Marine Pollution Bulletin 131 (2018) 633–645

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Marine sponges as a powerful tool for trace elements biomonitoring studies in coastal environment

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ARTICLE INFO

Keywords:
Marine sponges
Trace elements
Bioaccumulation
Lead isotope ratios
Marine environment

ABSTRACT

In this work, we performed a comparative study on six marine sponge species collected along the French Mediterranean and Irish coasts for their TEs accumulation. Intra and inter-species variabilities were examined. Among the Mediterranean species, *Cymbaxinella damicornis* accumulates significantly more As and Cu than others sponge species; *Chondrilla nucula* more Ni and Mo and *Acanthella acuta* more Ag. Among Irish samples, *Hymeniacidon perlevis* showed higher accumulation properties for most of TEs in comparison to *Halichondria panicea*. Bioconcentration Factors were $>$ 1 in all species for most of TEs. This study suggests that TEs bioaccumulation is most likely associated to differences in morphological features and/or to specific bacterial communities associated to different species. The determination of Pb isotope ratios revealed mainly natural Pb sources for Mediterranean and Kilkieran Bay's samples, and rather anthropogenic influence for Belfast samples. This study confirms that sponges represent a powerful tool for biomonitoring studies.

1. Introduction

The occurrence of trace elements (TEs) in aquatic environments is related to natural sources, but also to anthropogenic inputs from industrial activities. TE contaminations in the marine environment occur worldwide and the assessment of the pollution status is required, leading to the publication of several studies on this subject (Li et al., 2000; Caccia et al., 2003; Fang et al., 2014; Parra et al., 2015; Cabrita et al., 2017; Ashraf et al., 2017). Environmental surveys are often performed on water samples but, in marine ecosystems, the very low TEs concentrations and the high salinity of seawater cause severe limitations in the measurements (Søndergaard et al., 2015). Monitoring studies on TEs contamination are often focused on sediments and biota. Indeed, sediments act as sink and reservoirs of contaminants thus displaying higher TEs contents and not presenting problems related to short residence time such as for water (Varol, 2011; Liu et al., 2015). Marine organisms find also application as tools for characterizing the state of a marine ecosystem as some of them are recognized to accumulate TEs. They represent a good alternative especially in rocky shores where sediments are not easily found. Sessile and active filter feeding invertebrates are often used to determine temporal and spatial variation of TE in aquatic systems (Weis and Weis, 1999; Denton et al., 2006; Dahms et al., 2014). An ideal biomonitor should be a natural accumulator of the element of interest and possibly with high concentration factor, in order to highlight possible difference between times or sites (Rainbow, 2002).

Historically, bivalves are considered as ideal biomonitor organisms as exemplified by the "mussel watch program" (Cantillo, 1998) also for their importance as widespread consumed seafood. More recently, sponges gained attention as possible biomonitors of TEs contamination as they are widespread, abundant in some ecosystems, long-living, easily sampled, sessile filter-feeders and highly tolerant to several pollutants (de Mestre et al., 2012; Batista et al., 2014). Additionally, sponge communities can remain stable for long periods, making them suitable model organisms for monitoring studies. Sponges pump large quantities of seawater (100–1200 $mL\,h^{-1}\,g^{-1}$), more than any other marine invertebrates (Olesen and Weeks, 1994). These organisms have a high capacity for TEs accumulation (Patel et al., 1985; Padovan et al., 2012), exhibiting higher filtering capacity than bivalves (Negri et al., 2006; Gentric et al., 2016). They are considered as "biological particle traps" due to their ability to concentrate a wide range of chemicals from both the suspended and dissolved phases of the water, with usually high bioconcentration factors (BCF) (Perez et al., 2005; Cebrian et al., 2003). The detection of large quantities of TEs in sponges suggests either a high tolerance to diverse type of chemicals or the existence of detoxification systems (Aly et al., 2013). These characteristics make them

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https://doi.org/10.1016/j.marpolbul.2018.04.073
Received 6 November 2017; Received in revised form 25 April 2018; Accepted 28 April 2018

suitable as a model organisms applied in TEs monitoring projects, and their use has been proposed in several studies (Negri et al., 2006; Venkateswara Rao et al., 2009; Illuminati et al., 2016). Sponges have also been reported as efficient environmental bioremediators of different chemicals or even microbes such as the organochlorine pesticide lindane (Aresta et al., 2015) and the bacterium *Escherichia coli* (Milanese et al., 2003). These characteristics, combined with a demonstrated interest for sponges as a source of novel pharmaceuticals (Anjum et al., 2016), open the way for self-financing sponge remediation programs (Gifford et al., 2007).

The main objective of this work was the assessment of TEs pollution in several sponge species of different morphologies and collected in different areas. A comparative study on TEs bioaccumulation was performed on six sponge species collected on the Southern French Mediterranean coast and in Ireland. These areas have been selected because of their differences in terms of TEs biogeochemical background and anthropogenic inputs. The bioaccumulation potential of these sponges was examined for a broad range of TEs, comparing with values measured in sediment samples collected in the same area. Additionally, measurements of Pb isotope ratios were performed for the first time in sponges and allowed us to give insights on the principal sources of Pb contamination in the studied zones.

2. Materials and methods

2.1. Sampling

Sponge and sediment samples were collected in three sampling sites: the Mediterranean coast, in the Grotte du Lido at Villefranche sur Mer, France (N 43° 41′ 59.0″, E 07° 19′ 31.5″) and two coastal sites in Ireland, Greenisland in the Belfast Lough (N54°41′24.383″, O 5° 51′ 36.633″) and Kilkieran Bay (N 53° 21′ 22.625″, O 9° 42′ 17.153″) in Galway county (Fig. 1). Sediment samples were collected during each sampling session, using an acid pre-cleaned polyethylene tube. Sponges were collected using a plastic knife and placed in separate plastic bag. Different sponge species were sampled: *Acanthella acuta*, *Cymbaxinella damicornis*, *Chondrilla nucula* and *Haliclona fulva* in the Mediterranean coast; *Halichondria panicea* and *Hymeniacidon perlevis* in Ireland. A list of samples with details on morphology and known bacterial associated population is presented in Table 1. These sponge species were described in details in a recently published paper (Orani et al., 2018). At least three specimens of similar size were randomly selected for each sponge species and during each sampling. Sediments and four species of Mediterranean sponges were collected by SCUBA diving at 20 m depth on February and September 2016 (winter and summer). During the first sampling, three specimens of *C. damicornis* were collected deeper in the cave while the remaining two specimens were from the entrance. During the second sampling, three specimens of *C. nucula* were collected at 5 m depth while three other specimens at 20 m. In Ireland, sediments and sponges were hand-sampled in intertidal zones. Samples from Kilkieran Bay and from Belfast were collected in September 2016 and in October 2016, respectively.

2.2. Sample preparation

All solutions were prepared with double deionized water obtained from Millipore water purification system (Elix & Synergy) (resistivity of 18.2 MΩ cm^{-1}, Total Organic Carbon < 5 μg L^{-1} and microorganisms < 0.1 UFC mL^{-1}). All PTFE and Teflon containers used for sample preparation and analyses were pre-cleaned using a procedure consisting of 24 h bath in 10% HNO_3 (prepared from proper dilution of 65% analytical grade HNO_3, Fisher Chemicals) and careful rinsing three times with Milli-Q water. Sediment and sponge samples were freeze-dried, ground in agate mortar, and kept in closed PTFE tubes placed in a desiccator.

For trace elements analysis by ICP-MS, a microwave digestion was carried out into a closed microwave system (Ethos One, Milestone). Teflon reactors were filled with an aliquot of about 50 mg of sponge sample (or 100 mg of bulk sediment sample), with 5 mL of HNO_3 (Trace Metal Grade, 67 to 70% *w*/w, Fisher Chemical) and 2 mL of HF (Ultra Trace Elemental Analysis 47–51% w/w, Optima, Fisher Chemical). Temperature program used for acid digestion consisted of a 20-min

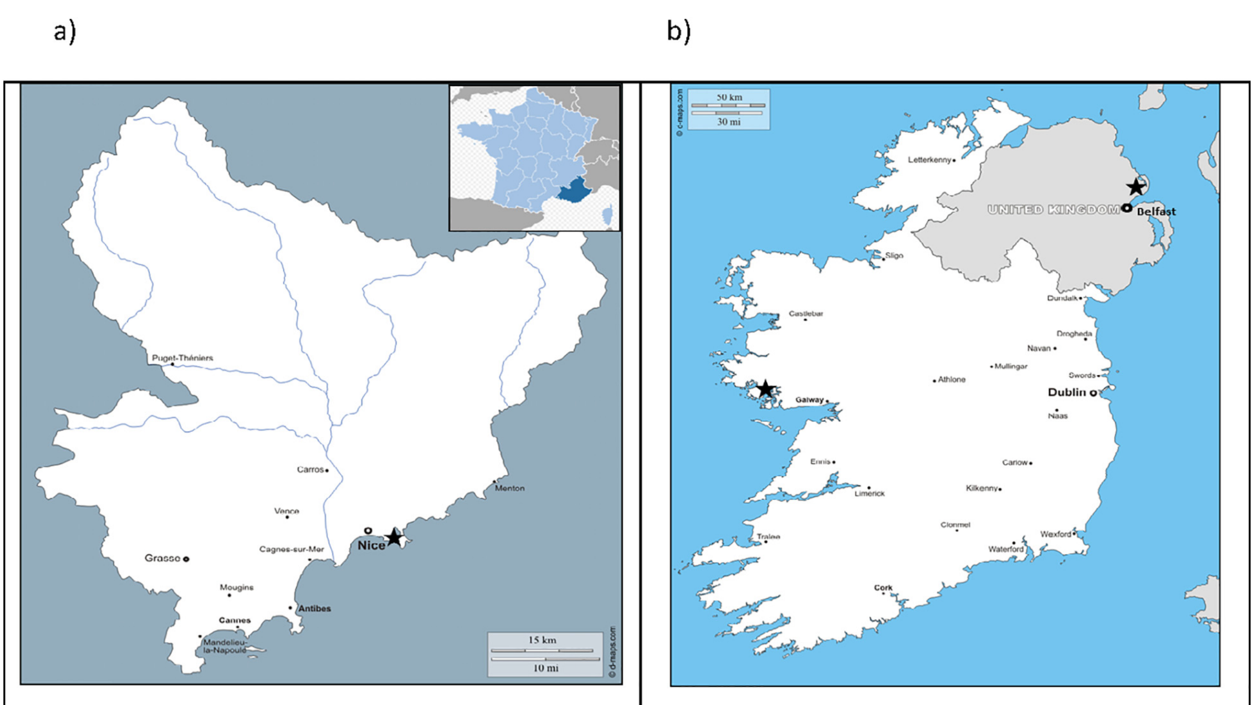

Fig. 1. Maps showing the sampling sites (indicated with black stars) located a) in the French Mediterranean coast (http://d-maps.com/carte.php?num_car=110470&lang=en) and b) in two locations along the Irish coast (http://d-maps.com/carte.php?num_car=14642&lang=en). Copyright d-maps.com