Science of the Total Environment 476–477 (2014) 181–188

Contents lists available at ScienceDirect

Science of the Total Environment

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

Temporal trends of contaminants in cod from Icelandic waters

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HIGHLIGHTS

- Contaminants have been determined in cod (*Gadus morhua*) north of Iceland since 1990.
- Concentrations of POPs have decreased during the last 20 years.
- No signs of decreasing trends were observed for the trace elements except for zinc.
- Biological covariates are important when determining temporal trends.

ARTICLE INFO

Article history:
Received 20 September 2013
Received in revised form 26 December 2013
Accepted 2 January 2014
Available online 24 January 2014

Keywords:
Contaminants
Persistent organic pollutants
Metals
Cod
Trends

ABSTRACT

Contaminants have been analyzed in cod (*Gadus morhua*) since 1990 as part of the national monitoring program for the environmental conditions in the sea around Iceland. The aim of this study was to determine the temporal trends of persistent organic pollutants (POPs: polychlorinated biphenyls (PCBs), *p,p′*-dichlorodiphenyl dichloroethene (*p,p′*-DDE), hexachlorobenzene (HCB), hexachlorocyclohexanes (HCHs), chlordanes (CHLs) and toxaphenes (Tox)) and trace elements (As, Cd, Cu, Hg, Pb, Se and Zn) in cod over the last two decades at two different locations in the Arctic Ocean north of Iceland. The relationship between the contaminant concentrations and biological covariates was also determined. All of the POPs showed decreasing trends but the trace elements showed no clear signs of trend except arsenic which showed an increasing trend and zinc which showed a decreasing trend. The concentration of the POPs were lower or similar in the Icelandic cod compared to cod sampled in Norway, the Barents Sea and in the Baltic Sea, except for HCB which was higher in the Icelandic cod compared to the Norwegian cod. The concentration of the trace elements As, Cu, Hg and Zn were similar in the Icelandic cod compared to cod sampled in Norway and Greenland but the concentration of Cd was higher in the Icelandic cod. The inclusion of the biological covariates was found to be important for the statistical analysis. The POPs had a positive relationship with liver fat content but negative relationship with liver weight. The trace elements had a negative relationship with liver fat and liver weight except As which had positive relationship with liver weight. Only positive relationships were observed between the contaminant concentrations and length.

1. Introduction

The Arctic is sparsely populated with very limited industrial activity and is therefore considered a pristine area. However, contaminants like persistent organic pollutants (POPs) which have anthropogenic origin are found all over the Arctic and sub-Arctic (Ólafsdóttir et al., 2005; Riget et al., 2010) although they have rarely been used there. The POPs are transported from sources at lower latitudes, to higher ones by long-range transport (Pacyna et al., 1985; Wania and Mackay, 1993). Most time-series of POPs in the Arctic have shown decreasing trends, nonetheless, a few series have shown increasing trends (Riget et al., 2010). Although trace elements occur naturally in the environment a significant amount comes from human activity such as from fossil fuel combustion, non-ferrous metal production and waste incineration (AMAP, 2005). The analysis of POP and metal concentrations in mussels (*Mytulis edulis*) around the coastline of Iceland mostly indicated reducing levels from 1990 to 2010, but revealed three minor local sources of the contaminants (Sturludottir et al., 2013). Increased levels of mercury in the Arctic biota have been observed in the Canadian

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http://dx.doi.org/10.1016/j.scitotenv.2014.01.005

Arctic and in Greenland (Muir et al., 1999; Riget et al., 2011). The concentration of mercury in some Arctic species such as pilot whales and beluga exceed the toxicological threshold limits and increasing concentrations are alarming (Dietz et al., 2013).

Fish liver is often used as a monitoring matrix for POPs and metals in the marine environment as their concentrations are elevated in the liver either due to high lipid content (POPs) or certain organ affinity (trace elements) and thus give more reliable results of the usually low levels. The livers can be very variable in size and composition depending on the nutritional status of the individual which has great influence on the concentration of contaminants in the livers (Auðunsson, 1999). The contaminants are either lipophilic or lipophobic and the fat content of the liver is therefore considered an important covariate when determining temporal or spatial trends. Other biological factors are also expected to affect the concentration of contaminants such as: age, length, and dry and total weight of the liver (Auðunsson, 1999; Green and Knutzen, 2003; Riget et al., 2000).

Contaminants have been analyzed in cod (*Gadus morhua*) liver and muscle since 1990 as a part of the national monitoring program for the environmental conditions in the sea around Iceland (Jorundsdottir et al., 2012). The cod studied in the national monitoring program has mainly been caught north of Iceland where the ocean can be divided into two areas with different types of waters, relatively warm and saline Atlantic water to the west and mixture of Atlantic water and cold and low-salinity Polar water to the east (Valdimarsson and Malmberg, 1999). Cod caught in these two areas may also have different genetic structures. A study by Pampoulie et al. (2006) on the genetic variability of the Icelandic cod showed a significant difference in the genetic structure in cod that spawned at the main fishing grounds at the SW coast and at the NE coast of Iceland. Marteinsdottir et al. (2000) have shown that first year cod caught off the NE coast are younger (born later in the year) than the ones caught off the NW coast. This indicates that juveniles in the NE area are mainly from local spawning areas whereas more of the juveniles at the NW area come from the spawning grounds to the SW of Iceland.

The cod feeds mainly on capelin (*Mallotus villosus*) and other fish but the northern shrimp (*Pandalus borealis*) and other decapods are also important in the cod diet (Jaworski and Ragnarsson, 2006). Regional differences in cod diets have been observed where the northern shrimp is more common in the diet of cod in the NW area than at the NE area and small crustaceans of the order *Euphausiacea* are more common at the NE than at the NW area (Pálsson, 1983). Temporal changes in the cod diet have been observed from 1988 to 2010 where the consumption of capelin and northern shrimp has fluctuated (Pálsson and Björnsson, 2011). Diet preferences may influence biomagnifications of contaminants (Ruus et al., 1999; Skarphedinsdottir et al., 2010) and therefore factors such as season, location and fish size can affect the concentrations of contaminants as feeding depends on these factors and fish becomes a larger proportion of the cod diet as the cod grows (Jaworski and Ragnarsson, 2006).

The aim of this study was to use the data collected as a part of the national monitoring program to determine temporal trends of POPs and trace elements in cod liver and mercury in cod muscle over the last two decades at two different locations in the Arctic Ocean north of Iceland. The relationship between the contaminant concentrations and biological covariates is also determined.

2. Materials and methods

2.1. Sampling method and locations

Sampling of cod (*G. morhua*) was carried out from 1990 to 2011 using sampling guidelines from OSPAR/ICES. Cod of length 30–45 cm were collected in March in the annual bottom trawl survey carried out by the Icelandic Marine Research Institute. Samples were taken from two locations NW and NE of Iceland (Fig. 1). One or two samples were taken each year from the NW location and one from the NE location. Each sample contained 25 individuals which were gutted at time of sampling and the livers were put in a pre-weighed and pre-cleaned glass jars and both the livers and the fish were frozen at −20 °C until sample preparation. Further handling of the samples was carried out in the laboratory. Each individual was weighed, the length of the fish measured, the gender determined, otoliths were removed for age determination, the fish was filleted, skinned and the muscle weighed (Table 1). The 25 muscles from each sample were homogenized and kept frozen until chemical analysis was performed. The 25 livers were divided into four to six sub-samples according to the weight of the livers, livers with similar weight were pooled together, except in 1992 and 1995 when all the livers were pooled into one group. The liver

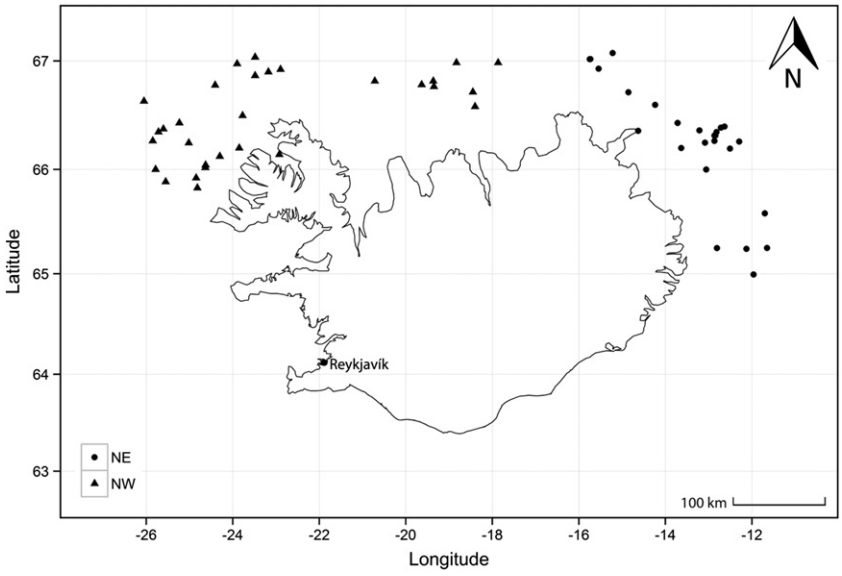

Fig. 1. Sampling locations of cod (*Gadus morhua*) north off Iceland from 1990 to 2011.