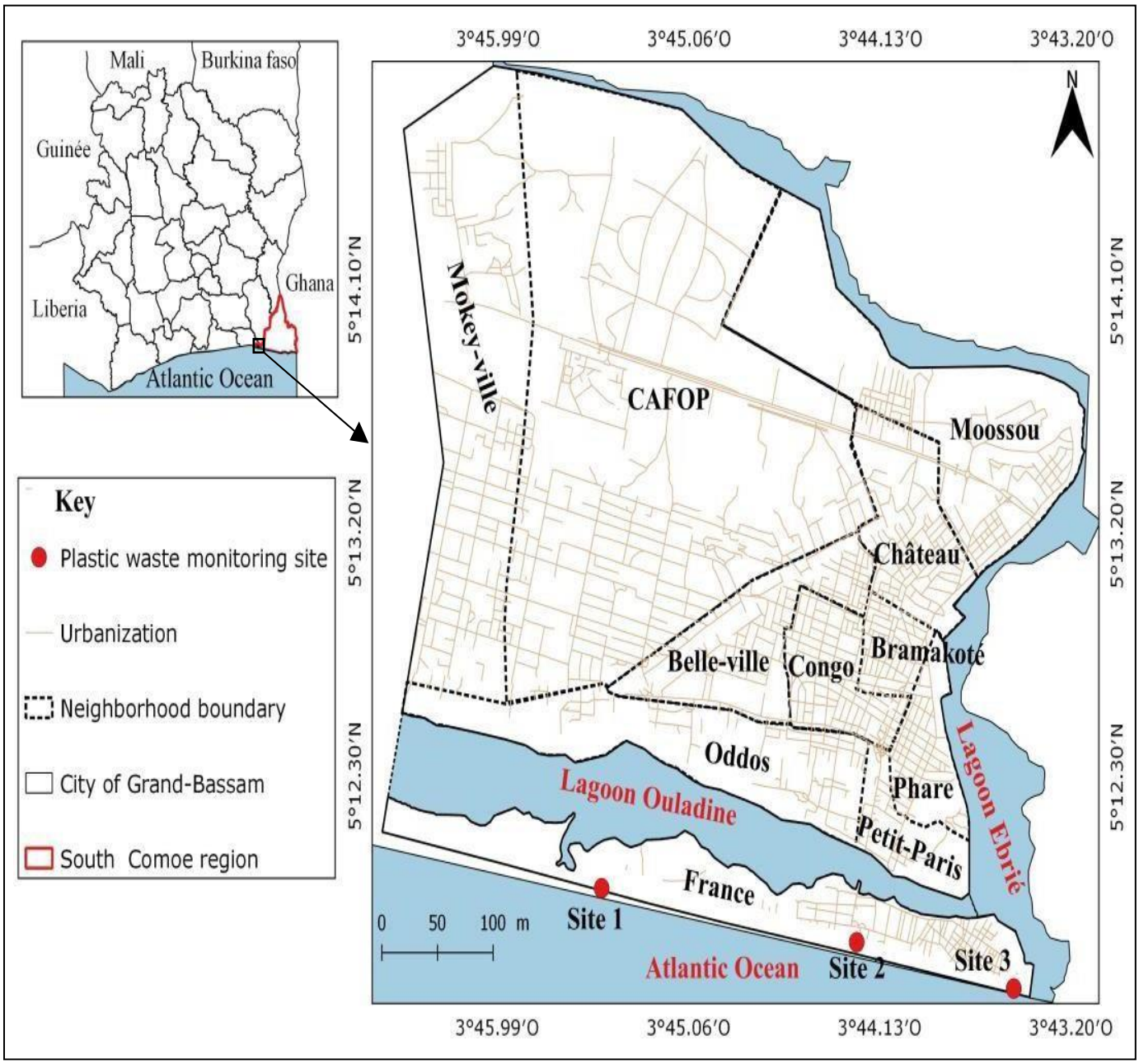

Fig. 1: Geographical location of the city of Grand-Bassam and location of plastic waste monitoring sites

(Source: Téya and al., 2022)

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Plate 1: Illustration of the three (03) beaches (sites) chosen for the monitoring of plastic waste on the Grand-Bassam coast (photo A= site 1; photo B= Site 2; photos C and D= Site 3)

(Source: Téya and al., 2022)

C. Frequency of readings

From March 2022 to October 2022, eight (08) sampling campaigns were conducted at the three (03) sites following the four (04) climatic seasons (big dry season, big rainy season, small dry season and small rainy season) of the study area. The quantity and composition of plastic waste deposited on the coastline can show strong variations according to the sites, seasons and characteristics. The campaigns covering the long dry season, the long rainy season, the short dry season and the short rainy season were conducted in March, April, September and October respectively, with two (2) campaigns per climatic season. The campaigns per season were conducted on Sundays and Mondays (early mornings between 6:00 and 7:00) in order to better take into account the contribution of tourists and the public who mostly visit the beaches on weekends.

D. Transect selection and characterization of plastic waste

Once the beach is selected, a 25-meter area (transect) representing the reference area for waste monitoring is delineated (photos A and B). This 25-meter transect is identified as representative of the site's plastic waste load. The selected area is examined from the shoreline to the top of the beach during each collection campaign. The collection is done using a "rake" and all anthropogenic waste found in the selected area is grouped, sorted by category and then weighed (photos C, D, E and F). The plastic waste was divided into seven (7) categories namely Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Polyethylene Terephthalate (PET), Polypropylene (PP), Polystyrene (PS) and others.

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Plate 2: Illustration of the plastic waste quantification campaign on the beaches of Grand-Bassam (photo A= Waste monitoring site; photo B= Transect measurement; photos C and D= Waste collection and grouping; photo E= Sorting by category; photo F= Waste weighing)

(Source: Téya and al., 2022)

E. Processing and analysis of quantification data

The processing and analysis of the data obtained during the quantification of plastic waste from the Grand-Bassam coastline made it possible to express the production and composition of said waste according to the sites and seasons. The hypotheses of normality of the data distribution and homogeneity were verified using the Shapiro-Wilk and Levene tests respectively. These tests showed that the data follow the normal distribution and that the samples have the same size. Subsequently, a statistical analysis, more precisely parametric ANOVA tests with 1 (one) factor (5% significance test), allowed us to decide on the significance of the variations observed at the level of production and a multivariate discriminant analysis called "step by step" ascending (5% significance test) allowed us to identify, among all the independent variables (composition), those that best discriminate the observations into classes. For the specific case of the productions, when the variables show a difference for $P < 0.05$ between groups (sites and seasons), Tukey's test is used for the two to two comparison. For this purpose, the R software, version R-4.1.2 was used with the installation of the "R Commander" package for parametric 1 (one) factor ANOVA tests and the Statistica software, version 10 was used for the discriminant analysis.

III. RESULTS

A. Seasonal production of anthropogenic waste on the beaches of Grand-Bassam

Fig. 2, presents the average seasonal mass production of anthropogenic waste on the beaches of Grand-Bassam. Overall, the quantities of anthropogenic waste on Grand-Bassam beaches range from 6.18 kg (Site 1, PSP) to 18.52 kg (Site 3, PSS) for a 25 meter transect. Regardless of the season, the minimum and maximum quantities of anthropogenic waste encountered on the beaches of Grand-Bassam are recorded respectively at Site 1 (S1) and Site 3 (S3).

Fig. 3 shows that the composition of anthropogenic waste on the beaches of Grand Bassam is largely dominated by plastic waste, which accounts for 45.63% of total production. It is followed by organic matter with 30.44%.

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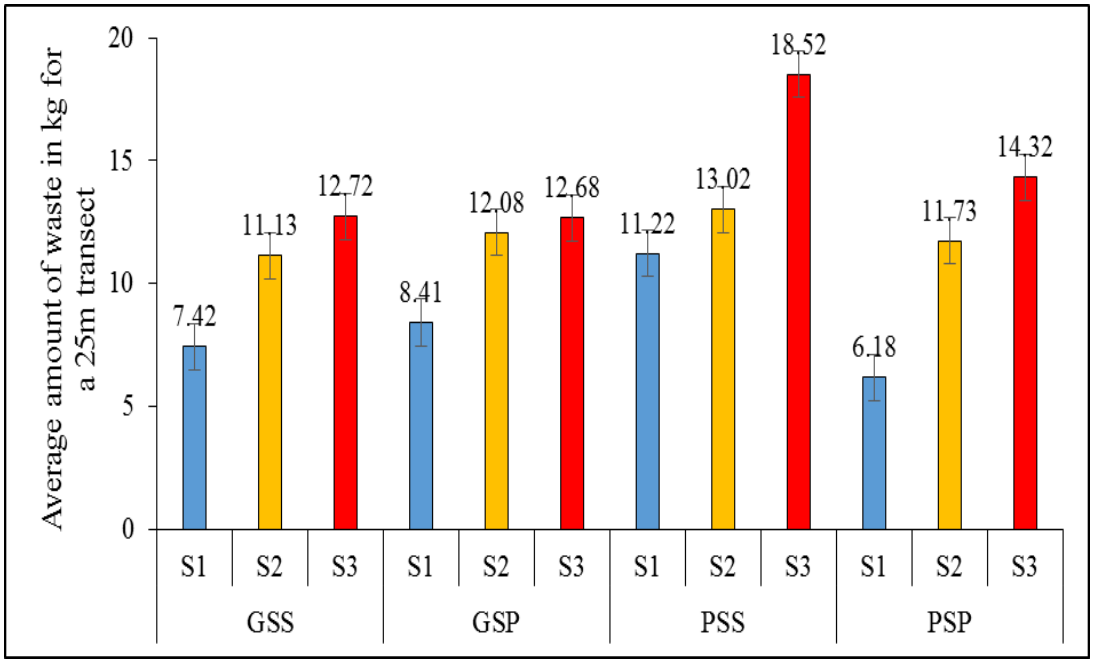

Fig. 2: Average seasonal mass production of anthropogenic waste on the beaches of Grand-Bassam
With GSS= Great Dry Season; GSP= Great Rainy Season; PSS= Little Dry Season; PSP= Little Rainy Season; S1= Site 1; S2= Site 2; S3= Site 3.

(Source: Téya and al., 2022)

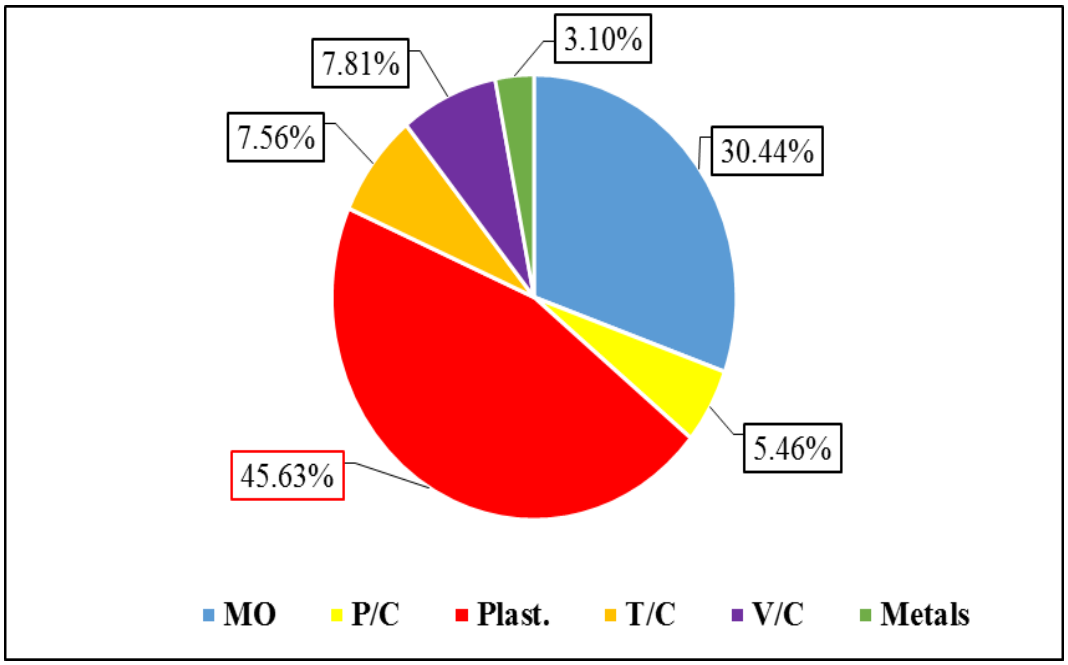

Fig. 3: General composition of anthropogenic waste on the beaches of Grand-Bassam
With: MO= Organic Matter; P/C= Paper/Cardboard; Plast. = Plastics; T/C= Fabrics/Leathers; V/C= Glass/Ceramics.

(Source: Téya and al., 2022)

B. Seasonal production of plastic waste on the beaches of Grand-Bassam

Figure 4 shows the average seasonal mass production of plastic waste on the beaches of Grand-Bassam. Overall, the amount of plastic waste on Grand-Bassam beaches varies from 2.67 kg (Site 2, GSS) to 9.8 kg (Site 3, PSS) for a 25 meter transect. During the long dry season, plastic waste varies from 2.67 kg (S2) to 5.58 kg (S3). In the long rainy season, it varies from 2.26 kg (S2) to 5.5 kg (S3). Considering the short dry season, the quantities of plastic waste on the beaches of Grand Bassam vary between 4.8 kg (S2) and 9.8 kg (S3). During the short rainy season, the waste varies from 3.51 kg (S2) to 8.79 kg (S3). Regardless of the season, the minimum and maximum quantities of plastic waste encountered on the beaches of Grand-Bassam are recorded respectively at site 1 (S1) and site 3 (S3).

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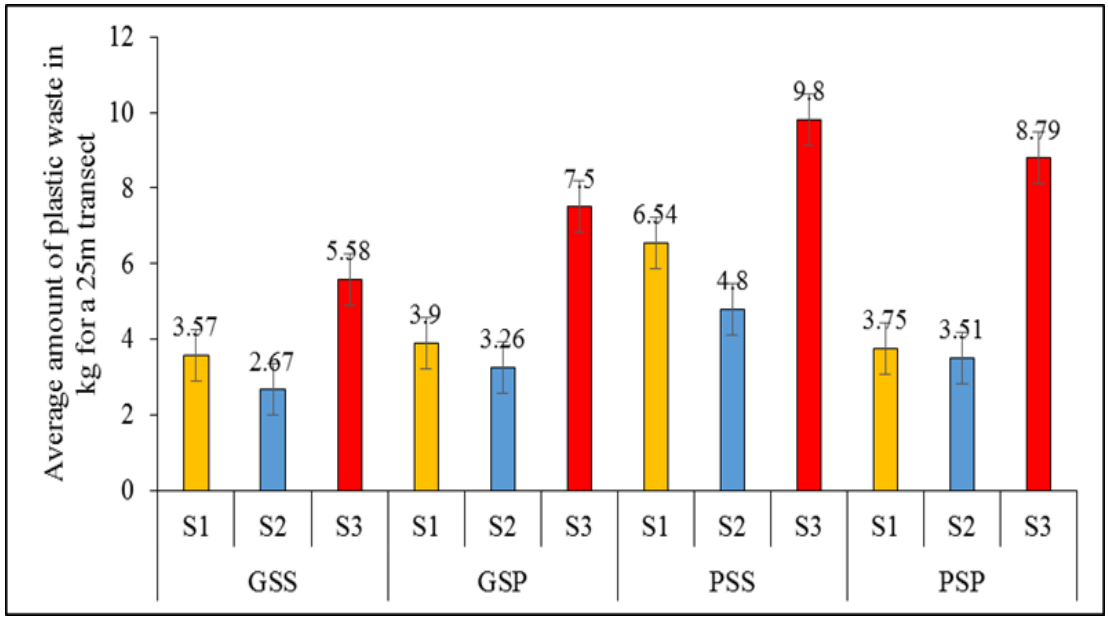
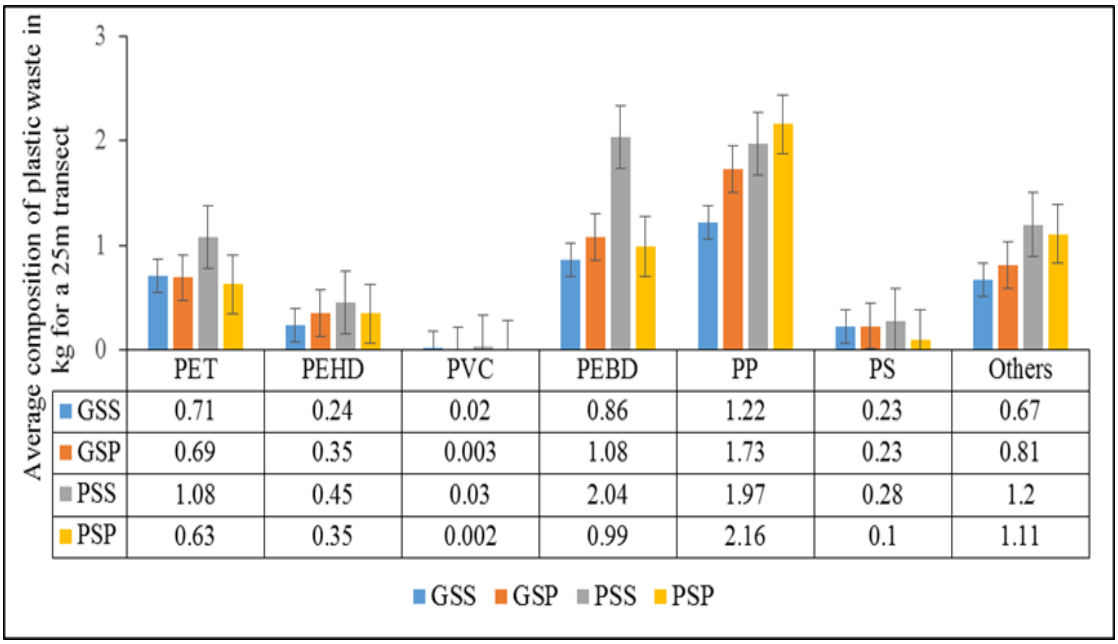


Fig. 4: Average seasonal mass production of plastic waste on the beaches of Grand-Bassam.
With GSS= Great Dry Season; GSP= Great Rainy Season; PSS= Little Dry Season; PSP= Little Rainy Season; S1= Site 1; S2= Site 2; S3= Site 3.

(Source: Téya and al., 2022)

C. Seasonal composition of plastic waste on the beaches of Grand-Bassam

Fig. 5 shows the average composition of plastic waste on the beaches of Grand Bassam according to the seasons for a 25 m transect. PET varies from 0.63 kg (PSP) to 1.08 kg (PSS). HDPE varies between 0.24 kg (GSS) and 0.45 kg (PSS). PVC varies from 0.002 kg (PSP) to 0.03 kg (PSS). As for LDPE, it varies between 0.86 kg (GSS) and 2.04 kg (PSS). As for PP, it varies from 1.22 kg (GSS) to 2.16 kg (PSP). The PS and other plastics for what concerns them, they oscillate respectively between 0.1 kg (PSP) and 0.28 kg (PSS) and between 0.67 kg (GSS) and 1.2 kg (PSS). Whatever the category of plastic waste considered, the largest quantities on the beaches of Grand-Bassam are observed during the short dry season except for polypropylene (PP).



	PET	PEHD	PVC	PEBD	PP	PS	Others
GSS	0.71	0.24	0.02	0.86	1.22	0.23	0.67
GSP	0.69	0.35	0.003	1.08	1.73	0.23	0.81
PSS	1.08	0.45	0.03	2.04	1.97	0.28	1.2
PSP	0.63	0.35	0.002	0.99	2.16	0.1	1.11

Fig. 5: Average seasonal composition of plastic waste on the beaches of Grand Bassam.
With GSS= Great Dry Season; GSP= Great Rainy Season; PSS= Little Dry Season; PSP= Little Rainy Season; PET= polyethylene terephthalate; HDPE= high density polyethylene; PVC= polyvinyl chloride; LDPE= low density polyethylene; PP= polypropylene; PS= polystyrene

(Source: Téya and al., 2022)

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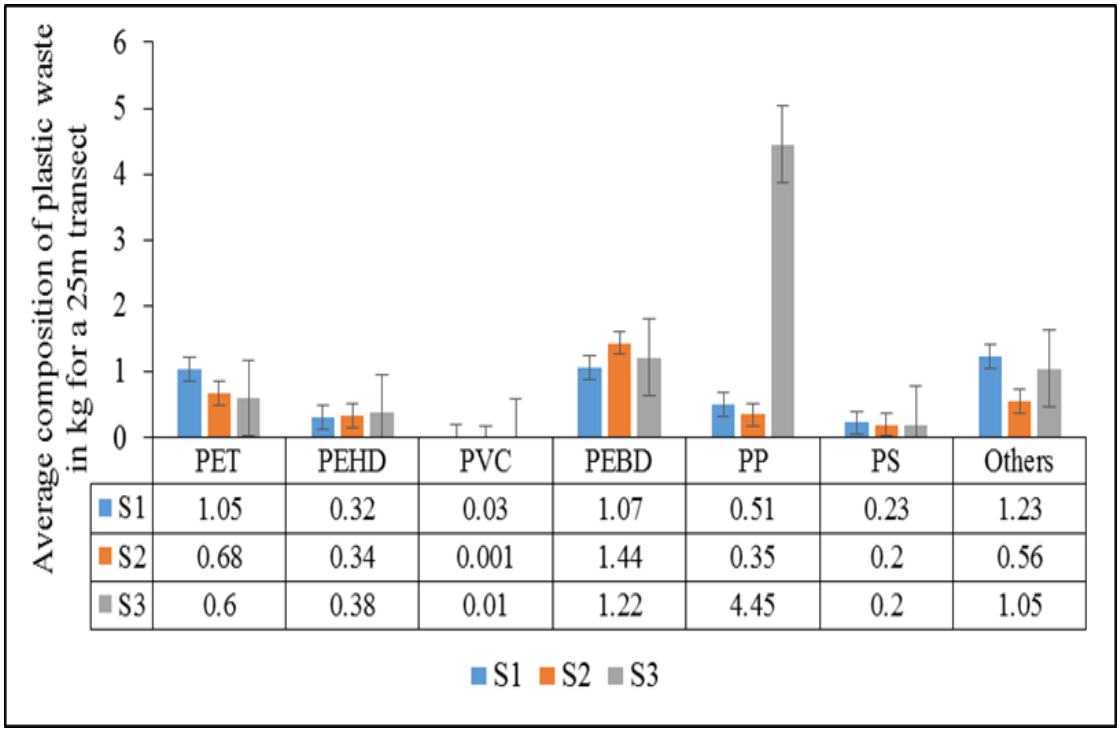
D. Spatial composition of plastic waste on the beaches of Grand-Bassam

Fig. 6 shows the average composition of anthropogenic waste on the beaches of Grand-Bassam according to the sites for a 25 m transect. Thus, polyethylene terephthalate (PET) ranges from 0.6 kg (S3) to 1.05 kg (S1). The high density polyethylene (HDPE) varies between 0.32 kg (S1) and 0.38 kg (S3). The polyvinyl chloride (PVC) for what concerns them varies from 0.001 kg (S2) to 0.03 kg (S1). As for the low density polyethylene (LDPE), it varies between 1.07 kg (S1) and 1.44 kg (S2). As for polypropylene (PP), it varies from 0.35 kg (S2) to 4.45 kg (S2). The polystyrene (PS) and other plastics for what concerns them, they oscillate respectively between 0.2 kg (S2 and S3) and 0.23 kg (S1) and between 0.56 kg (S2) and 1.23 kg (S1). Plastic categories such as polyethylene terephthalate (PET), polyvinyl chloride (PVC), polystyrene (PS) and other plastics are more concentrated at Site 1 (S1) while high density polyethylene (HDPE) and polypropylene (PP) are concentrated at Site 3 (S3). Only low density polyethylene (LDPE) is obtained in large quantities at site 2 (S2).



	PET	PEHD	PVC	PEBD	PP	PS	Others
S1	1.05	0.32	0.03	1.07	0.51	0.23	1.23
S2	0.68	0.34	0.001	1.44	0.35	0.2	0.56
S3	0.6	0.38	0.01	1.22	4.45	0.2	1.05

Fig. 6: Average spatial composition of plastic waste on the beaches of Grand Bassam.
With PET= polyethylene terephthalate; HDPE= high density polyethylene; PVC= polyvinyl chloride; LDPE= low density polyethylene; PP= polypropylene; PS= polystyrene; S1= Site 1; S2= Site 2; S3= Site 3.

(Source: Téya and al., 2022)

E. General composition of plastic waste on the beaches of Grand-Bassam

Fig. 7 presents the general composition of plastic waste from the beaches of Grand-Bassam. Thus, this composition is largely dominated by polypropylene (PP) and low density polyethylene (LDPE) with respectively 33.35% and 23.43% of the total production of plastic waste from the beaches of Grand-Bassam (photos A and B). They are followed by other plastics and polyethylene terephthalate (PET) with respectively 17.83% and 14.64% (photos C and D). As for high density polyethylene (HDPE) and polystyrene (PS), they represent respectively 6.52% and 3.97% of the total production of plastic waste from the beaches of Grand-Bassam (photos E and F). Polyvinyl chloride accounts for 0.26%.

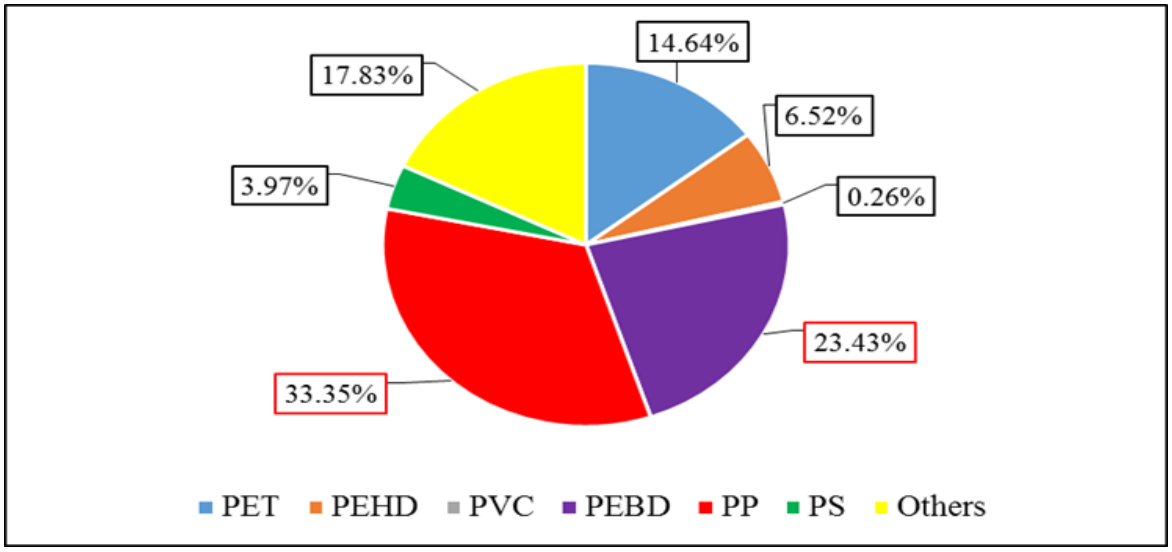


Fig. 7: General composition of plastic waste on the beaches of Grand-Bassam
With: PET= polyethylene terephthalate; HDPE= high density polyethylene; PVC= polyvinyl chloride; LDPE= low density polyethylene; PP= polypropylene; PS= polystyrene.

(Source: Téya and al., 2022)

Plate 3: Typology of plastic waste found on the beaches of Grand-Bassam (A= PP= polypropylene fishing net; B= LDPE= low density polyethylene; C= PET= polyethylene terephthalate; D= HDPE= high density polyethylene; E= other plastics and F= PS= polystyrene

(Source: Téya and al., 2022)

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F. Annual inter-site and inter-season variability of plastic waste production on the beaches of Grand-Bassam

Fig. 8 presents the annual inter-site and inter-season variability of plastic waste production on the beaches of Grand-Bassam. Thus, the production of plastic waste on the beaches of Grand-Bassam varies significantly (ANOVA, $p = 0.001 < 0.05$ and $F = 12.78$), from one site to another. In sum, according to the Tukey test, the production obtained at site 2 (3) is significantly different ($p < 0.05$) from those obtained at sites 1 and 2. On the other hand, no significant variation is observed between the productions observed at site 1 (S1) and site 2 (2). In addition, the ANOVA test reveals that there is no significant difference between the quantities of plastic waste according to the four seasons considered ($p = 0.24 > 0.05$ and $F= 1.66$).

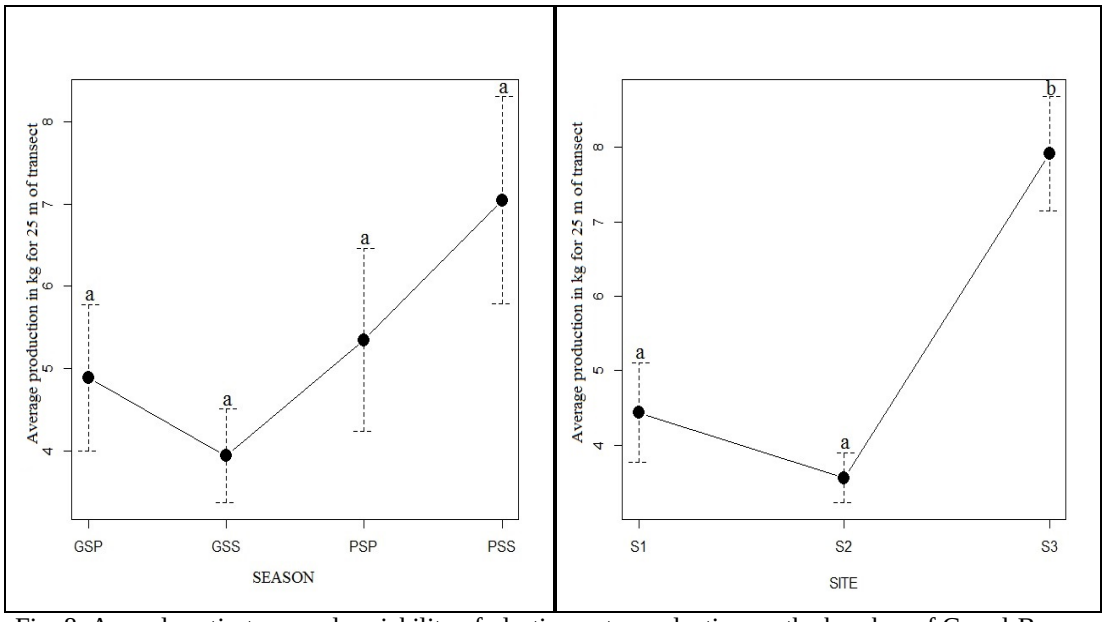

Fig. 8: Annual spatio-temporal variability of plastic waste production on the beaches of Grand-Bassam

Items sharing an alphabetical letter in common do not differ significantly (Tukey test, $p > 0.05$). *With: GSS= Great Dry Season; GSP= Great Rainy Season; PSS= Little Dry Season; PSP= Little Rainy Season; S1= Site 1; S2= Site 2; S3= Site 3.*

(Source: Téya and al., 2022)

G. Annual inter-seasonal intra-site variability of plastic waste production on the beaches of Grand-Bassam

The results of the ANOVA test show that except for site 1 (S1), the production of plastic waste on the beaches of Grand-Bassam varies significantly from one season to another (ANOVA, $p < 0.05$) (Table I). Indeed, Tukey's test reveals that the amount of plastic waste obtained at site 2 (S2) in the short dry season is significantly different ($p = 0.00034 < 0.05$) from that obtained in the long dry season, the long rainy season and the short rainy season. In addition, at site 3 (S3), Tukey's test reveals that the amount of plastic waste varies significantly ($p < 0.05$) between the long dry season and short rainy season and between the long dry season and short dry season.

(*In red = significant result; in green = non-significant result***)**

Parameters	**Intra-site**		
	S1	S2	S3
GSP	3.90^{a}	3.26^{a}	7.50^{ab}
GSS	3.57^{a}	2.67^{a}	5.58^{a}
PSP	3.75^{a}	3.51^{a}	8.79^{b}
PSS	6.54^{a}	4.80^{b}	9.80^{b}
F	1.48	13.8	25.13
P	**0.32**	**0.00034**	**0.0011**

Table 1*:* Inter-seasonal intra-site variability of plastic waste production on the beaches of Grand-Bassam

Items sharing an alphabetical letter in common do not differ significantly (Tukey test, p > 0.05). With: *GSS= Great Dry Season; GSP= Great Rainy Season; PSS= Little Dry Season; PSP= Little Rainy Season; S1= Site 1; S2= Site 2; S3= Site 3.*

(Source: Téya and al., 2022)

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H. Annual inter-site intra-season variability of plastic waste production on the beaches of Grand-Bassam

The results of the ANOVA test show that the production of plastic waste on the beaches of Grand-Bassam varies significantly between sites over the seasons (ANOVA, $p < 0.05$) (Table II). Clearly, Tukey's test reveals that except for the short dry season, the amount of plastic waste obtained at site 3 (3) is significantly different from that obtained at sites 1 and 3 over the seasons. On the other hand, no significant variation is observed between the productions observed at site 1 (S1) and site 2 (2) regardless of the season, which is not the case between site 2 (S2) and site 3 (S3).

(*In red = significant result*)

Parameters	**Intra-season**			
	GSP	GSS	PSP	PSS
S1	3.90^{a}	3.57^{a}	3.75^{a}	6.54^{ab}
S2	3.26^{a}	2.67^{a}	3.51^{a}	4.80^{a}
S3	7.50^{b}	5.58^{b}	8.79^{b}	9.80^{b}
F	31.66	73.78	79.75	6.48
P	0.003	0.00014	0.000058	0.031

Table 2*:* Inter-site intra-season variability of plastic waste production on the beaches of Grand-Bassam

Items sharing an alphabetical letter in common do not differ significantly (Tukey test, p > 0.05). With: *GSS= Great Dry Season; GSP= Great Rainy Season; PSS= Little Dry Season; PSP= Little Rainy Season; S1= Site 1; S2= Site 2; S3= Site 3.* (Source: Téya and al., 2022)

I. Inter-season and inter-site variability of plastic waste composition on the beaches of Grand-Bassam

The results of the discriminant analysis as presented by Table III show that the general composition of plastic waste on the beaches of Grand-Bassam does not vary significantly from one season to another (Discriminant Analysis, $p = 0.33 > 0.05$). Similarly, from one site to another, this general composition does not vary significantly (Discriminant Analysis) except for polypropylene (PP).

(In *green = non-significant result, in red = significant result*)

Parameters	**Inter-season (GSS, GSP, PSS, PSP)**	**Inter-site (S1, S2, S3)**
F	**2.07**	**27.57**
P	**0.33**	**0.015**
Categories	/	PP

Table 3: Results of the annual variability test (*Discriminant Analysis*) of beach plastic litter composition between seasons and between habitats

With: *GSS= Great Dry Season; GSP= Great Rainy Season; PSS= Little Dry Season; PSP= Little Rainy Season, S1= Site 1; S2= Site 2; S3= Site 3; PP= Polypropylene.*

(Source: Téya and al., 2022)

J. Inter-seasonal intra-site and inter-site intra-seasonal variability in the composition of plastic waste on the beaches of Grand-Bassam

The results of the discriminant analysis recorded in Table IV, show that the composition of plastic waste on the beaches of Grand-Bassam varies significantly between seasons for sites 1 and 3 (Discriminant Analysis, $p < 0.05$) but not for site 2 (Discriminant Analysis, $p > 0.05$). If at site 1 (S1), polyethylene terephthalate (PET) that differed significantly from one season to the next; at site 3 (S3), however, it was low-density polyethylene (LDPE), polystyrene (PS) and other plastics that differed significantly from one season to the next. In addition, the composition of this plastic waste varies significantly within the same season, from one site to another (Discriminant analysis, $p < 0.05$). In the long dry season, low density polyethylene (LDPE) and polypropylene (PP) differed significantly from one site to another; in the long wet season, polypropylene (PP) and polystyrene (PS) differed significantly from one site to another. For the short dry season, only polypropylene (PP) differs significantly from one site to another. Finally, for the short rainy season, polypropylene (PP) and other plastics differed significantly between sites.

(In green= non-significant result, in red = significant result)

Parameters	INTER-SEASON (GSS, GSP, PSS, PSP)			INTER-SITE (S1, S2, S3)			
	S1	S2	S3	GSS	GSP	PSS	PSP
F	8.47	1.99	36.95	41.01	50.5	68.01	30.44
P	0.02	0.32	0.0002	0.001	0.0006	0.0004	0.01
Categories	PET	/	LDPE PS Other	PEBD PP	PP PS	PP	PP Other

Table 4: Results of the test of variability (*Discriminant Analysis*) within site and within season of the weight composition of plastic waste on the beaches of Grand-Bassam

With: *GSS= Great Dry Season; GSP= Great Rainy Season; PSS= Little Dry Season; PSP= Little Rainy Season, S1= Site 1; S2= Site 2; S3= Site 3; PET= Polyethylene Terephthalate; LDPE= Low Density Polyethylene; PS= Polystyrene; PP= Polypropylene.*

(Source: Téya and al., 2022)

IV. DISCUSSION

The characterization campaigns allowed us to have an indication of the quantities of anthropic waste present at the three (3) selected sites on the beaches of Grand-Bassam. The data obtained showed that on a 25 m long stretch of beach, the quantity of waste collected was about 11.62 kg. The highest abundance of waste on the beaches of Grand-Bassam is recorded in the short dry season (14.25 kg) for the seasons and on-site 3 (14.57 kg) for the sites. The large quantities of waste obtained during the short dry season on the one hand, and on-site 3 on the other, could be explained by the vacations and the site 3, transformed almost into a dumping ground. Indeed, the collection period corresponding to the short dry season took place in the first week of September. During this period, which determines the end of the vacations, the beaches are crowded with people who come from all over to have fun before the start of the new season. All this is accompanied by a production of anthropic waste on the beaches. As for site 3, due to its geographical position, it receives in addition to the waste produced by beach visitors, solid waste from the fishing village. This actively contributes to the volume of waste generated on the site. The survey of the four (04) seasons has shown the preponderance of plastic materials on all the beaches. Specifically, plastic waste represents 45.63% of the total production of anthropogenic waste on the beaches of Grand-Bassam. This predominance of plastics on the beaches is not typical of Grand-Bassam in that it is also observed by Chaouch et al. (2007) on the beaches of Annaba (Algeria), Basilico et al. (2019) on the beaches of Mayotte and Dzaoudzi (France), and AND (2020) on the beaches of Jijel, Ain Temouchent and Tipaza (Algeria). However, the rate of plastic material obtained on the beaches of Grand Bassam is higher than that found by Chaouch et al. (2007) and lower than that found by Basilico et al. (2019) and AND, (2020). These authors indicate respectively a rate of 14.17 %, 83% and 87 %. The main sources of plastic waste encountered at the sites would be coastal landfills, settlements, sewage system, fishermen. Beach users also leave considerable amounts of waste on the shore. In addition, plastic waste is discarded by people living near the beaches. The amount and composition of plastic waste deposited on the beaches of Grand-Bassam show strong variations across sites, seasons, and characteristics (ANOVA test, $p > 0.05$ and discriminant analysis). These seasonal and spatial fluctuations were also observed by Pieper et al. (2015) on the beaches of Porto Pim (Portugal). However, the composition is largely dominated by polypropylene (PP) and low density polyethylene (LDPE) with 33.35% and 23.43% of the total amount of plastic waste collected on the beaches of Grand-Bassam, respectively. The predominance of polypropylene (PP) could be explained by the fishermen installed on site 3. These fishermen regularly abandon their nets that have become defective. These nets, which are mostly made of polypropylene (PP), weigh up to eight (08) kg. The results corroborate those of Sciacca et al. (2016) on the beaches of Tristan da Cunha (Great Britain) and Hawaii (United States). This author indicates proportions of PP ranging from 31 to 47%. In addition, the predominance of low-density polyethylene (LDPE) would be explained by the large participation of tourists and the public who frequent regularly the beaches of Grand-Bassam. For as Zerowaste (2018) argues, the plastic materials abandoned by tourists and the public are mainly composed of Low Density Polyethylene (LDPE). The National Waste Agency in 2020 in its report on the characterization of coastal waste argues that the main sources of waste on the beaches are tourism. It adds that 86% of the waste found on the beaches comes from tourists. For the Institut Veolia (2019), plastic waste encountered in the oceans is composed of more than 50% of packaging. However, the results contradict those of EDA (2020) which indicate that high density polyethylene (HDPE) plastics are most abundant on the beaches of Jijel, Ain Temouchent and Tipaza in Algeria.

V. CONCLUSION

Results from the Grand-Bassam beach surveys indicate that the quantities of waste vary from 6.18 kg (Site 1, PSP) to 18.52 kg (Site 3, PSS) for a 25 meter transect. Plastic waste represents 45.63% of the total waste collected on the beaches. This plastic waste varies from 2.67 kg (Site 2, GSS) to 9.8 kg (Site 3, PSS) for a 25 meter transect. It

appears that the composition of these plastics is largely dominated by polypropylene (PP) with 33.35% and low density polyethylene (LDPE) with 23.43% of the total production of plastic waste on the beaches of Grand-Bassam. The data thus obtained constitute a basis for the public authorities to develop a management system that guarantees the minimum impact on the environment and public health. Indeed, one of the root causes of the accumulation of plastic waste on beaches is the linear use of resources from their production to their final disposal, through their single and short term use. The main measures to manage this waste should focus, on raising awareness among consumers, citizens and tourists but also on the full implementation of circular economy programs in this case the promotion of eco-design and/or policies to significantly reduce the use of these plastics.

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