Preliminary investigation of the heavy metal content of *Capitella capitata* (polychaete, annelid) from Largo Bay, Firth of Forth and Garroch Head sludge dump site, Firth of Clyde

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Heavy metal concentrations in marine sediments can be elevated by various waste disposal activities (Forstner & Wittmann 1981), including sewage sludge dumping (Mackay 1985). These sediment-bound metals may remain within the sediment, or be remobilised into the water column, or accumulated by animals. This can be reflected in elevated metal concentrations in animals associated with the sediments, such as molluscs (Davies & Pirie 1980), demersal fish (McKie 1983) and benthic fauna (Bryan 1984).

Deposit feeding by benthic infauna is important in the cycling of elements in estuarine ecosystems (Brown 1986). The ingestion of sediment particles and their associated metals may increase the metal concentrations in the tissues of these animals. Heavy metals derived from sediments may move through the food chain to benthic-feeding fish and subsequently through commercial species (such as cod or saithe) to the human consumer. *Capitella capitata*, a deposit-feeding polychaete worm, is found in high densities in areas receiving enhanced inputs of organic material such as pulpmill effluent (Warren 1977) and sewage sludge (Topping & McIntyre 1972). Its comparatively large size and dominance in the population makes it an attractive organism for study on sludge disposal grounds.

Capitella capitata from a sewage sludge dump site in the Firth of Clyde (Garroch Head) and from an area receiving piped sewage effluent in the Firth of Forth (Largo Bay) were collected and analysed for cadmium, copper, zinc, lead, iron and mercury. The samples analysed included worms containing gut sediment and worms with evacuated guts. The evacuation procedure involved maintaining the animals for 2–4 days in individual chambers containing acid-washed sand and sea water. The presence of sediment in the gut was checked by microscopic observation and only animals with apparently clear guts were taken for analysis.

The results for cadmium, copper, zinc, lead, iron and mercury are shown in Table 1. At Garroch Head only the mercury concentrations were significantly lower in worms with evacuated guts than in non-evacuated animals, whereas at Largo Bay all metals except copper were significantly lower in evacuated animals. The zinc and lead concentrations of animals from Largo Bay were significantly less than those of animals from Garroch Head. The high concentrations of iron (1·4–2·6%) in sediments has led to its use as an indicator of contamination of biological samples by sediment. In general, organisms that have evacuated their guts contain less iron than the non-evacuated animals.

In many cases, a linear relationship was found between the concentrations of iron and other metals in these worms. The occurrence of higher concentrations of the other elements in the samples containing higher iron concentrations suggests that the measured concentrations of all these elements are influenced by sediment

Table 1. Measured (mean (and standard deviation) of four groups of ten worms) and estimated metal concentrations ($\mu g\, g^{-1}$) in *Capitella capitata* from Garroch Head and Largo Bay.

	Cadmium	Copper	Zinc	Lead	Iron	Mercury
Garroch Head						
Evacuated gut	0·49 (0·14)	26·5 (11·4)	207 (17·1)	13·5 (7·4)	2115 (533)	0·05 (0·03)
Non-evacuated gut	0·82 (0·40)	42·9 (15·1)	175 (30·5)	32·4 (14·4)	3801 (1295)	0·34 (0·02)
Estimated	0·12–0·29	8–14	167–184	4·5–8	1000–1500	—
Largo Bay						
Evacuated gut	0·37 (0·13)	10·3 (1·9)	73 (6·2)	4·2 (3·2)	1114 (187)	0·03 (0·01)
Non-evacuated gut	0·77 (0·12)	11·2 (0·7)	101 (14·1)	8·7 (1·0)	2616 (182)	0·13 (0·04)
Estimated	0·22–0·38	7·6–8·6	55–65	1–3·1	750–1250	—

retained in the gut, and that some of the evacuated samples discussed here may not be completely free of sediment. Plots of metal to iron ratios against iron concentrations in *C. capitata* showed that the ratios for the non-evacuated animals are similar to those of the bulk sediment from which the samples were derived. Overall the data reported here suggest that the gut evacuation procedure used was not reliable, and that some sediment was carried through the procedure. This was confirmed by the presence of small amounts of sediment material in the acid digests of all samples except those of lowest iron content.

It is therefore not possible at this stage to determine directly the true trace element content of *C. capitata* tissue, because of the gut contamination. However, it may be reasonable to estimate the iron content of such samples from the above ratio and hence from the linear relationship of metal to iron concentration to estimate the true concentration of the element. The estimated values for cadmium, copper, zinc and lead are shown in Table 1. For all metals (other than cadmium) the estimated concentrations in sediment free *C. capitata* from Garroch Head are slightly higher than in those from Largo Bay. This contrasts with the measured values when only zinc and lead were found to be significantly different between the two sites and illustrates the effect of including samples which had not undergone complete evacuation of the gut contents. The estimated concentrations appear to reflect the much higher metal concentrations in the sediments at Garroch Head. The marked exception is cadmium, which is found at similar concentrations in worms from both sites, but is undetectable in Largo Bay sediments. The mercury concentrations measured, and those estimated for the other trace metals, are generally within the range of reported concentrations for polychaete worms.

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Hydrocarbons and their microbial degradation in the Firth of Forth

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Monitoring of hydrocarbons and assessment of their microbial degradation in the Firth of Forth is part of a larger programme undertaken by the Department of Agriculture and Fisheries for Scotland to monitor the levels of hydrocarbons in the marine environment (Massie *et al.* 1985a,b; 1986) around the coast of Scotland and to investigate the possible effects of oil exploration and production on fisheries. The reception terminal for the oil from the Forties field is at Grangemouth and the tanker loading facility is at Hound Point. The estuary, however, receives oil and hydrocarbons from combustion of fossil fuels from many sources around its shores, such as industrial complexes, coal-fired power station, the naval dockyard and shipping.

Initially all water and surface sediment samples obtained by water bottle and grab, respectively, are screened by UV fluorescence and the hydrocarbons present expressed as crude oil or diesel "fluorescence equivalents". Selected samples are then examined in greater detail by capillary gas chromatography (aliphatic hydrocarbons) and gas chromatography/mass spectrometry (aryl hydrocarbons). The potential of microbial populations in water and/or sediments to degrade the hydrocarbons are determined using 1-^{14}C naphthalene, 1-^{14}C hexadecane and 7,10^{14}C benzo(a)pyrene.

There was a strong gradient of hydrocarbon concentrations in the sediments of the estuary. The stations at Bridges and Hound Point were most heavily contaminated with the stations becoming less contaminated approaching the sea. The 3- and 4-ring aromatic compounds predominated in the aromatic fraction, but all sediments examined showed an accumulation of 5- and 6-ring compound (similar to those seen in North Sea sediments remote from oil-related activities). The relative composition and the ratio of benzo(e)pyrene to benzo(a)pyrene