Bodily Distribution, Accumulation and Excretion of Mercury in a Fresh-Water Mussel

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In central Italy there is a large area of volcanic origin, which includes several mountains, the highest being Mount Amiata. This mountain and some of the smaller ones nearby (Labro, Civitella, etc.) are the site of some of the richest cinnabar ore deposits in all Europe. Mining activities have been fluorishing for centuries. At present several companies mine the cinnabar and one large company extracts the mercury, which represents a good portion of the world production (about 18%). Methods of extraction and the collateral preparation processes there are similar to those of other areas of the world and have been reported elsewhere (see also JOHNS a. BRADLEY 1966). During the latter processes a certain amount of the metal is lost and dicharged, and finds its way into the waters of several small creeks leaving the mountains. Most of these creeks are affluents of the Paglia river (an affluent of the Tiber), which besides their waters, receives those of the effluent of a factory through a 4-5 Km-long pipe.

Recently the waters, flora and fauna of the Paglia have been a matter of interest for several scientists (BOMBACE et. al. 1973, BACCI e RENZONI 1973). During some expeditions to collect fish for mercury analysis we found a large population of Unio cfr.elongatulus Pfeiffer about 25 kms south of the source of the Paglia. Since this fresh water mussel is a typical benthic species of the bottom of many rivers and therefore highly representative of the water conditions, we thought that a study of the mercury concentration in its body and some additional experiments would be interesting for possible future use of this species for monitoring programs. We are referring here the results of such a investigation.

MATERIALS AND METHODS

Several hundreds of mussels were collected at the end of summer, when the water level of the river in that area

Bulletin of Environmental Contamination & Toxicology,
Vol. 15, No. 3 © 1976 by Springer-Verlag New York Inc.

was between 1 and 2 meters. Within four hours after the collection, the specimens were brought to the laboratory and put in large tanks with mildly aerated clean water. After 48 hours (sufficient time to completely eliminate the mantle cavity water and the feces) and after several changes of water, 74 specimens (15 of small size - around 3 cm length - and 59 of various sizes - from 4.8 to 9.7 cm of length) were taken and measured (length, height and thickness). After sacrificing and opening the specimens, the shells, the whole soft part of the smaller individuals, some organs or fragments of organs and some tissues of the larger individuals were separated and immediately frozen.

Several dozens of large specimens were maintained in laboratory-tanks where the water was changed daily. Together with the clean new water the animals received several liters of water taken from a small natural pond in the nearby botanical garden and containing a large supply of food, mostly phytoplancton and organic detritus. From time to time a small quantity of laboratory-grown algae (mostly Synaechocystis aquatilis) was added to the water. The temperature of the water varied from 11 up to 14 °C. At intervals of 15, 30 and 60 days, groups of 10 specimens were sacrificed, opened and the same organs or tissues as in the former group were separated and immediately frozen.

The total mercury concentration of all this frozen material was determined at a later date with an Atomic Absorption Spectrophotometer after the usual procedures of extraction (see RENZONI et al. 1973).

RESULTS

The total mercury concentration in the valves (shell) does not exceed 0.2 ppm with an average of 0.12 ppm in a dozen individuals of various sizes and ages; in the whole soft parts of the 15 small individuals the Hg concentration ranges from a minimum of 0.192 ppm to a maximum of 0.385 ppm (average 0.280 ppm). In the larger individuals the mercury concentration was determined for 6 organs or tissues (digestive gland, foot, gill, gonad, mantle and muscle) as well as for the valves. The data obtained from 10 specimens are reported in Tab. 1 (lines 0). The most interesting result seems to be the distribution of the metal in the organs and tissues of the bivalve, with the digestive gland at the highest level and the muscle at the lowest. Although the Hg content in the various organs and tissues shows a

certain degree of variability from one individual to another, the overall results seem to demonstrate an evident subdivision into two groups of components with substantially different mercury contents: on the one hand the digestive gland, gonad and gill with an high Hg content and on the other the three other structures with lower content.

In the (adductor) muscles, the most examined tissue for mercury accumulation in almost all species studied so far, the values of the mercury content from 59 specimens of different length (from 48 mm to 97 mm) have been graphed versus the length of the specimens (Fig. 1) and clearly show an evident accumulation of mercury in the muscle as the size (and hence age) of the individuals increases.

The experiments conducted in the laboratory with individuals collected in the same river and on the same day as those described above, were performed to study the mercury-releasing rate of all 6 organs and/or tissues and the rhythm of its elimination. Values obtained at 15,30 and 60 days after the collection are reported in Tab. 1 (lines b,c,d) and, for a better evaluation and visualization of the phenomenon, graphically drawn in Fig. 2. (For the ease of the readers and to avoid intersections, we subdivided the two groups of structures evaluated).

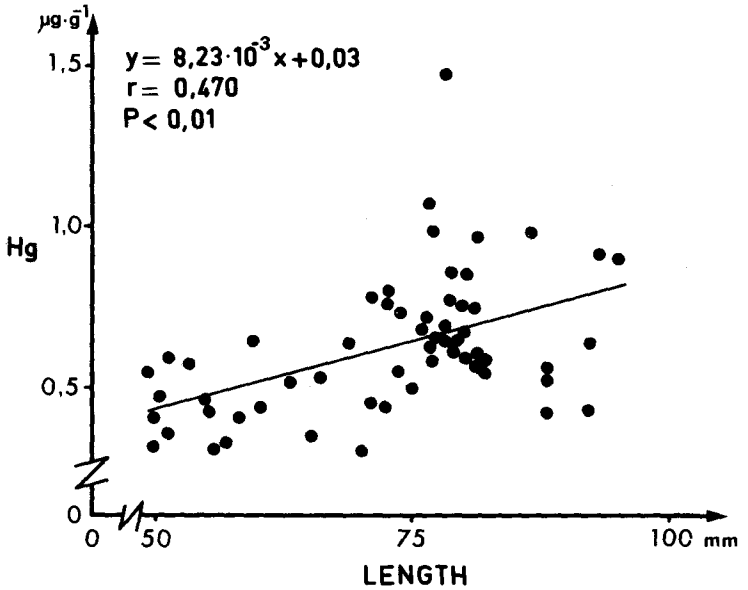

Fig. 1 - Mercury content of the adductor muscles plotted against the length of the specimens.

TABLE 1

Mercury distribution in organs and tissues of Unio e. after their collection (0) and after various periods (15,30 and 60 days) in clean water in laboratory.

ORGANS or TISSUES	TIME	$\bar{X}$	S.E.	95% C.L.
Digestive gland	0	1.403	0.107	1.156 - 1.650
	15	1.070	0.107	0.826 - 1.314
	30	0.955	0.069	0.799 - 1.111
	60	0.705	0.065	0.558 - 0.854
Gill	0	1.259	0.139	0.938 - 1.580
	15	0.732	0.088	0.531 - 0.933
	30	0.692	0.057	0.561 - 0.823
	60	0.598	0.058	0.467 - 0.729
Gonad	0	1.232	0.210	0.748 - 1.716
	15	0.621	0.093	0.410 - 0.832
	30	0.563	0.038	0.477 - 0.649
	60	0.390	0.054	0.266 - 0.514
Mantle	0	0.866	0.106	0.621 - 1.111
	15	0.495	0.103	0.260 - 0.730
	30	0.493	0.035	0.414 - 0.572
	60	0.344	0.040	0.252 - 0.436
Foot	0	0.855	0.060	0.716 - 0.994
	15	0.654	0.126	0.368 - 0.940
	30	0.622	0.054	0.499 - 0.745
	60	0.431	0.043	0.334 - 0.530
Adductor muscle	0	0.818	0.051	0.699 - 0.927
	15	0.586	0.065	0.438 - 0.734
	30	0.544	0.041	0.450 - 0.638
	60	0.421	0.113	0.129 - 0.715

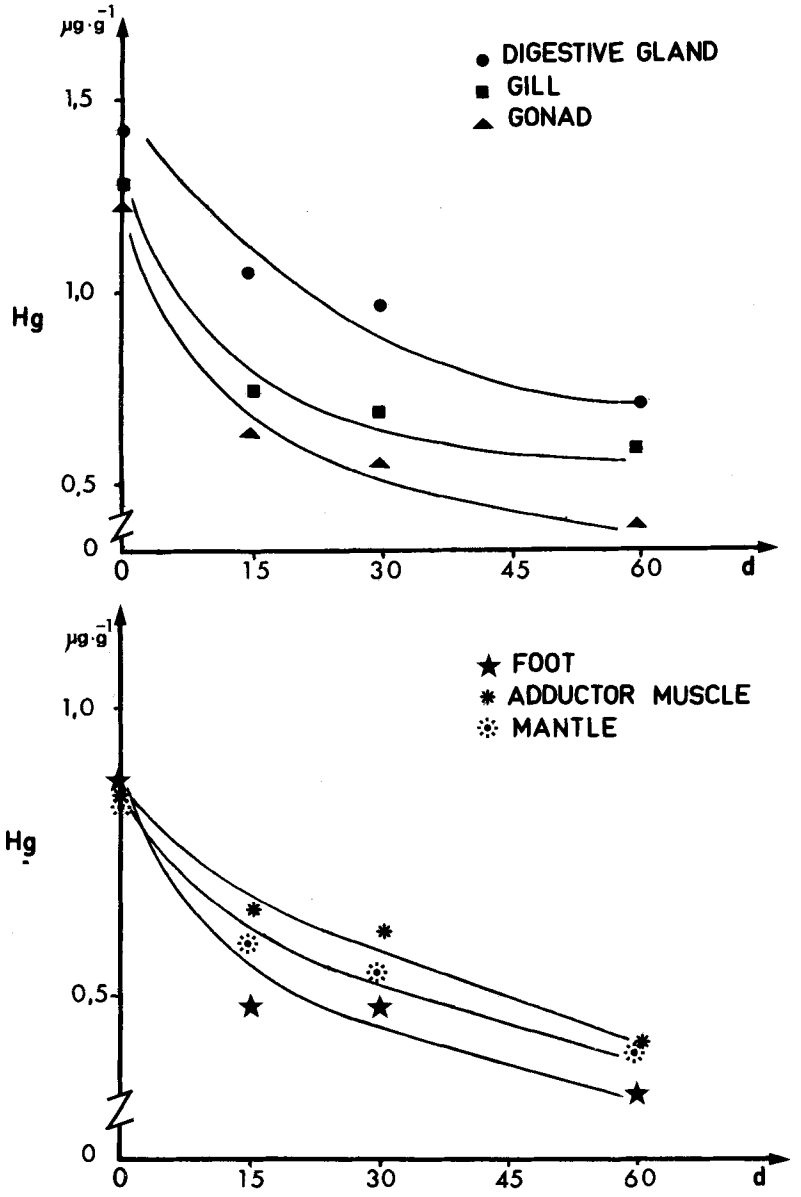

Fig.2 - The half-biological time of the six structures increases in the following sequence:gonad, mantle,gill, digestive gland,foot and adductor muscle. It ranges from 15 to 35 days in the first three structures, and is around 60 days for the other three.

The degree of mercury elimination is quite rapid in almost all structures during the first 15 days of clean-water treatment, and remarkably so in the gonads, where the half-biological time is reached after 16 days.

DISCUSSION

Among the various considerations that can be drawn from our data, the most evident seems to be the extent to which the metal has diffused in the water of the river (20-25 kms) from the main sources of contamination. The fact that even very young specimens of the benthic species in question show a high mercury content in their soft parts taken as a whole is an indirect demonstration of a consistently high concentration of the metal, either in the food of the mussel or in the water of the river. The wide distribution is also proved by data obtained in muscles of fishes collected in this section of the river (BACCI a. RENZONI) and in other representatives of animal life (BOMBACE et al.).

The fact that, among the various tissues examined, the digestive gland and the gill present the highest content of Hg, quite in accordance with the results of laboratory experiments with the marine bivalves, Venerupis philippinarum (YOSHIDA et al. 1967) and Venus decussatus (ÜNLÜ et al. 1972), demonstrates that also in this(fresh-water) bivalve collected in a polluted river, the mercury uptake is through the water and the food chain.

Mercury accumulation with age in adductor muscles of this species is quite in agreement with the findings of other authors (see LÖFROTH 1970, WALLACE et al. 1971, KECKES a. MIETTINEN 1972) in various groups of animals especially fish, and this seems to show that once this metal has arrived in the animal body, its turnover in muscle tissues has a similar trend even in taxonomically distant groups.

Instead the results relative to the Hg excretion rate by our fresh-water mussel show some discrepancies with respect to those reported for another fresh-water

bivalve (Pseudanodonta complanata), MIETTINEN et al. 1969, and for other bivalves MIETTINEN et al. 1972, UNLU et al. 1972. The comparison of these data shows: a) a longer half-biological time in our material than in Tapes decussatus (UNLU et al.), where in laboratory experiments the Hg was accumulated either from the sea water of through the food chain; b) a considerably shorter half-biological time in our material than in Tapes d., Psedanodonta c., etc. (UNLU et al.,MIETTINEN et al.) where the mercury was injected into the foot muscle. There is evidence that the rate of mercury excretion is not only dependent on the means of accumulation (UNLU et al.), but also on the form under which the metal is supplied and reaches the animal body.(MIETTINEN et al. 1972). Indeed there are great differences in the environmental conditions between our material, collected in a polluted river, and that of MIETTINEN et. al. maintained in laboratory conditions and supplied with various mercury compound through different routes.

Therefore in the light of these findings (MIETTINEN et al. 1969, MIETTINEN et al. 1972, ÜNLÜ et al. 1972) and of some collateral gas-chromatographic determinations, showing that about 90% of the mercury found in the muscle of our bivalve is methyl-mercury, we may conclude that the Hg in our material is a mixture of the two forms, inorganic and organic, reaching the mussel from the river water and food, and that the differences in the excretion-rate pattern with respect to other bivalves may be largely due to the different ratios of the two mercury forms in the animal body.

The mercury lost in the river during the process of its extraction from cinnabar is in inorganic form and methylation does not seem to occur (see SAHA 1972) in the animal body of most species, including the taxonomically close marine bivalve, Venus japonica,(IRUKAYAMA et al. 1962) . However it has been repeatedly proved that methylation occurs in natural conditions either by microbial or by plant transformation. And this seems to be the case in our river, where this process evidently occurs, on the bottom, in the section between the effluent discharge and our Unio-collecting station, a section that also collects some untreated domestic sewage.

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