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Title: Metals and Metalloids concentrations in three genotypes of pelagic *Sargassum* at the Atlantic Ocean Basin scale

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Running title (5 words): Morphotypes, Arsenic, *S. natans, S. fluitans,* Caribbean Sea

Abstract

Since 2011 in Caribbean Islands have witnessed unprecedented massive strandings of a pelagic brown algal *Sargassum* spp. that have damaged coastal ecosystems and disrupted the economy.

Brown algae have a high capacity to concentrate heavy metal contaminants. Through accumulation of heavy metals during their journey, floating Sargassum can play a role in contaminant transfer from off-shore to the coast. In July and August 2019, three genotypes of *Sargassum* (*S. fluitans* III, *S. natans* I and *S. natans* VIII) were sampled in seven stations regularly spaced along a 3400 km transect from the middle of the Atlantic Ocean to the Guadeloupe islands (French West Indies). For each of the 72 samples of *Sargassum*, concentrations of 15 heavy metal(loid)s elements were analyzed by Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). Mean metal concentrations in all morphotypes and stations were ranked in the following descending order: As > Fe > Al > Mn > Cd > Zn > Ni > V > Cu > Cr > Hg. The metalloids As was the most abundant contaminant in all our samples with a mean concentration of As is 92.72 ~~µg.g^{-1}~~ ppm and an maximum value of 115 ~~µg. g^{-1}~~ ppm which is accordance with concentrations previously observed in the Caribbean area (80-150 ppm). Those value are above different maximum safety level and strategies proposed for valorization of Sargassum should consider this content As contamination levels to avoid environmental and health issues. At the scale of the Atlantic Ocean, metallic element concentration do not present spatial longitudinal gradient. Genotypes of *Sargassum* present different metal(loids) contamination distinct patterns observed with distinction between S. *fluitans* III and the two genotypes of *S. natans* (I and VIII).

I Introduction

Sargassum is one of the most diverse genera of brown algae, with more than 350 species described (Guiry and Guiry, 2022). Among this genus, only two historically-defined species are strictly holopelagic (floating) during their entire life cycle, and forming rafts in the Atlantic Ocean: *Sargassum fluitans* and *Sargassum natans* (Parr, 1939; Stoner, 1983). Recently organellar genomic sequencing has differentiated morphotypes of *S. fluitans* III from *S. natans* IV and VIII (Amaral-Zettler et al., 2017). The presence of Sargassum seaweed in the Atlantic Ocean was reported in the 15th century by Christophe Columbus and in the middle of 19th century by the German merchant marine (Gower and King, 2011). The distribution of *Sargassum* was historically limited to the Sargasso Sea, the eastern edge of Gulf Mexico and to the Azores islands (Lapointe, 1995). An increase in its distribution range was recently detected though satellite imaging detection including the western Atlantic tropical region and the South America from the northeastern Brazil to the Caribbean islands (Gower et al., 2013; Guiry et al., 2014). The role played by oceans surface currents in controlling the distribution and stranding of *Sargassum* algae on shorelines still remains unclear (Coston-Clements et al., 1991). Pelagic *Sargassum* have begun blooming in the North Equatorial Recirculation Region (NERR), and with the wind (driven Langmuir-circulation) (Rhyter,1956) and ocean currents (Loop current and Gulf Stream), are transported throughout the North the Atlantic Ocean, to the Sargasso Sea, Gulf of Mexico and Caribbean Sea (Johnson et al., 2013; Wang et al., 2019). Sargassum rafts provides an essential ecosystem habitat and refuge for different marine organisms (Ross and Casazza, 2008; Witherington et al., 2012) and notably for marine species of high economic importance (Hu et al., 2016; Lapointe et al., 2014).

For the first time in the summer 2011, for the first time unprecedented massive quantities of *Sargassum* spp. stranded in the eastern Caribbean Islands and in the islands of the lesser Antilles (Franks et al., 2011; Gower et al., 2013). Pelagic Sargassum were also reported in some places where they were never previously spotted such as north eastern Brazil (Széchy et al., 2012). A recurrent Great Atlantic *Sargassum* Belt in the NERR is now being reported annually by the Moderate Resolution Imaging Spectro- radiometer (MODIS), this belt extend over Atlantic Ocean to the Caribbean Sea (Wang et al., 2019). In 2018 it extended over 8850km and carried more than and estimated 20 million metric tons of *Sargassum* wet biomass (Wang et al., 2019). The stranding of *Sargassum* algae on the coast created important environmental impacts threatening endangered species such as sea turtles (Casazza and Ross, 2008; Maurer et al., 2015) and leading to the disappearance of seagrass ecosystems at large spatial scales (Rodríguez-Martínez et al., 2019). *Sargassum* stranding also impact principal economic sources of most coast through tourism, re-stricting harbors and fisheries (Langin, 2018). Stranded *Sargassum* also presents important human health issues: respiratory disease, neurological problems, and cardiovascular lesions (Resiere et al., 2018). In addition to those visible effects, stranding of the brown algae could also present pernicious and invisible impacts as they present the ability to concentrate heavy metals from their environment (Volesky and Holan, 1995) and could consequently release those contaminants in stranding areas. Holopelagic *Sargassum* spp. are indeed known to present high levels of inorganic arsenic (Dassié et al., 2021; Devault et al., 2020). The high metal absorption capacity of *Sargassum* is due to alginate present in cells walls with a high metallic affinity (Davis et al., 1999; Vieira and Volesky, 2000).

A previous study provided an evaluation of metallic concentrations in an undifferentiated mixture of three morphotypes of *Sargassum* spp. from a transect to the middle of Atlantic Ocean to the lesser Antilles (Martinique) (Dassié et al., 2021). This approach can mask specific trends in morphotype contamination as closely related species of the same genus can present different abilities to absorb metal contaminants (Foster, 1976; Romera et al., 2007).

The present study measured the metallic contamination (14 different elements) in each of the three recognized *Sargassum* genotypes: *S. natans* I, *S. natans* VIII, *S. fluitans* III, in seven sampling stations, along a 3600 km transect extending from the middle of the Atlantic Ocean (open sea) to the Guadeloupe islands (French West Indies).

II Study Methodology

II.1 Study sites

From July to August 2019, 72 samples of *Sargassum* were collected from seven different stations during the RV *Pelagia* sargasso cruise PE-455 NIOZ (Royal Netherlands Institute for Sea Research). The expedition stretched from the middle of Atlantic Ocean to the Guadeloupe Islands (French West Indies) (Fig.1). In this region *Sargassum* spp. are frequently present from the Eastern edge of the Gulf Stream as far as the Azores and to the Atlantic Ocean (Gower et al., 2013).

II.2 Fields collection

During the cruise, the three genotypes of *Sargassum* algae were regularly sampled when algae were available and the weather conditions were favorable. Fresh *Sargassum* were collected manually from a small boat using a net from the surface to 5m depth using a net. After collection, the samples were separated by genotypes: *S. fluitans* III, *S. natans* I and *S. natans* VIII (Amaral-Zettler et al., 2017; Oyesiku and Egunyomi, 2014; Schell et al., 2015) and 40 to 80 g wet weight of each morphotype was washed with fresh water, placed in paper wraps and introduced into a oven-dried for 48 h at 50°C. Back in the laboratory, samples were homogenized using a vibro-grinder with metallic balls of 5mm (Retsch® MM 400).

II.3 Heavy metals analyses

The concentrations of 15 elements (Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, Sr V, Zn and Hg), were analyzed using an Inductively Coupled Plasma Optical Emission Spectrometer (Spectrometer ICP-OES 700®, Agilent Technologies). For each sample, a fixed amount of algal powder (70-80mg) was placed in a plastic tube closed with 1 mL of nitric acid (HNO3 67%) was added. The powder sample was then mineralized for 3 h at 100°C (Environmental – EXPRESS HotBlock® - 54). After mineralization, 5 mL of deionized water was added to each sample. With the same process, we analyzed the certified reference materials (DOLT-5, TORT-3, IAEA-413). For Hg, approximately 15 mg of each sample was analyzed by using flameless atomic absorption spectrometry (AMA 254, SYMALAB, France). With the same process, we analyzed certified reference materials (IAEA-407). The results of metal concentrations in *Sargassum* samples are expressed in µg.g^{-1} (ppm) dry weight. Hg concentrations were only measured in stations 1, 5 and 6.

II.4 Data analyses

The variance and the homogeneity in each sample were verified by the Shapiro's and Level' tests (with significance at the 95 % confidence level). Difference between means in elements concentrations of each sample species and the difference in concentration of metals elements between each species and genotype were tested using the non-parametric test Kruskal-Wallis test.

Methods of multivariate statistics with Principal Component Analyses (PCA) were executed on RStudio® and RCran, using following the packages: FactoMiner (Husson et al., 2020), factoextra (Kassambara and Mundt, 2020), ggplot (Wickham et al., 2020) and corrplot (Wei et al., 2021) in order to visualize the 15 elements (Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, Sr V, Zn and Hg), and select metallic elements with higher influence in data structuration. From PCA, temporal fluctuation of four principal elements (Al, As, Cu, Fe) were presented whereas metallic elements (Co, Pb, Se, Sr and Hg) below the limit of detection (LOD) were not presented.

III Results

Among the fourteen elements analyzed in *Sargassum* tissues, eight elements (Al, As, Cr, Fe, Mn, Ni, V, and Zn) were the most frequent elements encountered and they were detected in 100% in the samples and above the limit of detection (LOD). Cd and Cu were detected in 87.7 % and 87.2% of samples respectively. The elements Co, Sr, and Pb were below the LOD.

Metal classed according to decreasing concentration in all samples including all stations and all morphotypes were: As > Fe > Al > Mn > Cd > Zn > Ni > V > Cu > Cr > Hg. Among all non-essential elements, As and Hg were the most and the least abundant elements respectively.

We used Principal Component Analysis (PCA) to determine the influence of metallic elemental concentrations at the basin spatial scale and between the three *Sargassum* types (Figure 2). We focused on the first two dimensions of PCA for the interpretation. The first principal component

(PC1) revealed 28.1% of the total variance and the second, 19.4% (PC2) of the total variance. PC1 distinctly discriminated the variables Fe (30.7%), Al (17.1%) and the As (9.6%), and PC2 clearly discriminated the variables Mn (0.6%) and Ni (0.5%).

The PCA analysis showed the two genotypes *S. natans* I and *S. natans* VIII, were characterized by high concentrations of As whereas *S. fluitans* III was more characterized by higher Al and V (Figure 2.A) concentrations.

The PCA analysis of *Sargassum* by the station showed an absence of any tendency for spatial preference, as stations are grouped together independently of their geographical origins. The Station 6 is separated from the others stations and more influenced by Cd, Zn, Ni and Cr (Figure 2.B).

Five metallic elements stand out in our PCA analyses: Fe (86%), Al (48%), V (37%), and As (27%).

There was significantly more As in *S. natans* VIII than in others two genotypes in all stations (Kruskal-Wallis test p-value < 0.05). There was significantly less Fe and Al (Kruskal-Wallis test p-value < 0.05) in the morphotype *S. natans* VIII than in two others genotypes in four of the stations (Figure 2.A).

IV Discussion

The present study constitutes a first assessment of metallic and metalloid concentrations in *S. natans* I, *S. natans* VIII and *S. fluitans* III along a transect at the Atlantic Ocean basin scale.

Analyses, revealed that contamination by metallic elements *i)* the metalloid As and the metallic element Fe is the most abundant in the three genotypes of *Sargassum* *ii)* did not present a longitudinal gradient, and *iii)* were significantly different between the three genotypes of holopelagic *Sargassum*.

Methodological considerations

Holopelagic *Sargassum* spp. are naturally covered by calcareous epifauna: bryozoans, tube-forming polychaetes, and crustose coralline algae (Weis, 1968). Calcareous material can increase or decrease chemical elements absorption (Huffard et al., 2014). In our samples epifauna was rare. Moreover, algae without visible epifauna were preferentially selected in order to limit potential bias due to epifauna in collected samples.

The concentrations of metallic elements vary in leaves, stems, and air bladders of *Sargassum* (Sadeghi et al., 2014). In our samples the entire algae biomass was dried and ground before being analyzed without separating each tissue type. The respective abundances of each tissue can change naturally according to seasons, water temperature and location (Critchley, 1983). Observed variations in contamination can be due to variation of respective abundance of each tissue more than to variation of environmental contamination. The sampling strategy was chosen in order to have a general overview of metallic contamination of *Sargassum* but this potential bias must be kept in mind when interpreting our result.

Metal and Metalloid: As and Fe

As, is a metal(loid) present naturally in the open and coastal marine environment, at a concentration level of 15 and 25nM as hydrogen arsenate (Fattorini et al., 2006). Only certain forms of As can be toxic, as inorganic forms presents higher toxicity than the organic forms (trivalent state As III and the pentavalent state As V) (Yuan et al., 2007, Circuncisao et al., 2018). In our study, the metalloid element As was the most present element in all samples. Dissolved As is the most largely, rapidly and greatly absorbed dissolved metalloid compared to other metalloids (Penrose, 1974; Neff et al., 1997). For *Sargassum*, most experimental studies conclude that As is the most commonly present metal(loid) (Dassié et al., 2021; Devault et al., 2021, 2020).

In the present study, the mean concentration of As was 92.72 μg.g^{-1} in all samples with a maximum value of 115 μg. g^{-1}. Those values are in the range of values previously observed in the Caribbean area with As level fluctuating between 80 and 150 ppm in coastal waters (Dawczynski et al., 2007; García-Sartal, 2012; Rodríguez-Martínez et al., 2020), and in the open ocean between 0.1 and 382 μg.g^{-1} (Dassié et al., 2021). For all others elements, *Sargassum* concentrations were below the French standard limit for the enrichment of organic soil product, but higher than the fixed French norm of 18 ~~μg. g^{-1}~~ ppm for the As (NFU 44-051- ISSN 0335-3931). As was also above the maximum level (~40 ~~μg. g^{-1}~~ ppm) established in Europe for seaweed derived food products and material derived from seaweed utilization (European Commission, 2019), and above the limits recommended for agricultural soils in others countries (Rodríguez-Martínez et al., 2020). In 2017, this elevated As led ANSES (France's Food Safety Agency) to exclude the use of *Sargassum* spp. for food (humans and animals) in the Caribbean area (ANSES 2017).

A general trend observed across all samples was the difference between concentrations of As and Fe. This difference was not observed in *Sargassum* from the open-ocean Atlantic (Dassié et al., 2021). The organic form of the iron (Fe) is an essential micronutrients in the marine environment (Gledhiir and Buck, 2012). Fe is the fourth most abundant element on Earth and but its concentration in sea water is very low (Johnson et al., 1997; Liu and Millero, 2002). Experiments revealed that increasing the concentration in inorganic As would present a negative influence in the variation of the Fe in *Sargassum patens* due to the action of phosphate transporters (Mamun et al., 2019).

The concentration of As detected in this study was higher in *S. natans* VIII, than in the two others forms. The composition of holopelagic *Sargassum* forms has changed over time since in the 1930s, only *S. natans* I and *S. fluitans* III were the most abundant forms (Parr, 1939) but since 2014, the rare form *S. natans* VIII became more abundant (Schell et al., 2015) and was shown to also be genetically distinct from *S. natans* IV (Amaral-Zettler et al., 2017). The dominance of this genotype presenting the highest concentration of As will hamper its utilization and must be taken into consideration for a future valorization of *Sargassum* spp., which hamper their utilization. The metalloid As is present in coastal and open ocean, with higher concentration in some location. Consequently, management strategies must consider this constant As contamination.

Spatial considerations

Present results reveal an absence of a contamination trend associated with samples locations. This absence of longitudinal gradient of metallic contamination could be linked with the pelagic nature of Sargassum. At the scale of the Atlantic Ocean Basin, *Sargassum* are in perpetual motion, and actually their precise movements and trajectories still remains unclear. Satellite images proves high variability in the distribution of *Sargassum* according to the time and the current (Gower et al., 2013; Gower and King, 2011). Undrogued Stokes drifters (USD) buoys were shown to represent the drifting of *Sargassum* with respect to current shear (Haza et al., 2008; Laxague et al., 2018) and wave-driven stokes (Fraser et al., 2018). In order to understand the role of surface currents in *Sargassum* movements, stoke drifter were launched during our sampling cruise and allowed determination of minimum, average and maximum speeds of *Sargassum* in this area during this period (July-August 2019) representing respectively 0.081, 0.32 and 0.46 $m.s^{-1}$ (van Sebille et al., 2021). According to those measurements, minimum, average and maximum time needed to travel between the two nearest stations (stations 3 and 4), would be respectively 11, 16 and 65 days respectively. An experimental study carried out over on 40 days revealed that the absorption of metals elements by the benthic *Sargassum thunbergii*, is clearly noticeable after ≥3 days (Wu et al., 2010).

The absence of spatial gradient could also be explained by a scenario of a rapid renewal of *Sargassum* biomass. *Sargassum* clumps and rafts move rapidly, making the measurement of their biomass and the evaluation of their production difficult (Wang and Hu, 2021). However, the strong seasonality in aggregation of *Sargassum* slicks (Oviatt et al., 2019) and rapid blooms implies that production could be important. In this context of rapid renewal, *Sargassum* would not have time to accumulate metals during their transportation and would consequently present a constant contamination. As a result, abundances of metal elements would not increase in *Sargassum* along their journey in the Atlantic due to *i)* a relatively slow motion of algae at basin scale *ii)* a short absorption time of metallic element *iii)* a relatively rapid renewal of *Sargassum* biomass.

A similar transect in the open ocean Atlantic (from the center of the Atlantic Ocean to the coast of Martinique) also revealed an absence of a longitudinal gradient of concentration in metallic elements in *Sargassum* (Dassié et al., 2021). Similarly, a coastal study also highlighted an absence of a longitudinal gradient of concentration in metallic elements during the journey of *Sargassum* from the South to the North coast of Mexico (Rodríguez-Martínez et al., 2020).

Despite the absence of a longitudinal gradient of metallic concentration at Atlantic basin scale, several of our stations periodically presented higher As concentration. In Stations 3, high As levels might be explained by the close proximity with the mid-Atlantic ridge emitting metallic elements (Mitra et al., 1994). Higher As concentrations in the stations closet to the coast, like Station 7 was previously observed (Dassié et al., 2021) and could be linked with metallic elements from anthropogenic activities (Breuer and Pichler, 2013) or coastal volcanic activities (Fernandez et al., 2007). Similarly, *Sargassum* arriving close to the coast are known to integrate components with terrestrial origin such as the Chlordecone pesticide (Devault et al., 2021).

This absence of a longitudinal gradient of metallic elements concentrations, highlights that the Sargassum which runs aground along the coast of the Caribbean islands, doesn't have a particular contamination specificity allowing a similar management and permitting a standardized treatment in the Caribbean area in the future.

Pelagic *Sargassum*: the three genotypes

Metallic compositions differ between the three forms of *Sargassum* that also represent closely related but distinct genotypes on the genomic level. The morphotype *S. natans* VIII presented higher metalloid As concentrations and lower Fe concentration than *S. natans* I and *S. fluitans* III. An opposite trend was previously observed with highest As content in *S. natans* I and lowest in *S. natans* VIII (Davis et al., 2021). Observed As contents fluctuating from 20 to 231 ~~µg. g^{-1}~~ ppm, were in the range of value for those morphotypes (Milledge and Harvey, 2016; Milledge et al., 2020).

The absorption of metal and metalloid elements can be influenced by the morphological fractal structure of brown algae presenting a higher area-to-volume ratio increasing potentials attachment and entrance of metals (Torresi et al., 2017; Woignier et al., 2011). The morphotype *S. natans* VIII does not have thorns on its stem and presents a structure less complex with fewer interstitial spaces and larger leaves (Schell et al., 2015). Despite this lower area-to-volume ratio of *S. natans* VIII, the present study did not reveal lower concentrations of metals in this morphotype than in the two others. If structural morphology was the only parameter influencing metals concentration in *Sargassum*, the trend would be similar for all metals and they would all present a lower abundance in *S. natans* VIII. That was not the case for the metalloid As, therefore aspects other than morphological structure must consequently influence concentrations of metallic elements.

The chemical composition of morphotypes can influence metal concentrations. Cell walls of brown algae are characterized by the presence of phycolloid elements (Khotimchenko et al., 2001). These phycolloid compounds are involved in several chemicals mechanisms like ion entrapment in polysaccharide networks increasing the absorption capacity of metal elements (Volesky and Holan, 1995; Zeraatkar et al., 2016). According to brown seaweed species, abundance of phycolloids can change and can influence the ability to absorb metallic elements (Davis et al., 1999; Fourest and Volesky, 1997; Haug et al., 1966). The morphotype *S. natans* VIII contains higher abundance of phycolloids components than the others (Davis et al., 2021). These singular chemical compositions could explain the better absorption of metalloid As by *S. natans* VIII than by *S. natans* I and *S. fluitans* III.

Genotype encompasses phenotypic characteristics such as morphology and physiology. Morphotypes of holopelagic *Sargassum* are genetically distinct but closely related (Amaral-Zettler et al., 2017). In the present study, each species was characterized by a particular metallic composition pattern. Morphotypes of *S. natans* (I and VIII) metallic compositions were more similar to each other than to *S. fluitans* consistent with their genetic relatedness. The ability to absorb metal is a reduced aspect of all phenotype characteristics, however our conclusions about resemblances between morphotypes are in accordance with genetic differentiation actually admitted.

Conclusion

Different green strategies and solutions are proposed to exploit stranded *Sargassum* and to reduce their pressure on impacted the coastal areas. Our study confirmed the high As content of *Sargassum* at a large spatial scale. In this context some strategies of *Sargassum* valorization such as construction materials and bioenergy (Chávez et al., 2021; López Miranda et al., 2021) should be favored over others such as fertilizer production that should be considered with caution to avoid environmental and health issues. *Sargassum* could also cause environmental and health problems through the discharge of contaminants into the coastal marine environment. *Sargassum* genotypes present different contamination patterns and the abundance of each morphotypes have been changing during recent years. In this context of abundance changes, the global metal contamination of floating *Sargassum* spp. will likely also change in the future.

Author Contributions

OC conceived the research, collected the samples, identified *Sargassum* species, carried out sample preparation, acquired the data, performed data analyses, , conducted the analytical research and interpretation, and wrote the first draft of the paper. JG funded the analysis research. EPD carried out some sample preparation, analyses and data acquisition. MB proofreaded the manuscript. PYG contributed to the data analysis. LA-Z led the NIOZ PE455 oceanographic expedition, helped to collect samples and edited/proofread the manuscript. PYP contribute to editing and proofreaded the manuscript. All co-author edited and revised the manuscript.

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Table and figures

Table 1 − 1Elements concentration (ppm = µg·g) of pelagic Sargassum spp. collected from 7 different stations along a transect to the middle Atlantic Ocean to the Lesser Antilles (Guadeloupe – French West Indies) with their respective standard error (standard deviation divided by the squared root of the number of data), and the average in bold. Below the table there are recovery rates obtained from the analyses of certified reference material (TORT-3, DOLT-5, IAEA 413, and IAEA 407

	Al	As	Cd	Cr	Cu	Fe	Mn	Ni	V	Zn
S1	25,01 ±5,32	87,92 ±13,87	0,70±0,09	4,16±1,11	1,53 ±0,49	60,87 ±15,85	19,42 ±5,69	3,07±0,26	1,33 ±0,08	6,68 ±0,83
S2	35,67 ±12,66	85,43 ±10,43	0,86±0,05	0,52±0,16	1,67 ±0,13	48,83 ±16,75	19,89 ±7,15	3,30±0,67	8,17 ±0,69	8,17 ±1,36
S3	15,93 ±4,02	95,93 ±13,17	1,01±0,11	0,735±0,37	<LOD	31,24 ±8,92	23,71 ±7,21	3,93±0,58	1,43 ±0,03	8,30 ±1,33
S4	28,54 ±16,88	88,60±8,78	1,05±0,81	0,72±0,12	2,15 ±0,81	38,94 ±22,11	22,82 ±6,48	3,95±0,25	2,24 ±0,64	5,30 ±1,30
S5	24,53 ±19,56	99,53±9,06	1,04±0,01	2,30±0,82	3,51 ±0,80	47,34 ±21,14	24,76 ±13,17	5,08±1,28	1,90 ±0,96	6,07 ±0,91
S6	16,05 ±1,81	88,23±8,78	82,88 ±120,15	4,66±1,60	3,87 ±0,69	52,69 ±13,56	24,27 ±8,29	5,86±2,25	1,38 ±0,26	7,11 ±0,86
S7	29,69 ±2,88	103,44 ±9,53	0,48±0,024	2,39±1,01	4,24 ±0,33	49,87 ±10,69	22,44 ±9,62	4,16 ±0,001	2,42 ±1,28	4,65 ±0,39
Mean	**25,06**	**92,72**	**12,57**	**2,21**	**2,68**	**47,11**	**22,47**	**4,18**	**2,6**	**6,61**
IAEA413 recovery rate (%SD)		101,55 ±3,92	97,96 ±12,88	100,70 ±10,39		94,55 ±51,23	97,01 ±7,12	97,57±8, 34		98,70 ±7,99
DOLT-5 recovery rate (%SD)		100,21 ±0,018	95,28±0,19		93,85 ±0,38	91,20 ±14,60				98,75 ±1,65
TORT-3 recovery rate (%SD)		115,59 ±0,77	92,93±0,69		93,47 ±5,32	82,27 ±3,28	85,76 ±0,37	87,97 ±0,08	89,90 ±0,10	98,71 ±1,73

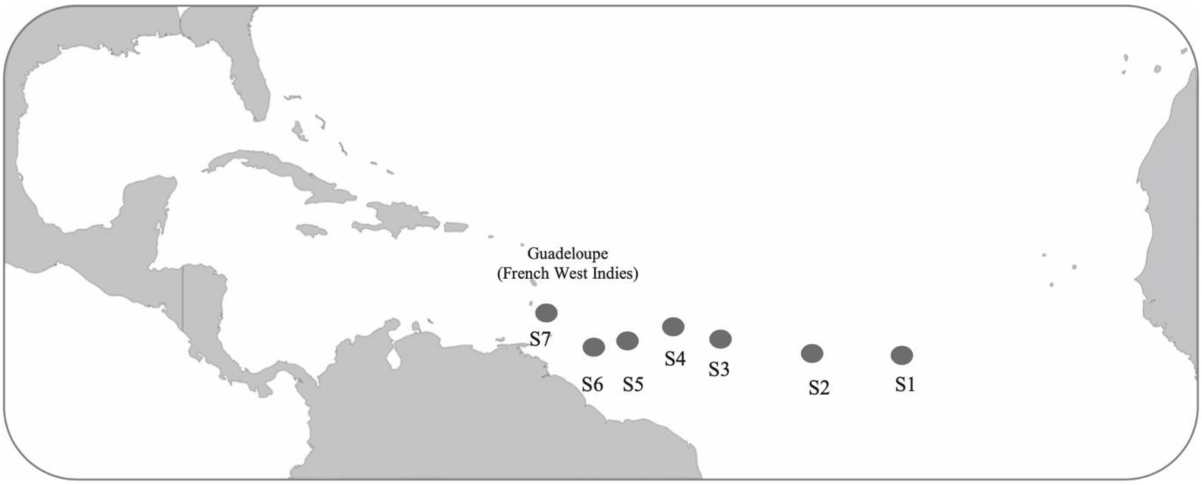


Figure 1 Sampling sites. Location of the sampling sites : S1 (6°98'N; -31°80'W), S2 (6°87'N;-34°42'W), S3 (8°02'N;-47°07'W), S4 (8°45'N;-47°07'W), S5 (8°42'N; -49°73'W), S6 (12°39'N; -56°78'W), S7 (16°13'N; -61°37'W) of Sargassum sp. along the transect from Middle Atlantic Ocean to Guadeloupe (French West Indies), during the cruise expedition RV-Pelagia PE-455 (NIOZ) between July and August 2019.

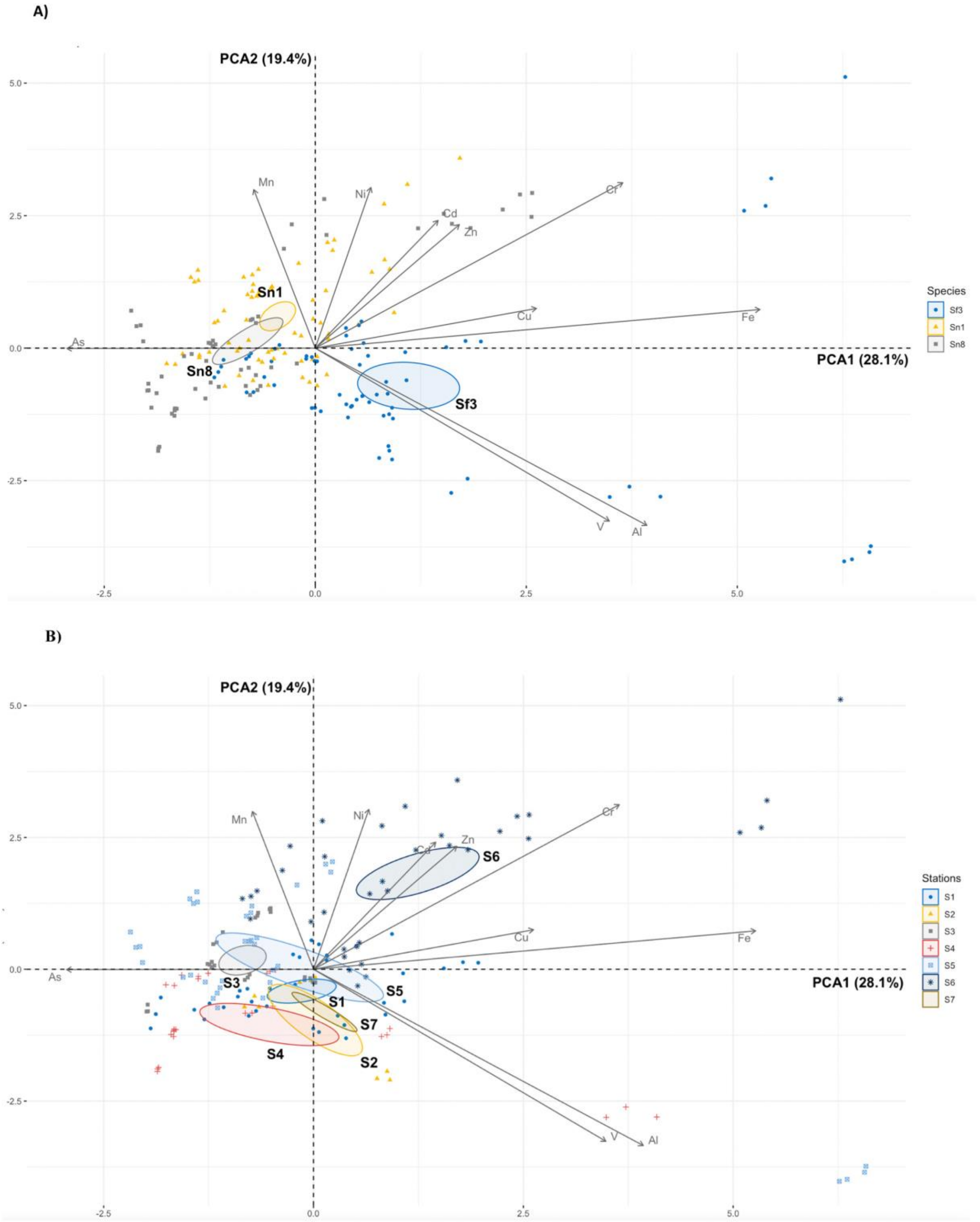
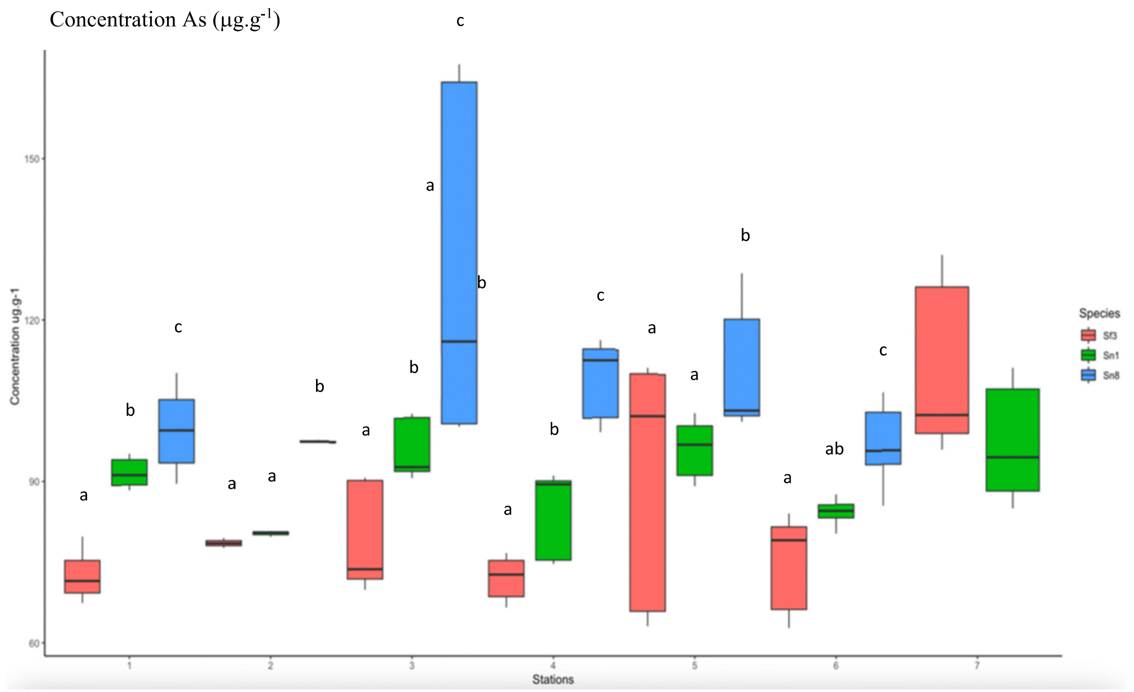
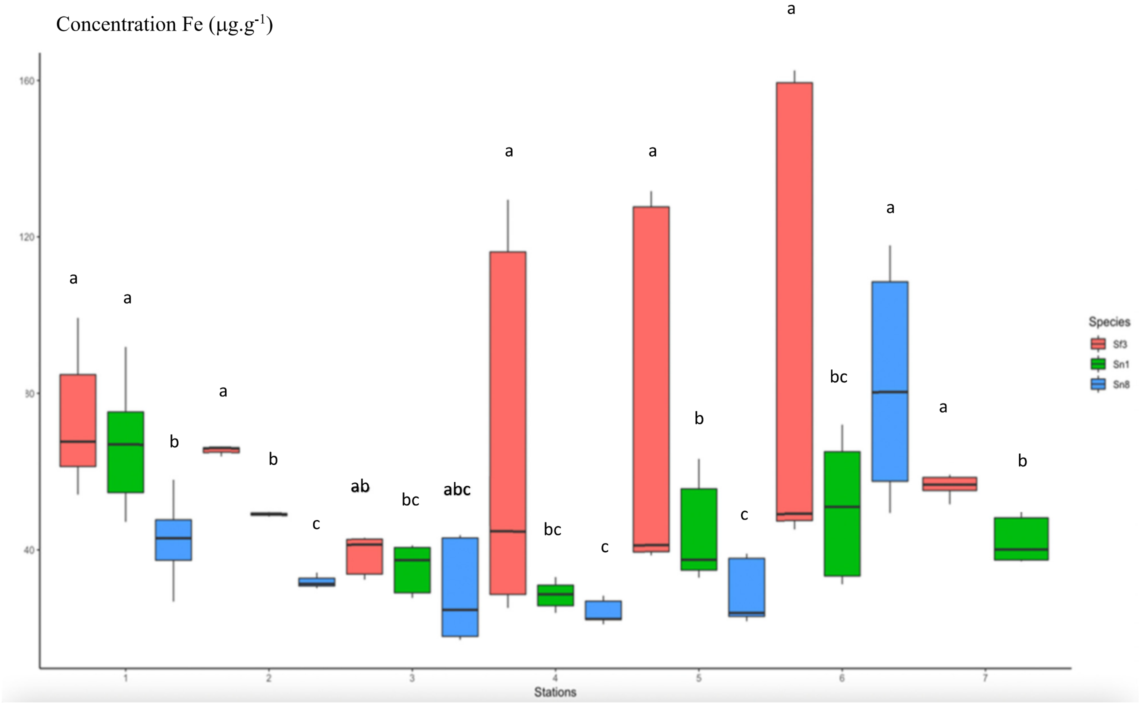


Figure 2 Principal Component Analyzes (PCA) in Dim1 (28.1%) and Dim2 (19.4%) A) represented the relationship between Sargassum sp. metallic elements and the species for the three morphotypes: Sn1 (Sargassum natans I), Sn8 (Sargassum natans VIII), Sf3 (Sargassum fluitans III). B) represented the relationship between Sargassum sp. metallic elements and the sampling sites: S1 (Station 1), S2 (Station 2), S3 (Station 3), S4 (Station 4), S5 (Station 5), S6 (Station 6), S7 (Station 7).



Concentration As ($\mu g.g^{-1}$)



Concentration Fe ($\mu g.g^{-1}$)

Figure 3 Elements metals concentration for the spatial variability Concentrations of five most frequent elements ($\mu g.g^{-1}$) in the sargasso algae collected from 7 different stations (S1, S2, S3, S4, S5, S6, S7) along the transect from Middle Atlantic Ocean to Guadeloupe (French West Indies), between July and August 2019. The horizontal axis represented the stations and the each morphotypes. The color of the boxplot represents the sargasso morphotypes. The horizontal black lines represent the median for each station.

The letters represent the difference significantly between the three morphotypes for each station (S. natans I, S. natans VIII and S. fluitans III), using a non-parametric test ANOVAs based on the Kruskal-Wallis (test p-value < 0.05).

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