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THE DETERMINATION OF MERCURY IN SEA WATER AND BALTIC SEDIMENTS BY COLD VAPOUR AAS

Contents:: 1. Introduction, 2. Experimental, 3. Results and discussion, 4. Conclusions; Streszczenie; References.

1. INTRODUCTION

Mercury belongs to the category of inorganic pollutants in the hydrosphere which are potentially harmful for marine organisms, in higher concentrations, either directly or following accumulation in the food chain [6]. Due to the high volatility of mercury compounds, a great part of the annual world production escapes into the oceans. The well known specific situation of the Baltic, which is exposed to the anthropogenic influences of 7 highly industrialized countries, requires particular attention and detailed investigations. Municipal sewage, for instance, always contains significant amounts of mercury, even if particular industrial or other sewage sources are absent. Estimates indicate that the amount discharged with municipal sewage is approximately 0.2 g per person per year [4]. Assuming a total drainage area of 1.65×10^6 km^2 with 140×10^6 people, a total quantity of 28 tons of Hg per year could be extrapolated as anthropogenic input.

As regards the content of mercury compounds in Baltic water, very few data are available at present [14, 15, 17]. The spectra of published values include concentrations of mercury comparable with data from the Atlantic [14, 5], but also amounts [17] which are nearly in the order of magnitude as those from the Minamata Bay (Japan) determined after the outbreak of the „Minamata disease" [18].

To detect the load of a sea area by heavy metals using analyses of water samples is often complicated. Short-time local emissions cause strong fluctuations which can only be compensated by a great number of measurements of samples different in space and time. The sediment was therefore frequently used as an indicator of the environmental pol-

lution and the development history of a sea. The volume of data on the mercury content of Baltic sediments is also limited at present [9, 10, 13], however.

The paper gives a summary of our results of mercury analyses in water and sediment samples taken from the Baltic. Special attention is devoted to the different chemical and physico-chemical forms of this element.

2. EXPERIMENTAL

2.1. Sea water

The samples were taken in 1977 during seasonal cruises of the r/v „Prof. A. Penck" in the Baltic. In January/February the sampling was carried out with the intention of characterizing the regional distribution of Hg. In July, whilst moored in the Arkona Basin, investigations on chemical forms of mercury were carried out for an ecological experiment using 30-dm^3 plastic containers. The analysis of water sampled during BOSEX (Baltic Open Sea Experiment) should afford a preliminary idea as to the temporal variations of the mercury content. In addition, some experiments concerning the choice of appropriate decomposition procedure and storage conditions were carried out in the laboratory.

The chemistry of the mercury determination is based on the method developed by Hatch and Ott [7] and modified by Olafsson [11] for sea water. It includes the reduction of ionic or labile mercury compounds (both inorganic and organic) with stannous chloride to the elemental state and the accumulation of the metal vapour expelled by a carrier gas by means of amalgamation on gold foil. The analyses were carried out an open Coleman MAS-50 mercury analyzer system including a „gold trap" heated by a resistance wire.

The carrier gas was argon. The chemicals and reagents used were commercially guaranteed „mercury free" quality or were additionally purified. Mercury standards were prepared from the Merck „Titrisole". Traces of mercury in the deionized water and in the carrier gas stream were removed by tretment with permanganate and active charcoal, respectively.

Procedure

One hundred and fifty cm^3 of sea water (pH 1.5) were placed in a 300 cm^3 BOD bottle and treated with 1 cm^3 of conc. HNO_3 and 2 cm^3 of a $20^0/_0$ Sn (II) solution for 30 min. The mercury vapour was

driven off by a stream of argon passed at a rate of 15 dm^3/h over a period of 30 min and the metal was trapped on the gold foil. After drying the foil for 2 min, it was heated in the gas stream which was subsequently passed through an absorption cell. The decrease in the transmission was recorded. To determine the total amount of mercury, the samples had to be decomposed by oxidation of organic matter with a mixture of permanganate and peroxodisulphate in a sulphuric acid solution for at least 12 h. After destroying the excess of the oxidants by hydroxylamine hydrochloride the analyses were continued as described. The difference between the labile and total Hg was attributed to the stable (mostly organic) fraction.

To avoid contamination risks, the water samples were usually not filtered. When determining particular forms of mercury, however, the filtration was necessary and was carried out using an in-line filtration device which included a peristaltic pump, a 47 mm (in diameter) polypropylene filter hoder and Nuclepore filters (pore size 0.4 µm).

2.2. Sediments

During February-March 1978 samples of sediments were taken in the Western Baltic (Mecklenburger Bucht) using a 4.5-m long corer. The tube of the coring device was driven into the bottom by a vibrator. To avoid contamination, the metallic walls were lined with a plastic material. The subsamples were placed in carefully cleaned polyethylene bottles and kept at —20°C until analysis could be carried out ashore.
Procedure

—A sample of the wet homogenized sediment (1—1.5 g) was placed in a teflon bomb, treated with 2 cm^3 of conc. HNO_3 and 5 cm^3 of conc. H_2SO_4, tightly closed and heated at 150°C for 1 h. After cooling, the contents of the bomb were twice centrifuged. The supernatant was transferred to a 100 cm^3 graduated flask and treated for at least 2 h with 2 cm^3 of a saturated $KMnO_4$ solution. The volume was then made up to about 80 cm^3 and hydroxylamine hydrochloride was added until the solution became colourless. For the subsequent AAS measurement this procedure was used with a few modifications only. For instance, the sample volume was changed to 25 cm^3 and the size of the reaction vessel had to be reduced accordingly.

Apart from mercury, other trace metals such as Fe, Mn, Zn, Cr, Ni, Pb, Cu, Co and Cd, as well as the contents of organic and inorganic carbon and particulate fractions of sand, silt and clay were also determined.

3. RESULTS AND DISCUSSION

3.1. General methodological investigations

Prior to discussing the results of mercury determinations in water and sediments, it seemed worthwhile to specify different forms of this element occurring in the natural environment. To detect these forms, 30 dm³ of the fresh unfiltered water taken from the Arkona Basin was enriched with $Hg(NO_3)_2$ to increase the concentration of mercury by 150 ng/dm³. Bearing in mind the distribution of mercury in control samples, the quantity of $Hg(NO_3)_2$ added was distributed during 3 days storage in a plastic container into the following franctions:

Fraction A (labile, soluble)	1.9%
Fraction B (stable, soluble)	42.2%
Fraction C (labile, particulate)	0.6%
Fraction D (stable, particulate)	19.9%
Total	64.6%

The difference (100%—64.6%=35.4%) is likely to be adsorbed on the walls of the container. Similar investigations with the addition of Zn, Cd, Pb and Cu salts showed that the fractions of these elements adsorbed on the walls were of minor importance under the same conditions. This illustrates once more the extraordinary nature of mercury in natural systems as compared with other metals (see also [1] and [2]).

To choose appropriate pH value for the storage of samples, experiments with sea water kept under different conditions were run. The fractionation of Hg measurd at pH 7—8 (Table 1) was similar to that observed in the plastic container. An optimum seemed to occur at pH around 1.5, particularly for the labile fraction. As expected, the contribution of particulate forms of mercury decreased upon lowering the pH

Fig. 1 shows the exponential decrease of the content of labile Hg in a sample at pH 8. Over a period of 35 days the concentration dropped to 1.5% of the initial value.

To check the optness of choice of the decomposition procedure, some filtered samples from the Arkona Basin (February 1978) were oxidized by different procedures. The rate of these reactions is shown in Fig. 2. In a 0.03% permanganate solution the labile mercury was released very quickly. Peroxodisulphate acted significantly slower at similar concentration. To ensure quantitative recovery of the predominant part of the stable bound mercury in samples of quite different composition, we recommended 12-h oxidation with a $KMnO_4 — K_2S_2O_8$ mixture. The use of the peroxodisulphate was suggested by some authors to decompose those substances which are resistant to the permanganate alone.

Table 1. Variations of different fractions of mercury in relation to the pH
Tab. 1. Zmienność różnych frakcji rtęci w zależności od pH

	Sample NO — Nr próbki							
	1	2	3	4	5	6	7	8
	pH							
	8	7.5	7	2.5	1.7	1.5	0.7[a]	0.4[a]
% adsorbed on the walls [b] % zaadsorbowanej na ściankach	47.8	35.6	22.7	6.4	2.2	1.9	1.5	0.9
— desorbed by acid, labile zdesorbowanej kwasem, labilnej	33	25	15	3.6	1	1	0.8	0.6
— desorbed by acid, stable zdesorbowanej kwasem, trwałej	14	10	7	2.5	1.2	0.9	0.7	0.3
— exchangeable only after oxidation; wymiennej jedynie po utlenieniu	0.8	0.6	0.7	0.3	0.0	0.0	0.0	0.0
Fractions per cent [c] Frakcje, % [c]								
A	0.7	6	8	106	104	101	82	72
B	68	74	74	101	103	106	110	110
C	0.3	2	2	2	1	1	0	0
D	138	115	118	76	58	43	7	7

[a] Calculated value. — Wartość obliczona.
[b] After 35 days, based on initial concentration of total Hg. — Po 35 dniach, w stosunku do całkowitego początkowego stężenia Hg.
[c] After 28 days, based on initial concentration of different franctions. — Po 28 dniach, w stosunku do początkowego stężenia różnych frakcji.
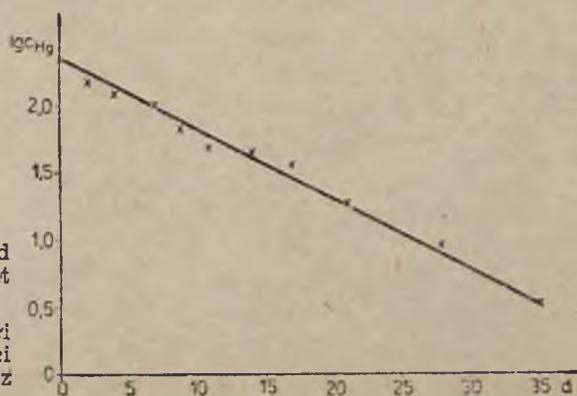

Fig. 1. Decrease of dissolved labile Hg during storage without preservation (pH 8)

Rys. 1. Spadek zawartości rozpuszczonej, labilnej rtęci podczas przechowywania bez konserwacji (pH 8)
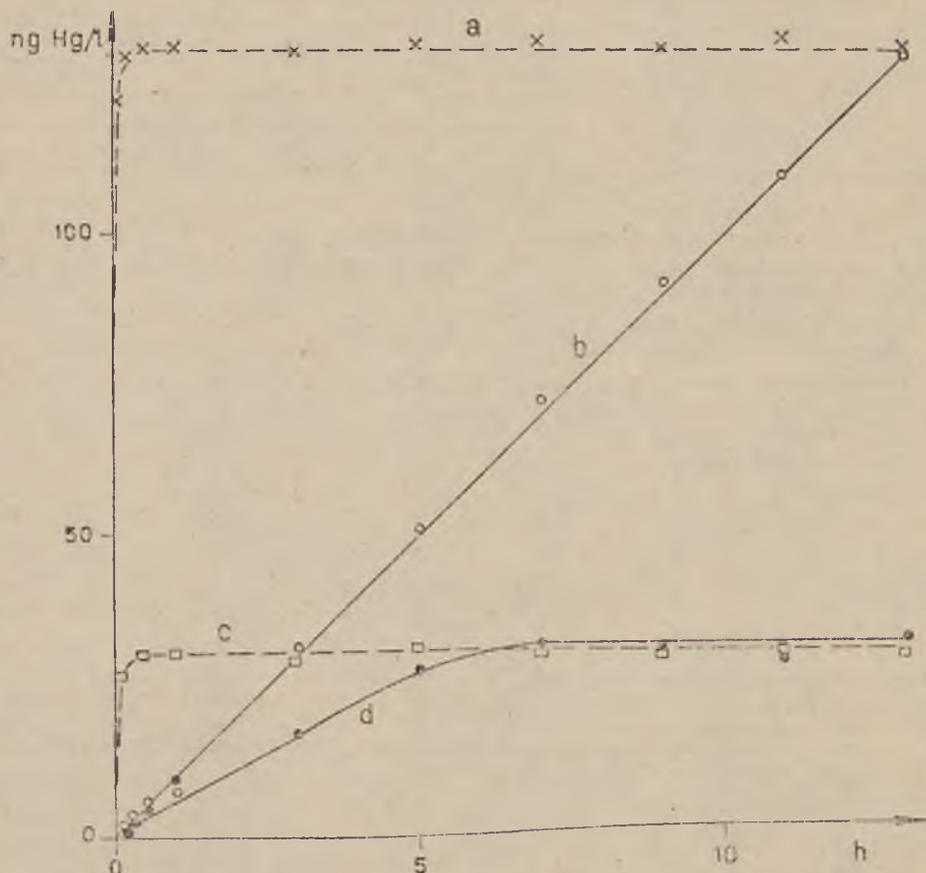
Fig. 2. Rates of the reactions of decomposition of organomercury compounds (sea water, S: 8.7‰)
a, b — 100 ng of diphenylmercury per dm^3 of sea water
c, d — sea water neat
— — 0.08% $K_2S_2O_8$; — — 0.03% $KMnO_4$

Rys. 2. Szybkość reakcji rozkładu związków rtęcioorganicznych (woda morska, S = 8.7‰)
a, b — 100 ng dwufenylortęci w dm^3 wody morskiej
c, d — czysta woda morska
— — 0.08% $K_2S_2O_8$; — — — 0.03% $KMnO_4$

3.2. Mercury in the Baltic water

As can be seen in Tables 2 and 3 and in Fig. 3, the concentration of labile mercury usually varies between 5 and 40 ng/dm^3 in the western, central and southern areas of the Baltic Sea. The range of the stable forms is broader and more expressive. For instance, the mercury pollution was sometimes described by total amounts of the metal only, whe-

Table 2. Mercury in the Baltic water
Tab. 2. Rtęć w wodzie bałtyckiej

Labile fraction — Frakcja labilna				Total amounts — Zawartość całkowita			
Samples Próbki	Range Zakres (ng/dm³)	Mean Średnia (ng/dm³)	Standard deviation Odchylenie standartowe (%)	Samples Próbki	Range Zakres (ng/dm³)	Mean Średnia (ng/dm³)	Standard deviation Odchylenie standartowe (%)
			31.1—13.2.1977				
54	0.9—65	14	± 91	50	4—266	48	±128
			8 and 16.7—1977 (OKEX)				
14	2 —23	6	±104	14	7— 35	21	± 48
			6—21.9.1977 (BOSEX)				
51	0.5—36	8	± 86	48	24—225	88	± 47

reas the contribution of the labile Hg was not markedly enhanced. This can be caused by the buffering capacity of orginic matter dissolved in water. Remarkable was also the distribution of mercury at station 200 (IBY 4 B) was also exceptional.

The increased levels of the two main forms of mercury at depths of 40 and 80 m can be explained in terms of special hydrographical conditions of this region. A similar phenomenon was also observed with other elements. During the investigations in February, May and November 1973 and in October 1975 at this station at depths varying between 20 and 80 m, the levels of Zn, Cd and Pb exceeded, by 1—2 orders of magnitude, those found in other areas of the Baltic Sea including the adjacent eastern Bornholm Basin (station 213 — IBY 5 A). These findings were cofirmed by the results reported by Olausson and associates [13]. In a 2-cm surface layer of the sediment taken in the western Bornholm Basin these authors found the mercury levels twice as high (135 ppb) as in the eastern area of this basin (62 ppb) and about 4—5 times higher than to the north of the explored area. Similar findings were also reported for the lead contents in sediments taken at different stations [13].

The relatively small number of data points precluded more general remarks as to the mercury level of the Baltic. Sea. Similar problems emerged when discussing the results of investigations carried out during BOSEX 77. Fig. 4 shows temporal variations of the labile and total amounts of mercury at different depths. The labile fraction constituted on average 9.5% of the total amount. In the surface layer, richest in dissolved organic carbon (DOC) (3.0—5.3 mg/dm³, mean

Table 3. Mercury levels at some selected stations in the Baltic (1977)
Tab. 3. Zawartość rtęci w niektórych wybranych stacjach na Bałtyku (1977)

Sta-tion No. Nr stacji	Position — Pozycja		Sampling date Data pobr. próbek	Depth Głębok. (m)	S ‰	t °C	Hg (ng/dm³)	
	Longitude (E) Długość geogr.	Latitude (N) Szerokość geogr.					labilne labilna	total całk.
023	11°03.3'	54°03.5'	31.1.	1.2	16.68	0.49	—	38
				10.3	17.30	1.09	25	46
				21.0	17.95	1.73	31	44
0.20	11°27.8'	54°11.3'	1.2	9.6	16.80	1.53	15	33
				19.6	19.31	2.76	16	36
				22.0	19.53	2.78	14	38
0.12	11°33.0'	54°18.9'	1.2	1.4	11.51		42	76
				10.3	14.79		42	61
				22.6	18.88		16	22
041	12°03.7'	54°24.4'	1.2	1.3	9.43	1.01	14	20
				10.2	14.27	1.29	11	24
				16.6	18.11	1.42	11	—
0.30	12°47.0'	54°43.4'	2.2	0.9	10.39	0.64	16	27
				10.3	10.42	0.86	22	35
				19.8	17.55	2.26	20	—
150	14°02.6'	54°36.7'	4.2	0.6	8.24	1.42	4	4
				9.3	8.23	1.41	9	42
				18.3	8.26	1.35	4	17
103	13°59.3'	55°03.8'	4.2	1.8	8.42	1.91	4	11
				20.7	8.43	1.90	4	16
				30.8	8.44	1.90	5	14
				40.3	8.68	3.26	4	16
				44.2	12.96	2.70	7	9
142	14°32.2'	55°24.3'	6.2	1.5	7.66	2.07	5	17
				9.3	7.65	2.03	5	—
				20.1	7.79	1.95	3	—
				29.9	7.89	2.00	2	—
				40.3	8.10	2.32	4	22
				49.7	8.66	2.63	6	33
200	15°20.0'	55°23.0'	8.2	1.3		2.11	1	4
				9.9	7.58	2.11	3	4
				20.2	7.59	2.12	4	6
				29.8	7.69	2.10	4	—
				40.4	8.13	3.13	13	105
				49.7	9.00	4.42	10	24
				70.8	16.16	6.23	11	19
				80.5	16.98	6.97	65	208
				89.2	17.44	7.03	16	32
233	19°17.0'	54°52.0'	12.2	1.6	8.06	2.04	4	217
				49.7	8.25	2.92	9	32
				106.1	13.49	7.98	9	93
113	13°30.0'	54°55.5'	16.7	1	4.6	15.0	2	16
				5			2	34
				10	11.1	15.0	2	33
				20	10.6	14.1	1	19
				30	11.8	9.9	4	16
				40	15.2	10.6	23	35
				45			2	15
295	18°44.0'	56°06.0'	8.9	2.0	7.60	15.96	15	95
				49.7	7.99	2.77	12	70
				90.2	11.34	4.88	7	86

4.0 mg/dm³) [8], the contribution of this fraction was only 6.5%. In the bottom water with DOC levels of 1.6—3.3 mg/dm³ (mean 2.3 mg/dm³), about 15.5% of the dissolved mercury was bound in the labile fraction.

The relationships between the stable/labile fractions and the DOC values were only qualitative. This is not surprising when one takes into consideration the following points: (i) only about 10% of the or-
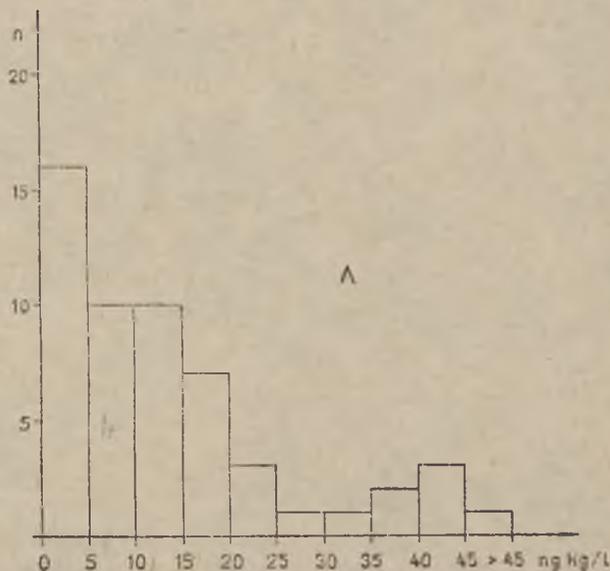

Fig. 3. Distribution of mercury contents in the southern, middle and western parts of the Baltic (January — February 1977)
A — labile fraction; B — total amount

Rys. 3. Rozkład zawartości rtęci w południowej, środkowej i zachodniej części Morza Bałtyckiego (styczeń — luty 1977)
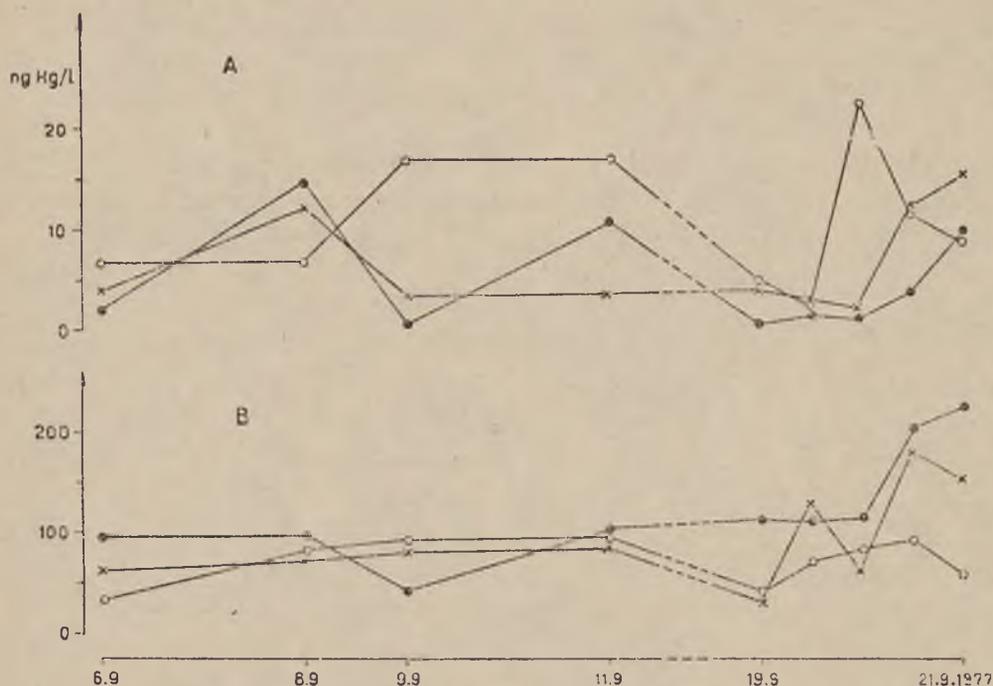A — frakcja labilna, B — zawartość całkowita

Fig. 4. Variations in the labile and total quantities of Hg at the BOSEX station 295 (September 1977)
A — labile fraction; B — total amount; • — 1 m; x — 50 m; o — 90 m

Rys. 4. Wahania ilości rtęci labilnej i całkowitej na stacji BOSEX 295 (wrzesień 1977)
A — frakcja labilna, B — zawartość całkowita, • — 1 m, x — 50 m, o — 90 m

ganic substances making up the DOC have been identified so far; (ii) the composition of the DOC may vary within greatly; (iii) mercury shows enhanced affinity to certain classes of substances or functional groups.

No correlation could also be found with other parameters such as the salinity, temperature, oxygen and nutrient levels etc. Indirectly, a variety of biochemical and geochemical processes, the inflow of oceanic water into the Baltic and the presence of discontinuity layers, may all affect the levels of particular forms of mercury significantly.

A camparison of these values with a small number of those published by other authors is difficult owing to differences in the methods employed, areas explored and times of carrying out the measurements. As demonstrated by recent intercalibration experiments, the differences are sometimes quite significant [12]. They are mostly due to modifications in the sampling and decomposition procedures which are associated with various sources of contamination and various fractional distribution of particular chemical forms of mercury.

3.3. Mercury in the Baltic sediments

Recent aquatic sediments contribute much to the balance of matter in the environment. Hence, they can also reflect the pollution of a sea area. From the results of our measurements (Fig. 5) conclusions can be drawn as to the anthropogenic contribution to the pollution by trace metals. To determine the ,,anthropogenic factors", mean values of the surface concentrations of the metals (0—6 cm) were related to those at a >100-cm depth. The factors shown in Table 4, provide mean values of 5 subsequent measurements. The increase in the mercury level on the surface of bottom sediments is greatest as compared with that of any other element. This is also confirmed qualitatively by the trace metal profiles shown in Fig. 5.

Table 4. Factors of the anthropogenic influence on the composition of bottom sediments in the Baltic

Tab. 4. Współczynniki wpływu antropogenicznego na skład osadów dennych w Morzu Bałtyckim

Hg	Fe	Mn	Zn	Cr	Ni	Pb	Cu	Co	Cd
3.2	1.0	1.0	1.5	1.2	1.1	1.3	1.2	1.5	2.1

Table 5. Correlation of Hg with other components (Significance levels: $|r| \geqslant 0.48$ (95%); $|r| \geqslant 0.61$ (99%))

Tab. 5. Korelacja Hg z innymi składnikami (Poziomy istotności: $|r| \geqslant 0.48$ (95%); $|r| \geqslant 0.61$ (99%))

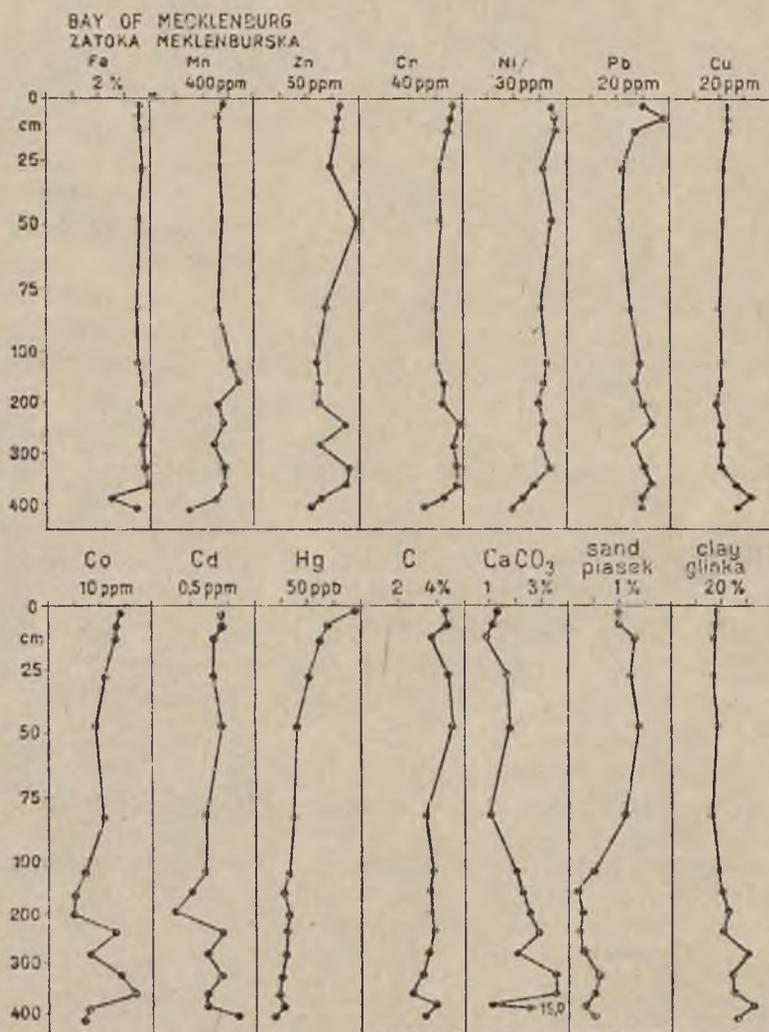| Component Składnik		x	s	r_{Hg}
Hg	(ppb)	39.9	20.2	1
Fe	(%)	3.59	0.32	0.020
Mn	(ppm)	538.7	78.0	0.126
Zn	(ppm)	90.1	16.0	0.214
Cr	(ppm)	67.1	7.5	0.226
Ni	(ppm)	45.9	6.7	0.663
Pb	(ppm)	28.7	4.0	0.119
Cu	(ppm)	22.1	3.2	—0.032
Co	(ppm)	10.3	3.5	0.371
Cd	(ppm)	0.77	0.19	0.199
Corg.	(%)	3.75	0.55	0.585
Cinorg.	(%)	2.87	3.56	—0.429
Sand	(%)	0.69	0.41	0.618
Silt	(%)	78.5	4.5	0.525
Clay	(%)	20.2	4.7	—0.554

Fig. 5. Composition of bottom sediments in the western Baltic (Feb. 27th, 1978, depth 24.3 m, core 4.43 m)

Rys. 5. Skład osadów dennych Bałtyku zachodniego (27.2.1978, głębokość 24,3 m rdzeń 4,43 m).

To find correlations between the mercury content and other geochemical parameters of the sediments, correlation coefficients, r, were calculated (Fig. 5). There are significant positive correlations with the contents of nickel, organic carbon, silts and sand. Mercury is negatively correlated with the clay fraction and less significantly with inorganic carbon. The results showed the expected close correlations between the amount of organic matter and the mercury level and confirmed once more the organic origin of the metal. The mechanisms responsible for these significant correlations have not been completely explained as yet.

They can only be elucidated as soon as more experimental evidence is accumulated.

3.4. Mercury balance of the Baltic

The enrichment of the bottom sediments in mercury was estimated based on the arithmetic means of the concentrations in the upper 6-cm layer. This layer is equivalent to a time span of about 30 years assuming a sedimentation rate of 2 mm per year. The value of 2.55 g/cm³ was assumed for the density of the solid phases. It is well known that the sedimentation takes place mostly in the central and deeper parts of basins. Assuming the mean sedimentation rate of 2 mm per year for 25% of the Baltic area, the total mercury amount deposited during one year can be estimated from the composition of the sediments. The mercury balance of the Baltic Sea was calculated on a basis of the volume of 21714,2 km³ and an area of 415,125 km² [3].

Table 6. Mercury balance of the Baltic Sea
Tab. 6. Bilans rtęci dla Morza Bałtyckiego

Water — Woda		
Labile fraction — Frakcja labilna	(ng/dm³)	11
	(t)	43
Total — Zawartość całkowita	(ng/dm³)	68
	(t)	267
Sediment — Osad		
Average at a depth of 0—6 cm	(ppb)	75
Średnio w warstwie od 0 do 6 cm		
Deposited — Wytrącona	(µg m⁻² yr⁻¹) [a]	36
	(t yr⁻¹) [b]	30
Input — Dopływ (t yr⁻¹) [c]		29
Residence time — Okres przebywania		
Labile fraction — Frakcja labilna	(yr — rok)	1.5
Total — Całkowita zawartość	(yr — rok)	8.9

[a] Sedimentation rate 2 mm per year — Szybkość sedymentacji 2 mm na rok.
[b] For 50% of the Baltic area — Dla 50% powierzchni Bałtyku.
[c] Sommer, 1977. — Wiosna 1977 r.

The values listed in Table 6 for the mercury balance are only preliminary. They should be corrected, for instance, for the amounts trans-

ferred to the North Sea. It is not surprising that the data for the total annual input reported by Somer [16] don't agree with those calculated from the composition of the surface layer of the bottom sediments. This indicates that the assumed sedimentation rate, the surface area of the depositional zone of the Baltic Sea and the data for the immission of mercury must be improved.

4. CONCLUSIONS

The following conclusions can be drawn from the results of our investigations on the mercury content of the Baltic water and sediments:

(i) The labile forms of mercury in the water samples often constitute only a low fraction of the total amount. In future more attention should be paid to the nature and behaviour of the stable bound forms of mercury;

(ii) The available data on the mercury content is very limited at present. To be able to characterize the pollution of the Baltic with mercury, measurements should be carried out using intercalibrated and agreed methods;

(iii) The relations between the content of suspended matter in the Baltic water and the mercury levels are still poorly understood. Detailed investigations on the interaction between particular forms of suspensions (inorganic, organic, particle size) and their accumulation capacity should be carried out;

(iv) Analyses of the bottom sediments revealed significant anthropogenic impact on their trace metals levels. Of about 30 tons of mercury entering the Baltic annually, only 30% are of natural origin;

(v) The importance of different pathways of the input of mercury compounds into the Baltic environment is still unknown. Carefully planned experiments, particularly for the estimation of atmospheric input, are needed;

(vi) Correlation factors between the mercury levels and other parameters of the sediments reveal a close interdependence with the content\of organic carbon. To get more information on diagenetic and authigenic processes, detailed investigations of the binding forms of this element in the sediments should be carried out.

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OZNACZANIE RTĘCI W WODZIE MORSKIEJ I OSADACH BAŁTYKU METODĄ ZIMNYCH PAR AAS

Streszczenie

W pracy przedstawiono i przedyskutowano wyniki oznaczeń rtęci w próbach wody i osadów pobranych w Bałtyku. Specjalną uwagę poświęcono różnorodnym formom chemicznym i fizykochemicznym występowania tego pierwiastka. Oznaczono formy występowania labilne i trwałe. Badania metodyczne wykazały duży wpływ wartości pH na zmiany form w czasie przechowywania prób. Wydaje się, że w Bałtyku dominującą jest związaną organicznie forma trwała rtęci, powiązana w sposób ilościowy ze stężeniem rozpuszczonego węgla organicznego.

Na podstawie zawartości rtęci w rdzeniach osadów można było oszacować udział antropogeniczny i roczny ładunek wnoszony do Błtyku. Oszacowano także bilans i okres przebywania tego metalu w wodzie Bałtyku.

Obliczając współczynnik korelacji ustalono istnienie ścisłego powiązania między zawartością rtęci w badanych próbach osadów dennych a zawartością innych składników (np. węgla, niklu).

Opisano szczegółowo zastosowane metody analityczne.

REFERENCES

1. Brügmann L., *Vorkommen und Analytik von Spurenmetallformen in Gewässern*, Acta hydrochim. hydrobiol., 1977, 5, p. 421 — 429.
2. Brügmann L., *On the occurrence of chemical forms of Zn, Cd, Pb, Cu and Hg in the Baltic*, Fourth Soviet-Swedish Symposium on the Baltic Sea Pollution, Riga, September 1977.
3. Ehlin U., Mattison I., Zachrisson G., *Computer based calculations of volumes of the Baltic area*, 9th Conference of the Baltic Oceanographers, Kiel, 1974.
4. Engwall R. B., *Swedish municipal and industrial discharges into the Baltic*, Ambio Special Report No. 1, 1972, p. 41 — 49.
5. Fitzgerald W. F., Lyons W. B., *Mercury concentrations in open-ocean waters: Sampling procedure*, Limnol. Oceanogr., 1975, 20, p. 468 — 471.

6. G e s a m p , *Reports and studies No: 2: Riview of harmful substances*, Unitions, Nations, New York 1976.

7. H a t c h W. R., O t t W. L., *Determination of submicrogram quantities of mercury by atomic absorption spectrophotometry*, Anal. Chem., 1968, 40, p. 2085 — 2087.

8. I r m i s c h A., *Unpublished results.*

9. N i e m i s t ö L., T e r v o V., *Preliminary results of heavy metal contents in some sediment cores in the Northern Baltic Sea*, 11th Conference of the Oceanographers, Rostock, April 1978.

10. N i e m i s t ö L., T e r v o V., *Preliminary results of some harmful substances in sediments of the BOSEX area*, 11th Conference of the Baltic Oceanographers, Rostock, April 1978.

11. O l a f s s o n J., *Determination of nanogram quantities of mercury in sea water*, Anal. Chim. Acta, 1974, 68, p. 207 — 211.

12. O l a f s s o n J.,*Report on the ICES international intercalibration of mercury in sea water*, Marine Chemistry, 1978, 6, p. 87 — 95.

13. O l a u s s o n E., G u s t a f s s o n O., M e l l i n T., S v e n s s o n R., *Current level of heavy metal pollution and eutrophication in the Baltic proper*, Meddelande fran Maringeologiska Laboratoriet Göteborg No. 9, May 1977.

14. P o d e r s e n K., L a r s e n B., *Milj o styrelsen, Baeltprojektek, Kemiske og Biologiske Unders o gelser*, Copenhagen 1976.

15. P e d e r s e n K., L a r s e n B., *Mercury in the Sound*, ICES, C.M. 1977/E:54.

16. S o m e r E., *Heavy metals in the Baltic*, ICES, C.M. 1977/E:9.

17. T r z o s i ń s k a A., Ś l ą c z k a W., B r z e z i ń s k a A., *Hydrochemical investigations in the Gdańsk Basin*, 3rd Soviet-Swedish Symposium on the Baltic Sea Pollution, Stockholm, September 1975.

18. U i J., *Discussion to the pollution of Minamata Bay and Minamata desease,* Advan. Water Poll. Res., 1966, 3, 167 — 174.