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High Concentrations of some Heavy Metals in Tissues of the Mediterranean Octopus

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Recent studies have shown high concentrations of cobalt-60 (NAKAHARA et al. 1979) and of both natural and artificial alpha-emitting nuclides (GUARY et al. in preparation) in the branchial hearts of the cephalopod Octopus vulgaris; a similar effect was however not found in an experiment involving caesium-137 (SUZUKI et al. 1978). The general behaviour of trace elements in this situation is clearly of interest, and we report here the results of determinations of Cd, Cu, Fe, Mn, V and Zn in all the tissues of the O. vulgaris; particular attention is paid to the branchial hearts and the hepatopancreas.

MATERIAL AND METHODS

Fifty four cephalopods (19 males, 35 females, average wet weight 640 g) were collected near the coast of Monaco. Animals were dissected immediately after fishing. Gut contents were excluded as completely as possible. Tissues were pooled, weighed and dried at 100°C for several days to a constant weight. Acid digestion of two different 300 mg aliquots of each tissue was carried out following the method of FOWLER & OREGIONI (1976). The six elements were analyzed by flameless atomic absorption spectrophotometry. A deuterium arc background corrector was used for Cd, Zn and Mn analyses. Orchard leaves standards (N.B.S.) were also measured and the results obtained were in good agreement with the certified values. Our data were checked further by analyzing another group of five octopus by the same procedure.

RESULTS AND DISCUSSION

Our data are summarized in Table 1. The concentrations of Cd, Cu, Fe, Mn and Zn in the whole animal O. vulgaris are comparable with those reported by BRYAN (1976) for the cephalopod Alloteuthis subulata. It is seen from this table that the

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Table 1

Heavy metal concentration (μg/g dry weight) in the tissues of Octopus vulgaris. Mean and standard deviation of three analyses. Concentration factor relative to sea water in parenthesis. The values for sea water are expressed in μg/l and are taken from a) FUKAI & HUYNH-NGOC (1977) b) GOLDBERG et al. (1971).

	Cd	Cu	Fe	Mn	V	Zn
Sea water	0.1 a)	0.3 a)	2 b)	2 b)	2 b)	2 a)
Whole animal	1.2 ± 0.1 (2×10^3)	260 ± 70 (1.5×10^4)	140 ± 10 (1×10^4)	5 ± 0.5 (4.5×10^2)	0.7 ± 0.1 (6×10^0)	150 ± 50 (1×10^4)
Hepatopancreas	50 ± 10 (2×10^4)	2500 ± 700 (3×10^6)	700 ± 130 (1×10^5)	7 ± 0.5 (1×10^3)	4.5 ± 1 (8×10^2)	1450 ± 400 (3×10^5)
Branchial hearts and appendages	0.3 ± 0.1 (3×10^2)	500 ± 40 (4×10^5)	650 ± 150 (8×10^4)	13 ± 3 (1.5×10^3)	25 ± 2 (3×10^3)	65 ± 15 (8×10^3)
Muscle (Mantle)	0.08 ± 0.04 (2×10^2)	26 ± 2 (2×10^4)	30 ± 5 (3×10^3)	3 ± 2 (3×10^2)	0.3 ± 0.2 (3×10^1)	70 ± 30 (5×10^3)
Digestive tract	0.12 ± 0.01 (3×10^2)	90 ± 10 (7×10^4)	10 ± 1 (1×10^3)	14 ± 1 (1.5×10^3)	0.4 ± 0.1 (5×10^1)	130 ± 30 (1×10^4)
Kidney	1.5 ± 0.1 (3×10^3)	340 ± 60 (2×10^5)	60 ± 40 (6×10^3)	20 ± 1 (2×10^3)	0.4 ± 0.2 (4×10^1)	140 ± 30 (1×10^4)
Gonad male	0.1 ± 0.04 (2×10^2)	50 ± 8 (3×10^4)	30 ± 10 (2.5×10^3)	9 ± 0.5 (8×10^2)	0.3 ± 0.1 (3×10^1)	360 ± 200 (3.5×10^4)
Gonad female	0.02 ± 0.01 (4×10^1)	60 ± 6 (4×10^4)	20 ± 10 (2.5×10^3)	8.5 ± 0.5 (8×10^2)	0.2 ± 0.2 (2×10^1)	100 ± 60 (1×10^4)
Gill and branchial glands	0.05 ± 0.01 (1×10^2)	300 ± 40 (2×10^5)	40 ± 20 (4×10^3)	10 ± 0.5 (1×10^3)	0.5 ± 0.2 (5×10^1)	120 ± 20 (1×10^4)
Skin (Mantle)	0.04 ± 0.01 (5×10^1)	50 ± 4 (2×10^4)	30 ± 10 (1.5×10^3)	7 ± 1 (4×10^2)	0.3 ± 0.1 (2×10^1)	50 ± 10 (3×10^3)

Table 2

Percentage distribution of heavy metals in the tissues of *Octopus vulgaris* (values calculated on a wet weight basis)

	Cd	Cu	Fe	Mn	V	Zn	% wet weight
Hepatopancreas	98.1	77.7	69.4	10.4	32.2	56.5	3.8
Branchial hearts and appendages	0.02	0.6	2.3	0.7	6.3	0.1	0.2
Muscle (Mantle)	0.18	0.7	2.7	4.1	2.0	1.8	6.2
Digestive tract	0.12	1.2	0.4	8.9	1.3	2.2	2.7
Kidney	0.30	1.1	0.6	3.1	0.3	0.6	0.7
Gonads	0.02	0.3	0.4	4.2	0.3	1.4	1.1
Gill and branchial glands	0.01	1.4	0.6	2.3	0.5	0.7	1.0
Skin (Mantle)	0.02	0.5	0.7	2.9	0.5	0.6	3.3
Arms and cephalic part	1.2	16.5	22.9	63.4	56.6	36.1	81.0

hepatopancreas is the major site of concentration for four of the six elements measured, Mn and V being the two exceptions. This situation too is in agreement with the observations of BRYAN (1976), which showed that it was in the digestive gland of molluscs (bivalves and gastropods) that the highest concentrations of most heavy metals were found. Our results (Table 2) show, moreover, that the hepatopancreas contains between 32 and 98% of the whole animal content of Cd, Cu, Fe and Zn.

Insofar as the metabolisable trace elements are concerned, a very high concentration of iron (1920 ppm dry weight) has been measured previously in the hepatopancreas of the octopus by GHIRETTI-MAGALDI et al. (1958). This iron concentration probably reflects the large amount of ferritin found by NARDI et al. (1971) in this organ. Similarly, very high concentrations of copper (1300-4900 ppm dry weight) have been measured in the hepatopancreas of the octopus by GHIRETTI-MAGALDI et al. (1958), GHIRETTI & VIOLANTE (1964) and ROCCA (1969). Also MARTIN & FLEGAL (1975) have shown that zinc is equally strongly concentrated in the hepatopancreas of the squid *Loligo opalescens*.

The presence of high concentration of metabolisable elements such as iron, copper and zinc in the digestive gland of the octopus is perhaps not surprising, but the very high concentration of cadmium (50 ppm dry weight) in this organ is certainly noteworthy. It is comparable with that measured in the liver of the Californian squid *L. opalescens* (MARTIN & FLEGAL 1975) and represents a concentration factor from sea water of 20000. Another metallic element which can occur as a pollutant and which is concentrated by the digestive gland of the octopus is mercury; thus RENZONI et al. (1973) have shown that this organ concentrates the mercury produced by a large chloralkali factory in the Thyrrhenian sea to a level of 200 ppm wet weight, i.e. by a factor 30 to 100 times that found in muscle. In the case of vanadium too the concentration factor of 800 for the hepatopancreas is substantial, and our data support the idea that trace metals can be stored in this organ. Such a mechanism, which enables the animal to avoid too high a level of contamination in other vital organs is probably related to the detoxification process already observed in other molluscs (MARTOJA et al. 1977, COOMBS 1977, COOMBS & GEORGE 1978).

For manganese and vanadium the hepatopancreas does not show the highest concentration factors. Manganese tends to be most concentrated in the kidney, although its distribution throughout the animal is fairly uniform. High levels of manganese were previously demonstrated in the kidneys of two molluscs *Pecten maximus* and *Chlamys opercularis* (BRYAN 1973). The vanadium situation needs to be discussed in more detail, because data for this element in marine organisms are rare. Whole animal concentrations seldom exceed 1 ppm dry weight (VIALE 1978, BLOTCKY et al. 1979, IKEBE & TANAKA 1979), except in certain species of ascidians where levels of 100 to 1000 ppm dry weight are reached (SWINEHART et al. 1974, DANSKIN 1978). Almost no data for vanadium in the different organs and tissues of marine organisms are available, although a recent study (MIRAMAND et al. in press) has shown that concentrations in soft tissues of the bivalve *Mytilus galloprovincialis* vary between 0,1 ppm (muscle) and 3 ppm (viscera) dry weight. In comparison, the value of 25 ppm dry weight we have found in the branchial hearts is thus remarkable, all the more so when one considers that this organ, which comprises only 0,2% of the whole animal, contains about 6% of the total vanadium body burden (Table 2). The vanadium concentration in the branchial hearts is six times higher than that in the hepatopancreas and 50 to 100 times higher than that in the other tissues. The relative uptake of vanadium in this organ is comparable with its accumulation of cobalt-60 (NAKAHARA et al. 1979) and the transuranic elements (GUARY et al. in preparation). It is probable that, as for the hepatopancreas, a role of storage and detoxification can be attributed to branchial hearts vis a vis certain pollutants.

The high concentration of iron (650 ppm dry weight) and cooper (500 ppm dry weight) in this organ are also noteworthy, and they are exceeded only by the levels found in the hepatopancreas. The high iron content is in agreement with the resultsof GHIRETTI-MAGALDI et al. (1958), and can be explained by the presence of large quantities of adenochromes (12 mg/g wet weight) in the cells of the branchial hearts. These pigments can, indeed, contain more than 2% by weight of iron (NARDI & STEINBERG 1974). As for the high cooper content, it can be explained by the presence in this organ of the respiratory pigment hemocyanin, which contains about 0,25% of this metal (LONTIE & WITTERS 1973). In contrast to vanadium, iron and cooper, the other trace elements we have measured (cadmium, manganese and zinc) are not concentrated in the branchial hearts to any noteworthy extent.

Further studies are clearly needed to explain this difference in behaviour between vanadium, cobalt and certain alpha-emitting nuclides, on the one hand, and trace elements such as caesium and cadmium on the other.

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