Comparative Study of Toxicity, Uptake and Distribution of Cadmium and Mercury in the Sea Water Adapted Eel *Anguilla anguilla*

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There is no evidence whether Cd and Hg are biologically essential but their toxicity for organisms is well known (FRIBERG et al. 1974 ; FRIBERG and VOSTAL. 1972). One of their main properties regarding biological effects is their ability to bind to organic substances, principally to sulfhydryl groups.

Data about Cd and Hg toxicity for fish are rather extensive (DOUDOROFF and KATZ. 1953 ; BOETIUS. 1960 ; BALL. 1967 ; EISLER. 1971 ; PICKERING and GAST. 1972). Some informations describing the distribution of these metals in tissues of experimentally intoxicated fishes are also available (BÄCKSTRÖM. 1967 ; MIETTINEN et al. 1972 ; BOUQUEGNEAU. 1973 ; EISLER. 1974 ; ROWE and MASSARO. 1974).

However no comparative study of the effects generated by Cd and Hg on the same species of fish has to our knowledge been reported. This is the aim of the present paper.

In our experiments, Cd and Hg are directly added to sea water. Indeed data seem to indicate that for both metals, uptake from water would be much more important than from food (HANNERZ. 1968 ; JERNELÖV and LANDNER. 1969 ; BOUQUEGNEAU et al. 1976).

MATERIALS AND METHODS

Fresh water eels were adapted during at least eight days to unpolluted North Atlantic sea water. Fishes were then placed in polyethylene bags containing aerated sea water (5 l per animal) to which various doses of Cd or Hg were added as $CdCl_2$ and $HgCl_2$. Water was changed every day. Its temperature stayed always close to 18°C. Fishes were not fed during the experiments.

Tissue samples were analyzed for Cd by atomic absorption spectrophotometry (Perkin-Elmer 103) after mineralization in HNO_3 65% (2.5 ml per g fresh tissue) and dilution. Hg was determined by flameless atomic absorption spectrometry (Coleman Mercury Analyser System MAS 50) after mineralization in H_2SO_4 95% and H_2O_2 30% (10 ml H_2SO_4 and 2 ml H_2O_2 per g fresh tissue).

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RESULTS

1. Evaluation of the toxicity of Cd and Hg

Fig.1 presents mortality curves realized according to the classical method described more particularly by SPRAGUE (1969). Each curve was performed with about 10 fishes. It is clear that $HgCl_2$ is much more toxic than $CdCl_2$. It appears that 1 ppm Hg and 50 ppm Cd are lethal concentrations for the eel. The concentrations of 0.1 ppm Hg and perhaps 30 ppm Cd can be considered sublethal. We could keep eels more than six months in sea water containing 13 ppm Cd. This latter concentration is thus certainly sublethal for the eel.

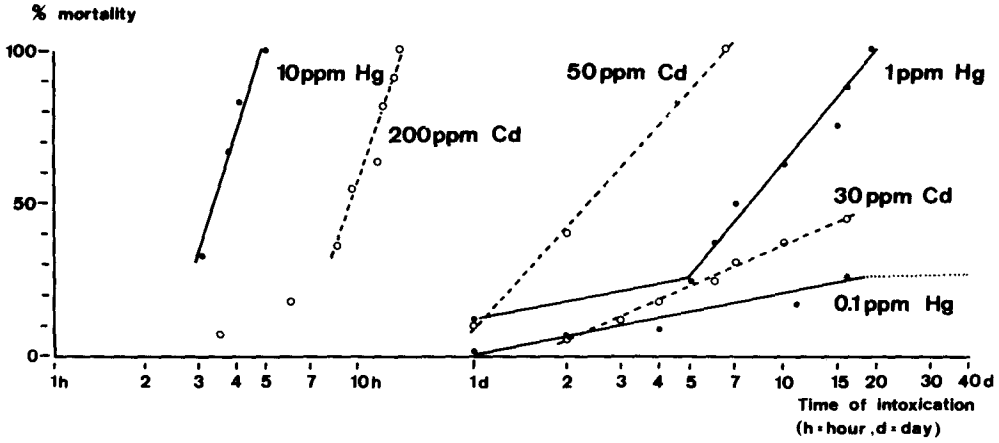

Fig.1 Mortality curves for sea water adapted eels exposed to different constant concentrations of $CdCl_2$ or $HgCl_2$ in natural sea water.

2. Uptake and tissue distribution of Cd and Hg at sublethal exposures

The distribution of Cd and Hg in the organs of eels after 60 days of exposure to 0.13 ppm Cd or after 32 days of exposure to 0.10 ppm Hg are compared in table 1. It presents mean concentrations expressed as µg/g wet weight and obtained from at least 3 animals. From these metal concentrations in the different organs and from the weight fractions of these organs, the metal load (expressed in µg) of each organ can be calculated for a fish whose weight is reduced to 100 grams. The total body load is determined by summation of the load of each organ.

TABLE 1
Comparison between Cd and Hg distribution in intoxicated eels

Organs	0.13 ppm Cd 60 days	0.10 ppm Hg 32 days	Weight of organs, g	0.13 ppm Cd, 60 days		0.10 ppm Hg, 32 days	
	Cd conc. (ppm wet wt).	Hg conc. (ppm wet wt).		Cd load (µg)	% of total body load	Hg load(µg)	% of total body load
Muscles	0.2	13.4	75.5	15.1	27.1	1011.7	66.1
Skin	0.4	18.8	10.6	4.2	7.5	199.3	13.0
Digestive tract	6.7	14.5	2.1	14.1	25.3	30.4	2.0
Liver	4.8	48.5	1.2	5.8	10.4	58.2	3.8
Kidneys	16.0	115.7	0.7	11.2	20.1	81.0	5.3
Gill filaments	2.0	66.9	0.5	1.0	1.8	33.4	2.1
Spleen	1.4	110.0	0.2	0.3	0.5	22.0	1.4
Bile	0.4	18.0	0.1	< 0.1	0.1	1.8	0.1
Other organs			9.1	4.0	7.2	95.0	6.2
Total body	0.56	15.3	100.0	55.7	100.0	1532.8	100.0
Concentration factor	4.3	153.3					

We use the concentration factor defined by the ratio :

$$\frac{\text{Concentration of metal in animal (ppm wet weight)}}{\text{Concentration of metal in water (ppm)}}$$

It appears immediately that both pollutants behave quite differently.

a) The accumulation of Hg is much more important than that of Cd. This is true for all the organs and consequently for the whole animal.

b) The two metals are distributed quite differently in the organs. Results expressed as Cd and Hg concentrations in the organs indicate that in both cases, the maximum concentrations are attained in the kidneys[1]. Next come the digestive tract and the liver in the case of Cd, the spleen, the gills and the liver in the case of Hg.

Examination of results presented as metal load of the organs shows that Cd is principally contained in the viscera whereas Hg is principally contained in the muscles. Indeed, in the first case, the digestive tract, the kidneys and the liver, in spite of their very little weight fraction (4% of the total body weight) contain together 56% of the Cd body load. In the Hg intoxicated eels, these organs account for only 11% of the Hg body load, the muscles 66%.

DISCUSSION AND CONCLUSIONS

Our results show that eels are much more susceptible to $HgCl_2$ exposure than to $CdCl_2$ exposure. This is also true for many other species (WALDICHUK. 1974). This fact could be simply explained by the great difference of the respective concentration factors and be related to a much lower permeability to Cd than to Hg at the level of their uptake pathways. Indeed gills, the principal absorption site for Hg (OLSON and al. 1973 ; BOUQUEGNEAU. 1975) seem to be much less permeable to Cd than to Hg.

The dissimilarity between the distribution of both metals in the eel organs is in agreement with the results of workers using either Hg or Cd on different fish species. The great difference observed by us between the accumulation of Cd and Hg by the eel muscles is also corroborated by the data on Cd and Hg concentrations found in fishes caught in various parts of the world. In contrast to the case of Hg, alarming Cd concentrations have never been reported in fish flesh even in very polluted areas. Concerning the low capacity of Cd accumulation by muscles, it must be

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[1] Note that in the case of Cd intoxications carried out at higher concentrations (but below the lethal threshold), maximum Cd concentration is attained in the liver and not in the kidneys (NOËL-LAMBOT, unpublished results).

pointed out that an intoxication of 120 days in sea water containing as much as 13 ppm Cd raises the Cd concentration of the eel muscles only to 0.6 ppm (against 277 ppm in the liver and 113 ppm in the kidneys, NOËL-LAMBOT, to be published).

Owing to this very low Cd accumulation capacity of fish muscles, it is very improbable that sea pollution by Cd could ever lead to Cd levels in fish dangerous for man, in so far as the ingestion by fish of contaminated food does not induce a more important accumulation of Cd than the direct uptake described here, which seems to be the case from the data available (see introduction). Therefore a control of the Cd concentration in fish caught for human consumption does not seem to be required. However, the control of the Cd content of the viscera, as well as that of Hg, would be useful in the case of small species eaten whole and in the case of fish used to make flour.

We have shown (BOUQUEGNEAU et al. 1975 ; NOËL-LAMBOT, to be published) that in a number of eel organs, Cd and Hg occur principally bound to a cystein-rich protein, metallothionein.
This protein seems to have a role in detoxification of both metals (PULIDO et al. 1966 ; SUDA et al. 1974 ; RUGSTAD and NORSETH. 1975). Its synthesis is induced in response to administration of these metals (WEBB. 1972 ; CHEN et al. 1975) and it has been shown (PIOTROWSKI et al. 1974) that the increase of the Cd or Hg load of rat liver or kidney is linked to the increase of their metallothionein content.
Thus in order to explain the very dissimilar accumulation and distribution of Cd and Hg within the eel body one must take into account not only the possibility of different membrane permeabilities to both metals but also the problem of their binding within the cells. In order to conclude, we think that the knowledge of the affinity of metallothionein for Cd and Hg and of the ability of both metals for inducing the synthesis of the protein in the different organs will probably contribute to explain our observations.

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