practical at Island Copper Mine in Canada. The mine is now within about 5 years of its predicted 25 year lifetime. The deep (almost 300 m) pit is only a few metres from the original fjord shoreline. One of the reclamation options is to open up the pit to the fjord so that it becomes a marine ecosystem. Here there might be an opportunity to follow not only ecosystem succession after marine inundation, but such beneficial options as extending the local salmon farm industry into the flooded pit, and managing it for maximum harvests.

The point of this article is that our engineering capability is inevitably leading us towards very large scale, even global, topographic and enviro-chemical changes. It has done so to date faster than our capability for assessment, prediction and prevention of many of the larger catastrophic changes; witness Bhopal and Chernobyl. Observational science can only conduct hindsight assessments, i.e. what happened after the event. Environmental science should be extended to large scale experiments, using not only scientist-designed tests, but, more important, treating some appropriate industrial developments as controllable experiments in the interests of society.

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Concentrations of Organochlorine Compounds in the Blubber of Seals from Eastern and North-eastern England, 1988

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Samples of blubber from common seals (*Phoca vitulina*) found dead in eastern England and grey seals (*Halichoerus grypus*) found dead on the Farne Islands have been analysed for a range of organochlorine pesticides, individual chlorobiphenyl congeners and total polychlorinated biphenyls (PCB). No significant differences were seen between results for the two seal species. HCB and HCH concentrations were low, and total DDT and PCB concentrations (ranging from 0.99–8.0 and 5.7–33 μg g^{-1} wet wt respectively) were at the lower end of the reported range for seals from the North and Baltic Seas. PCB profiles were dominated by congeners 138 and 153, and amongst the DDT group of compounds the pattern of abundance was DDE > DDT ⩾ TDE.

Recent media reports of the deaths of large numbers of common seals (*Phoca vitulina*) around the northwest coast of Europe, apparently as a result of infection with a previously undescribed virus from the morbilli genus (Osterhaus & Vedder, 1988; Osterhaus *et al.*, 1988; Kennedy *et al.*, 1988; Mahy *et al.*, 1988; Cosby *et al.*, 1988), have correlated the severity of the outbreak with pollution in the North Sea. There is strong evidence that the high levels of organochlorines which have been recorded in the blubber of seals in the Dutch Wadden Sea and the Baltic Sea have contributed to the low fertility which has been observed in these areas (Anon., 1988). In the present disease outbreak attention has again focused on organochlorine contaminants, and specifically on PCBs which have been demonstrated to increase the vulnerability of laboratory rats to infection (Wassermann *et al.*, 1979). In order to establish the current levels of organochlorine contaminants in the blubber of seals on the east coast of England, where the disease was first reported in the UK, we have analysed samples from common seals and grey seals (*Halichoerus grypus*) found dead around the Wash and at the Farne Islands (Fig. 1).

Methods

Cubes of blubber approximately 2.5 cm on each side were removed from the region of the sternum of 10

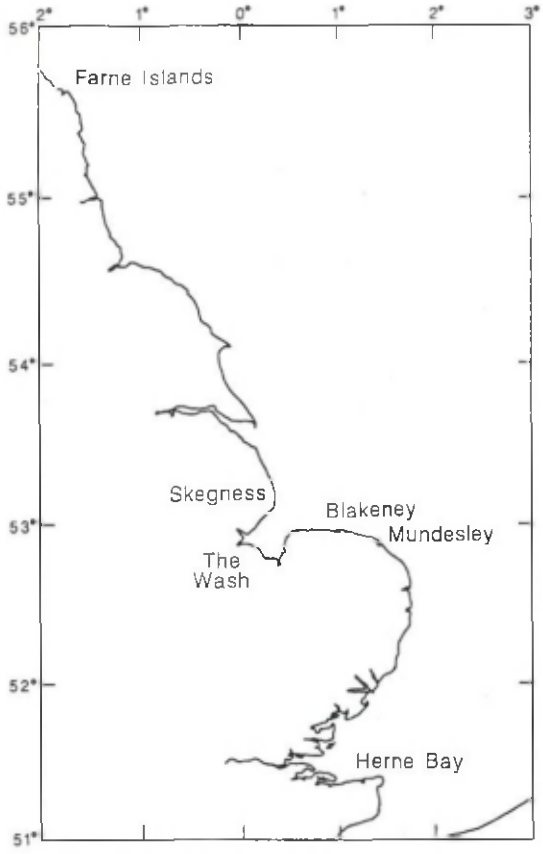

Fig. 1 Location of the sampling sites.

recently dead common seals and 3 grey seals. Where possible animals less than 18 months old were sampled in order to minimize the effects of age-related accumulation.

Samples were placed in pre-cleaned Soveril tubes with PTFE lid-liners and stored at −20°C within 10 h of collection. Organochlorine compounds were analysed by capillary gas chromatography using fused silica columns with electron capture detection, following Soxhlet extraction with hexane and clean-up and fractionation of the extract by column chromatography on alumina and silica. Full details of the procedure are given elsewhere (Allchin *et al.*, in press). In this paper ΣPCB refers to polychlorinated biphenyl concentrations expressed on a formulation basis as Aroclor 1254, obtained by summation of four major peaks. Individual chlorobiphenyl congeners are numbered according to Ballschmitter & Zell (1980), and comprise the primary list agreed for monitoring purposes by the International Council for the Exploration of the Sea (ICES) (Anon., 1986). Analytical quality control for the chlorobiphenyl congener data was carried out by parallel analyses of fish-oil reference materials certified for the 7 congeners analysed (CRM 349 and 350; Bureau of Community Reference, Brussels, Belgium). The results obtained were in good agreement with the certified values.

There are considerable technical difficulties in the analysis of animal tissues for organochlorine compounds. Analytical exercises undertaken by ICES have shown that overall interlaboratory comparability in this field has been poor, although the use of certified reference materials now becoming available should enable laboratories to improve their accuracy and hence the comparability between results from these laboratories. In order to obtain some truly comparable data for tissue concentrations of organochlorines, samples of seal tissue from many sites are currently being analysed by a single laboratory (ICES, 1988). A further multi-laboratory intercomparison exercise utilizing marine mammal tissue is also currently underway. The design of this exercise is based on stepwise development, starting with distributed standards.

Although high levels of many environmental contaminants have been recorded in the tissues of marine mammals, only the organochlorines have been associated with significant problems (Anon., 1988a). No analyses were carried out for polychlorinated dibenzofurans and dibenzo-*p*-dioxins. These compounds are known to be particularly toxic to mammals but analyses of samples of seal blubber from Spitzbergen, northern Norway, the Kattegat and the Baltic Sea collected before the epidemic (Olsson *et al.*, 1988) have shown levels similar to those seen in normal human tissues and it was not considered that the levels posed a hazard to the seals. Furthermore it was suggested that the seals were capable of either excreting or metabolising both classes of compounds.

Results and Discussion

Organochlorine compounds, because of their lipophilic nature, tend to accumulate in blubber. Positive correlations of organochlorine concentrations with age in male seals have been demonstrated in some studies (Reijnders, 1980) but as females can pass on part of their body burden annually to their offspring, any such relationship would be less pronounced or absent in their case. High concentrations may be found in seal pups because these compounds are transferred to the offspring during pregnancy and subsequently via milk. Values for comparison have, where possible, been selected to reflect the fact that the majority of the data from this study relate to pups and yearlings.

The results of the analyses are given in Tables 1, 2, together with the sample details. Organochlorine concentrations are similar in both grey and common seal tissues. HCB and HCH concentrations are low, with β-HCH absent from all samples and the more persistent α-isomer generally present at higher concentration than γ-HCH (lindane). These concentrations are of the same order as those reported for Arctic ringed seals (*Pusa hispida*) from Spitzbergen in 1986 (Oehme *et al.*, 1988). Concentrations of DDT and its metabolites occur with DDE > DDT ≫ TDE, and ΣPCB concentrations are higher by more than a factor of 3 than ΣDDT concentrations (ΣDDT = DDE + TDE + DDT). Values for ΣDDT concentrations and for the ratio of DDT to DDE observed for grey seals at the Farne Islands in this study are lower than those recorded by Donkin *et al.* (1981) in samples collected in 1972 (Table 3); however this apparent reduction may be due to differences in analytical methods. A reduction of the relative amount of DDT to DDE in the period 1972–1988 would nevertheless be in line with expectations, because the use of DDT in its major applications in agriculture was

TABLE 1

Concentrations of organochlorine compounds in blubber tissue of common seals *Phoca vitulina* (μg g^{-1} wet wt). HEL, hexane extractable lipid; ΣPCB quoted as Aroclor 1254; 28, etc., chlorobiphenyl congeners numbered as in Ballschmitter and Zell (1980). Mean excludes sample from Skegness as this sample contained some skin and connective tissue as well as blubber.

Location	Date of Death	Age (years)	% HEL	HCB	α-HCH	β-HCH	γ-HCH	Dieldrin	*pp'*-DDE	*pp'*-TDE	*pp'*-DDT	ΣPCB	28	52	101	118	138	153	180
Skegness	10/8/88 ♀ captive	< 1	50	0.011	0.018	< 0.001	0.26	0.076	0.7	0.048	0.27	6.7	0.014	1.1	0.14	0.17	0.65	0.9	0.26
Mundesley	4/8/88 ♂ wild	< 1	89	0.007	0.032	< 0.001	0.005	0.22	2.8	0.071	1.5	20	0.015	0.73	0.24	0.27	1.8	2.4	0.82
Herne Bay	12/8/88 ♂ wild	< 1	57	0.006	0.048	< 0.001	0.009	0.33	4.6	0.095	3.3	33	0.033	0.79	0.4	0.49	3.0	3.6	1.1
Blakeney	17/8/88 ♀ wild	12	71	< 0.001	0.019	< 0.001	< 0.001	0.26	2.8	0.021	2.2	29	0.012	0.5	0.11	0.11	1.4	2.1	1.2
Blakeney	17/8/88 ♂ wild	3	72	0.005	0.015	< 0.001	0.004	0.12	1.6	0.016	0.76	12	0.006	0.35	0.15	0.14	1.1	1.4	0.53
Blakeney	17/8/88 ♀ wild	< 1	76	0.005	0.018	< 0.001	0.004	0.13	2.4	0.026	0.99	21	0.005	0.48	0.17	0.08	1.6	2.4	1.0
Blakeney	25/8/88 ♂ wild	2	78	< 0.001	0.013	< 0.001	< 0.001	0.13	2.7	0.019	0.84	22	0.006	0.84	0.19	0.17	1.9	2.6	0.89
Blakeney	25/8/88 ♀ wild	1	80	0.004	0.024	< 0.001	0.011	0.12	3.1	0.058	1.5	23	0.011	0.83	0.29	0.29	2.2	2.8	0.84
Blakeney	25/8/88 * wild	1	78	0.004	0.023	< 0.001	< 0.001	0.19	4.2	0.045	1.8	27	0.014	1.1	0.42	0.18	2.5	3.2	1.1
Blakeney	25/8/88 ♂ wild	1	51	0.002	0.016	< 0.001	0.003	0.53	3.4	0.040	1.9	24	0.01	0.38	0.31	0.17	2.1	2.6	0.8
			Mean	0.004	0.023	< 0.001	0.004	0.23	3.1	0.043	1.6	23	0.012	0.67	0.25	0.21	2.0	2.6	0.92

*Sex not recorded.

TABLE 2

Concentrations of organochlorine compounds in blubber of grey seals *Halichoerus grypus* from the Farne Islands (μg g^{-1} wet wt). (Abbreviations as for Table 1).

Date of Death	Age (years)	% HEL	HCB	α-HCH	β-HCH	γ-HCH	Dieldrin	*pp'*-DDE	*pp'*-TDE	*pp'*-DDT	ΣPCB	28	52	101	118	138	153	180
1/9/88 wild ♀	< 1	83	0.18	0.05	< 0.001	< 0.001	0.27	3.6	0.11	2.5	20	0.007	0.38	0.23	0.33	2.1	2.5	0.71
1/9/88 wild ♀	< 1	79	0.21	< 0.001	< 0.001	< 0.001	0.19	3.6	0.1	1.6	28	0.17	0.36	0.19	0.23	2.7	4.2	1.2
1/9/88 wild ♀	27	86	0.013	< 0.001	< 0.001	< 0.001	0.02	0.58	0.091	0.32	5.7	0.07	0.3	0.05	0.07	0.45	0.74	0.44
		Mean	0.13	0.017	< 0.001	< 0.001	0.16	2.6	0.1	1.5	18	0.08	0.35	0.16	0.21	1.8	2.5	0.78

progressively phased out between the late 1970s and 1984.

The range of chlorobiphenyl congeners present in the PCB fraction corresponds quite well with that to be anticipated if Aroclor 1254 were the major original source formulation (Fig. 2); thus the early peaks are much reduced. The chlorobiphenyls are dominated by congeners 138 and 153 (both 2,4,5-substituted hexachlorobiphenyls) and in common with other studies (Boon & Eijgenraam, 1988; Muir *et al.*, 1988) 153 was always present at the highest concentration. The persistence of 138 and 153 is related to their resistance to enzymatic metabolic processes (Boon & Eijgenraam, 1988) in fish and mammals. The ratio of concentrations of congeners 138 and 153 in the blubber of the common seals was very similar, with a mean of 0.75 (coefficient of variation 7.43%, n=10) despite the differences in age and sex. Fewer samples of blubber were analysed from grey seals, but the corresponding mean was 0.70. No significant differences can be seen in our data between seals from colonies to the north and south of major industrialized rivers such as the Tyne, Tees and Humber, presumably because of the movement of both the seals and their food, and mixing of contaminants in the coastal zone in which they live and feed.

Table 3 gives reported data for the compounds and classes determined in our study with those reported from other areas in NW Europe. Data for a number of species have been compared because interspecific variation seems to be much smaller than regional variation. In view of the current state of interlaboratory comparability, it is not possible to be too categoric about comparative concentrations, but the indications are that contaminant concentrations in seals from the east coast of England are at the lower end of the range of published data. Reijnders (1980) showed a relationship between ΣPCB and ΣDDT concentrations (μg g^{-1} fat weight) in blubber of common (harbour) seals from the Dutch, German and Danish Wadden Sea, where:

$$\Sigma PCB = 12.5\ \Sigma DDT - 36.3 \qquad (r = 0.81)$$

for data collected between 1974 and 1978. This relationship varies with geographical area and with time in one area, reflecting changes in inputs.

Our own data for both common and grey seals together yield:

$$\Sigma PCB = 3.81\ \Sigma DDT + 6.13 \qquad (r = 0.94)$$

Historically the highest ΣPCB and ΣDDT concentrations were found in the Wadden Sea and the Gulf of Finland. ΣPCB and ΣDDT levels for grey and ringed seal yearlings from the Gulf of Finland and Bothnian Bay have shown some reduction over the period 1976–83 following decreases in their concentrations in several fish populations along the Finnish coast (Helle *et al.*, 1985).

The reduction in concentrations has been more rapid for DDT compounds than for PCBs, probably as a result of the earlier and more effective controls on its use (Helle *et al.*, 1985). Around the North Sea ΣPCB concentrations exceed those of ΣDDT. There are some indications that DDT concentrations have reduced in the livers of fish from the North Sea over the period 1975–1985 (Anon., 1988b). However, during that period ΣPCB concentrations were higher off the Belgian coast than along the east coast of England; also, chlorobiphenyl congener concentrations were high in the Scheldt Estuary, German Bight and the Gulf of Finland for the same tissue, but no comparable congener data were presented for samples from eastern England. Concentrations of ΣPCB at the higher end of the range shown in Table 3 have been linked with the widespread infertility observed in seals from the Wadden Sea and the Baltic Sea (Reijnders, 1986), and with sterility in grey seals and ringed seals (*Phoca hispida*) in the Baltic (Helle *et al.*, 1976). Neither of these problems has been observed in UK seals (Anon., 1987).

In conclusion, the organochlorine concentrations

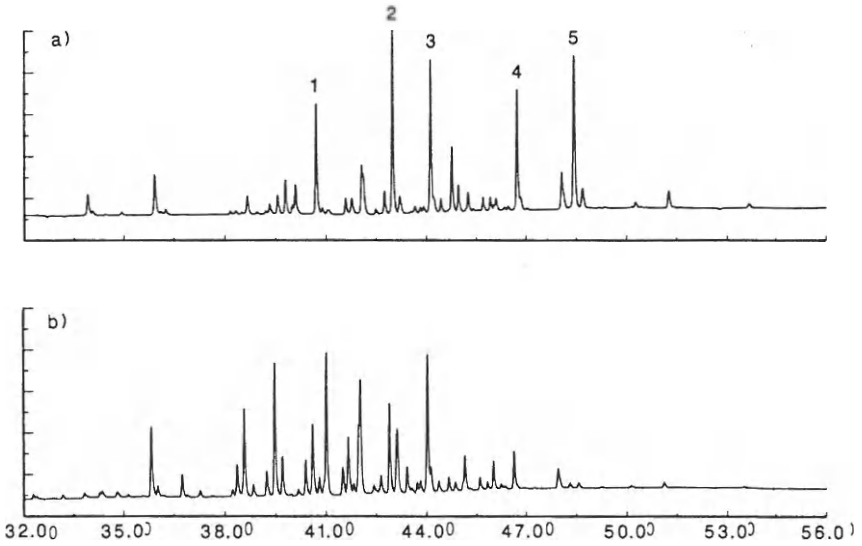

Fig. 2 Chromatograms of (a) seal blubber extract and (b) standard solution of Aroclor 1254. The numbered peaks correspond to: 1, pp'-DDE; 2, 3 and 4, chlorobiphenyl congeners 153, 138, and 180 respectively; 5, an internal standard (mirex) used for quantification.

TABLE 3

Mean organochlorine concentrations in the blubber of seals around the North Sea area (μg g^{-1} fat wt). Species: C—Common (Harbour) seal, *Phoca vitulina*; G—Grey seal, *Halichoerus grypus*; A—Arctic ringed seal, *Pusa hispida*; S—Saimaa ringed seal, *Phoca hispida saimensis*; B—Baltic ringed seal, *Phoca hispida botnica*. Range of values indicated in brackets for total PCB and total DDT.

	E. England	Farne Is. NE. England		Spitzbergen*	Norway		Gulf of Bothnia		Baltic proper	L. Saimaa E. Finland	Gulf of Finland		Denmark and Schleswig-Holstein	German North Sea coast	Dutch Wadden Sea	
Species	C	G	G	A	C	G	A	G	G	S	G	B	C	C	C	C
HCB	0.006		0.16	0.022	0.05	0.14										
α-HCH	0.033		0.021	0.13									0.5		0.3	
β-HCH	< 0.001		< 0.001	0.007									0.3			
γ-HCH	0.006		< 0.001	0.006										0.32		
Dieldrin	0.33	0.38	0.19	0.071										0.22	0.5	
pp'-DDE	4.4	8.1	3.1	1.2							29	64	11		16	
pp'-TDE	0.061		0.12								2.3	2.7	0.6		1.8	
pp'-DDT	2.3	9.7	1.8	0.39							20	30	5.5		9.0	
ΣDDT	6.8	18	5.0		2.1	2.8	200	210	420	36	51	96	17	9.3	30	
	(3.3–14)	(4.3–36)	(1.2–7.5)		(1.2–4.6)	(0.6–8.2)				(5.2–100)	(7.9–110)	(11–200)	(4.0–47)	(2.5–31)	(3.3–130)	
ΣPCB	33	33	22		16	6.6	110	100	140	37	66	96	110	180	130	210
	(17–58)	(4.1–89)	(6.9–34)		(13–23)	(1.9–15)				(5.1–93)	(31–140)	(14–340)	(23–340)	(31–640)	(5.0–680)	(24–640)
28	0.012		0.1	0.015												
52	0.67		0.42													
101	0.25		0.19													
118	0.21		0.25													
138	2.0		2.2	0.32												
153	2.6		3.0	0.37												
180	0.92		0.94	0.12												
Reference	This study	a	This study	b	c	c	d	d	d	e	f	f	g	h	g	i
Year	1988	1972	1988	1986	1977	1977	– – – – – pre-1976 – – – – –			1977–81	1976–1982		1975/6	1974–6	1975/6	1978?

*Results in μg g^{-1} wet wt. References: a, Donkin *et al.* (1981); b, Oehme *et al.* (1988); c, Ofstad and Martinsen (1983); d, Helle *et al.* (1976a); e, Helle *et al.* (1983); f, Perttila *et al.* (1986); g, Reijnders (1980); h, Drescher *et al.* (1977); i, Duinker *et al.* (1979).

reported in this paper give no support to suggestions that gross pollution is adversely affecting seals on the English east coast. The concentrations may, however, be sufficient to result in some additional stress to animals when they mobilize their lipid reserves during illness or starvation.

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Detergents as a Condition of Pollution from Coastal Marine Aerosol

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Experimental evidence of damage of a *Pinus pinea* foliage by detergent surfactants in aerosol from marine water solutions is shown. Typical natural non-detergent surfactants from the coastal marine environment, such as humic acids, do not cause *per se* damage although they could become a vehicle of polluting agents in marine aerosols. Taking into account that the damage mechanism due to the detergents can be generalized to all type of coastal vegetation, this damage is suggested in a first instance as an indication of marine pollution.