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Part 6

AN APPROACH TO ELABORATE A PASSIVE TRANSPORT MODEL

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INTRODUCTION

The evolution of a marine constituent results from the advection by the currents, the dispersion by molecular diffusion, turbulence at scales in time and space compatible with the studied environment, the vertical migration movements of for example of sediment particles due to gravity and buyoncy, the chemical and biological interactions with the other constituents.

If the space and time variations of the concentration of a given constituent are depending only on the velocity field, the dispersion flux and possible inputs-outputs, its behaviour can be described by a single evolution equation called a passive dispersion model (Nihoul, 1975). It is clear that even in the case a non-passive constituent it is preferable to base the prediction of its evolution on a passive dispersion model when the interaction processes are not entirely understood or cannot be formulated with sufficient accuracy and if one disposes of long time averages (several years). Indeed, such models always provide valuable estimates of 1) the distribution of non-passive constituents by, at least,appraising their possible transport by the sea motions and 2) the relative importance of possible unknown interaction processes when compared to the distribution of a real passive constituent as NaCl.

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In previous papers, bulk concentrations of heavy metals in the Belgian coastal waters (Decadt et al, 1982), as well as boundary conditions at the air-sea interface (Dehairs et al, 1982a, 1982b) and at the sea-land interface such as the Scheldt estuary (Baeyens et al, 1982) are discussed together with the hydrodynamical data. They make it possible to calculate passive circulation patterns of dissolved Cd, Cu, Pb and Zn as well as total Hg through the four subareas defined on our sampling grid (fig.1).

Relying upon the carbon cycle (mean phytoplankyon productivity and grazing of zooplankton) and the mean cadmium content of zooplankton, Elskens (1973) inferred that in the offshore area, adjacent to our coastal zone, the maximum quantity of cadmium involved in the plankton box is about 4.3 tons.year^{-1}. Compared to the several hundred tons of cadmium transported in and out that area, these fluxes too and from the food web are negligible. Unfortunately, we do not have sufficient data on the heavy metal content in zooplankton consequently we are not able to carry out the same calculations for our area.

Nevertheless, it is not obvious that the heavy metal flow related to biological activity is also negligible in our area since Decadt et al (1982) showed that the organo-complexed fraction may represent up to 80% of the total dissolved content (sea part II). Other processes such as for example adsorption, desorption, mobilisation, precipitation,... may appear also important ; in that case the passive dispersion model will show a production or disappearance of the given metal inside the considered box.

HYDRODYNAMICAL CHARACTERISTICS

Since we are mainly interested in the overall transport patterns of the selected trace metals (Cd, Cu, Hg, Pb and Zn), residual currents should be specified. Unfortunately, on the scale of the boxes defined within our sampling grid (15-30 km), no such residual flow lines are available. Only at some lateral boundaries are these flows known from measurements (3.3 km^3.year^{-1} from the Scheldt estuary to box III and 0.3 km^3.year^{-1} from the coast to both boxes I and II) and computations (642 and 962 km^3.year^{-1} inflow to boxes I and II respectively,according to Nihoul & Ronday (1976)). However, the mean salinity distribution in the area (fig.2) is well known (Unité de Gestion du Modèle Mer du Nord, pers.comm.).

Applying the law of mass conservation on this conservative parameter yields the residual flow pattern shown in fig.3. The overall diffusion coefficient deduced from the computations equals

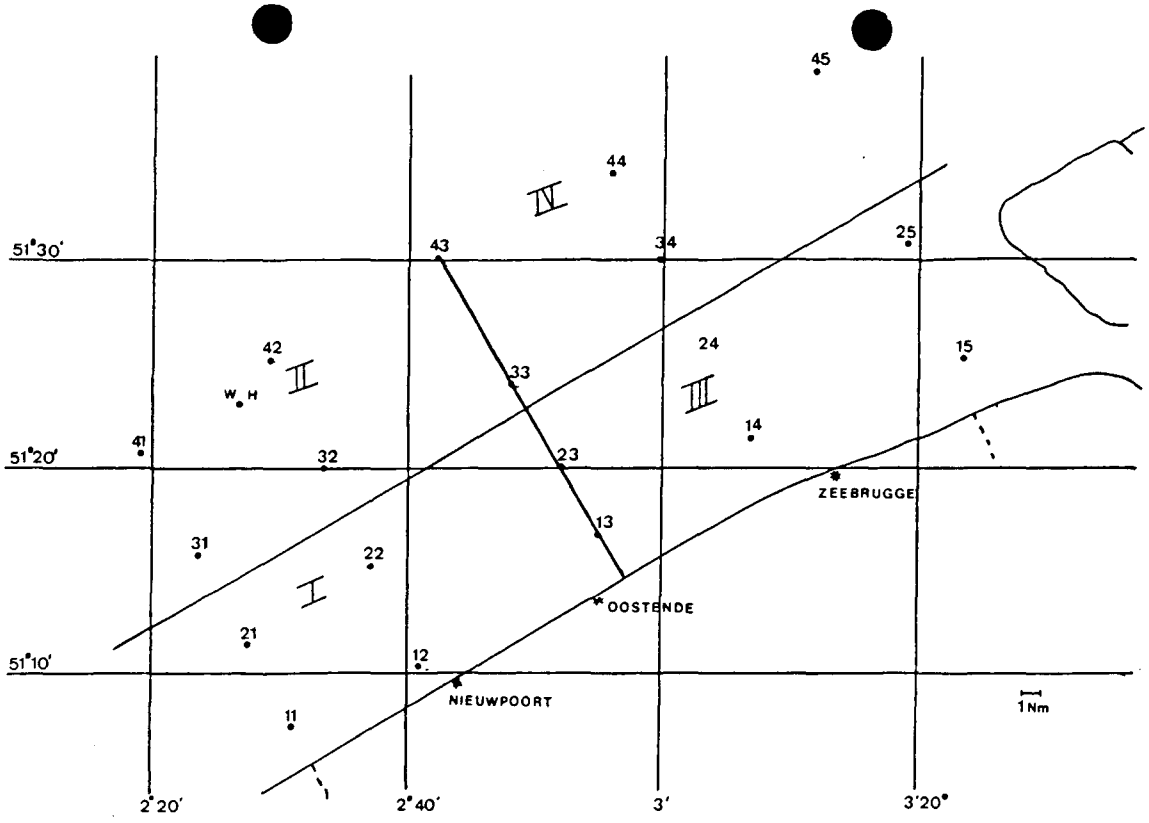

Fig.1 : Location of sampling stations in the North Sea (Belgian Coast)

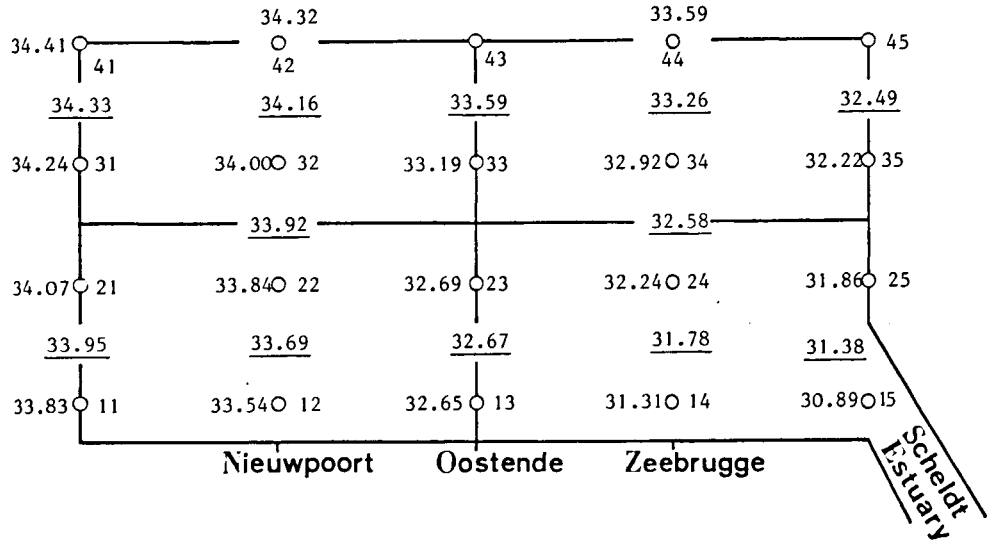

Fig.2 : Schematic salinity distribution in the Belgian Coastal Area - mean observed values (1977-1981) in ‰.
(—— calculated as the mean of the two adjacent values)
O : sampling stations

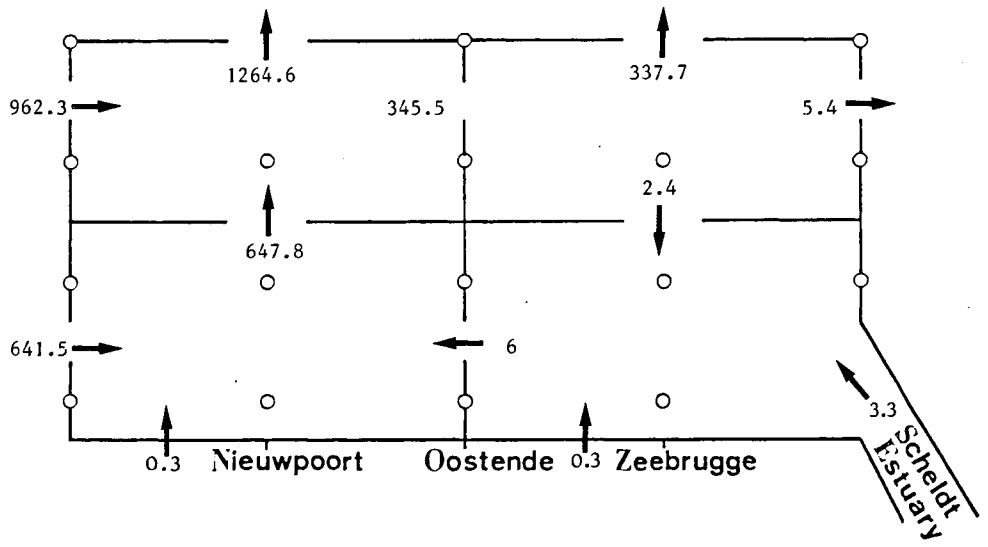

Fig.3 : Residual circulation in the Belgian Coastal Zone (flows in $km^3.y^{-1}$; overall diffusion coefficient : 466 $km^3.y^{-1}$).

466 $km^2.year^{-1}$. Under the given boundary conditions, these results corroborate the existence of a gyre (cyclic residual circulation) off the Belgian coast, as predicted by mathematical models based on the mechanical variables describing the system's hydrodynamics (Nihoul & Ronday, 1976).

However, the possible existence of such a gyre must be considered with care. Indeed a decrease of the inflow at the lateral boundaries of boxes I and II to 222 and 333 $km^3.year^{-1}$ respectively, changes the circulation pattern to a non-cyclic one as is indicated by fig.4. In that case the overall dispersion coefficient amounts to 436 $km^3.year^{-1}$.

TRACE METALS CIRCULATION PATTERNS

The residual trace metals circulation patterns shown in fig. 5 to 9 are based on the residual currents illustrated in fig.3 and the mean metal concentrations determined in each of the twenty sampling stations (Decadt et al, 1982). Since no data were available for the coastal trace metal inputs, we considered them, arbitrarily, as negligible.The input from the atmosphere to the sea has been calculated by Dehairs et al (1982a) but since the atmospheric fall-out in each box may be considered as similar, this flux does not affect the residual trace metal flow patterns.

Results obtained for dissolved cadmium (fig.5) indicate that there may be a net production in box III and a net consumption in boxes I, II and IV. Even, when taking into account a variation of at least 10% on the greatest flow in or out the box (this variation is acceptable from the point of view of errors still involved in the used analytical techniques (Gillain et al, 1982), there is still a reasonable probability that under the given flow conditions, production of dissolved Cd occurs in box III and disappearance in boxes I and IV. Following the same method for the other metals, one may suggest that :

- for dissolved Zn (fig.6), there is production in box IV and consumtion in boxes II and III,
- for dissolved Pb (fig.8), there is production in boxes I and IV and consumption in boxes II and III,
- for dissolved Cu (fig.7), there is production in box III and consumption in boxes I and II,
- for total Hg (fig.9), there is production in boxes II, III and IV.

Until now, we are not able to evaluate and to give a clear explanation for these trace metal flow patterns, but we have to keep in mind that this is only a first attempt to built up a passive dispersion model - with the hope to later produce interactive ones - and that with the great uncertainty of the used residual currents values these trace metal flow patterns can only be used

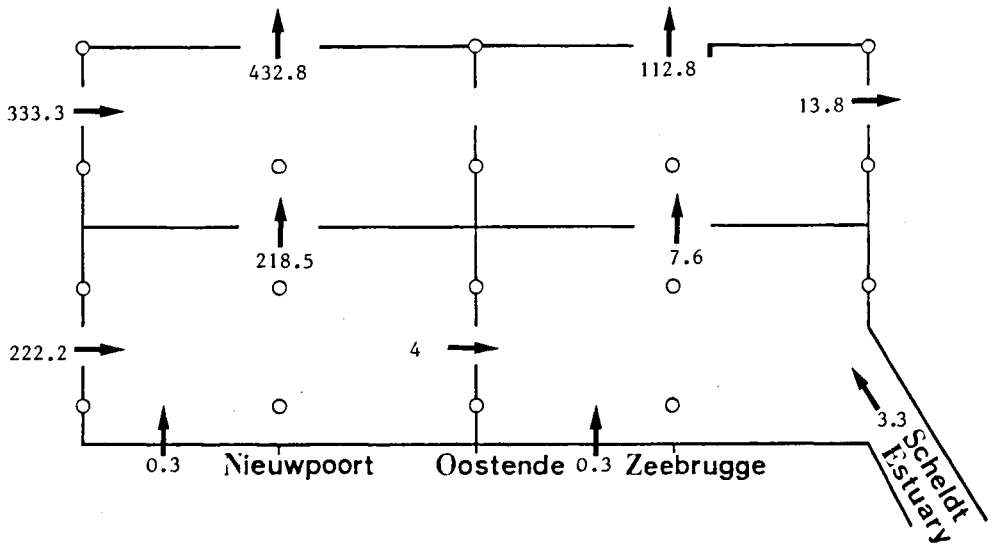

Fig.4 : Residual circulation in the Belgian Coastal Zone (flows in $km^3.y^{-1}$; overall diffusion coefficient : 436 $km^3.y^{-1}$).

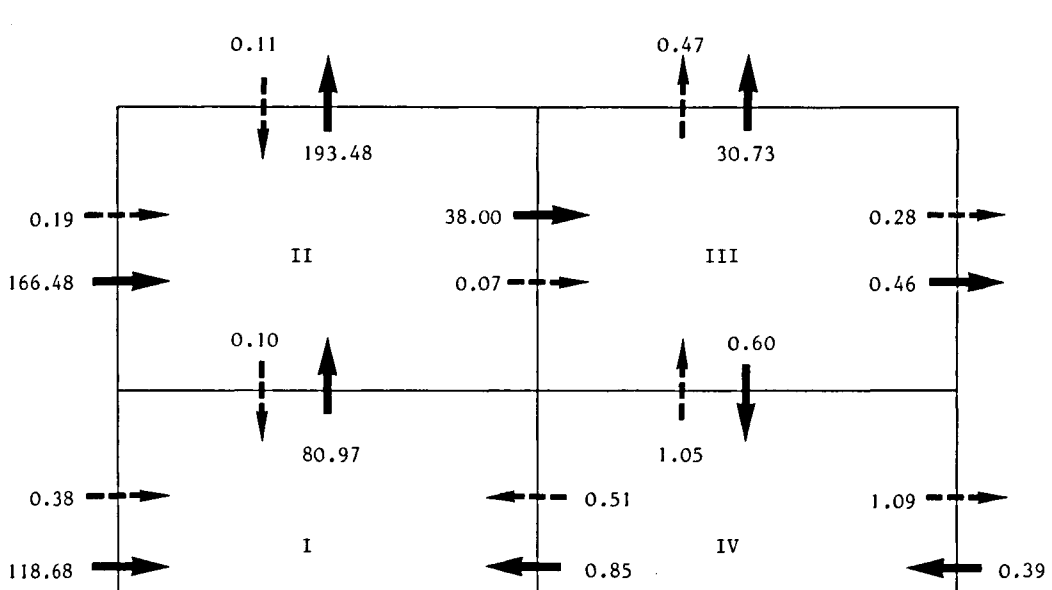

Fig.5 : Passive dispersion patterns for cadmium (flows in T Cd.y^{-1}).
Arrow : advection ; broken arrow : diffusion.

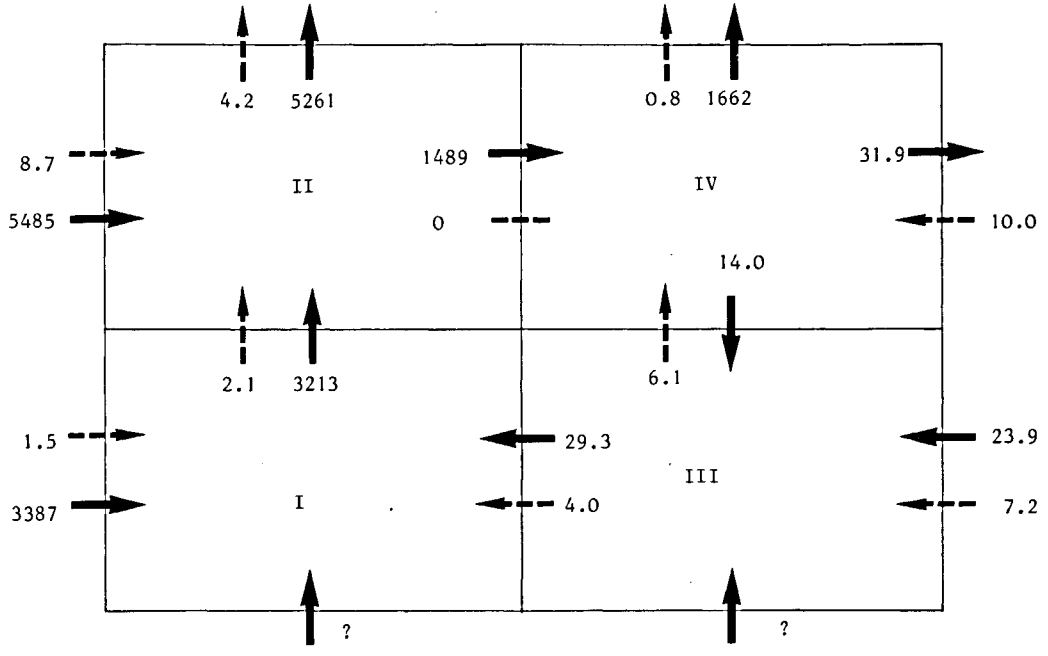

Fig.6 : Passive dispersion patterns for Zn (flows in T Zn.y^{-1})
Arrow : advection ; broken arrow : diffusion.

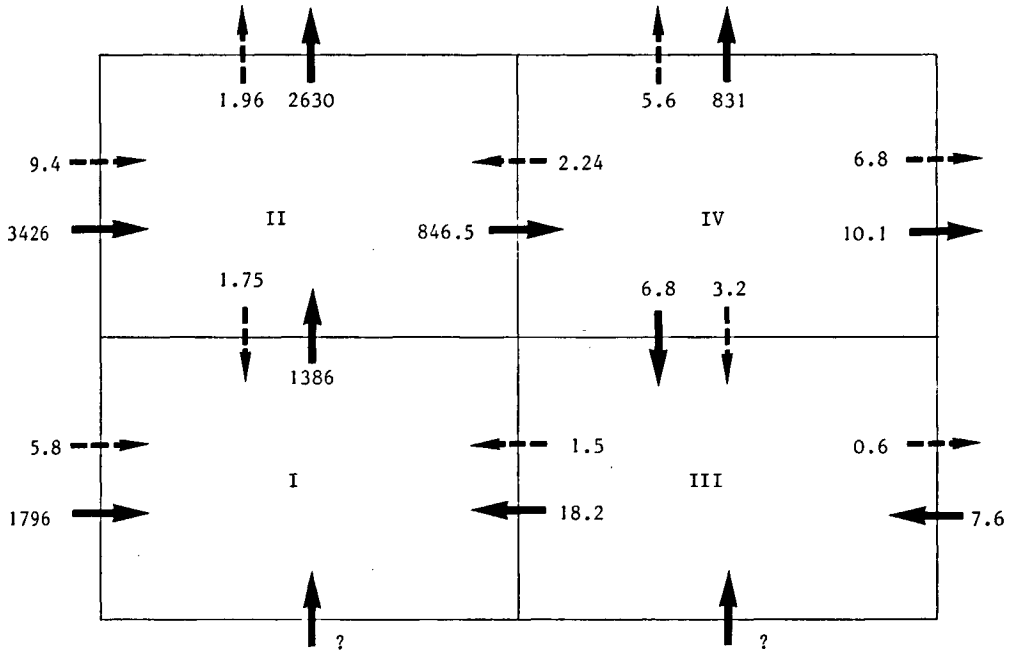

Fig.7 : Passive dispersion pattern for Cu (flows in T Cu.y^{-1})
Arrow : advection ; broken arrow : diffusion.

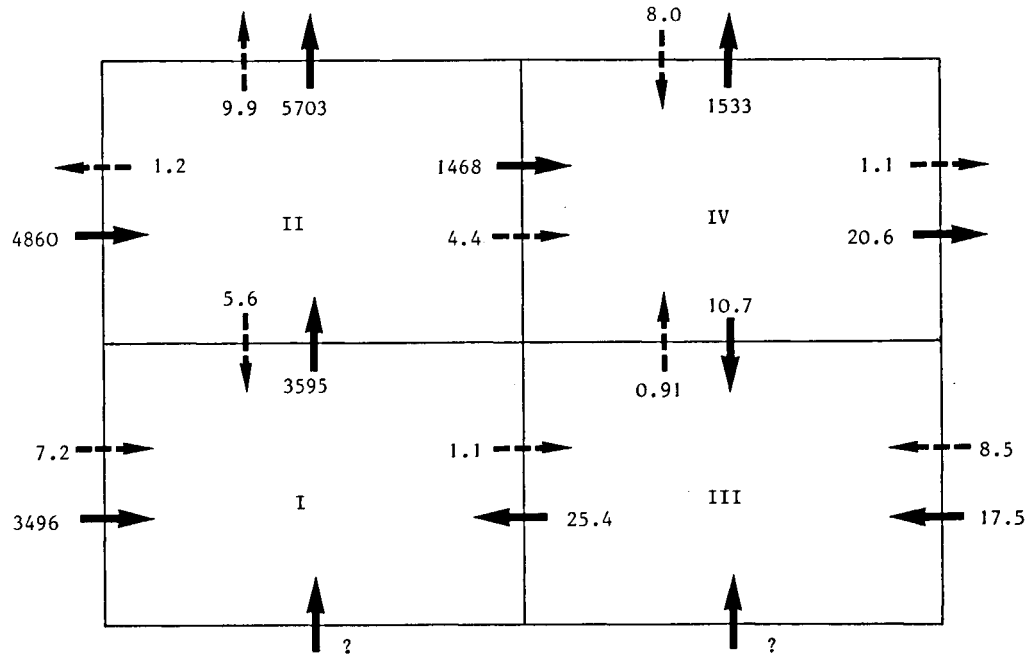

Fig.8 : Passive dispersion patterns for Pb (flows in T Pb.y^{-1})
Arrow : advection ; broken arrow : diffusion.

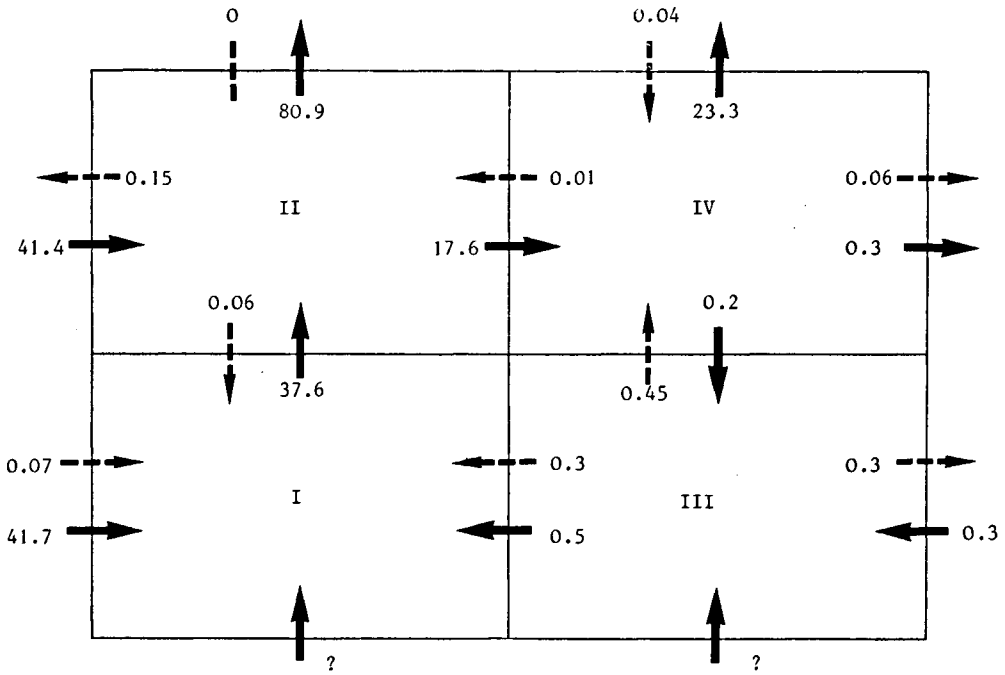

Fig.9 : Passive dispersion patterns for total mercury
Arrow : advection ; broken arrow : diffusion.

as an indication. It looks clear however that the dissolved trace elements we have determined do not have a conservative character and that more elaborate interactions will have be taken into account.

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