



Baseline

Assessment of trace element contamination and bioaccumulation in algae (*Ulva lactuca*), mussels (*Perna perna*), shrimp (*Penaeus kerathurus*), and fish (*Mugil cephalus*, *Saratherondon melanotheron*) along the Senegalese coast



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ABSTRACT

Concentrations of 11 elements were quantified in five marine species from different trophic levels of a food web (algae, mussel, shrimp and fish), representative for shallow Senegalese coastal waters, and including species of commercial importance. Significant differences in element concentrations and bioaccumulation were demonstrated, revealing the utility of employing a suite of organisms as bioindicators to monitor metal contamination in coastal areas. There was no clear seasonal pattern in concentration of elements, however inter-site differences were observed. Calculations of transfer factors for all the studied elements showed that transfer factors from water were greater than those from sediments. For shrimp and mussel, the concentrations of Pb and Cd were below the EU's maximum level for human consumption, however high concentrations of arsenic in shrimp were recorded at all sites.

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The west African coast, including the Senegalese coast, is among the most productive marine ecosystems due to the presence of the Canary Current upwelling (Romeo et al., 1999), and more than 400 000 t of seafood are landed annually in Senegal (FAO, 2006). Senegal is a developing country, highly reliant on its coastal zone resources, and where consumption of marine fish, mollusks and shellfish provides 75% of the protein needs of the population (FAO, 2006) as well as representing an important economic activity. However, substantial development of urban and industrial activities along the Senegalese coast and lakesides, and/or inadequate wastewater treatment, has resulted in increasing inputs of chemical contaminants in particular to the marine environment (Diop et al., 2014). While it is known that element concentrations in water and sediment do not necessarily predict the levels of these contaminants in biota (Wang et al., 2010), biomonitoring using species from different taxonomic groups with distinct ecological niches or feeding trophic levels enables a fuller assessment of the extent of any contamination (Pérez-Cadahía et al., 2004). Among the large variety of pollutants found in the marine environment, metals represent a key type because they can be easily assimilated and accumulated in living tissues and food webs. The bioaccumulation and biomagnification of metals in fish and other seafood products may also affect human health (Copat et al., 2003). Regulations from the European Union (EC, 2014 and

2015) have established several maximum levels in fish and other seafood products for cadmium, lead and mercury.

The objective of this study was to evaluate the contamination status of several elements in five marine species from different trophic levels of a food web, representative for shallow Senegalese coastal waters, and with commercial and/or human health relevance: the green algae (*Ulva lactuca*), the brown mussel (*Perna perna*), shrimps (*Penaeus kerathurus*) and two fish species, namely flathead mullet (*Mugil cephalus*) and tilapia (*Saratherondon melanotheron*). The concentrations of 11 elements (arsenic, As; cadmium, Cd; chromium, Cr; copper, Cu; iron, Fe; manganese, Mn; nickel, Ni; lead, Pb; selenium, Se; vanadium, V and zinc, Zn) were measured at five sites in samples taken in both dry and wet seasons of 2013. Previous results on sediment and water trace element contamination (Diop et al., 2014; Diop et al., 2015) were used to calculate the transfer factors (TFs) from water and sediment.

The study area is located along the Senegalese coast in the extreme west of the African continent (Fig. 1). Five sampling sites were selected as representative of the coastline with respect to degree of anthropogenic pressure (see Diop et al., 2016). Site 1 (Saint Louis) is located away from important human anthropogenic pressure but near the mouth of the Senegal River which carries numerous pollutants (Diop et al., 2014). Three sites located near Dakar town are characterized by high degree of urban activity and consequent domestic waste and/or industrial discharges: Soumbédioune (Site 2); Hann (Site 3) and Rufisque

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Fig. 1. Map showing the sampling sites along the Senegalese coast.

(Site 4). Site 5 (Joal) is located in the south of the country and at some distance from significant anthropogenic influences.

In this work, five marine species were chosen to gain an overall picture of the elemental pollution along this coast, and encompass macroalgae, bivalves, crustaceans and two fish species. The choice was based on the frequent consumption of these species by the population inhabiting the Senegalese coast, but also provided good coverage of several trophic levels and the opportunity to evaluate elements' spatial distribution.

At each site and for each season (dry season in January or wet season in August during a typical rainfall year of 2013), 500 mg of algae, ten samples of mussel (taken only at the Dakar sites), and ten samples of shrimp, mullet and tilapia were taken. All the samples were immediately transported to the laboratory on ice. Each mussel, shrimp and fish were measured for total length (nearest 1 mm) and weighed (nearest 0.1 g) in order to standardize sample size between sites. Mussel and shrimp soft tissues and fish livers were removed by stainless steel scalpel and Teflon forceps at a laminar flow bench (Class 100, US Federal Standard 209a) and then stored individually in previously labeled polypropylene bags at -20°C until analysis.

Samples were prepared for chemical analysis by the procedure described by Diop et al. (2016). Concentrations of elements were determined by an Inductively Coupled Plasma with a Mass Spectrometer

Table 1

Mean $\pm$ SD of trace elements concentration (mg kg^{-1} dw) in marine organisms sampled in dry (S1) and wet (S2) seasons. LOQ: Limits of quantification; * indicates significant differences at $p < 0.05$.

Species	Season	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Se	V	Zn
<i>U. lactuca</i>	S1	2.29 $\pm$ 1.82	0.34 $\pm$ 0.25	1.91 $\pm$ 2.51	2.32 $\pm$ 1.47	448 $\pm$ 583	2.89 $\pm$ 0.86	1.67 $\pm$ 1.67	0.79 $\pm$ 1.02	0.2 $\pm$ 0.08*	9.24 $\pm$ 14.49	7.72 $\pm$ 6.86
	S2	2.06 $\pm$ 0.70	0.30 $\pm$ 0.29	1.37 $\pm$ 1.16	6.23 $\pm$ 6.55	362 $\pm$ 385	8.78 $\pm$ 8.85*	1.06 $\pm$ 0.32	2.64 $\pm$ 3.45*	0.13 $\pm$ 0.06	6.97 $\pm$ 5.73	14.7 $\pm$ 15.1
<i>P. perna</i>	S1	7.38 $\pm$ 2.39	3.03 $\pm$ 3.83*	1.00 $\pm$ 0.46	9.39 $\pm$ 2.65	180 $\pm$ 67	2.59 $\pm$ 1.32	6.93 $\pm$ 5.17	1.37 $\pm$ 1.21*	0.93 $\pm$ 0.27*	1.97 $\pm$ 2.06	156 $\pm$ 41*
	S2	7.11 $\pm$ 2.52	0.68 $\pm$ 0.62	1.67 $\pm$ 1.80	8.70 $\pm$ 1.39	532 $\pm$ 688*	2.45 $\pm$ 1.17	3.33 $\pm$ 2.26*	0.37 $\pm$ 0.19	0.67 $\pm$ 0.26	5.99 $\pm$ 5.61*	86.5 $\pm$ 21.6
<i>P. kerathurus</i>	S1	7.52 $\pm$ 3.59	0.05 $\pm$ 0.05	0.20 $\pm$ 0.10*	18.5 $\pm$ 7.5	6.83 $\pm$ 4.13	0.19 $\pm$ 0.06	0.01 $\pm$ 0.01	0.01 $\pm$ 0.01	0.66 $\pm$ 0.23	<LOQ	44.0 $\pm$ 4.4
	S2	11.7 $\pm$ 4.8*	0.19 $\pm$ 0.21*	0.13 $\pm$ 0.07	24.3 $\pm$ 10.4	16.3 $\pm$ 17.3	0.37 $\pm$ 0.24*	0.06 $\pm$ 0.02*	0.01 $\pm$ 0.01	0.80 $\pm$ 0.34	0.03 $\pm$ 0.03	60.1 $\pm$ 11.2*
<i>S. melanotheron</i>	S1	1.93 $\pm$ 1.88	0.77 $\pm$ 0.93	0.19 $\pm$ 0.15	935 $\pm$ 1407	860 $\pm$ 612	1.07 $\pm$ 1.03	0.45 $\pm$ 0.41	1.43 $\pm$ 1.65	4.25 $\pm$ 3.31	0.8 $\pm$ 1.31	82.2 $\pm$ 21.8
	S2	1.91 $\pm$ 1.57	1.18 $\pm$ 1.94	0.64 $\pm$ 0.47	657 $\pm$ 895	665 $\pm$ 513	4.20 $\pm$ 6.61*	0.38 $\pm$ 0.30	0.57 $\pm$ 0.43	5.90 $\pm$ 3.34	8.41 $\pm$ 19.24	80.9 $\pm$ 25.4
<i>M. cephalus</i>	S1	5.99 $\pm$ 2.68	2.31 $\pm$ 3.39	0.35 $\pm$ 0.04	180 $\pm$ 179	601 $\pm$ 512	1.29 $\pm$ 0.79	0.22 $\pm$ 0.19	0.08 $\pm$ 0.08	4.39 $\pm$ 2.06	1.31 $\pm$ 2.00	98.0 $\pm$ 37.4
	S2	9.37 $\pm$ 4.51*	1.79 $\pm$ 2.66	0.49 $\pm$ 0.18*	373 $\pm$ 438	751 $\pm$ 423	1.47 $\pm$ 0.84	0.44 $\pm$ 0.32*	0.39 $\pm$ 0.44	10.98 $\pm$ 8.36*	2.18 $\pm$ 2.05	160 $\pm$ 86*

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