

This Report not to be cited without prior reference to the authors.

International Council for
the Exploration of the Sea

C.M. 1978/E:47
Marine Environmental Quality Committee
Ref.: Hydrography Committee



Distribution and behaviour of mercury in the
North Sea and Scheldt Estuary.

by W. Baeyens⁽¹⁾, G. Decadt⁽²⁾, I. Elskens⁽²⁾

(1) Beheerseenheid Model Noordzee en Schelde
R.A.C. - Vesaliusgebouw 2/3
1010 BRUSSEL

(2) University of Brussels (V.U.B.)
Laboratory for Analytical Chemistry
Pleinlaan 2
1050 BRUSSEL

Distribution and behaviour of mercury in the North Sea
and Scheldt Estuary

by W. Baeyens, G. Decadt, I. Elskens.

Abstract : The first part of the present study deals with the thermodynamical stability and the equilibrium concentrations of many of the most significant inorganic as well as some organic mercury species in seawater and brackish water. The results obtained are very useful for the interpretation of mercury distributions observed.

The second part deals with the concentrations of mercury found in the main compartments of the North Sea and the Scheldt estuary ecosystems. Determinations of mercury in the watercolumn, the sediments, fish, shellfish and zooplankton are presented and exchange fluxes between these compartments are discussed.

The results yield a reasonably detailed picture of the mercury distribution in the North Sea and the Scheldt and suggest the most probable pathways.

Résumé : La première partie de cette étude concerne le calcul de la stabilité thermodynamique et des concentrations à l'équilibre des composés du mercure inorganique les plus importants et de certains composés organiques en eau de mer et en eau saumâtre. Les résultats obtenus sont très utiles pour l'interprétation des distributions de mercure observées.

La seconde partie traite des concentrations du mercure trouvées dans les principaux compartiments des écosystèmes de la Mer du Nord et de l'Estuaire de l'Escaut. Des déterminations du mercure dans la colonne d'eau, les sédiments, les poissons, les invertébrés et le zooplancton sont présentées et les flux d'échange entre ces compartiments sont discutés.

Les résultats donnent une image détaillée de la distribution de mercure dans la Mer du Nord et dans l'Escaut et suggèrent les voies de transferts les plus probables.

Distribution and behaviour of mercury in the North Sea

and Scheldt Estuary

W. Baeyens, G. Decadt, I. Elskens.

Introduction.

As a consequence of the dense population and high degree of industrialization around the Southern Bight of the North Sea, pollution has increased to such a level that it has become necessary to assess and, where possible to manage, the impact of domestic and industrial wastes on the finite and relatively small water mass of the Southern Bight. Although the global impact of the Southern Bight on the whole North Sea seems to be relatively unimportant (G. Weichart, 1973), one must take into account that, on a local scale, this situation implies very high stationary concentrations of pollutants and possible changes in the system within a relatively short time scale. Mercury, owing to its high toxicity, is a pollutant which requires particular attention.

Mercury, in its various chemical forms, enters the environment from a number of different sources, industrial effluents (chlor-alkali, pigments, electrical apparatus, catalysis etc.) being the principal ones, but wastes of agricultural origin, atmospheric input, dumping etc. should not be disregarded. Its distribution and evolution depend on a variety of factors, such as the hydrodynamic characteristics and the physico-chemical conditions of the area, the assimilation of mercury by living organisms, including transfer through foodchains, and its interactions with other constituents of the marine environment which can modify its form in the watercolumn, in the sediments or within the bodies of the living organisms. In view of the complexity of these phenomena (mercury can undergo a large number of interactions), a stepwise multidisciplinary approach is the only way to resolve the problem. In this paper we discuss the first step, a description of the mercury content in the main compartments of the ecosystem as well as some exchange fluxes between them. This provides the basis for further steps which leads eventually to the construction of a mathematical circulation model for mercury, capable of predicting its evolution in space and time.

The southern part of the North Sea, (Fig. 1) which is the area covered by this study, can be described as a well mixed coastal sea, heavily polluted

owing to its shallow depth (the mean depth is 15m) and the large supply of pollutants. The residual circulation pattern (Ronday, 1977) shows the existence of a gyre off the Belgian coast, which increases the residence time of the pollutants in that area and consequently increases the local degree of pollution.

Considerable amounts of waste material reach the North Sea via rivers such as the Rhine, Thames, Elbe, Scheldt etc., although they contribute to different degrees. For our study of mercury transport we chose the Scheldt estuary, which belongs to the partial mixed type, is strongly tidal (the tidal amplitude reaches 3.8m at the mouth and increases to 4.9m at Antwerp, at km 75) and includes a great number of tidal flats. The mean fresh water discharge amounts to 80 m³ per second, resulting in a rather small residual current.

I. Theoretical considerations on the behaviour of mercury in aqueous media.

The form in which mercury will be present in the environment, depends principally on the initial released form, the thermodynamic stability of this compound and the transformation rate of the released form to a more stable one. Standard free energies of formation are known for many of the most significant inorganic species of mercury which can be present in water. Data on organo-mercury compounds are not available except for liquid dimethylmercury.

Knowing the free energy values (Wollast, 1972, Hem, 1970) and the activities of the various inorganic compounds and of liquid dimethylmercury, it is easy to calculate the electrochemical and chemical equilibrium curves between them and, as a result, to obtain the relatively most stable form for various Eh-pH fields. These stability fields for mercury species, both dissolved in sea water and in the solid and liquid phases, have been calculated by Wollast (Wollast, 1972) for a wide range of pH and redox potential values at normal temperature and pressure. The results are shown in Figure 2 and 3. However, because the water composition he has chosen (Garrels, 1965) is only representative of seawater, his conclusions, which are valid for the North Sea, cannot be extended to the brackish water zone we are dealing with in the estuary. Therefore we have recalculated the stability diagrams for the same system of elements (Hg - Cl - S - H₂O), at 25°C and 1 atmosphere. The activities of the various substances are: 10⁻⁷ moles per litre for the mercury species, 10⁻³ moles per litre for sulphur and 8.5 10⁻² moles per litre for chlorine. The chlorine and sulphur activities are of the same order of magnitude as those naturally occurring in the brackish zone while the mercury activity is

that found in industrial effluents. The resulting Eh-pH diagrams for the solid and liquid species and for the dissolved species are shown in Figures 4 and 5. The predominant compounds are indicated for every region; the solids are identified by the abbreviation "c", liquids by "l" and the dissolved species by "aq" or their ionic state. By superimposing the diagrams in Figures 2 and 3 it is possible to calculate the solubility of mercury in seawater in the range of pH and Eh considered (results are shown in Fig. 6). In an analogous way, using Figs. 4 and 5, we obtain the solubility of mercury in brackish water (results are shown in Fig. 5).

These diagrams clearly indicate the main features of the theoretical behaviour of the inorganic mercury compounds in sea and brackish water under equilibrium conditions. At the pH values likely to occur in surface seawater and brackish water, liquid metallic mercury is the stable solid compound except at high Eh values ($Eh > 350$ mV) where mercury (I) chloride (calomel) is more stable. In mildly reducing conditions, such as are likely to occur in the interstitial water of the sediments, mercury will precipitate as HgS (cinnabar). The organometallic compound dimethylmercury is not thermodynamically stable in either of the two systems (seawater and brackish water).

It would appear that, in well aerated seawater, the anionic complex $HgCl_3^-$ is the most stable compound over the whole range of pH considered, whereas, in brackish water, $Hg(OH)_2$ becomes predominant at high pH. This is in a good agreement with observations made by Hem (Hem, 1970) for the fresh water system. The area of dominance of $HgCl_3^-$, or $HgCl_2$ at low chloride concentrations, becomes smaller as the Cl^- concentration decreases. Mercury (I) compounds are not stable except at very low chloride concentrations (Hem, 1970). The solubility in aerated water of the $HgCl_3^-$ or $Hg(OH)_2$ complex is very high and may reach several grams per liter.

The predominant mercury species in solution over much of the range of moderately oxidizing conditions ($pH > 4$) is dissolved metallic mercury. Its solubility is nearly constant over the whole area of dominance, but is much lower, namely 25 ppb, than those of $HgCl_3^-$ or $Hg(OH)_2$. This means that if the electrochemical potential is lowered to 200 mV in seawater or 250 mV in brackish water, mercury may precipitate as liquid mercury. Such concentrations however, are not likely to occur. In reducing conditions such as may occur in the sediments, or in anaerobic water, HgS_2^{--} is the most stable dissolved species for a pH greater than 5, and $Hg(SH)_2$ at lower pH values. The solubility of these species is very low. Cinnabar, the stable solid compound in this area of Eh-pH, has a solubility of less than a nanogram per litre. However, under very strong reducing conditions and a pH greater than 9, HgS_2^{--} becomes very soluble and cinnabar may redissolve. Because sulphide concentrations are higher in sea-

water than in fresh water, cinnabar is more soluble in the sea sediments, which makes the mobility of mercury in the interstitial water much higher.

We have not discussed organomercury compounds although methyl mercury is one of the most important mercury forms in fish (Johnels, 1967, Herman & V.D. Stappen, 1977), in sediments (Jensen, 1969) and perhaps even in some other compartments of the eco-system. Unfortunately, no free energy value could be found or estimated. Therefore this species could not be considered in constructing the diagrams.

A lot of valuable information about aqueous mercury chemistry is obtainable from the Eh-pH diagrams. However, when interpreting in situ measurements, we have to bear in mind that the theory applies to a system at equilibrium, which is a rather idealized situation. In natural waters it is common to find species that are not in equilibrium, because transformation rates to more stable compounds can be very slow. This is one reason why methylmercury, although it might be thermodynamically less stable than some inorganic species, should not be ignored. Another general remark is that most mercury species are much more soluble in organic solvents than in water (Moser & Voigt, 1957), which can cause the removal of mercury from water by aquatic organisms.

II. The North Sea.

1. Measurements and results:

Various forms of mercury in different compartments of the eco-system have been measured as part of the Belgian National R-D program on the Environment - Sea Project: Mathematical Model 1970-1976. Special attention has been paid to sampling and storage procedures to avoid as far as possible contamination or loss prior to analysis. Previously determinations of particulate and "dissolved" mercury concentrations had been carried out in an area covering the Eastern Part of the Southern Bight of the North Sea, but now, attention is focussed on the distribution of total mercury in a smaller area off the Belgian Coast. The seawater samples are collected with a centrifugal pump made of Teflon, stored in polyethylene bottles, rapidly frozen at -40°C and maintained at -20°C prior to analysis. They are quickly thawed immediately before they are required for analysis which is carried out with a semi-automatic system, based on the method of Hatch and Ott (Hatch and Ott, 1968). Analyzing and flushing times are kept constant by a series of automatically operating valves; the resulting flow scheme is represented by Fig. 7.

As an illustration of the spatial distribution of total mercury in the Belgian Coastal Zone, we show some preliminary results in Table 1 and Fig.8.

Plankton samples are collected with a 100 µm mesh nylon net, rinsed several times with distilled water to remove the seawater salts and frozen at -20°C in polyethylene bottles. Due to the great heterogeneity of these samples they have to be treated in various stages before the final determination of mercury. After they have been quickly thawed, the samples are successively lyophilised during 24 hours in a Leybold-Heraeus GT2, ground in a mechanical agate mortar in order to reduce the size of the particles to less than 100 µm and dried again in the lyophiliser during 12 hours before weighing. The final phase of the analysis comprises the wet digestion of 300 mg subsample, according to the technique described by Janssen (Janssen, 1976) and the determination of mercury in this residue as described above for seawater samples. Tests on the homogeneity of the subsamples clearly indicate that an amount of 300 mg is representative of the gross sample. In order to take into account the amount of exogeneous material present in these samples, determinations of carbon, nitrogen and silica have also been carried out (Elskens, 1977).

Table 2 shows the results of mercury determinations on plankton, made on samples collected during cruises in 1975.

Besides the determination of mercury in seawater and plankton, concentrations have also been measured in fish and shellfish (organic and inorganic mercury) by Herman & V.D. Stappen (Herman & V.D. Stappen, 1977). Results are shown in Tables 3, 4, 5.

2. Discussion:

The set of results obtained during the North Sea project, gives us a quite detailed picture of the mercury distribution in different compartments of the eco-system (watercolumn and living organisms). The mean mercury values are summarized in table 6.

TABLE 6

Mean mercury content of various compartments of the ecosystem

watercolumn: total	0.3 µg/l
fish	150 ppb (fresh material)
shellfish	50 ppb (" ")
zooplankton	1550 ppb (" ")

At the present time it is still too early to draw conclusions on the spatial distribution of mercury in seawater especially as far as coastal inputs and dumping activities are concerned. However, the first results show that the mercury concentrations at points under the influence of the Scheldt estuary are higher than at any other places in our sampling network.

In addition, a pronounced seasonal variation (Fig. 9) has been observed at station 14. Since the variations in the total mercury concentration in the watercolumn are mainly related to input-output fluctuations, the interpretation of the observed pattern requires a careful analysis of these factors.

In analysing the concentrations of mercury in living organisms, a distinction must be made between the different trophic levels. Direct adsorption on phytoplankton, which is the main cause of contamination, has been studied by Vloebergh & Perpeet (Vloebergh & Perpeet, 1977). The concentration is considerable and amounts to 15 to 20 percent of that found in detrital particulate matter despite the lower adsorption capacity of the phytoplankton. For zooplankton and shell fish, as for fish, two main routes of transfer within the marine food chains must be considered. They are direct uptake from the water and indirect uptake through ingestion of phytoplankton, zooplankton, organic matter etc.. This latter pathway is common to the three groups of living organisms just mentioned. Rates of indirect uptake have been studied by Elskens (Elskens, 1977) and the values he found for zooplankton and pelagic and demersal fish in the Southern Bight are respectively 3.42 mg Hg per m², 0.41 mg Hg per m² and 0.019 mg Hg per m². However, the accumulation rates are significantly lower due to the excretion of 80 to 90 percent of the amount ingested.

Mytilus edulis (mussels) are often selected for the assessment of the existing level of marine pollution, because their particular characteristic of filtering large amounts of seawater makes them very sensitive to waterquality changes. The direct effect of Hg⁺⁺ on *Mytilus edulis* has been studied by Vloebergh et al (Vloebergh et al, 1977), using a radioactive tracer technique. The results show that the target organs, where accumulation is highest, are the gills and the digestive tract. For fish, the gills appear to be the most likely site of attack (Bouquegneau, 1977). Direct accumulation through this organ seems to be very important, leading to the conclusion that the effect of the two possible pathways will cumulate. While seawater concentrations will affect membrane permeability and enzyme activity in peripheral metabolic systems directly exposed to seawater, the body burden of toxic substances will disturb internal metabolic systems.

Independent of the pathway, the accumulation of mercury can reach a very high level in these organisms, because they produce low molecular weight proteins containing a large number of - SH groups, which have high affinities for heavy

metals like mercury and cadmium. The release, when back in non-contaminated water, will be a comparatively slow process, due to the formation of these metallothioneins, and will involve the redistribution of mercury within the body. An important study on regression between total mercury content and length, weight and age of sole was recently made by Vyncke (Vyncke (*), 1978).

The ratio methylmercury to total mercury varies between 32 and 94 percent in fish and between 14 and 100 percent in shell fish with a value of 61 percent for shrimps (Herman & V.D. Stappen, 1977), but although this study is based on a great number of analyses, no conclusions can be drawn for the moment. As a general trend, according to Johnels et al (Johnels et al, 1967), the ratio inorganic to organic mercury decreases with the age of the fish.

III. The Scheldt estuary.

1. Measurements and results.

Research was focussed on the transport mechanisms of mercury in order to explain the observed longitudinal patterns. The high degree of pollution reduces the number of living organisms especially in the upper part of the estuary almost to zero. Very near the mouth, plankton and some benthic populations were found, but they are not considered in view of their scarcity and very local presence.

Longitudinal concentration profiles of particulate and "dissolved" mercury concentrations have been drawn from measurements on estuarine samples. The samples were collected with a centrifugal pump made of Teflon and immediately filtered on board the vessel through a 0.8 μ m poresize Millipore filter, using a closed pressure filtration system. The filtrate was acidified to a pH of one with pure nitric acid and stored for maximum three days in a BOD (glass) bottle. Filters were rapidly deep frozen and stored in plastic holders. Hoenig (Hoenig, 1977) had previously measured the particulate mercury concentration in a different way. To obtain a more representative sample, he collected the suspended matter using a centrifugal system (Alpha-Laval centrifuge), during half an hour and stored it in a polyethylene bottle.

The sample analysis was carried out in the same way as described above for the seawater samples. The results and the longitudinal profile of particulate mercury are shown in Table 7 and Fig. 10.

Sediment samples have been analyzed at only one point, at 60 km from the mouth, (Bouquiaux, 1977) and the mercury level detected was 1.8 ppm. Wollast (Wollast, 1977) has estimated the mean annual quantity of mercury, sedimentating in the box Rupelmonde - Doel (km 92 - km 61) at 1.2 ton and in the box Doel - Hansweert (km 60 - km 35) at 0.1 ton.

(*) "Het Rijkstation voor Zeevisserij", Oostende.

2. Discussion.

While longitudinal variations in pH are small - the results in Table 7 indicate that except for point 1, the pH values lie between 6.95 and 7.35 - the redox potential shows considerable longitudinal and seasonal variation. Fig. 11 shows some longitudinal Eh profiles for different periods of the year. Two specific zones in the estuary can be distinguished, one aerobic and the other more or less anaerobic. Downstream, from km 55 to the mouth, the redox potential has the normal value of aerated water so that dissolved HgCl_3^- is the most stable mercury species. In the upper region however, the potential fluctuates between -50 and 300 mV depending on the season and the locality, so that either HgCl_3^- or Hg^0_{aq} will be the stable compounds. In the estuary mercury concentrations are never high enough to provoke chemical precipitation.

Comparing the concentration of total particulate mercury, defined as $\mu\text{g Hg}$ -particulate per litre, to "dissolved" mercury, there is no doubt that adsorption mechanisms play an important role in the estuary.

Dissolved mercury will interact with particulate matter because the surface of separation between the particles and the water is characterized by a potential different of that of the bulk. Depending on the sign and magnitude of the electrokinetic potential of these solids, mercury can be adsorbed directly, and very strongly, on the fixed part of the double layer, or indirectly, and in general less strongly, on the outer side of this layer, where it acts as a counterion. However, besides the important part the potential plays in the adsorption process, it is apparent that the number of specific reactive sites on a particle must also be considered (for example tensioactive substances adhere to a particle in such way that they must be considered as a part of it, and they may contain large numbers of functional groups like -SH, -Cl, -COOH etc.; the same is valid for the organic particulate matter). Both factors will determine the adsorption capacity of a particle (Baeyens, 1977). Adsorption capacity studies of heavy metals on particulate matter such as clay (Reimers, 1974), hydrous iron and manganese (Gadde, 1974, Decadt, 1977) and organic matter (Baeyens, 1977, Vloebergh & Perpeet, 1975) are well known.

Because the absolute mercury concentration, defined as $\mu\text{g Hg}$ per g dry matter, varies very little from point to point, the total particulate mercury profile shown in Figure 10 must be due to the turbidity profile. This has maxima which are, in general, situated between km 40 and km 90 depending on the fresh water discharge.

The ratio total particulate to "dissolved" mercury is high, especially in the upper part of the estuary. Three factors will reduce this ratio as one goes downstream:

- a. Due to sedimentation only a small proportion of the particulate mercury reaches the sea; the main part will accumulate in the upstream sediments.
- b. Mercury originating in the industrial zone around Ghent is discharged into the Scheldt at 20 km from the mouth.
- c. The absolute mercury concentration decreases from km 50 to the mouth as we can see on Fig. 10.

While points a and b need no further comment, point c is attributed by Muller & Forstner (Muller & Forstner, 1975) to a dilution of the highly polluted upstream suspension, by suspended matter of marine origin, which is much less contaminated. Analogous observations have been made for other particulate heavy metals as well as for particulate carbon concentrations (Wollast, 1977).

REFERENCES

1. G. Weichart (1973), Pollution of the North Sea, *Ambio* 1973-2, 99-106.
2. F.C. Ronday (1977), La circulation résiduelle en Mer du Nord pg 207-255, *Modèles Hydrodynamiques, Vol 3, Rapport Final, Projet Mer* (ed. J.C.J. Nihoul et F.C. Ronday).
3. R. Wollast (1972), Distribution of mercury in the sediments of the North Sea, *Techn. Report 1972/Sed., Commission Interministérielle de la Politique Scientifique*.
4. J.D. Hem (1970), Chemical Behavior of Mercury in Aqueous Media, 19-24, *Mercury in the Environment, Geological Survey Professional Paper 713*.
5. R.M. Garrels (1965), *Solutions, Minerals and Equilibria*, pg 100-103, Harper and Row, New York.
6. Vyncke W. (1978), Results of the regression analysis studies, Belgium, ICES, Working group on marine pollution baseline and monitoring studies in the North Atlantic, *Poll. 78 Ag. 7/1/1*.
7. P. Herman et R. Vanderstappen (1977), Les niveaux de contamination des poissons, des invertébrés benthiques, de la faune et de la flore des brise-lames, pg 2-54, *Contamination des produits de la mer, Vol 9, Rapport final, Projet Mer* (ed. J.C.J. Nihoul et A. Distèche).
8. S. Jensen and A. Jernelov (1969), *Nature*, Vol. 223, N°5207, 753-754.
9. W.R. Hatch and W.C. Ott (1968), *Anal. Chem.*, Vol. 40, N°14, 2085-2087.
10. D. Janssen (1976), Dans Topping G. Preliminary Report on 1975 trace metal intercalibration exercise, ICES, Working group on Pollution Baseline Study and Monitoring Studies in the Oslo Commission and ICNAF areas Report, Copenhagen, may 1976.
11. I. Elskens (1977), Les niveaux de contamination du plancton par les métaux lourds, pg 91-120, *Contamination des produits de la Mer, Vol 9, Rapport final, Projet Mer* (ed. J.C.J. Nihoul and A. Distèche).
12. W. Baeyens (1977), Ph. D. Thesis, Vrije Universiteit Brussel.
13. R.S. Reimers and P.A. Krenkel (1974), *Journal WPCF*, Vol. 46, N°2, 352-365.
14. R.R. Gadde and H.A. Laitinen (1974), *Anal. Chem.*, Vol. 46, N°13, 2022-2026.
15. G. Decadt (1977), *Licentiaatsverhandeling, Vrije Universiteit Brussel*.
16. M. Vloebergh and Ch. Perpeet (1975), Etude de l'adsorption du mercure sur des particules organiques et inorganiques. *Belgian Nat. R.-D. Progr. Environment - Water - Sea - Project - Technical Report, Biol. Labo 01*.
17. I. Elskens (1977), Le transport de certains métaux lourds à l'intérieur de l'écosystème marin de la partie Sud du Southern Bight, pg 293-305, *Contaminations des produits de la mer, Vol 9, Rapport Final, Projet Mer* (ed. J.C.J. Nihoul et A. Distèche).

18. J.M. Bouquegneau, F. Noel-Lambot et A. Distèche (1977), Le problème de l'intoxication directe et indirecte par les métaux lourds, pg 266-292, Contamination des produits de la mer, Vol. 9, Rapport final, Projet Mer (ed. J.C.J. Nihoul et A. Distèche).
19. M. Hoenig (1977), Polluants inorganiques dans les sédiments et les suspensions de la mer du Nord et de l'Escaut, pg 193-209, Inventaire des Polluants, Vol. 6, Rapport Final, Projet Mer (ed. J.C.J. Nihoul et I. Elskens).
20. J. Bouquiaux et P. Herman (1977), Niveaux de pollution du réseau hydrographique belge, pg 7-46, Inventaire des Polluants, Vol. 6, Rapport Final, Projet Mer (ed. J.C.J. Nihoul et I. Elskens).
21. R. Wollast (1977), Transport et accumulation de polluants dans l'estuaire de l'Escaut, pg 191-218, L'Estuaire de l'Escaut, Vol. 10, Rapport Final, Projet Mer (ed. J.C.J. Nihoul et R. Wollast).
22. G. Muller and V. Forstner (1975), Heavy metals in sediments of the Rhine and Elbe estuaries: mobilization of mixing effects, Environ. Geology, 1, 1, 33-39.
23. A. Johnels, J. Westermark et al (1967), Pike and some other aquatic organisms in Sweden as indicators of mercury contamination in the environment, Oikos, 18, 323.

TABLE 1

CRUISE OF JULY 1977

Identification	Hg-total ($\mu\text{g}/\text{l}$)	Salinity ‰
M11.270777.1110.-	0.2	—
M21.270777.1210.-	0.16	34.06
M31.270777.1300.-	0.21	34.2
M41.270777.1410.-	0.11	34.3
M42.270777.1500.-	0.27	33.94
M32.270777.1550.-	0.18	34.9
M22.270777.1640.-	0.07	33.94
M12.270777.1740.-	0.32	33.86
M13.270777.1910.-	0.15	32.92
M23.270777.1950.-	0.17	32.74
M33.270777.2030.-	0.40	32.96
M43.270777.2130.-	0.17	32.69
M44.280777.1550.-	0.63	33.23
M34.280777.1630.-	3.28	32.67
M24.280777.1725.-	0.37	31.80

TABLE 2

CRUISE JULY 1975. HEAVY METALS CONTENT OF PLANKTON

Identification	Zone	Zn	Cd	Pb	Cu	Hg
		µg/g C	µg/g C	µg/g C	µg/g C	µg/g C
B 11 1975 M55.000775.1000.--	1 S	630	1,8	92	192	1,7
M1041.080775.1500.--	1 S	3161	4,0	172	270	2,8
M04.080775.1900.--	2	1792	9,7	167	585	8,2
M09.090775.0500.--	2	2101	3,8	151	484	15,5
M05.090775.1300.--	1 S	1435	6,1	413	239	4,8
M12.090775.1700.--	1 S	2746	5,0	88	1040	2,5
M11.090775.1930.--	1 S	1864	2,9	143	573	4,4
M17.100775.0430.--	1N	889	3,6	83	69	3,1
M16.100775.0715.--	1N	1523	15,2	162	558	4,9
M21.100775.1200.--	1N	2803	7,7	232	994	15,7
M22.100775.1230.--	1N	511	1,7	66	259	12,3
M25.100775.1600.--	2	4706	25,7	241	1614	27,9
M20.110775.0430.--	2	2383	10,5	323	1241	15,1
M15.110775.0900.--	2	2160	18,2	312	1336	127,4

Remark: The calculation of the concentrations in other units can be done using following coefficients:

- Zooplankton as a whole is considered to have a mean carbon content of 40% of dry matter
- Fresh material, drained and freed of impurities, is considered to have a water content of 80 to 90 % (this gives a mean dry residue of 15 %).

TABEL 3

MEAN MERCURY CONCENTRATION OF DRAINED FILLETS OF 14 FISH

SPECIES. BELGIAN COASTAL ZONE, 1975

SPECIES		n	TOTAL Hg (ppm)		
			\bar{x}	s	v%
Cod	<i>Gadus morhua</i> L.	6	0,16	0,06	37,5
Yellow Gurnard	<i>Gallionymus lyra</i> L.	10	0,09	0,04	44,5
Sandeel	<i>Ammodytes tobianus</i> L.	10	0,06	0,02	33,3
Flounder	<i>Pleuronectes flesus</i> L.	10	0,41	0,18	43,9
Herring	<i>Clupea harengus</i>	10	0,07	0,03	42,8
Dab	<i>Pleuronectes limanda</i> L.	10	0,08	0,02	25,0
Horse Mackerel	<i>Trachurus trachurus</i> L.	10	0,87	0,30	34,5
Whiting	<i>Merlangus merlangus</i> L.	50	0,21	0,11	52,3
Rockling	<i>Onos mustela</i> L.	10	0,22	0,08	36,3
Tub Gurnard	<i>Trigla lucerna</i>	10	0,11	0,03	27,3
Plaice	<i>Pleuronectes platessa</i> L.	50	0,11	0,04	36,3
Sole	<i>Solea solea</i> L.	25	0,19	0,09	47,3
Sprat	<i>Clupea sprattus</i> L.	13	0,10	0,02	20,0
Pout	<i>Gadus luscus</i> L.	10	0,16	0,09	56,2

TABEL 4

HEAVY METALS CONTENT OF BENTHIC INVERTEBRATA. BELGIAN COASTAL

ZONE, 1975

SPECIES	n	% H ₂ O	ppm (dry weight)				
			Hg total	Cu	Pb	Zn	Cd
<u>Crustacea:</u>							
Crangon crangon 1972	50	71	0,28	50,3	10,4	91,4	0,17
1975	50	71	0,22	44,0	3	87	0,16
Pagurus Bernhardus	6	60	0,13	87	2,1	95	0,22
" "	3	56	0,29	121	1,0	104	0,45
Carcinus maenas	2	66	0,15	28	2,4	86	0,07
Portunus puber	2	65	0,12	26	2,8	108	0,16
" "	1	62	0,11	93	1,3	115	0,37
Portunus holsatus	7	64	0,19	32	2,6	98	0,14
Macropipus holsatus	5	66	0,17	216	6,3	115	0,25
<u>Echinodermata:</u>							
Asterias Rubens	7	65	0,34	7,6	8,1	163	0,24
" "	3	67	0,51	8,4	3,7	195	0,38
Ophiura species	3	45	0,10	2,7	4,1	117	0,17
" "	1	42	0,14	3,0	3,2	149	0,28
Echinocardium cordatum	1	28	0,08	3,3	(128) ?	28	0,40
<u>Bryozoa:</u>							
Calcyonidium digitatum	3	84	0,19	8,6	6,6	107	0,63
Flustra foliacea	1	71	0,14	9,8	15,2	336	0,68
<u>Mollusca:</u>							
Buccinum undatum	5	61	0,32	107	0,64	47	0,18
<u>Annelida:</u>							
Lanice conchilega	3	33	0,03	2,6	9,8	45	0,16
<u>Pisces:</u>							
Gobius minutus	2	71	0,19	3,2	1,3	73	0,09
<u>Coelenterata:</u>							
Metridium senile	1	74	0,15	-	-	-	-

TABEL 5

MEAN METHYLMERCURY CONCENTRATION (MeHg) AND % MeHg (R) OF FISH FILLETS.

BELGIAN COASTAL ZONE

FISHING YEAR	COD		WHITING		PLAICE		SPRAT	
	MeHg ppm	R %	MeHg ppm	R %	MeHg ppm	R %	MeHg ppm	R %
1972	-	-	0,19	70	0,06	32	0,08	53
1973	0,11	73	-	-	-	-	-	-
1974	0,13	54	0,12	50	0,09	53	0,05	55
1975	0,16	94	0,17	85	0,12	100	0,08	80

TABLE 7

SCHELDT ESTUARY - CRUISE OF FEBRUARY 1975

POINT	KM	Hg-PARTICULATE $\mu\text{g}/\ell$	pH	Eh mV	SALINITY gr Cl^-/ℓ
1	2	0.130	7.75	385	13.0
4	20	0.265	7.35	325	10.2
7	35	0.225	7.05	315	6.3
10	46.5	0.345	7.05	320	4.0
12	54.5	1.050	7.30	320	1.6
14	59.5	0.502	7.25	320	0.9
16	64.5	0.250	7.15	312	0.5
18	68.5	0.200	7.15	318	0.4
20	73.5	0.115	7.10	275	0.3
22	78.8	0.310	7.00	320	0.3
24	82.8	0.240	6.95	280	0.3
26	87.5	0.190	7.00	280	0.3
28	92	0.250	7.10	290	0.3
30	97.5	0.300	7.15	300	0.3
32	103.5	0.160	7.25	340	0.3
34	113.5	0.210	7.30	345	0.35
36	121.6	0.230	7.30	350	0.35

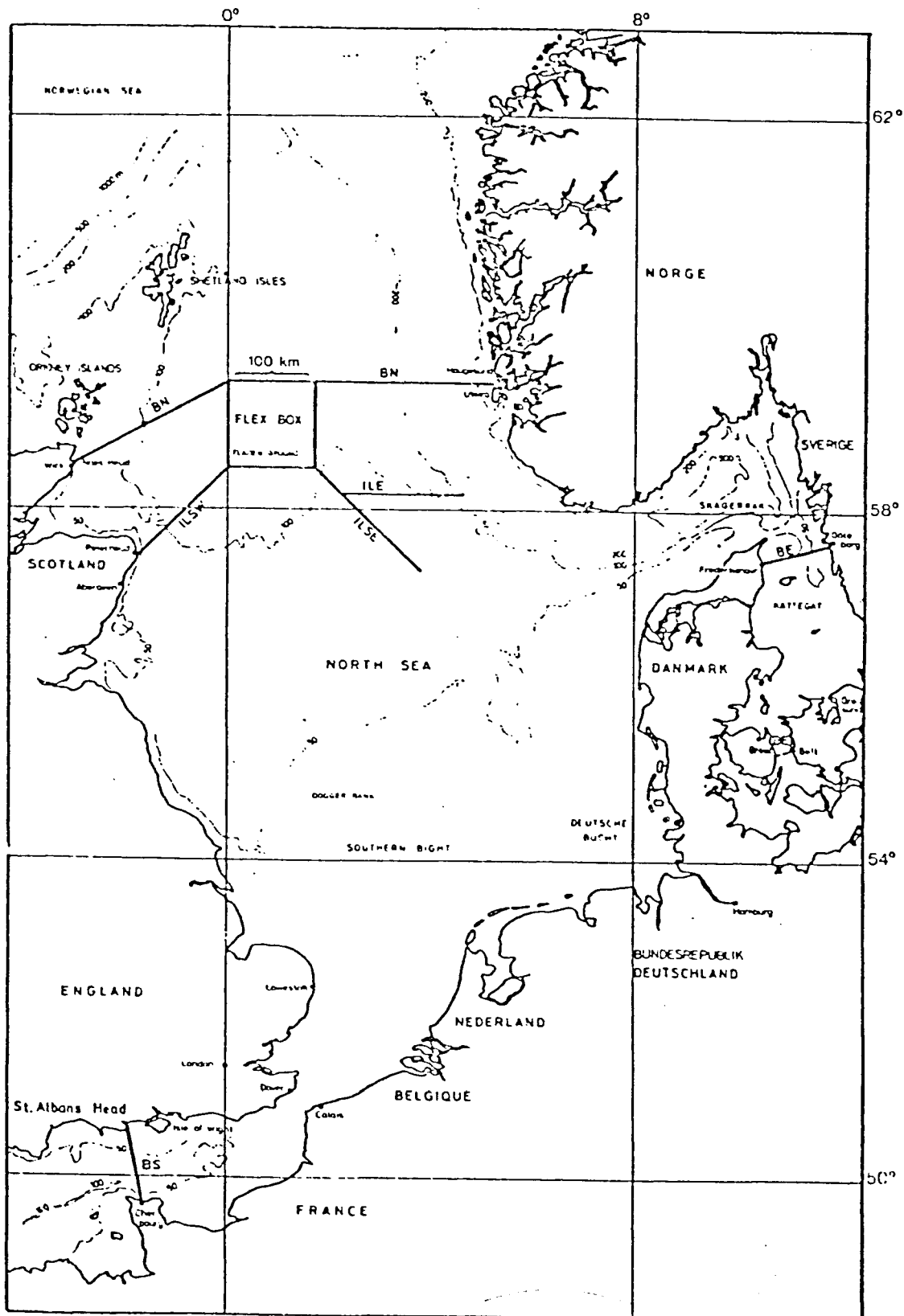


FIG. 1 ; THE SOUTHERN PART OF THE NORTH SEA.

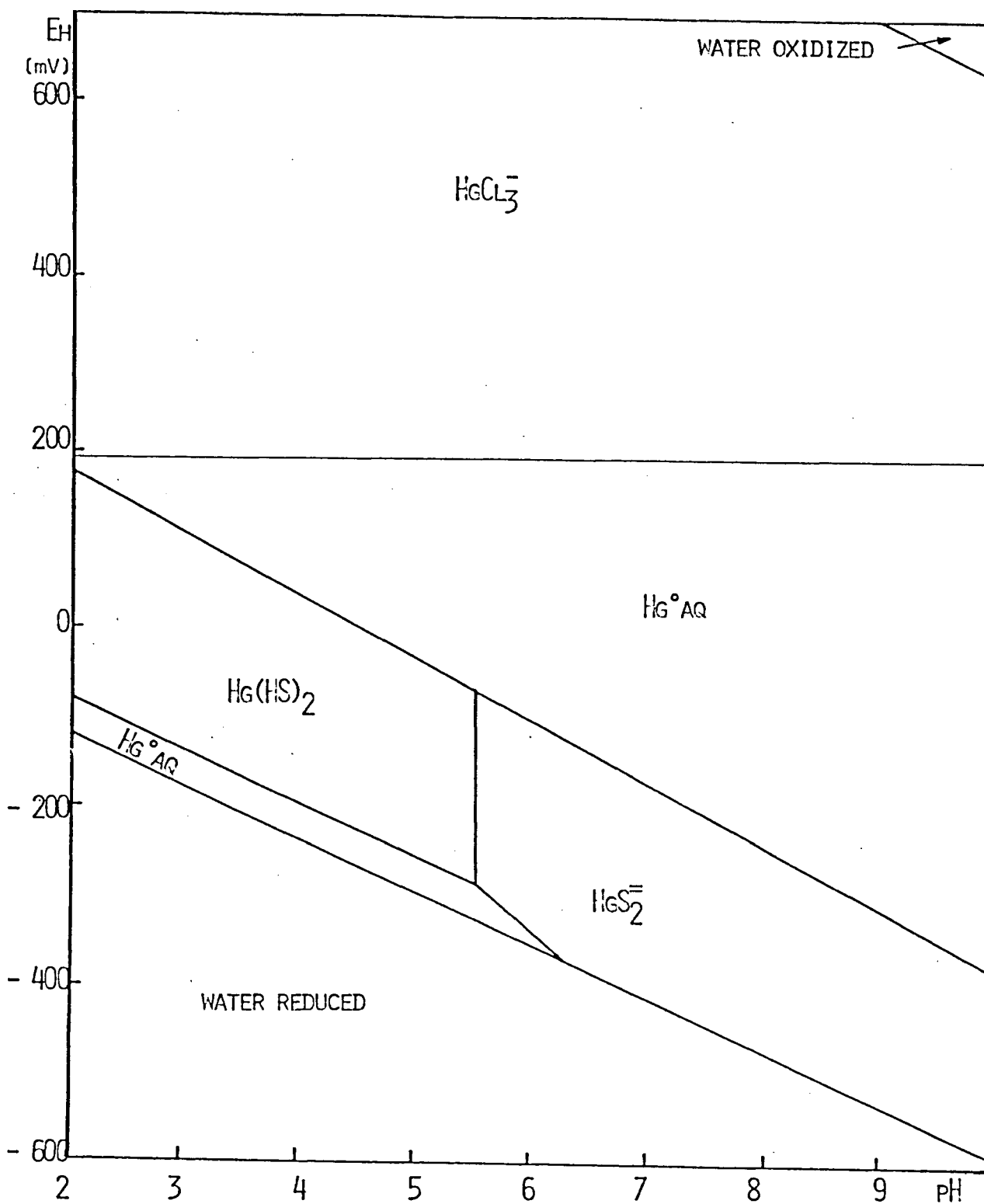


FIG. 2: FIELDS OF STABILITY FOR AQUEOUS MERCURY SPECIES AT 25°C AND 1 ATMOSPHERE PRESSURE IN SEAWATER. (WOLLAST, 1972).

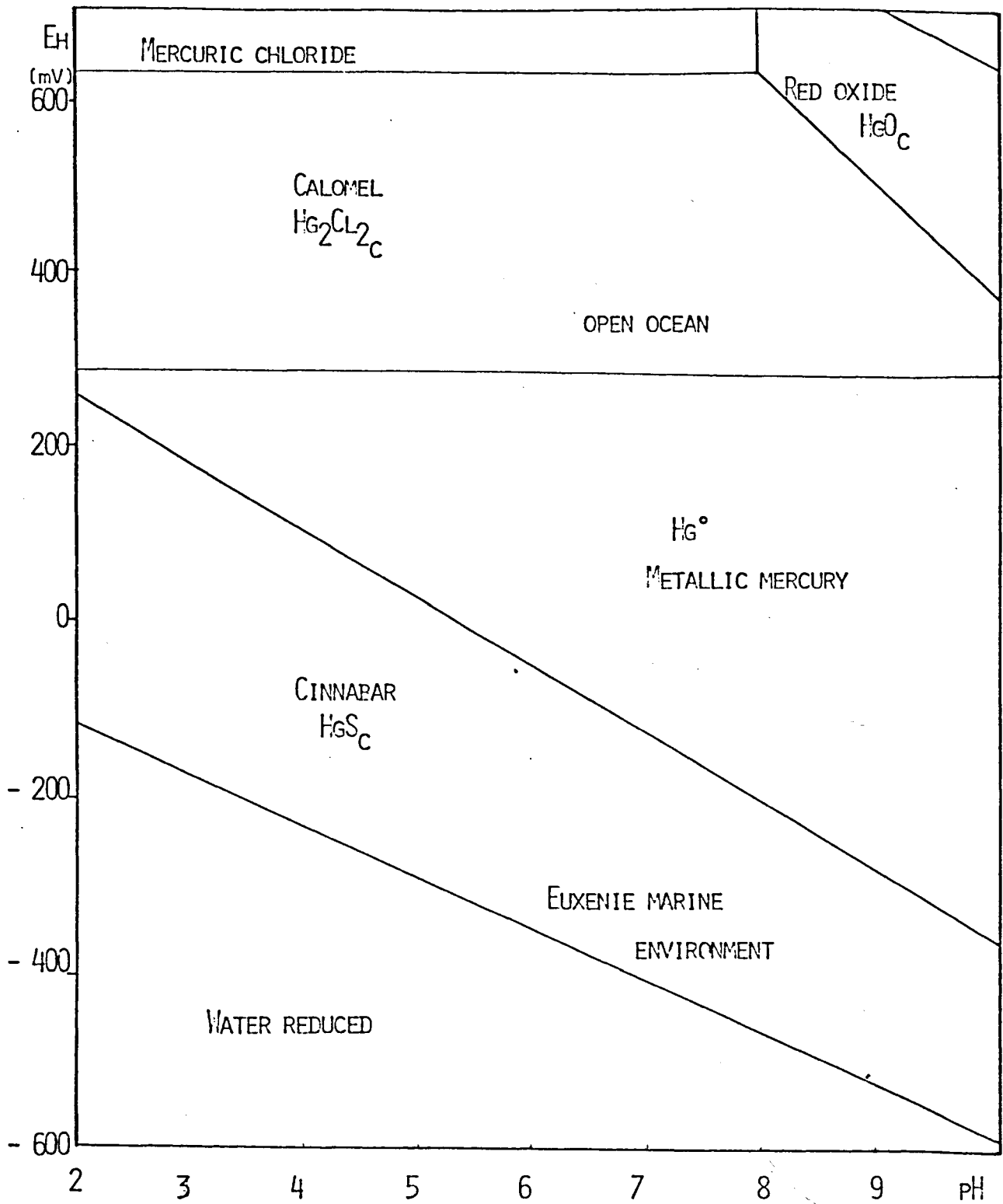


FIG. 3: FIELDS OF STABILITY FOR SOLID (C) AND LIQUID (L) MERCURY SPECIES AT 25°C AND 1 ATMOSPHERE PRESSURE IN SEAWATER. (VOLLAST, 1972).

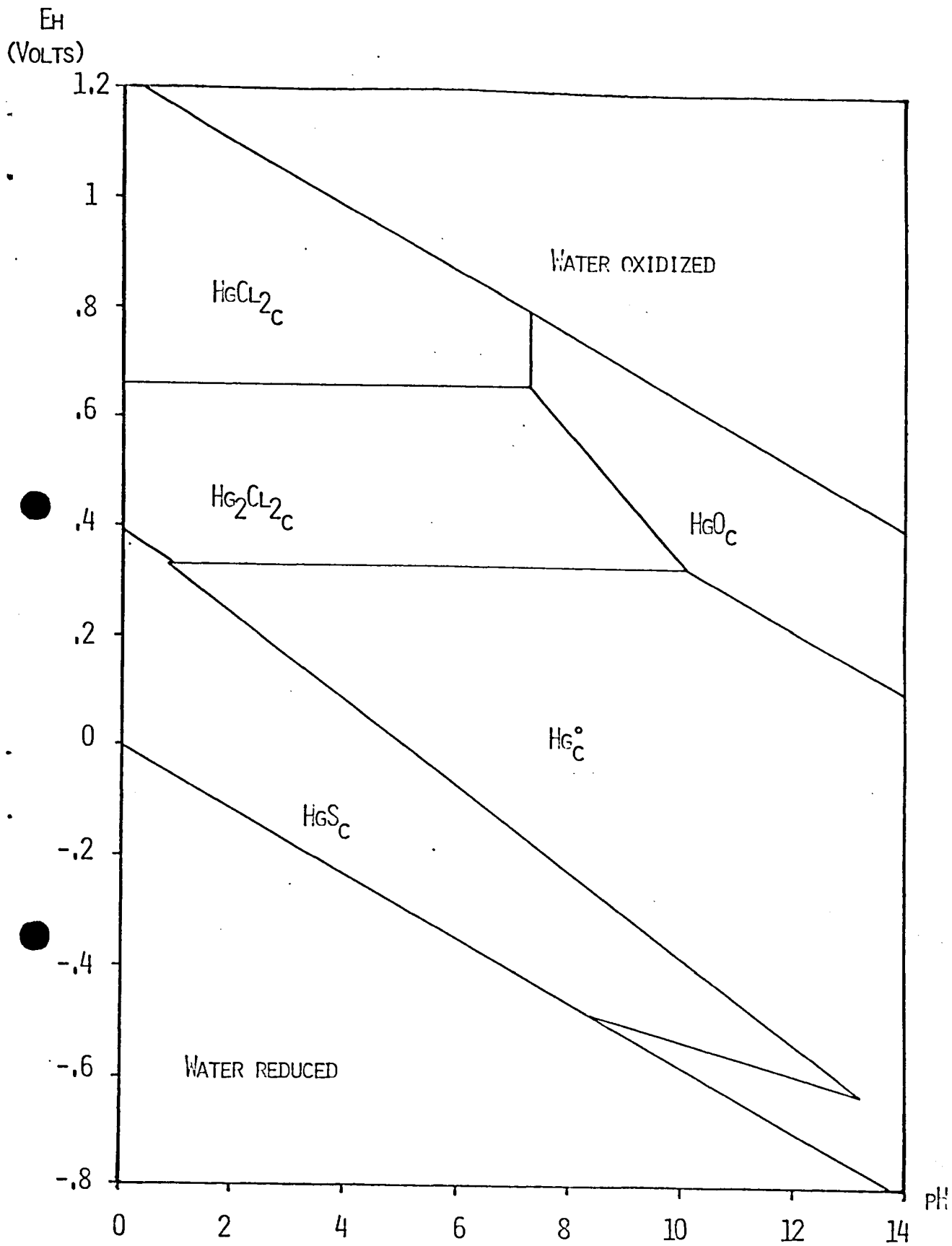


FIG. 4: FIELDS OF STABILITY FOR SOLID (C) AND LIQUID (L) MERCURY SPECIES AT 25°C AND 1 ATMOSPHERE PRESSURE IN BRACKISH WATER.

Eh
(VOLTS)

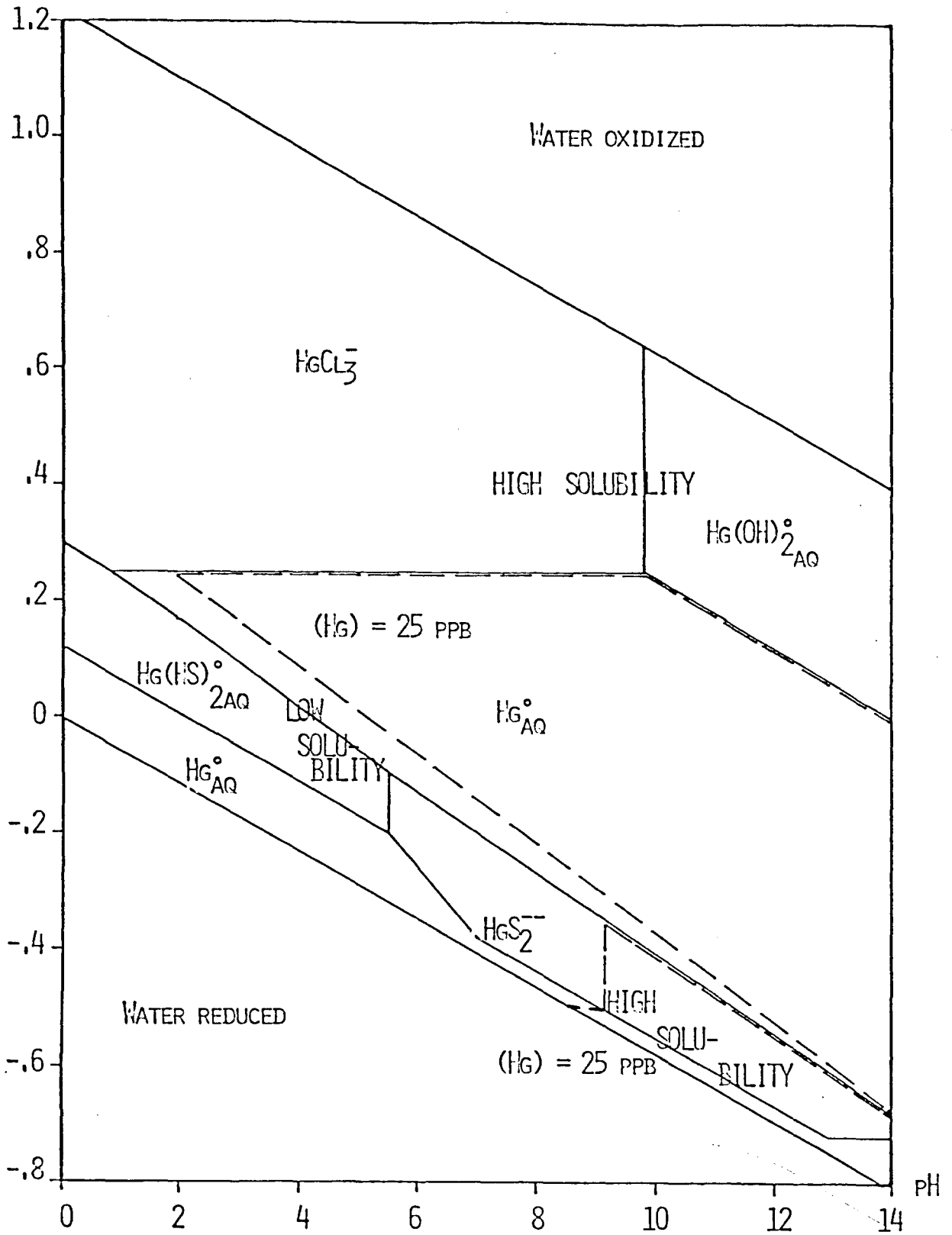


FIG. 5: FIELDS OF STABILITY FOR AQUEOUS MERCURY SPECIES AT 25°C AND 1 ATMOSPHERE PRESSURE IN BRACKISH WATER. DASHED LINE INDICATES APPROXIMATE SOLUBILITY OF MERCURY.

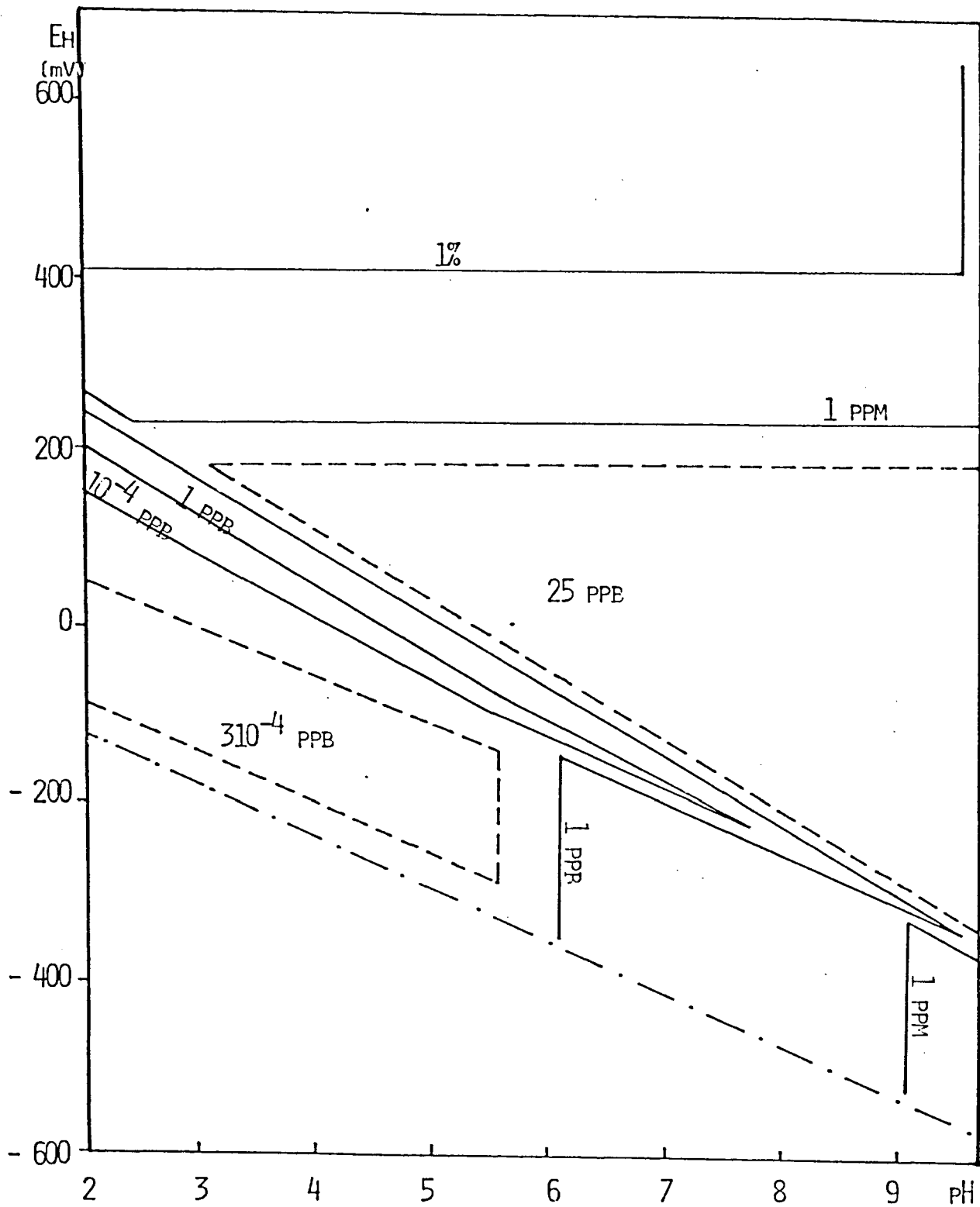


FIG. 6: SOLUBILITY OF MERCURY IN SEAWATER, (WOLLAST, 1972)

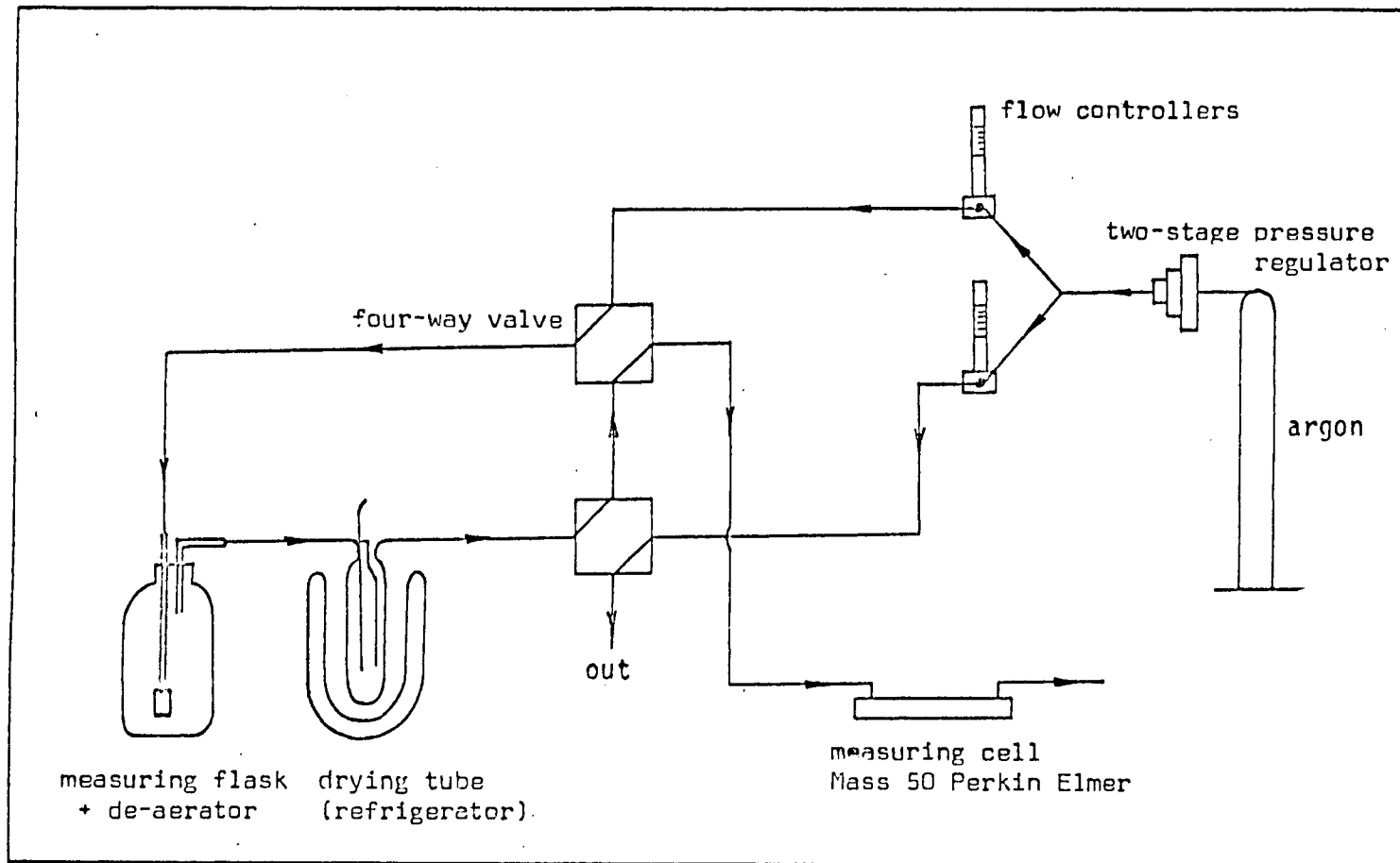


FIG. 7 : FLOW SCHEME OF THE SEMI-AUTOMATIC SYSTEM.

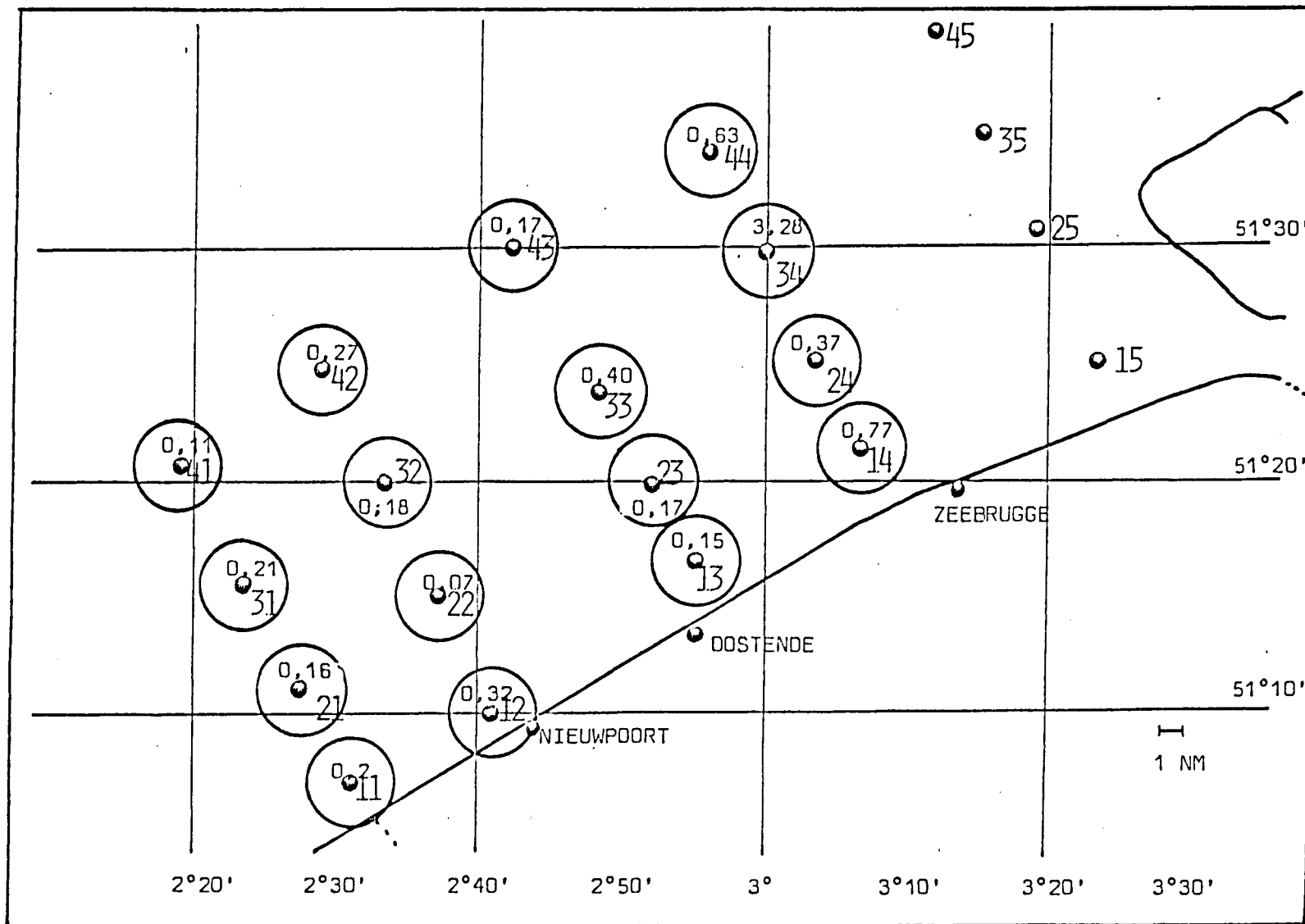


FIG. 8: TOTAL MERCURY CONCENTRATIONS (µg/L) IN THE NORTH SEA

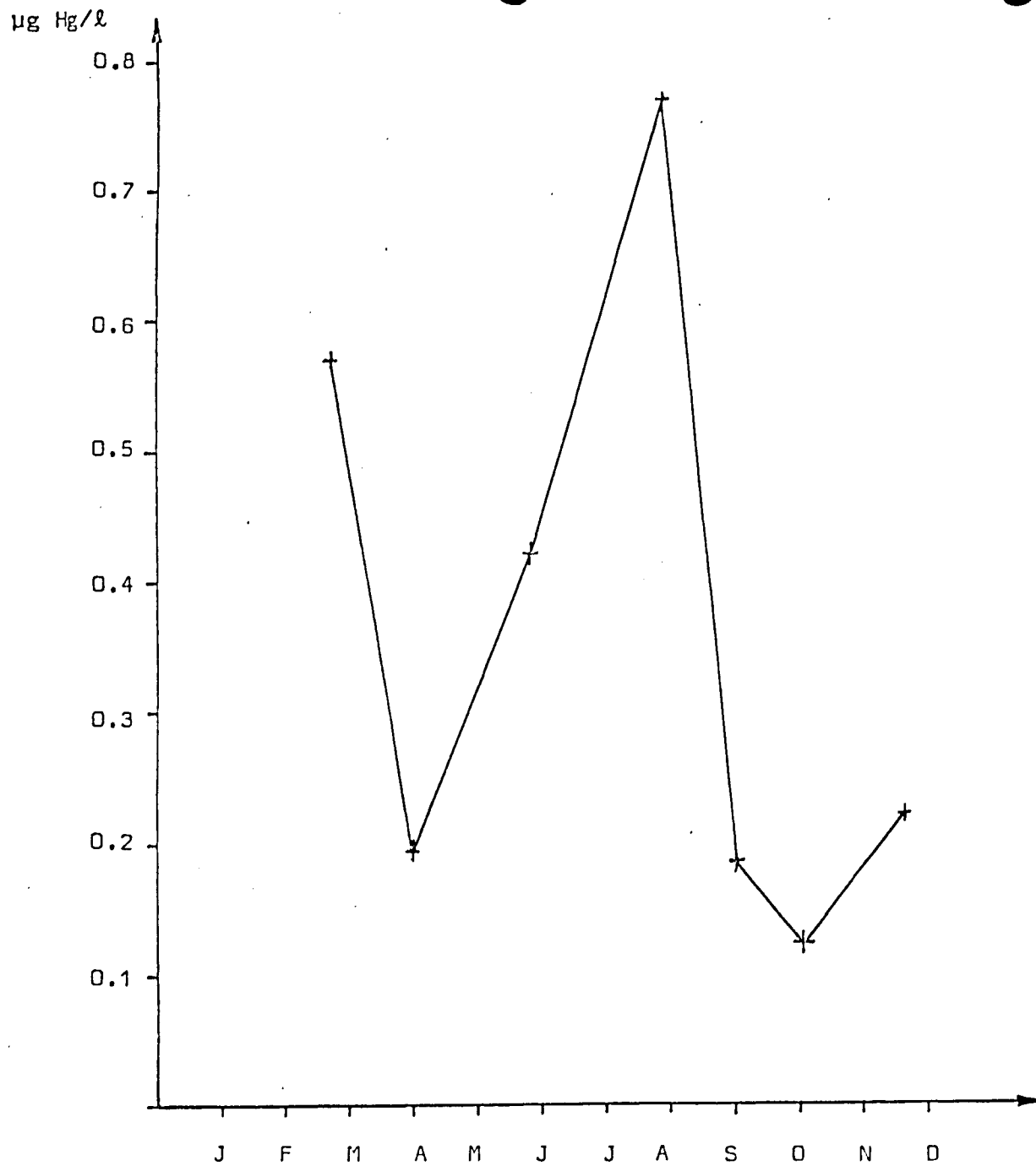


FIG. 9: SEASONAL VARIATION OF TOTAL MERCURY CONCENTRATION IN THE NORTH SEA AT POINT 14.

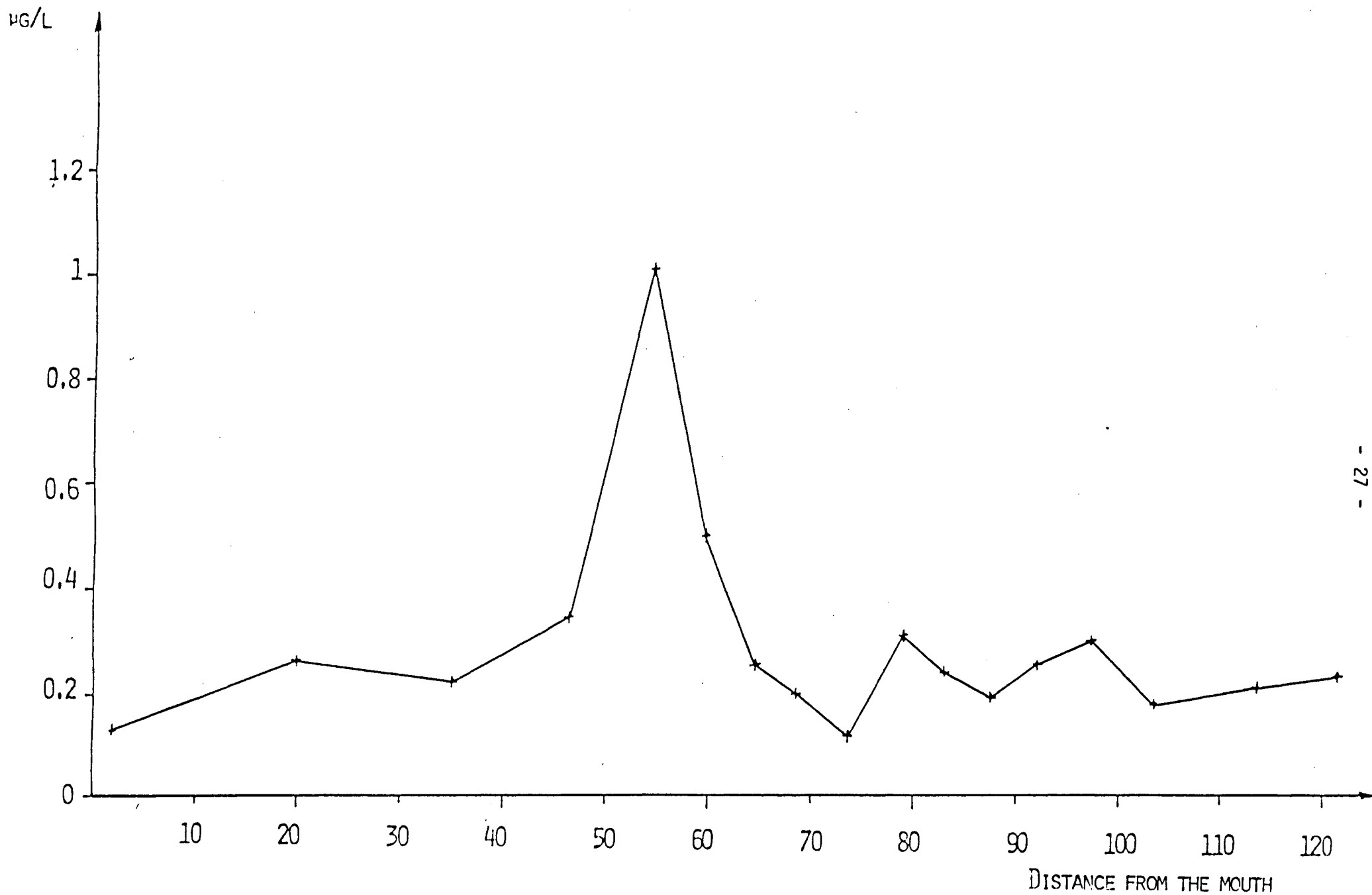


FIG. 10: LONGITUDINAL CONCENTRATION PROFILE OF PARTICULATE MERCURY IN THE SHELDT ESTUARY.

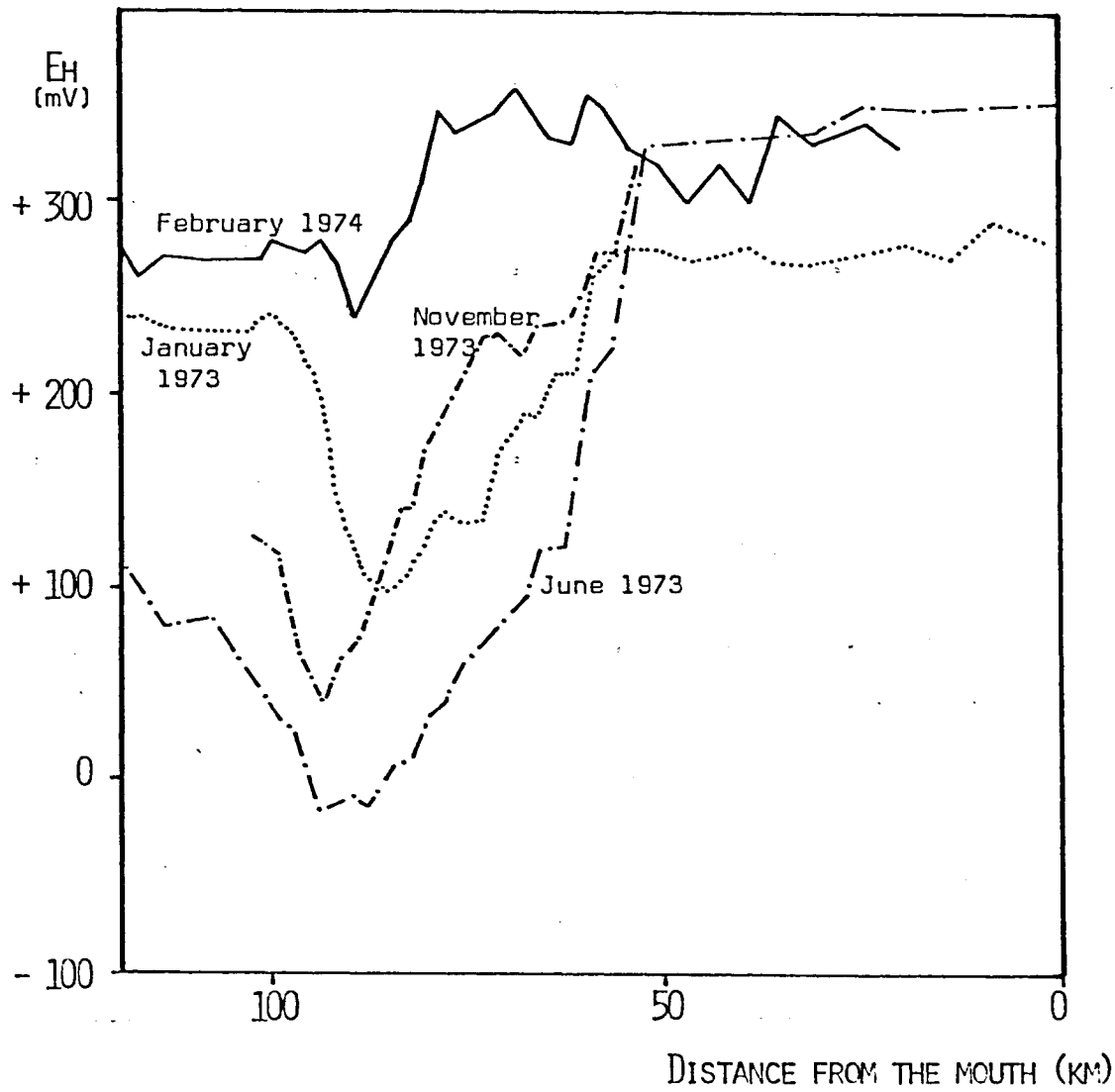


FIG. 11 : LONGITUDINAL PROFILES OF THE REDOX POTENTIAL IN THE SCHELDT ESTUARY.