ELSEVIER

Chemosphere 65 (2006) 2297–2303

CHEMOSPHERE

www.elsevier.com/locate/chemosphere

Detection of technetium-99 in *Ascophyllum nodosum* from around the Welsh coast

Lucie R. Oliver [a,*], William T. Perkins [a], Stephen M. Mudge [b]

[a] *Institute of Geography and Earth Sciences, University of Wales, Aberystwyth, UK*
[b] *School of Ocean Sciences, University of Wales, Bangor, Menai Bridge, Anglesey, UK*

Received 2 December 2005; received in revised form 8 May 2006; accepted 9 May 2006
Available online 30 June 2006

Abstract

The presence of the radionuclide ^{99}Tc in the marine environment is of concern to environmental scientists because of its conservative nature and high concentration factor in commercially valuable species. The brown seaweed *Ascophyllum nodosum* (Linnaeus) Le Jolis was used to biomonitor the spatial distribution of ^{99}Tc around the Welsh coast, an area relatively unstudied with respect to this isotope. Over the course of a year an inverse relationship was observed between the ^{99}Tc concentration in *A. nodosum* samples and approximate straight-line distance from Sellafield. These data show that detectable levels of a Sellafield derived radionuclide are reaching the Welsh coast despite the overall northward movement of the Sellafield plume.

Keywords: Radioactivity; Irish Sea; Seaweed; Biomonitoring; ICP-MS; Sellafield

1. Introduction

The increased presence of technetium-99 (^{99}Tc) in the marine environment following changes in the operations at European nuclear facilities is of interest to environmental scientists for a number of reasons. ^{99}Tc has a high bioconcentration factor in commercially valuable species such as the common lobster, *Homarus gammarus* (Linnaeus) and the Norway lobster, *Nephrops norvegicus* (Linnaeus) that under certain circumstances could be of concern to consumers (Busby et al., 1997; Leonard et al., 2001; Olsen and Batlle, 2003; Copplestone et al., 2004). ^{99}Tc has a half-life of 213 000 years and in the marine environment forms the soluble pertechnetate ion, TcO_4^-, which means that once ^{99}Tc enters the marine environment it is highly conservative and can be carried long distances from its point of entry (Aarkrog et al., 1988; Bonotto et al., 1988; McDonald and Busby, 1998; Brown et al., 1999; Kershaw et al., 1999, 2004; Kanisch et al., 2000; Lindahl et al., 2003).

The safe discharge of contaminants such as ^{99}Tc into the sea requires an adequate understanding of their fate in the marine environment, especially if there is any possibility of feedback to humans (Bourne and Assinder, 1991). One method employed in many investigations into the biological implications of releasing contaminants into the environment is that of biological monitoring. It is well documented that both *Fucus vesiculosus* (Linnaeus) and *A. nodosum* (Linnaeus) Le Jolis accumulate ^{99}Tc to a high degree and are useful indicators of the distribution of this element in the marine environment (Mitchell et al., 1989; Masson et al., 1995; Smith et al., 2001; Ilus et al., 2002). Brown seaweeds (mainly *F. vesiculosus*) are sampled by both the nuclear industry and government agencies such as the Food Standards Agency (FSA) as part of their annual reviews of the impact of Britain's nuclear industry on the environment.

The primary aim of this study was to map the distribution of ^{99}Tc around the Welsh coast using the brown seaweed *A. nodosum* as a biomonitor. This is an area that is

* Corresponding author. Tel.: +44 1248 382846; fax: +44 1248 716367.
E-mail address: ospe33@bangor.ac.uk (L.R. Oliver).

0045-6535/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.chemosphere.2006.05.014

Table 1
Locations, names and sampling frequencies of study sites

Site ID	Site Name	Latitude (°N)	Longitude (°E)	Distance from Sellafield	Sampling Frequency
1	Beachley	51.6141	−2.6477	630	Twice monthly
2	Porthcawl	51.4774	−3.6686	550	Twice monthly
3	Manorbier	51.6430	−4.8061	470	Twice monthly
4	Fishguard	51.9997	−4.9867	400	Twice monthly
5	Aberystwyth	52.4157	−4.0890	320	Twice monthly
6	Porthmadog	52.9145	−4.1356	260	Twice monthly
7	Nefyn	52.9408	−4.5361	200	Twice monthly
8	Cemaes Bay	53.4147	−4.4527	180	Twice monthly
A	Ramsey	54.3118	−4.3624	130	Once
B	Castletown	54.0717	−4.6543	90	Once
C	Walney Island	54.0816	−3.2476	50	Once
D	Bardsey Island	52.7531	−4.7936	45	Once

relatively unstudied with respect to ^{99}Tc despite the proximity of Welsh coastal waters to the principal source of this isotope in the NE Atlantic, the BNFL nuclear reprocessing facility at Sellafield. The commissioning of the thermal oxide reprocessing plant (THORP) and enhanced actinide removal plant (EARP) at Sellafield in 1994 led to a 20-fold increase in the discharges of ^{99}Tc into the Irish Sea. This was partly due to the processing of the backlog of irradiated fuel that had accumulated while THORP and EARP were built; the amounts discharged fell from 190 to 69 TBq per annum between 1995 and 1999 (McCartney and Rajendran, 1998; BNFL, 2002). Discharges increased to 85 TBq in 2002 but fell to 37 TBq in 2003 and new technology introduced by BNFL should continue to decrease discharge of ^{99}Tc to 90% of the 2002 levels in years to come (RIFE 9, 2004).

The geographical distribution of ^{99}Tc has been well documented for the waters immediately surrounding the Sellafield pipeline, the north Atlantic, North Sea and even as far north as the Arctic (Kershaw and Baxter, 1995; McDonald and Busby, 1998; Brown et al., 1999; Kershaw et al., 1999; Lindahl et al., 2003; Kershaw et al., 2004) which reflects the fact that the prevailing currents influencing the waters of the Irish Sea move from south to north (Leonard et al., 2001). There is, however, a certain amount of southward water movement in the Irish Sea (Bailly du Bois and Guegueniat, 1999), which enters the Irish Sea to the north of Anglesey and moves anti-clockwise around the Isle of Man before rejoining the main flow to exit through the North Channel, which means that any radionuclides released from the Sellafield pipeline could potentially have an effect on the coast of Wales. This is borne out by the fact that the FSA has found detectable levels of ^{99}Tc in marine biota from several sites around the Welsh coast (RIFE 9, 2004).

2. Study sites

In the period from August 1999 to June 2000 eight sites around the Welsh coast were visited at two-monthly intervals, from the Severn Estuary in the south, to the northern tip of Anglesey (see Table 1 and Fig. 1). Sites 4, 6 and 8 were selected due to their being sampled by other monitoring programs (BNFL, 2002; RIFE 9, 2004). In order to place the results from this study into a wider context, the ^{99}Tc content of the samples collected from the two-monthly study sites were compared to those found in plants collected on a 'one-off' basis from a number of other sites including two on the Isle of Man.

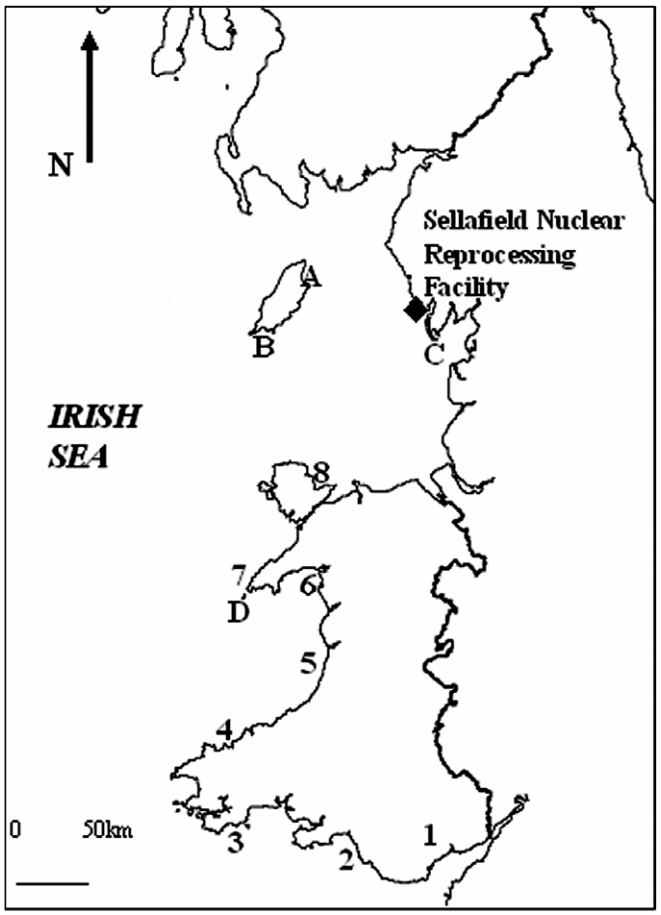

Fig. 1. Map showing location of study sites (map reproduced with kind permission of the Ordnance Survey).