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Bioavailability of Mercury in Several North-eastern U.S. *Spartina* Ecosystems[a]

Ronald J. Breteler[b,d], Ivan Valiela[c] and John M. Teal[b]
[b]*Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543, and [c] Boston University Marine Program, Marine Biological Laboratory, Woods Hole, Massachusetts 02543, U.S.A.*

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Mercury concentrations were measured in sediments, marsh grasses, mussels and fiddler crabs in salt marsh plots treated with a mercury-containing commercial sludge fertilizer and in clean and industrially contaminated marshes. Mercury accumulated in the roots of the marsh grass *Spartina alterniflora*, rather than in rhizomes or above-ground tissues. Mercury concentrations did not increase in marsh organisms within the plots treated with sewage sludge. Highest concentrations of mercury were found in animals living in the least organic marsh sediments. Mercury was closely associated with small (<0·5 mm) detrital particles. Only between 10 and 30% of the total soil mercury was complexed by the humic and fulvic acid fraction of the marsh soil.

Introduction

Past discharges of mercury to the coastal environment have resulted in several incidences of enrichments of this metal in salt marsh environments (see e.g. Windom *et al.*, 1976).

The release of mercury from these sediments depends on a wide range of biological and chemical factors, including its chemical form (Hogg *et al.*, 1978*a*), the presence of organic soil colloids (Cline *et al.*, 1973; Alberts *et al.*, 1974; Miller *et al.*, 1975), sediment resuspension (Lindberg & Harriss, 1977; Bothner *et al.*, 1980), reduction–oxidation potentials (Kudo *et al.*, 1975; Khalid *et al.*, 1977) and chlorinity (Reimers & Krenkel, 1974). This sedimentary mercury may become available for uptake by coastal organisms, resulting in elevated levels of this element in body tissues (Klein & Goldberg, 1970; Burton & Leatherland, 1971; Jones *et al.*, 1972; Fujiki, 1973; Windom *et al.*, 1976; Gardner *et al.*, 1978).

The mercury concentration of organisms is not necessarily related to the total soil mercury concentration but rather to the form in which this mercury is present in the sediments. The role of the biological formation of methylmercury in the transfer of this element from sediments to biota has been widely recognized (see e.g. Bisogni & Lawrence, 1975). Additional factors, such as the species-specific regulatory mechanisms (Bryan, 1976), age and body

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[a] Contribution No. 4498 from the Woods Hole Oceanographic Institution.
[d] Present address: Battelle Columbus Laboratories, William F. Clapp Laboratories, Washington Street, Duxbury, Massachusetts 02332, U.S.A.

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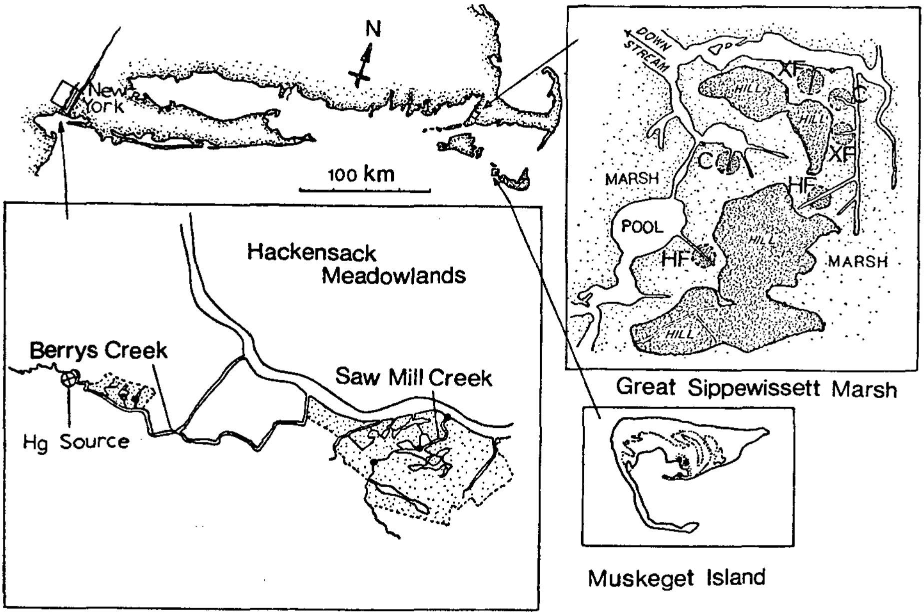

Figure 1. Study areas in Great Sippewissett Marsh (C = control marsh; HF = high fertilized marsh plots; XF = extra high fertilized marsh plots), Muskeget Island Marsh, and the Saw Mill Creek and Berrys Creek Marshes in the Hackensack Meadowlands. Solid circles indicate sampling stations.

weight (Cross *et al.*, 1973) have been discussed. To date, little attention has been given to the effect of the sediment itself on the availability of soil-bound mercury to biota.

In this report we present data of mercury concentrations in plants and organisms from salt marsh plots experimentally treated with mercury and from marshes where heavy industrial pollution provided mercury for long periods. In addition, we assess the effects of the organic content, soil texture, pH and reduction–oxidation potential of the sediment on the availability of mercury to marsh organisms and plants. The long-term fate of mercury in a salt marsh environment as well as the retention capacity of marsh soils for this element are discussed elsewhere (Breteler *et al.*, 1981).

Experimental

Duplicate experimental plots with a radius of 10 m were laid out in Great Sippewissett Marsh (Figure 1). These plots were treated throughout the growing season (April–November) with a fertilizer made from a metal-containing sewage sludge with an approximate mercury content of 1 part 10^{-6}. This material was spread by hand twice monthly during low tide at two levels: 50·4 g m^{-2} (HF plots) and 151·2 g m^{-2} (XF plots). The treatments took place from 1970–1976 (HF plots) and from 1974–1976 (XF plots). Two additional untreated plots were maintained as controls (C). Further details of the procedures used and the treatment effects are given in Valiela & Teal (1974). Valiela *et al.* (1973, 1974, 1975, 1976, 1978), Banus *et al.* (1974, 1975), Giblin *et al.* (1980) and Breteler *et al.* (1981).

Samples for this study were taken during 1977 and 1978 from Great Sippewissett Marsh (Cape Cod, Massachusetts) (Figure 1). Both marshes were dominated by the marsh cord grass *Spartina alterniflora* Loisel., but differed in composition and structure of the sediments. The sediments of Muskeget marshes were light textured, contained a large component of coarse sand, and were oxidized. Surface sediments from Great Sippewissett Marsh were finer grained and highly organic, contained only a minor component of sand or silt and were oxidized along the creeksides but reduced at higher intertidal elevations. Samples were also obtained from two marshes in the Hackensack Meadowlands (New Jersey), which have for many years received discharges of mostly elemental mercury from a former chemical plant site. Berry's Creek Marsh (3–9‰ salinity) and Saw Mill Creek Marsh (9–15‰ salinity) were situated 2 and 10 km downstream of the principal source of mercury respectively (Figure 1). While both marshes were dominated by *Phragmites communis*, all samples for this study were collected from patchy stands of tall *S. alterniflora*.

Fiddler crabs (*Uca pugnax* and *U. minax*) from all marshes, and mussels (*Modiolus demissus*), collected in the Massachusetts marshes, were rinsed with tap water on return to the laboratory. Mussels were shucked immediately, and 3–5 crabs and mussels were pooled, frozen, freeze-dried, and ground with glass mortar and pestle. Whole plants of *S. alterniflora* were cut from isolated stands bordering on or in tidal creeks from the Hackensack and Great Sippewissett marshes, rinsed with tap water, and divided into roots, rhizomes, culms, leaves and flowers. Ten plants were used for each sample. They were oven-dried (50 °C, overnight) and ground in a Wiley mill. Sediments were collected from the same sites as the grasses and invertebrates. They were stored frozen, freeze-dried, and subsamples were used for the determination of organic matter by weight loss on ignition (4 h at 500 °C) and total mercury.

Details of the analytical procedure used for mercury determinations are described elsewhere (Breteler *et al.*, 1981). The analytical uncertainty (2 S.D.) was less than 10% of mean sediment values and 5% for biological samples. To evaluate the loss of mercury due to pre-treatment procedures we analyzed replicate subsamples before any pre-treatment (wet), after freeze-drying, oven-drying, and after freeze-drying and grinding. These three ways of handling samples did not result in significant differences in mercury contents. Redox potentials (Eh) were measured *in situ* during low tide, using a bare platinum electrode and an $Ag/AgCl_2$ reference after equilibration for 15 min. pH was measured in core samples with a glass electrode and separate reference.

Marsh sediments were extracted with 0·5 N NaOH, 0·5 N HCl and 6 N HCl, respectively. Approximately 5 g of sieved (0·5 mm mesh), washed and freeze-dried sediment was mixed with 100 ml of the extractant in 150 ml Corex glass centrifuge tubes, shaken overnight, centrifuged (15 000×g for 1 h), and the supernatant decanted. Solids were washed with deionized water, freeze-dried and weighed. The treated sediments were analyzed for total mercury content. Subsamples of the extracted material were used for the determination of wet/dry ratios and organic matter content.

Results and discussion

Mercury in Spartina alterniflora

All plant parts of *S. alterniflora* showed an increase in mercury contents as levels of this element increased in sediments (Figure 2). Roots had the highest concentrations and also showed the steepest increase relative to increases in sediment mercury. Thus, while root concentrations were only slightly higher than those of other plant parts under natural conditions, up to two orders of magnitude differences were observed in grasses from mercury-contaminated areas. If mercury had been adsorbed on the epidermal cells of below-ground parts of *S. alterniflora*, rhizomes and the part of the stem growing below-ground would have elevated levels of mercury similar to those of the roots. Figure 2 shows that this is not the case,

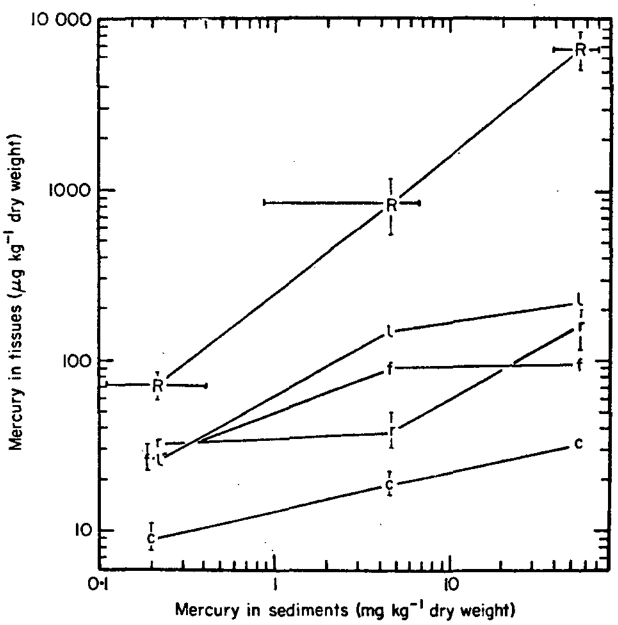

Figure 2. Mean mercury concentrations (ng Hg g^{-1} dry weight) ± S.E. in roots (R), rhizomes (r), culms (c), leaves (l), and flower structures (f) of tall morphology *S. alterniflora*. Horizontal bars, depicted only at (R) symbols, give the range of soil mercury contents (mg Hg kg^{-1} dry weight) of ambient sediments. Vertical error bars are presented when larger than the symbol used.

and mercury therefore evidently penetrated epidermal cells and subsequently associated with cell metabolites. Assimilation of mercury by plants may not be limited to ionic forms alone, but may include neutral organo-mercury complexes (Tiffin, 1977). The large difference between the mercury concentrations in roots and other parts of *S. alterniflora* indicates that transfer of this element is limited, suggesting the presence of a blocking mechanism (Beauford *et al.*, 1977; Wallace & Romney, 1977; Hogg *et al.*, 1978*b*). Even when the marsh cord grass was grown hydroponically in the presence of $HgCl_2$ (Rahn, 1973), only 1% of the total amount of mercury assimilated by the roots was transferred to the leaves, and 3% to the culms. Under field conditions Windom (1973) and Gardner *et al.* (1978) also found a considerably higher accumulation of mercury by roots of *S. alterniflora* than by the rhizomes.

Mean mercury concentrations in leaf tissues of *S. alterniflora* from the Hackensack Meadowlands attained values four-fold of those of the culms. These differences were found in the whole range of sediment mercury concentrations observed (Figure 2). By contrast, Gardner *et al.* (1978) reported mercury levels of culms and grass blades to be of approximately the same value. We expect that at least part of the mercury in the leaves is taken up directly from the water column, although the possibility that mercury is retained by storage tissues of the foliage may not be excluded. In the first place, grasses collected from the upper limit of the intertidal range contained significantly less mercury than those from the lower intertidal zone (83 *vs.* 121 ppb Hg; paired *t*-test, $P<0{\cdot}01$). Moreover, the mercury concentration of the below-ground part of the grass stems (125 ppb Hg) was intermediate between the lower above-ground part (0–10 cm; 273 ppb Hg) and the higher culm to which the blades were attached (33 ppb Hg). This is consistent with the hypothesis that the lower section of the grass, most frequently inundated by the river water, adsorbed the highest amount of mercury from the water column. The soluble mercury content (<0·45 µm) in the waters adjoining the creek sides averages 100 ng l^{-1} (P. Galluzzi, personal communication). Under experimental conditions, Rahn (1973) also found that mercury could be adsorbed from the water phase by leaves of *S. alterniflora*, while Erikson & Mortimer (1975) and Mortimer & Kudo (1975) reported a similar mechanism for submerged water plants.

In Great Sippewissett Marsh the total annual above-ground production of *S. alterniflora* amounted to less than 2 kg m^{-2} in fertilized, and about 0·5 kg m^{-2} in untreated marsh (Valiela *et al.*, 1976). An amount of organic particles equivalent to 40% of above-ground production is lost by tidal export (Valiela *et al.*, 1978). If 0·025 mg Hg kg^{-1} *S. alterniflora* were taken up from the sediments alone, then the total annual loss of this element from the marsh surface would amount to less than 1% of the soil mercury concentration. In contaminated marshes this percentage would be even lower, because a rise in the sediment mercury concentration caused a much less steep increase in the above-ground *S. alterniflora* tissues (Figure 2). Export of this grass from the marsh system to adjoining waters therefore does not seem to substantially deplete mercury from the soil of northeastern salt marshes. This finding is in contrast with reports for southern marshes (Windom, 1973 & 1975; Dunstan & Windom, 1975). In the latter study, however, mercury concentrations of *S. alterniflora*, probably whole plants, exceeded those of the sediments by four-fold, both on a dry weight basis; and mercury therefore appears to have been more available for uptake than was the case in our study.

TABLE 1. Mercury concentrations (ng Hg g^{-1} dry weight) ±S.E. of marsh soils and common grass and animal species. Samples are from experimental plots in Great Sippewissett Marsh. C=untreated marsh; HF and XF stand for high and extra high dosages of a mercury-containing fertilizer

	Mercury concentration (ng Hg g^{-1} dry weight)		
	C	HF	XF
Sediments covered with:			
Tall *S. alterniflora* (creek sides)	100±9	308±44	330±34
Short *S. alterniflora* (low marsh)	100±6	506±38	575±61
S. patens (high marsh)	112±10	539±45	572±40
Marsh grasses			
S. alterniflora (tall form)	19±1·9	—	21±1·5
S. alterniflora (short form)	22±3·2	—	21±1·5
S. patens	25±1·8	—	22±1·8
Marsh animals:			
Uca pugnax (fiddler crabs)	57±16	31±3	48±3
Modiolus demissus (ribbed mussels)	178±8	190±5	218±12
Crassostrea virginica (oysters)	568±47	516±15	—
Mercenaria mercenaria (soft clams)	305±45	266±13	—

Mercury in mussels and fiddler crabs

Mercury concentrations did not increase in the fiddler crabs *U. pugnax*, mussels, and the marsh grasses *S. alterniflora* and *S. patens* from the experimentally fertilized plots, in spite of the 3–6-fold increase in sediment mercury (Table 1). Perhaps fiddler crabs and mussels obtained at least part of the detrital food from uncontaminated marsh adjacent to the treated plots. However, these animals did accumulate considerable amounts of copper and cadmium from the metal-enriched plots (Giblin *et al.*, 1980). It therefore seems likely that the mercury, which we added in association with the sewage sludge, was unavailable for uptake by invertebrates and grasses alike. Since it is difficult to extract mercury from the

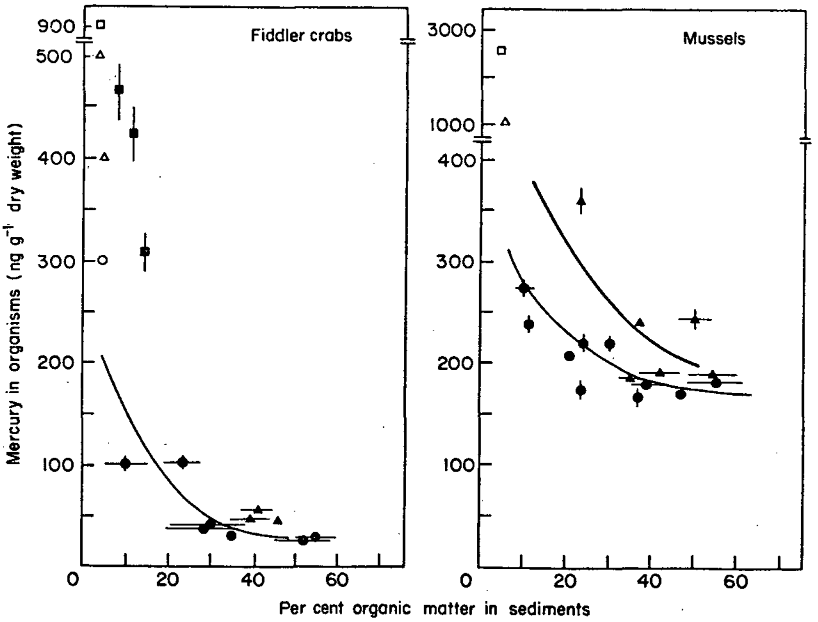

Figure 3. Mean mercury concentrations (ng Hg g^{-1} dry weight)±s.e. of fiddler crabs and mussels, plotted against the sediment organic matter content (range given). $n=3$–5. Increasing sizes of the symbols indicate increases in the mercury contents of the ambient sediments: (●) 0·05–0·29 mg Hg kg^{-1}; (▲) 0·3–0·6 mg Hg kg^{-1}; (■) 1·5–6 mg Hg kg^{-1}. Open symbols present data from Gardner *et al.* (1978). Curves are drawn by eye.

enriched sediments (Table 3, discussed below), the organomercury complexes apparently were too stable to be assimilated by the organisms after ingestion.

In the Hackensack Meadowlands, *U. pugnax* and *U. pugilator* were found abundantly in Saw Mill Creek Marsh where mercury levels reached 5±0·4 mg Hg kg^{-1} dry sediment. In contrast, no fiddler crabs lived in Berry's Creek Marsh (>50 parts 10^{-6} Hg). Both marshes exhibit similar characteristics with respect to vegetation types and soil; and we therefore postulate that fiddler crabs tolerated moderate elevations of sediment mercury concentrations but were unable to withstand the high levels found in Berry's Creek Marsh.

Effects of sediment organic matter on bioavailability of mercury

Mercury concentrations of mussels and fiddler crabs increased rapidly with decreasing organic matter contents of the marsh soil (Figure 3). This inverse relation was particularly evident when organisms were grouped according to the mercury contents of the ambient sediments. The relationship appeared to be exponential with a steep drop in mercury accumulation initially, followed by a gradual leveling in predominantly organic marshes. Thus, while the tissue mercury contents of these animals clearly depend on those of the ambient sediments under mostly sandy conditions, elevated levels of sediment mercury were unavailable for bioaccumulation in peaty marshes. For comparison, we included data from silty southeastern marshes which contain only 4±2% organic matter (Windom, 1975).

At any level of soil organic content, more mercury was accumulated by mussels than by fiddler crabs, even if differences in the ash-free organic contents of mussels (89%) and fiddler crabs (55%) were taken into consideration. While feeding patterns differ largely between the two species, both are detritovores and therefore ingest a form of organic matter

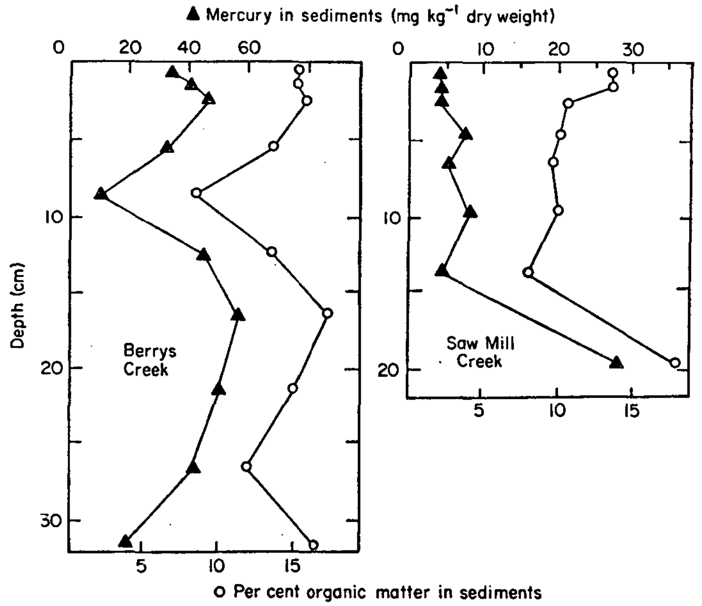

Figure 4. Per cent organic matter (○) and mercury concentrations (▲) in mg Hg kg^{-1} dry weight at various depths of cores from Saw Mill Creek and Berrys Creek.

TABLE 2. Mercury concentrations (mean ±S.E.) in mg kg^{-1} dry weight in live roots of *S. alterniflora* and in ambient sediment of salt marshes in New England and the Hackensack Meadowlands

Marsh sites	Number of stations	Mercury concentrations (mg kg^{-1}) Live roots	Sediments
Massachusetts marshes			
Great Sippewissett	2	0·04±0·01	0·18±0·05
Muskeget	3	1·4 ±0·09	0·05±0
Hackensack Meadowlands			
Berrys Creek	3	6·8 ±1·7	55·7 ±7·5
Saw Mill Creek #1	4	0·42±0·06	4·9 ±0·7
Saw Mill Creek #2	2	2·0 ±0·5	2·3 ±1·5

originating from the same source, i.e. decayed plant materials. Differences in tissue mercury concentrations therefore suggest different abilities of mercury regulation, either passive or active, by these organisms.

While mercury concentrations of estuarine sediments generally correlate well with the organic matter content (Lindberg & Harriss, 1974; Windom, 1975; and Bothner *et al.*, 1980), such relationship was less evident in the peaty New England marshes. This was largely due to the presence of coarse fibrous plant remains which had comparatively low mercury contents (Breteler *et al.*, 1981). However, since such materials were largely absent in the Hackensack Meadowlands, mercury levels in these latter marshes closely followed the organic matter content of the sediments. This relation could be clearly demonstrated in the surface layer of sediment cores (Figure 4), but was less evident when mercury concentrations approached background levels. The large fluctuations in mercury contents at various depths indicate that dilution processes, resulting from variations in the deposition of minerals, may distort evidence of past anthropogenic mercury discharges. The correlation between mercury and organic matter in the sediments would suggest that marsh soils with low organic matter contents contain relatively little mercury. Conversely, organisms living under those conditions appear to attain higher concentrations of this element.

Table 2 shows the concentrations of mercury in live roots of *S. alterniflora* and of ambient sediments. The results show that mean mercury concentrations of *S. alterniflora* roots from the predominantly sandy marsh soil attained levels up to 40-fold of those from the peaty marshes. This finding is consistent with the observation that mercury is better available to animals when the marsh soil contains little organic matter.

Although a single explanation for this phenomenon can not be presented at this time, the results suggest that certain conditions existing in low organic soils favor the physico-chemical and perhaps biological transformation of mercury into forms more readily available for uptake by biota. Alternatively, these conditions may retard the formation of stable organomercurials from naturally-introduced mercury of aquatic and atmospheric origin. Table 3 shows sediment characteristics of the marsh soils, including pH, Eh, and the percentage organic matter content. Eh values were determined under carefully standardized conditions and provide a measure of the relative oxidation state of the soil. It is interesting to speculate on the role of the soil texture concerning the bioavailability of mercury. Due to the large quantity of coarse minerals in Muskeget Island marshes, its soil was considerably more open than that of Great Sippewissett Marsh. Hogg *et al.* (1978*b*) showed that under experimental conditions roots of bromegrass attained the highest levels of mercury when growing on the lightest textured mercury-treated soils with the lowest organic content. A similar relation appeared to exist for tall morphology *S. alterniflora* in the New England marshes. We are not certain about the role of Eh concerning the latter relationship. No differences were found between the oxidation states of the rhizosphere of Muskeget and Great Sippewissett Marsh. Both marshes were largely oxidized, although reducing conditions were occasionally observed in the latter marsh at depths of 15 cm (Table 3). Nonetheless, with the majority of the root productivity taking place in the surface 5 cm (Valiela *et al.*, 1976), Eh did not seem to play an important role in the uptake of mercury by the grasses.

In Great Sippewissett Marsh pH values fluctuate between 5 and 6 in the subsurface (2–30 cm) soil. Values are higher in the surface zone, reaching up to 8. Due to the sandy nature of the Muskeget Marsh soil, acidic conditions were generally found only below the rhizosphere. We are unsure about the significance of these differences with respect to mercury mobilization, but do not see how pH could account for the high mercury levels of the roots of the latter marsh in the ranges observed.

Sediment characteristics in Berry's Creek Marsh were generally uniform between stations, and no relation of the nature discussed above could therefore be discerned. In contrast, distinct differences in pH and, to a lesser extent, Eh were found between the mid-creek stations (Station 1) and the mouth of Saw Mill Creek (Station 2) (Table 3). Station 2 was somewhat less oxidized than Station 1, and significantly more acidic. Concurringly, sediment mercury levels were lower in the latter station, while those of the roots were high (Table 2). Moreover, we measured a reduction in the mean grass length of 23% compared to grasses from Station 1. Since the pH optimum for the synthesis of methylmercury is 4·5 (Wood, 1974), conditions at Station 2 would appear ideal for the formation of this harmful and mobile form of mercury. The acidity of the latter marsh site therefore may partially explain the lower mercury content of the sediments and relatively high levels of the plant-root system. Worth noting in connection with this is the finding by Khalid *et al.* (1977) who concluded that redox potential and pH regulate the chemical form as well as the bioavailability of mercury in

TABLE 3. Sediment parameters of salt marsh sediments in New England and in the Hackensack Meadowlands. Eh (mV) and pH are means ±S.E. (n=4–8)

Marsh sites	Organic matter content (%)	Eh (mV)			pH		
		Depth in sediments			Depth in sediments		
		1 cm	5 cm	15 cm	0 cm	5 cm	15 cm
New England marshes							
Great Sippewissett	34±11	350±75	275±75	60±100	6·0±0·5	5·5±0·5	5·5±0·5
Muskeget	7±1	437±10	251±60	182±113	7·0±1·0	6·5±0·5	6·0±0·5
Hackensack Meadowlands							
Berrys Creek	16±1	284±38	64±14	189±48	6·2±0·1	6·0±0·1	5·8±0·1
Saw Mill Creek #1	14±1	21±33	—16±17	—66±23	5·7±0·1	5·6±0·1	5·8±0·1
Saw Mill Creek #2	9±1	—56±20	0±50	—144±16	5·6±0·1	5·2±0·5	3·6±1·0

TABLE 4. Mercury and organic matter losses (in % of original contents) ±S.E. after extraction with 0·5 N NaOH, 0·5 N HCl, and 6 N Hcl. Samples consist of 5 cm surface cores from untreated (C) and extra high fertilized (XF) plots within Great Sippewissett Marsh (GS) and from Saw Mill Creek (SM) and Berrys Creek (BC) in the Hackensack Meadowlands (HM). Parts 10^{-6}=mg kg^{-1} dry weight. OM= organic matter

Marsh	Intact soil parts 10^{-6} Hg	Mercury loss (%)			Intact soil % OM	Organic matter loss (%)		
		NaOH	HCl			NaOH	HCl	
		0·5 N	0·5 N	6 N		0·5 N	0·5 N	6 N
GS								
C	0·20±0·03	29·5±3·0	—7·9±9·0	30·7±15·6	42·0±10·1	47·6±3·7	8·8±5·8	31·2±2·2
XF	0·65±0·07	12·0±2·0	—4·8±3·0	71·8±3·7	45·2±1·8	39·5±1·6	13·7±2·4	29·3±2·4
HM								
SM	12·4±2·9	25·7±4·6	25·0±6·4	78·3±3·7	10·3±2·9	31·1±6·8	0·5±0·5	15·7±2·0
BC	80·0±10·0	10·0±1·5	7·7±2·3	83·3±4·3	14·3±0·6	32·9±2·5	1·1±0·6	16·4±0·2

riverbed sediments depending on the amount of mercury present. Our results suggest that, under moderately contaminated conditions, mercury becomes better available for bioaccumulation under more acidic conditions.

Altogether, mercury concentrations of salt marsh biota are controlled by multiple environmental factors, the most obvious of which are the organic content, pH and redox potential of the sediments.

Chemical extractions of mercury from marsh soils

Twelve per cent of the mercury added to the marsh as a result of the sludge treatments and 30% of naturally present mercury was extracted after treatment of surface sediments from Great Sippewissett Marsh with 0·5 N NaOH (Table 4). These percentages presumably indicate the mercury fraction bound by humic and fulvic acids (Holtzclaw *et al.*, 1978). We found a similar portion of mercury to be associated with soil organic acids in the contaminated sediments of the Hackensack Meadowlands. Between 30 and 50% of the total ash-free organic matter of the marsh soils was comprised of humic and fulvic acids. Since mercury concentrations and organic contents of the sediments correlated well (Figure 4), and coarse (>1·0 mm) plant remains contained only minor amounts of mercury (Breteler *et al.*, 1981), the results of Table 4 suggest that this element was predominantly associated with small detritus particles. Treatment of marsh soils with dilute and concentrated HCl progressively hydrolyzes organic matter and dissolves inorganic colloids. The results show that the bonding of mercury with the soil colloids was very firm, especially in the uncontaminated marsh soils. Thirty per cent of this element was released from the peat after treatment with 6 N HCl. In contrast, Hogg *et al.* (1978*a*) found up to 90% release of mercury from loamy sand and from loam soils using similar extraction conditions. This result indicates that mercury was bound tightly by the detrital soil particles. The stability of the mercury-organic matter associations in the soil colloids of coastal wetlands may, at least in part, explain the poor availability of this element to marsh biota.

Conclusions

The data presented here indicate that the application of a sludge fertilizer containing mercury to salt marshes covered with *S. alterniflora* does not result in a concentration increase of mercury in mussels, fiddler crabs or marsh cord grasses. However, when salt marshes are subject to very high anthropogenic mercury inputs, a considerable accumulation of this metal results in the *Spartina* root system; but translocation of mercury to above-ground tissues is very limited.

The availability of mercury to plants and marsh invertebrates appears to increase exponentially with decreasing amounts of organic matter. Therefore, when mercury discharges take place in sandy soils with little organic matter, a significant uptake of this pollutant may result in the associated biota, resulting in the possible contamination of species of importance to man. This study further demonstrates the need for a careful evaluation of the interrelations between mercury speciation, its contents in sediments and biota, and relevant environmental parameters, especially with respect to monitoring and baseline studies.

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