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Assessment of contaminant concentrations in sediments, fish and mussels sampled from the North Atlantic and European regional seas within the ICON project

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ABSTRACT

Understanding the status of contaminants in the marine environment is a requirement of European Union Directives and the Regional Seas Conventions, so that measures to reduce pollution can be identified and their efficacy assessed. The international ICON workshop (Hylland et al., in this issue) was developed in order to test an integrated approach to assessing both contaminant concentrations and their effects. This paper describes and assesses the concentrations of trace metals, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls in sediments, mussels, and fish collected from estuarine, coastal and offshore waters from Iceland to the Mediterranean Sea. For organic contaminants, concentrations progressively increased from Iceland, to the offshore North Sea, to the coastal seas, and were highest in estuaries. Metals had a more complex distribution, reflecting local anthropogenic inputs, natural sources and hydrological conditions. Use of internationally recognised assessment criteria indicated that at no site were concentrations of all contaminants at background and that concentrations of some contaminants were of significant concern in all areas, except the central North Sea.

1. Introduction

The monitoring and assessment of contaminants in European seas has been undertaken for many years to satisfy the requirements of the Regional Seas Conventions (RSCs), i.e. OSPAR for the NE Atlantic (including the North Sea), HELCOM for the Baltic Sea, MED POL for the Mediterranean Sea. From 2014, Descriptor 8 of the European Union Marine Strategy Framework Directive (MSFD; EC, 2008a) requires the monitoring of contaminants within regular assessment cycles and aims to achieve Good Environmental Status for European seas by 2020. States with coasts in more than one Regional Sea (e.g. France, Spain), have an operational requirement to harmonise approaches between RSCs and are making use of advice from the International Council for the Exploration of the Sea (ICES) to do this.

OSPAR Contracting Parties are committed to participate in its Coordinated Environmental Monitoring Programme (CEMP), under which a number of contaminants and biological effects are either mandatory, or voluntary determinants. Mandatory CEMP determinants include polycyclic aromatic hydrocarbons (PAHs) in sediment and shellfish, polychlorinated biphenyls (PCBs), polybrominated biphenyl ethers (PBDEs) and hexabromocyclododecane

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(HBCDD) in sediments, fish liver and shellfish, the toxic metals Cd, Hg and Pb in sediments and biota, and endocrine disruption (imposex) in gastropod molluscs. Voluntary (pre-CEMP) chemical determinants include chlorinated dioxins and furans, alkylated-PAHs, polyfluorinated compounds (PFC)s in sediment and biota, and PFCs in water. Pre-CEMP biological effects determinants include metals-specific effects, PAH-specific effects, and general biological effects (OSPAR, 2010a). Through its regional coordination role under the MSFD, OSPAR has made recommendations regarding the use of common and candidate indicators for monitoring under Descriptor 8 (Concentrations of contaminants are at levels not giving rise to pollution effects). Common indicators include metals, organotins, PAHs, PCBs, and PBDEs in sediments, metals and PCBs in fish, and metals, PAHs and PCBs in mussels; candidate indicators include biological effects, i.e. lysosomal membrane stability, external fish disease, cytochrome P450 (EROD) activity and biliary PAH metabolite concentrations (OSPAR, 2013). The current advice from the International Council for the Exploration of the Seas (ICES) is that the monitoring and assessment of environmental contaminants are fully integrated, with both contaminant concentrations and their biological effects being monitored, reported, and assessed in a coherent manner (Davies and Vethaak, 2012; Vethaak et al., in this issue). In the North Atlantic, OSPAR has developed criteria (background assessment concentrations (BACs) and environmental assessment concentrations, EACs) to assess the significance of observed contaminant concentrations (OSPAR, 2009), although under the MSFD European Environmental Quality Standards (EQSs) should be used where they are available (e.g. for some contaminants in biota). Similarly, regionally-specific assessment criteria are available for use in the Mediterranean (UNEP/MAP, 2011; Angelidis et al., 2011; Benedicto et al., 2012; see also Martínez-Gómez et al., in this issuea, b). During the ICES advice drafting stage, a multipartner project to examine the integrated approach to environmental assessment at the regional seas level was conducted (International Workshop on Integrated Assessment of Contaminant Impacts on the North Sea, ICON; Hylland et al., in this issue). Our paper describes and assesses the contaminant concentrations of sediment and biota samples collected from Iceland, the North Sea, the Baltic Sea, and the Mediterranean Sea during the ICON project. The exposure of ICON fish samples to PAHs is assessed in an accompanying paper on bile metabolites (Kammann et al., in this issue).

2. Material and methods

2.1. Sample collection

Samples were collected by shoreline sampling (mussels; 2008–2011), or from research cruises (fish, sediments) conducted in 2008 and 2009 by the participating laboratories utilising the research vessels *Scotia, Alba na Mara* (both Marine Scotland, UK), *Walter Herwig III* (Thünen-Institut für Fischereiökologie, Germany), *Francisco de Paula Navarro* (Instituto Español de Oceanografía (IEO), Spain) and *Gwendrez* (Ifremer, France). Fish and sediments from the Wadden Sea were collected from a small boat, with surface sediments collected by van Veen grab and flounder collected using a 3 m beam trawl. Mussels were hand collected between September and February and not during the spawning period in order that the animals had normal condition and lipid level. All sampling was in accordance with OSPAR guidelines (OSPAR, 1999). After collection, samples for chemical analysis were stored frozen (−20 °C) and dispatched on dry ice to Marine Scotland Science (MSS), Aberdeen, UK. Sampling site details are in Table 1 and locations are shown in Fig. 1. Occasional samples were lost or were found unsuitable for analysis; in such cases alternative data (from the same year) were obtained from national monitoring programs when they were available. To present and assess national data consistently with ICON data, a conversion factor of 5 was used to convert between mussel dry weight and wet weight where the moisture content was not available.

The upper 2 cm of sediment were collected (e.g. by Day or van Veen grab), thoroughly mixed and then frozen at −20 °C as separate aliquots for the determination of organic and inorganic compounds. Fish were collected by bottom or beam trawls, examined for external disease and dissected at sea for tissue sampling. Otoliths were removed and each fish subsequently aged by sclerochronology, except red mullet which were in the size range 12–18 cm and age was estimated as being Class I-III using specific size-age models (Kinacigil et al., 2001; Martínez-Gómez et al., in this issuea, b). In order to provide sufficient material for the chemical analyses, liver samples were pooled (5 pools of 5 same-sex fish per site for metals), minced and thoroughly mixed before being divided into aliquots for organic or metals analyses and frozen at −20 °C; flesh samples were treated similarly, though for

Table 1
Sampling site information.

Region	Site name	Site code	Site type	Latitude	Longitude	Samples collected
Iceland	Bjarnarhöfn	BH	Coastal	65.000	−22.970	Mussels
Iceland	Hvassahraun	HV	Coastal	64.023	−22.146	Mussels
Iceland	SE Iceland	IS1	Offshore	63.767	−16.404	Dab, haddock, sediment
Iceland	SW Iceland	IS2	Offshore	64.146	−22.280	Dab, haddock, sediment
North Sea	Egersund bank	EB	Offshore	57.708	5.295	Haddock, sediment
North Sea	Ekofisk	EF	Offshore	56.402	3.095	Dab, haddock, sediment
North Sea	Forth estuary - Alloa	AL	Estuary	56.110	−3.810	Flounder
North Sea	Forth estuary - Blackness	BL	Estuary	56.014	−3.480	Flounder, mussels, sediment,
North Sea	Firth of Forth - St Andrews Bay	SAB	Coastal	56.407	−2.739	Flounder
North Sea	Firth of Forth - offshore	FF	Offshore	56.300	−2.034	Dab, haddock, sediment
North Sea	Dogger Bank	DB	Offshore	54.748	2.271	Dab, sediment
North Sea	German Bight	GB	Offshore	54.338	7.537	Dab, sediment
Baltic Sea	Mecklenberg Bight, Baltic Sea	BA	Coastal	54.333	11.600	Flounder, dab, sediment
North Sea	Wadden Sea	WS	Coastal	52.965	5.017	Mussels, sediment
North Sea	Alde	AD	Estuary	52.096	1.561	Sediment
English Channel	Seine estuary	SE	Estuary	49.431	0.003	Dab, sediment
English Channel	Le Havre	LH	Estuary	49.423	0.209	Mussels
English Channel	Parfond (Seine Bay)	PAR	Coastal	49.385	−0.154	Dab, flounder, sediment
English Channel	Le Moulard	LM	Coastal	49.653	−1.238	Mussels
Mediterranean Sea	Cartagena	CAR	Coastal	37.562	−1.030	Red mullet, mussels, sediment
Mediterranean Sea	Marine Reserve of Cape Palos	CP	Coastal	37.653	−0.653	Mussels

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