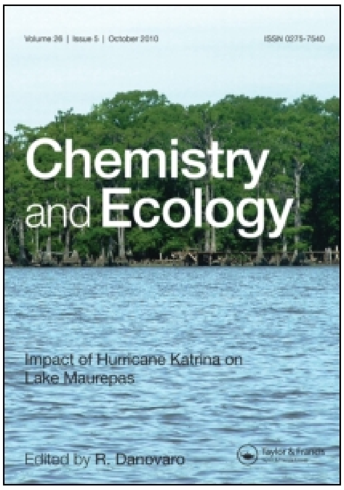

Chemistry and Ecology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455114

The Metal Content of Fish and Shellfish in Liverpool Bay

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To cite this Article Norton, M. G. and Murray, A. J.(1983) 'The Metal Content of Fish and Shellfish in Liverpool Bay', Chemistry and Ecology, 1: 3, 159 — 171
To link to this Article: DOI: 10.1080/02757548308070799
URL: http://dx.doi.org/10.1080/02757548308070799

Chemistry in Ecology, 1983, Vol. 1, pp. 159–172
0275–7540/83/0103–0159 $18.50/0

Printed in Great Britain

The Metal Content of Fish and Shellfish in Liverpool Bay

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(*Received May 25, 1982*)

Liverpool Bay supports a productive commercial fishery yet at the same time is also used as a site for the disposal of waste by dumping, as well as receiving discharge of effluent from pipelines, rivers and estuaries. This paper summarizes the results of the monitoring programme of fish and shellfish quality in Liverpool Bay carried out in recent years including two special surveys conducted in and around the sewage sludge dumping site in 1980 and 1981. The concentrations of trace metals are discussed in relation to inputs into the bay. Mercury concentrations in fish appear to vary with the two major imputs (sewage sludge dumping and industrial discharges). There is no evidence of widespread elevated concentrations of cadmium, lead, zinc and copper in fish and shellfish from the bay but there is some evidence of local contamination by these metals. None of the elevated concentrations of metals found appear to be significant from a public health viewpoint.

INTRODUCTION

Liverpool Bay (Figure 1) supports important commercial fisheries and shellfisheries, particularly for plaice, sole, cod, whiting, rays, queens, scallops and shrimps (Brander, 1980; Corlett and O'Sullivan, 1972). The bay also adjoins a densely populated and highly industrialized part of England drained by the Rivers Mersey and Dee, which receive a large number of sewage and industrial discharges. These rivers contribute substantial quantities of metals to Liverpool Bay which are supplemented by direct inputs from coastal discharges and from the dumping of sewage sludges, industrial wastes and dredged spoils (see Figure 1 for dumping site locations).

The Ministry of Agriculture, Fisheries and Food (MAFF) is responsible under the Dumping at Sea Act, 1974 for licensing waste disposal by dumping from vessels and also acts in an advisory capacity to the Regional

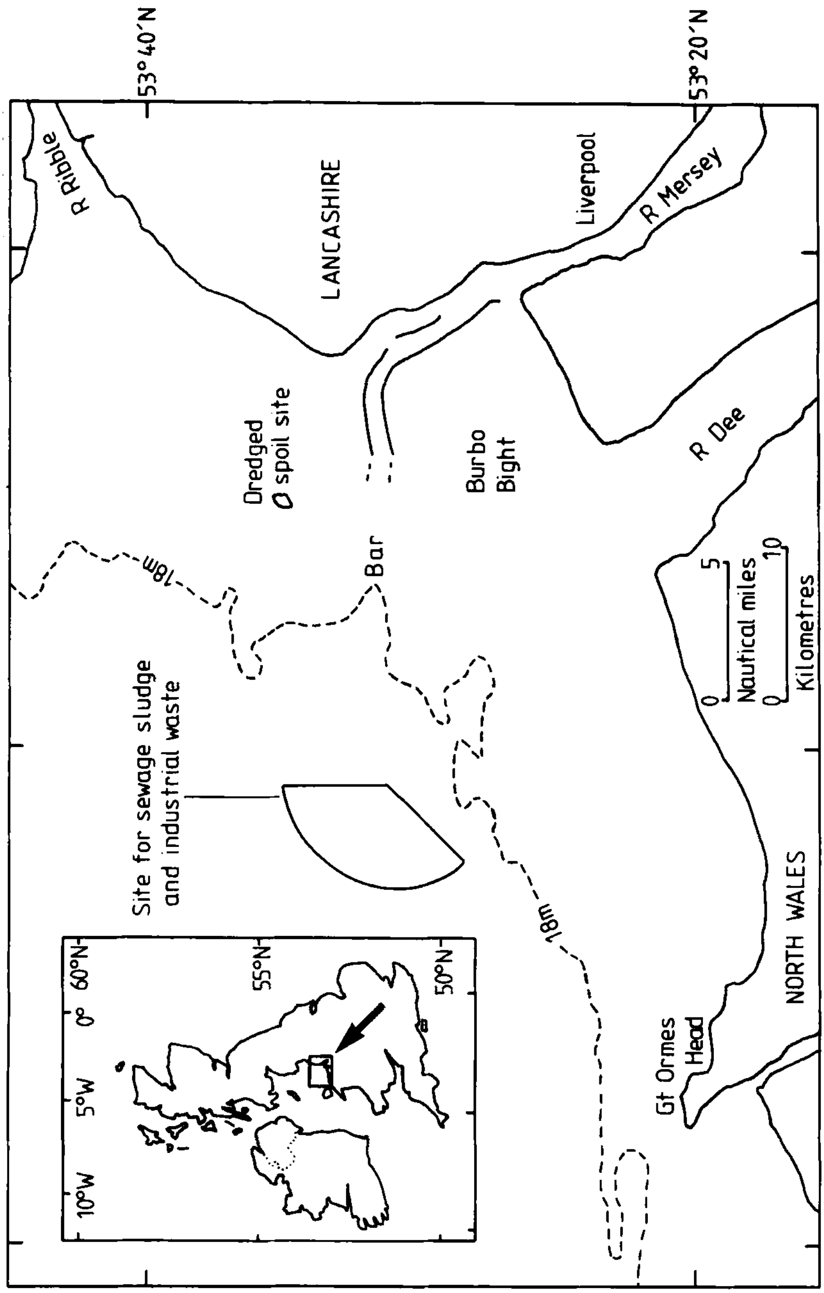

FIGURE 1 Liverpool Bay and the dumping sites for sewage sludge/industrial waste and for dredged spoil.

Water Authorities concerning the control of discharges to estuarine and coastal waters under Part II of the Control of Pollution Act, 1974. To meet these responsibilities and also to ensure the acceptability of marine foodstuffs for human consumption, MAFF has carried out regular surveys since 1970 of the metal concentrations in fish and shellfish from waters around England and Wales. Cooperative investigations in the North Sea and North Atlantic (including the Irish Sea) have also been undertaken with other countries mainly under the auspices of the International Council for the Exploration of the Sea. In recent years attention have been directed to inshore areas, such as Liverpool Bay, which are known to receive substantial inputs of metals from dumping activities and from other sources.

Results of analyses of fish and shellfish landed in England and Wales from 1970–5 have been published (Murray, 1979, 1981; Portmann, 1979) and a review of the results from specific areas used for the dumping of wastes has also been prepared (Murray and Norton, in press). Liverpool Bay has been the site of a special study of mercury inputs and their relationship to the concentration of that metal in fish muscle tissue (Preston and Portmann, 1981) in connection with the European Community Dangerous Substances Directive (CEC, 1976). These authors demonstrated a link between mercury inputs and concentrations in fish muscle for the years 1972 to 1979 and were able to make a model which allowed mercury concentrations in fish to be predicted from a knowledge of the mercury input to the bay; thus the input could be regulated in order to meet an acceptable concentration of mercury in fish flesh.

This paper presents the results of analyses of fish and shellfish from Liverpool Bay for mercury, cadmium, lead, zinc and copper from 1970 to 1981. Routine surveys from 1970–80 were based on samples from the main commercial fishing areas, but the 1980 and 1981 data include the results of two special surveys of fish and shellfish sampled from the region of the sewage sludge dumping ground and inshore towards the Mersey.

METHODS

Commercially valuable species of fish and shellfish were taken by trawl from commercial fishing vessels and MAFF research vessels. In 1980 and 1981, samples from areas near to and inshore of the dumping ground were taken by staff of the Marine Science Laboratories of the University College of North Wales as part of a contract with the Department of the Environment. All samples were analysed by MAFF.

Samples of fish usually comprised 10–20 individuals whose length, weight and sex were recorded. The metal analysis was in general carried out on the muscle tissue of individual fish although a few samples of muscle were bulked for analysis. Only the edible portion of shelfish was analysed, except for shrimps which were analysed whole and hermit crabs which were also analysed whole after removal of the host shell. The shellfish samples usually contained about 50 individuals and were bulked prior to analysis. The edible crabs were analysed individually and their size, weight and where possible, sex were recorded.

After preparation of the fish or shellfish tissue, the samples were mineralized with an equal mixture of concentrated nitric acid and hydrogen peroxide. The concentrations of cadmium, lead, zinc and copper in the resultant solution were determined by conventional flame atomic absorption spectrophotometry (AAS). Mercury concentrations were determined by a flameless AAS technique (Kirkwood, 1976). Further details of the methods of sample preparation and analysis have been published (Eagle *et al.*, 1978; Portmann, 1979; Murray, 1979).

INPUTS OF METALS TO LIVERPOOL BAY

Estimates of the quantities of metals entering Liverpool Bay from rivers, estuaries and coastal waters for 1976, together with the inputs of metals present in dumped wastes are given in Table I. It is seen that the relative

TABLE I

Inputs of metals into Liverpool Bay (kg d^{-1}) in 1976

Source	Hg	Cd	Cu	Pb	Zn
River discharge	1.0	93	205	ND	425
Direct sewage/ industrial discharges	7.8	44	145	129	4082
Dumping of sewage sludge	7.4	6	301	150	726
Dumping of industrial wastes	0	0	2	1	3
Dumping of dredged spoils	12	3.6	301	904	2190
Dumping of sewage sludge					
1977	6.8	5.8	318	180	644
1978	2.5	5.6	274	160	630
1979	1.9	5.3	222	151	553
1980	2.2	3.8	189	164	644

Sources: MAFF unpublished data
DOE/NWC (1979)

ND—not determined

TABLE II

Concentrations of metals in fish muscle tissue from Liverpool Bay 1970–80 (mg kg^{-1} wet weight)

		Mean (range) concentration								
Species	Year	Hg		Cu		Zn		Cd	Pb	
Dab	1970	0.52	(0.33–0.71)		—		—	< 0.2	1.6	—
	1973	0.18	(0.05–0.36)	0.3	(0.2–0.3)	4.8	(4.6–5)	< 0.2	0.4	(0.3–0.4)
	1974	0.34	(0.22–0.44)	0.4	(0.3–0.6)	3.1	(2.4–4.4)	< 0.2	0.3	(0.2–0.5)
	1976	0.31	(0.04–0.71)	0.3	(0.2–0.3)	4.2	(3 –6.5)	< 0.2	0.2	(< 0.2–0.7)
	1977	0.34	(0.15–0.75)	0.3	(0.2–0.4)	3.5	(3.5–7.4)	< 0.2	< 0.2	(< 0.2–0.4)
	1978	0.38	(0.08–0.72)		—		—	—		—
Whiting	1970	0.88	—		—		—	< 0.2	2.5	—
	1973	0.33	(0.13–0.54)	0.3	(0.2–0.4)	4.2	(3.5–5.2)	< 0.2	0.6	(0.3–0.7)
	1974	0.25	(0.12–0.36)	0.6	(0.3–0.8)	3.5	(2.2–4.2)	< 0.2	0.3	(< 0.2–0.5)
	1976	0.52	(0.19–1.2)	0.2	(< 0.2–0.4)	3.4	(2.7–4.4)	< 0.2	0.3	(< 0.2–0.6)
	1978	0.34	(0.1 –0.8)		—		—	—		—
	1979	0.26	(0.09–0.49)		—		—	—		—
Cod	1973	0.31	(0.11–0.47)	0.4	(0.2–0.6)	3.5	(2.4–4.5)	< 0.2	0.6	(0.3–1.2)
	1974	0.26	(0.19–0.34)	0.3	(0.2–0.5)	2.4	(1.6–3.2)	< 0.2	0.3	(0.2–0.4)
	1976	0.29	(0.08–0.44)	0.2	(0.2–0.5)	3.6	(2.8–5.1)	< 0.2	0.3	(< 0.2–1.5)
	1979	0.32	(0.11–0.54)		—		—	—		—
	1980	0.15	(0.02–0.55)	< 0.3	—	3.7	(2.8–4.6)	< 0.2	0.6	(< 0.2–1.8)
Plaice	1970	0.51	—		—		—	< 0.2	1.2	—
	1973	0.46	(0.22–0.80)	0.5	(0.3–0.5)	4.8	(2.2–5.6)	< 0.2	0.3	(< 0.2–0.6)
	1974	0.30	(0.13–0.5)	0.3	(< 0.2–0.5)	3.6	(2.2–5.0)	< 0.2	< 0.2	(< 0.2–0.4)
	1976	0.44	(0.11–1.4)	0.3	(< 0.2–0.5)	4.7	(2.6–8.9)	< 0.2	0.2	(< 0.2–0.5)
	1977	0.21	(0.08–0.38)	0.5	(0.3–0.7)	6.0	(4 –7.3)	< 0.2	< 0.2	(< 0.2–0.4)
	1978	0.15	(0.01–0.55)		—		—	—		—
	1979	0.21	(0.1 –0.52)		—		—	—		—
	1980	0.14	(0.07–0.28)	< 0.2	—	6.3	(4.6–7.5)	< 0.2	< 0.2	—

Table II (*Contd.*)

Species	Year	Mean (range) concentration								
		Hg		Cu		Zn		Cd	Pb	
Sole	1970	0.31	—		—		—	< 0.2	1.5	—
	1973	0.17	(0.06–0.53)	0.4	(0.2–0.5)	4.6	(2.1–6.4)	< 0.2	0.5	(0.3–1)
	1974	0.25	(0.20–0.34)	0.7	(0.5–0.9)	4.0	(3 –5)	< 0.2	0.5	(0.3–0.7)
	1976	0.14	(0.04–0.36)	0.3	(< 0.2–0.4)	3.9	(3 –5)	< 0.2	0.3	(< 0.2–1.2)
	1977	0.17	(0.09–0.58)		—		—	—		—
	1978	0.15	(0.07–0.4)		—		—	—		—
	1979	0.16	(0.09–0.25)		—		—	—		—
Dogfish	1977	1.9	(0.55–3)	0.6	(0.3–0.8)	11	(9.1–16)	< 0.2	1.6	(0.7–3.1)
Rays	1974	0.39	(0.17–1)	0.3	(0.2–0.6)	4.8	(3.3–7.9)	< 0.2	1.9	(0.2–4)
	1976	0.46	(0.22–0.68)	0.4	(0.3–0.5)	4.7	(3.3–8.4)	< 0.2	1.8	(0.3–3.1)

importance of each source in 1976 varied with the metal concerned. Dredged spoils were an important source numerically but several studies (Murray and Norton, 1979; Hirsch *et al.*, 1978) have shown the bioavailability of metals in such spoils to be low. If the inputs from dredged spoils are not considered further, the most important sources were sewage sludge dumping (copper and lead), direct sewage/industrial discharges (zinc) and rivers (cadmium). In 1976 sewage sludge and industrial discharges were responsible for about the same input of mercury. More recent inputs data are available only for dumped wastes and the annual inputs from sewage sludge dumping are thus included in Table I.

RESULTS

The results of the analyses of fish from the commercial fishing areas (mainly to the west of the sludge dumping ground) during 1970–80 are given in Table II and analyses of shellfish from 1970–6 in Table III. The results of the supplementary surveys in 1980 and 1981 of fish and shellfish obtained from and inshore of the dumping ground (Figure 1) are presented in Table IV. Typical concentrations of metals in fish and shellfish from other UK waters can be found in reports by Portmann (1979). Murray (1979, 1981) and Murray and Norton (in press). A description of the results of analysis for each metal now follows.

TABLE III

Concentrations of metals in shellfish from Liverpool Bay in 1970-76 (mg kg^{-1} wet weight)

Species	Organ	Year	Hg	Cu	Zn	Cd	Pb
Brown shrimp	Whole	1973	0.18	19	21	0.7	4.3
		1976	0.15	30	26	0.6	3.8
Edible crab	Body	1973	0.23	50	31	2.8	1.2
	Claw	1973	0.41	17	64	< 0.2	1.7
Hermit crab	Whole	1973	0.2	84	31	0.4	1.1
		1974	0.2	96	23	< 0.2	0.6
		1975	0.5	150	35	0.4	< 0.2
Queen	Muscle	1973	0.13	3.5	35	< 0.2	1.0
		1974	0.09	3.4	50	0.3	0.4
		1976	0.19	12	170	0.5	1.5
	Gonad	1973	0.05	7.5	90	0.7	2.9
		1976	0.07	4.6	57	0.6	0.4
	Whole	1970	0.22	18	17	0.7	0.7

TABLE IV

Concentrations of metals in fish muscle tissue and shellfish from and inshore of the sewage sludge dumping ground 1980–81 (mg kg^{-1} wet weight)

		Mean (range) concentration				
Area	Species (number)	Hg	Cu	Zn	Cd	Pb
Dumping area (1980)	Cod (14)	0.27 (0.08–0.4)	0.7 (< 0.2–5.8)	4.0 (3.3–5.9)	< 0.1	< 0.2 (< 0.2–2.5)
	Dab (15)	0.37 (0.16–0.93)	0.3 (< 0.2–0.5)	4.3 (3.3–5.7)	< 0.1	< 0.2
	Sole (7)	0.14 (0.09–0.35)	0.3 (< 0.2–0.7)	4.1 (3.2–4.6)	< 0.2	< 0.2
	Hermit crab (bulked)	0.37	80	34	0.3	< 0.4
	Queen (2 bulked samples of whole flesh)	0.09 (0.08–0.1)	9 (5.3–13)	55 (24–85)	0.9 (0.8–1)	2.5 (< 0.2–5.0)
Bar area (1980)	Cod (8)	0.24 (0.15–0.36)	0.4 (0.3–0.45)	3.5 (3.0–4.2)	< 0.2	< 0.2
	Dab (24)	0.41 (0.15–1)	0.4 (< 0.2–0.6)	7.2 (4.2–9.3)	< 0.2	< 0.2
	Plaice (12)	0.20 (0.1–0.53)	0.4 (< 0.2–0.6)	6.6 (5.1–9.0)	< 0.2	0.5 (< 0.2–0.8)
	Brown shrimp (bulked)	0.11	16	20	< 0.4	< 0.4
Bar area (1981)	Dab (10)	0.37 (0.16–0.77)	0.4 (< 0.2–0.6)	5.1 (4.5–5.6)	< 0.2	< 0.2
	Plaice (10)	0.26 (0.11–0.68)	0.4 (0.3–0.5)	5.0 (4.2–6.3)	< 0.2	< 0.2
	Ray (10 bulked)	0.29	0.4	3.2	< 0.2	0.7
Burbo Bight (1980)	Dab (25)	0.57 (0.25–1.3)	0.4 (0.25–0.5)	6.4 (4.6–9)	< 0.1	0.5 (0.2–1)
	Flounder (20)	0.71 (0.2–1.2)	0.5 (< 0.2–1)	20 (4.6–60)	< 0.2	< 0.3 (< 0.2–1.4)
	Plaice (27)	0.24 (0.1–0.68)	0.4 (< 0.2–0.7)	6.3 (5.2–8.6)	< 0.1	< 0.2
	Thornback ray (7)	0.49 (0.26–1.4)	0.4 (< 0.2–0.8)	4.0 (2.2–8.6)	< 0.2	< 0.2
Burbo Bight (1981)	Dab (10)	0.60 (0.24–0.91)	< 0.4 (< 0.2–0.7)	6.0 (4.4–6.9)	< 0.2	< 0.2
	Flounder (10)	0.42 (0.14–0.66)	< 0.2 (< 0.2–0.6)	7.5 (5.2–10)	< 0.2	< 0.2
	Plaice (10)	0.21 (0.08–0.53)	< 0.4 (< 0.2–0.9)	6.0 (4.6–8.0)	< 0.2	< 0.2
	Brown shrimp (bulked)	0.08	6.0	7.5	< 0.2	< 0.2

Mercury The concentrations of mercury in fish muscle during the period 1970–80 (Table II) and 1980–81 (Table IV) show that there has been a general decline since 1970, although mean concentrations are still higher than in fish from most other inshore areas around the U.K. The most noticeable fall in mercury concentrations took place between 1970 and 1973 and coincided with the introduction of measures to control the major industrial inputs to the bay (Preston and Portmann, 1981). The 1980/81 surveys included samples of fish from several areas within Liverpool Bay from the commercial fishing areas north and east of the dumping ground to areas inshore of the dumping ground. The exact location of capture within the area sampled did not appear to influence the mercury concentrations in most species of fish, except for dabs where higher concentrations were found in the samples from the Burbo Bight. In general therefore, samples of fish taken from anywhere in the bay are likely to be representative of the bay as a whole. Concentrations of mercury in shellfish were elevated in some samples, including the 1980 samples of hermit crabs taken from the dumping ground, but the limited number of samples analysed precludes any determination of temporal or spatial trends.

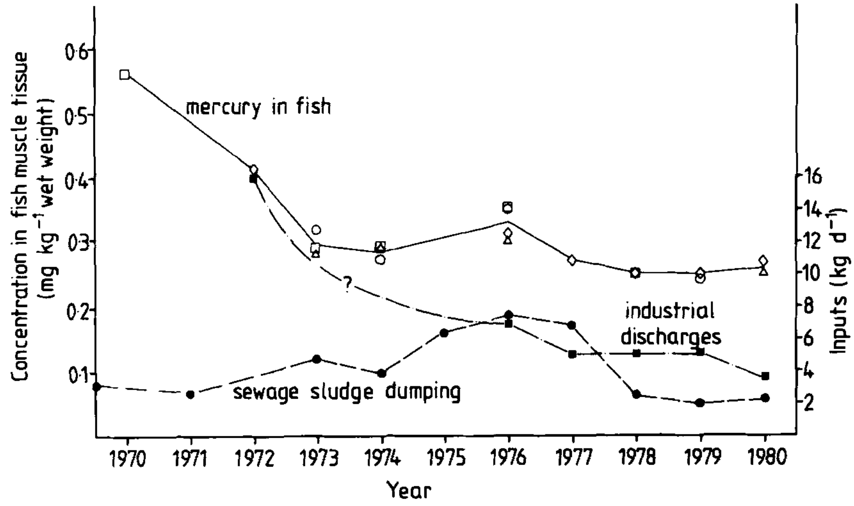

FIGURE 2 Concentrations of mercury in fish muscle tissue and inputs of mercury to Liverpool Bay from industrial discharges and sewage sludge dumping.
△ mean concentration of mercury in dab, cod, plaice, sole ☐ mean concentration of mercury in dab, whiting, plaice, sole ○ mean concentration of mercury in whiting, cod, plaice, sole ◊ mean of a sample reflecting dietary intakes (Preston and Portmann, 1981), ——— mean of all sets of measurements of mercury concentrations in fish, —●— input of mercury from sewage sludge dumping (from Head (1981) and MAFF records), —☐— input of mercury from industrial discharges (from Preston and Portmann (1981): 1980 figure a projected value).

The results in Tables II and IV show that due to sampling difficulties it has not been possible to analyse the same species of fish each year. Mercury uptake is influenced by physiological factors, especially age and different propensities to take up mercury. Thus, ideally analysis for temporal trends should use the same selection of species. To overcome this difficulty, three groups of four species have been selected to give an analysis of trends over the 1970–80 period (dab, cod, plaice, sole; dab, whiting, plaice, sole; and whiting, cod, plaice, sole) and the average mercury concentrations for each of these groups is shown in Figure 2. In addition, Preston and Portmann (1981) have estimated the mean concentration of mercury in samples of fish designed to reflect dietary intake and these data are also included in Figure 2. Changes in the input of mercury from sewage sludge and industrial discharges during the period of study are also shown.

From Figure 2 it would appear that between 1970 and 1980 the average concentration of mercury in fish flesh has been approximately halved and that this in general reflects the reduced input of mercury from industrial discharges and sewage sludge. The major reduction of mercury in fish flesh which occurred between 1970 and 1974 is most probably related to a fall in the amount of mercury derived from industrial discharges. However between 1974 and 1976 mercury levels in fish appeared to rise against a background of falling industrial input. This rise was probably the result of the increase in the amount of mercury introduced via sewage sludge which occurred over the same period. Between 1976 and 1978 levels of mercury in fish fell, probably as a result of the decrease in the mercury content of the sewage sludge. Since 1978 the mercury in fish flesh has remained constant at about 0.25 mg kg^{-1} (wet weight).

The relationship between the mercury input into Liverpool Bay and the concentration of mercury in fish flesh has been considered further for the years 1972–9 by Preston and Portmann (1981). These authors have also discussed the public health aspects of mercury contamination of fish and demonstrated that a mean concentration of mercury (assumed to be in the most toxic methyl form) of 0.3 mg kg^{-1} (wet weight) would provide an average safety factor of about 40 for the highest fish consumers found in the Liverpool Bay area. Therefore even though fish from Liverpool Bay contain somewhat elevated concentrations of mercury when compared with the same species of fish collected from areas free from significant anthropogenic inputs, the observed content of fish in this area is of very little significance from a public health viewpoint.

Probably because of the small number of samples (Table III), no trend was visible in the mercury concentrations in the shellfish during the period 1970–6.

Cadmium Cadmium concentrations in all samples of fish muscle were below the detection limit of the method used (0.2 mg kg^{-1}) as has been found in U.K. waters generally.

Concentrations in shellfish were mostly within the expected range (Table III) but some samples of brown shrimp and the 1980 samples of queens from the dumping ground contained cadmium at about twice the typical concentration found in other U.K. waters (Murray and Norton, in press). From the public health viewpoint, the concentrations observed are well below those which would exceed the provisional tolerable weekly intake (MAFF, 1973), even for consumers with a relatively high intake of fish and shellfish.

Lead Several difficulties have been encountered in the measurement of lead concentrations in biota, particularly in eliminating the problem of sample contamination during collection and tissue contamination during subsequent handling in preparation for analysis (Portmann, 1979). Lead concentrations in all species of fish appeared to decline over the years 1970–6 (Table II) but this is believed to have been due mainly to improvements in analytical methods. From 1976 onwards, lead concentrations in about half of the samples analysed were at or below the detection limit of the method used (0.2 mg kg^{-1}) and consistent with the concentrations found in the same species from other coastal areas. Most of the remaining samples exhibited lead concentrations only slightly above the detection limit except for dogfish and rays, some samples of which contained over 1 mg kg^{-1} lead. Studies in other areas show that the Elasmobranchs generally contain higher concentrations of lead than other species of fish but even so, the concentrations recorded in the Liverpool Bay samples are two to three times the concentrations typical of other waters. Concentrations of lead in some samples of shellfish (Table III) were also elevated when compared with those from other areas, particularly brown shrimp and queens taken from the sludge dumping area. The risks of sample contamination and difficulties of analysis of lead in biota suggest caution in interpreting these results and the earlier (pre-1976) results are certainly suspect. Whether the more recent (1976–81) data represent lead levels in the tissue or contamination of the skin or gut, the results do indicate localized instances of lead contamination, and probably represent what would be experienced by the consumer. However, even the higher concentrations observed are well below those requiring action under U.K. food regulations (Great Britain–Parliament, 1979).

Zinc and copper The annual mean concentrations of zinc in the muscle of most species of fish were usually in the range from 3 to 6 mg kg^{-1}, while the mean concentration of copper ranged from 0.2 to 0.7 mg kg^{-1} (Tables II and IV). There was very little indication of change over the study period in the concentrations of these metals, which were generally similar to those in the same species collected elsewhere. This might be expected since fish are capable of regulating the uptake of these elements (Pentreath, 1973). The only exceptions appeared to be dogfish (1977) (Table II) and flounder caught inshore in 1980 (Table IV) which contained concentrations of zinc approximately double those found in the same species elsewhere. Concentrations of zinc and copper in shellfish (Table III) were within the normal background range expected for the muscle of queens in 1976 (zinc and copper) and the hermit crab in 1975 (copper). There is thus no clear evidence of a general increase in the concentration of these metals in fish and shellfish in Liverpool Bay even though some local instances of contamination may have been recorded.

CONCLUSIONS

During 1970–81 the only metal which showed a systematic change of concentration in biota was mercury. The general decline in muscle concentrations which took place from 1970 appeared to reflect the overall decrease in the inputs of mercury in the industrial discharges to the Mersey and the direct dumping of sewage sludge into the bay. Average concentrations in fish from Liverpool Bay have remained virtually unchanged from 1978–80 and it seems unlikely that they will fall any further if the present inputs are maintained. The average levels of mercury in fish caught for human consumption in uncontaminated U.K. coastal waters are about 0.2 mg kg^{-1} (MAFF, 1971), while in Liverpool Bay the concentration at present lies around 0.25 mg kg^{-1} (wet weight). Detailed studies of the dietary uptake by above average consumers (Preston and Portmann, 1981) have shown that the concentrations of mercury in fish from Liverpool Bay are not sufficiently elevated to have any public health implications.

Although there appears to have been no general increase in the concentrations of the other metals present in either fish or shellfish, some samples of fish (particularly Elasmobranchs) contained elevated concentrations of lead and zinc. Additionally, some shellfish taken near the sludge dumping ground exhibited increased concentrations of cadmium, lead, zinc and copper. Natural variability or other biological factors may play a part in explaining some of these differences, but in view of the large amounts of metals discharged into Liverpool Bay, the possibility cannot be ignored that they are, at least in part, a reflection of man's activities.

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