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Research Note

Heavy Metals in Mussels (*Mytilus galloprovincialis*) from the Ionian Sea, Italy

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ABSTRACT

Concentrations of six heavy metals (Hg, Pb, Cd, Cr, Zn, and Sn) were determined in mussels (*Mytilus galloprovincialis*) collected between June and September 1997 from 10 locations along a sound formed by two inlets (Mar Piccolo) near the Gulf of Taranto (Ionian Sea, Italy). The average concentrations of the heavy metals found in mussels samples were 0.15 mg/kg for Hg, 1.19 mg/kg for Pb, 0.64 mg/kg for Cd, 0.31 mg/kg for Cr, 5.15 mg/kg for Zn, and 0.54 mg/kg for Sn. The concentrations of heavy metals in mussels from the first inlet did not differ greatly from those observed in mussels from the second inlet. The concentrations of heavy metals in the mussels analyzed were below acceptable levels for human consumption.

Mussels have been used as bioindicators for monitoring marine pollutants because they concentrate contaminants in their tissues and thereby reflect levels in the environment *(11).* The basin of Mar Piccolo lies to the north of Taranto, Italy, and is divided by two promontories into the first and second inlets. The basin is connected to Mar Grande basin (Ionian Sea) through two narrow passages known as the canals of Porta Napoli and Navigabile (Fig. 1). Mar Piccolo is a marine ecosystem where biological balances have been modified in relation to anthropogenic development and, in particular, large industry settlement. It has experienced the negative effects of pollution because of its semienclosed basin and has had marked problems of water exchange, which is due mainly to moderate sea tides. Some superficial rivers drain into the basin; e.g., Galeso River, which has a more significant flow, drains into the upper part of the first inlet, and Marrese Canal and Cervaro River drain into the upper part of the second inlet. Eight urban discharges drain directly into the basin; the most significant is Canale D'Aiedda (south second inlet). The basin, which has an area of $2{,}176 \cdot 10^4$ m^2 and a water volume of about $152 \cdot 10^6$ m^3, is the site of intensive mussel farming. Most seafood produced here is exported to European Economic Community countries, particularly Spain. Because this basin is a hypertrophic lagoon, it provides a very favorable environment for the growth of mussels. The high plankton and microorganism production and the elevated concentration of organic matter in solution provide mussels with the best trophic conditions.

The goal of the present work was to monitor heavy metal concentrations in mussels (*Mytilus galloprovincialis*) to determine whether health risks for consumers exist.

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MATERIALS AND METHODS

Sampling of mussels. Samples were collected between June and September 1995 from 10 sites in Mar Piccolo. These sampling locations are shown in Figure 1. The recommendations of the Food and Agricultural Organization for sampling, handling, and specimen storage, as described in the FAO Fisheries Technical Paper (1976), were followed. Samples were placed in polyethylene bags and stored below −20°C until analysis. Samples of *M. galloprovincialis* (with the bissus removed, 4 to 5 cm long, commercial size, and a mean weight [whole soft parts] of 1.6 ± 0.6 g) were analyzed in pools of 80 specimens. Mussels of the same size were selected to minimize variation in metal concentrations due to individual differences. The soft parts were carefully removed with a plastic knife and homogenized in a mixer to make up the sample from each site. To avoid contamination, all parts of the mixer that came into contact with the sample were covered with Teflon. The blades, made of stainless steel, were disposable.

Sample preparation. Pools from each location were used for metal determinations. For Pb, Cr, Cd, and Zn, about 5 g (wet weight) of sample was digested in a quartz Erlenmeyer flask with 11 ml of HNO_3-$HClO_4$ (8:3) using a hot plate heated to 150°C. Additional aliquots of nitric acid (maximum of 0.2 ml) were added until a completely colorless solution was obtained. After evaporation, the residue was dissolved in 2 ml of water, and, finally, the volume was made up to 25 ml with water *(4).* For Hg and Sn, about 5 g (wet weight) of sample was weighed into a conical flask and digested in 10 ml of H_2SO_4-HNO_3 (1:1). The flask was heated under reflux conditions until a completely colorless solution was obtained. After cooling, the resultant solution was diluted to a known volume (100 ml) with deionized water according to the method recommended by official Italian agencies *(7).* The samples were analyzed using an atomic absorption spectrophotometer (model 5000, Perkin-Elmer Corporation, Norwalk, Conn.) with a graphite furnace (HGA-500, Perkin-Elmer) for Pb, Cr, Cd, and Sn and an air-acetylene flame for Zn. Hg was determined by the cold-vapor technique after reduction by $SnCl_2$ (A.V.A. Thermo Jarrel

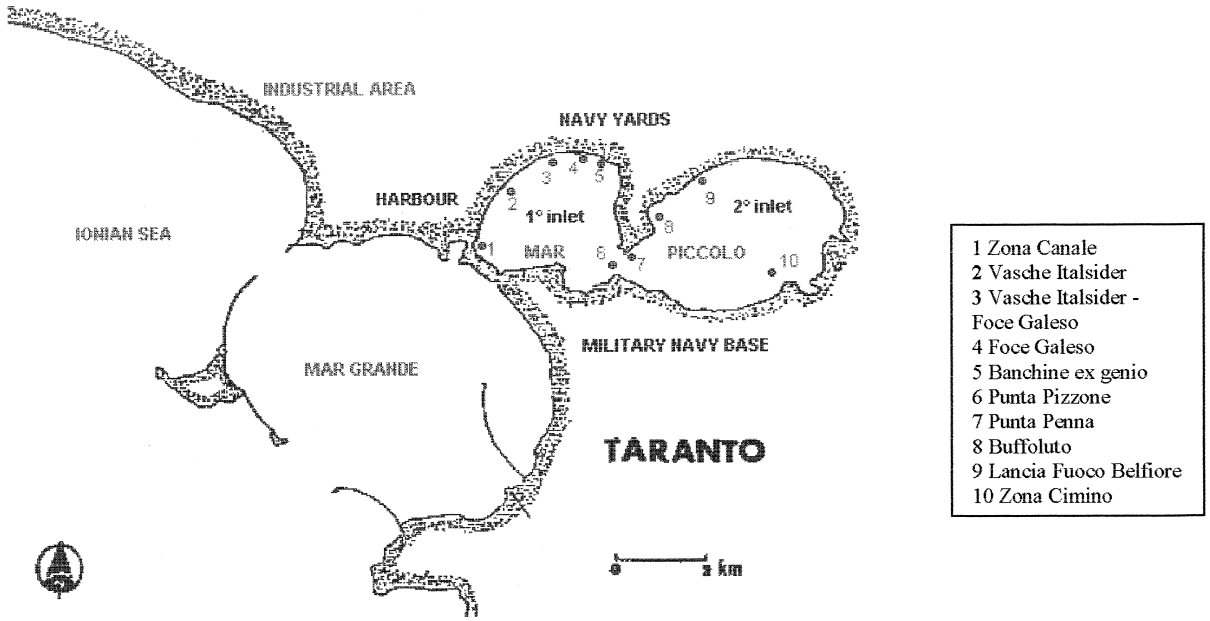

FIGURE 1. *Sampling sites in Mar Piccolo, Taranto, Italy.*

Ash, USA). Samples of mussels from each site were analyzed in triplicate. The accuracy of the method was evaluated by analyzing a certified reference material, TORT-2, from the National Research Council of Canada. Recovery for each of the six metals was at least 86%.

RESULTS AND DISCUSSION

The concentrations and average values for heavy metals in mussel samples are reported in Table 1. The concentration of Hg ranged from 0.05 to 0.23 mg/kg, with an average concentration of 0.15 mg/kg. The highest levels of this metal were found in mussels from locations 1 (Zona Canale), 4 (Foce Galeso), and 10 (Zona Cimino). These values were much lower than the maximum residual level of 0.5 mg/kg recommended by the European Economic Community *(8).* The levels of Pb ranged from 0.86 to 1.70 mg/kg, with an average concentration of 1.19 mg/kg. Mussel samples from location 4 (Foce Galeso) exhibited the highest level of Pb, 1.70 mg/kg. These values were lower than the maximum residual level of 2 mg/kg recommended by Italian authorities *(5).* The average concentrations of Cd and Cr found in mussels from the 10 locations were 0.64 and 0.31 mg/kg, respectively. Mussels collected from location 4 (Foce Galeso) had the highest concentrations of Cd and Cr, 0.70 and 0.77 mg/kg, respectively. The values of Cd did not exceed the maximum residual level of 2 mg/kg recommended by the Italian authorities *(3).* Concentra-

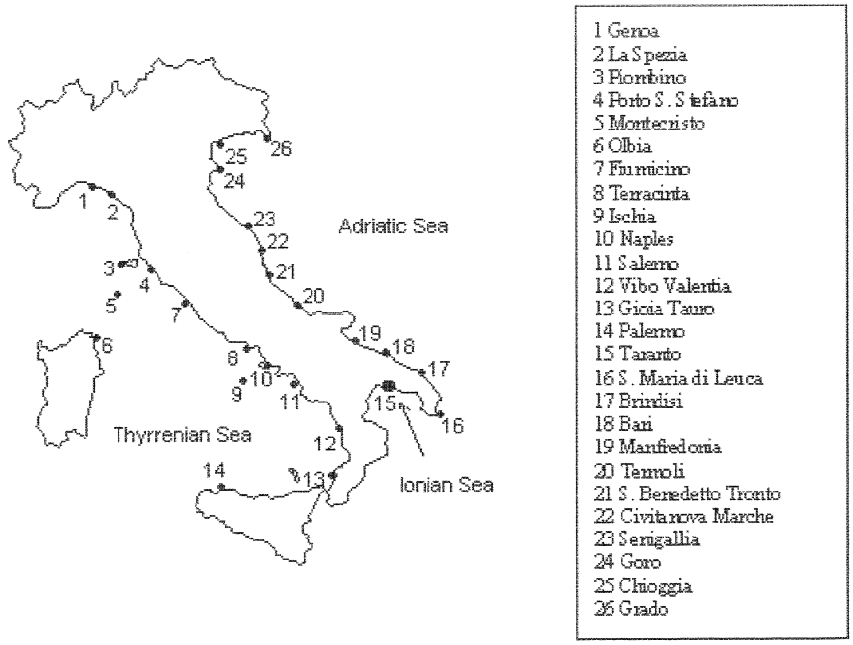

FIGURE 2. *Other Italian sampling sites compared with those of Mar Piccolo.*

TABLE 1. *Concentrations (mg/kg wet weight, mean ± SD) of heavy metals in* M. galloprovincialis *from 10 locations along the coastal area of Mar Piccolo (Ionian Sea)*

Location	Hg	Pb	Cd	Cr	Zn	Sn
1	0.23 ± 0.02	1.19 ± 0.05	0.65 ± 0.03	0.21 ± 0.02	5.55 ± 0.04	0.49 ± 0.01
2	0.05 ± 0.01	1.14 ± 0.03	0.71 ± 0.02	0.24 ± 0.02	5.76 ± 0.05	0.51 ± 0.02
3	0.19 ± 0.02	1.07 ± 0.03	0.69 ± 0.04	0.21 ± 0.01	5.14 ± 0.06	0.51 ± 0.02
4	0.22 ± 0.03	1.70 ± 0.05	0.70 ± 0.02	0.77 ± 0.02	3.85 ± 0.04	0.73 ± 0.02
5	0.05 ± 0.01	1.15 ± 0.02	0.68 ± 0.02	0.36 ± 0.01	5.28 ± 0.05	0.46 ± 0.01
6	0.17 ± 0.02	0.97 ± 0.02	0.68 ± 0.02	0.44 ± 0.02	5.56 ± 0.03	0.91 ± 0.02
7	0.13 ± 0.02	0.94 ± 0.03	0.70 ± 0.03	0.30 ± 0.03	5.44 ± 0.02	0.45 ± 0.03
8	0.12 ± 0.01	1.54 ± 0.03	0.44 ± 0.05	0.17 ± 0.02	4.42 ± 0.03	0.48 ± 0.02
9	0.12 ± 0.01	1.34 ± 0.02	0.44 ± 0.02	0.17 ± 0.02	5.01 ± 0.02	0.45 ± 0.01
10	0.21 ± 0.02	0.86 ± 0.02	0.66 ± 0.04	0.25 ± 0.01	5.52 ± 0.06	0.45 ± 0.02
Mean						
1997	0.15 ± 0.06	1.19 ± 0.25	0.64 ± 0.09	0.31 ± 0.17	5.15 ± 0.56	0.54 ± 0.14
1991[a]	0.30 ± 0.07	0.96 ± 0.08	0.53 ± 0.05	0.29 ± 0.04	5.30 ± 0.19	0.32 ± 0.12

[a] Data from previous studies *(6, 12).*

tions of Zn ranged from 3.85 to 5.76 mg/kg, with an average concentration of 5.15 mg/kg. The highest level of Zn, 5.76 mg/kg, was found in mussel samples from location 2 (Vasche Italsider). The concentrations of Sn in mussels from the 10 locations ranged from 0.45 to 0.91 mg/kg. The highest level, 0.91 mg/kg, was found in location 6 (Punta Pizzone). The concentrations of metals found in mussels did not vary greatly between the two inlets (Table 2). Statistical analysis, in fact, showed that levels of metals detected in mussels from the first inlet did not differ significantly ($P > 0.05$, Student's t test) from levels in mussels from the second inlet. Nevertheless, mussels taken from the mouth of the Galeso River (location 4) contained the highest metal concentrations. Table 1 is a comparison of mean metal concentrations in mussels collected from 10 locations in the present study with those from studies performed in 1991 using mussels from the same locations *(6, 12).* The present survey shows that concentrations of Hg found in the mussels collected from all locations were lower than those reported in the previous study *(12),* whereas the levels of Pb, Cd, Cr, Zn, and Sn were higher or comparable *(6, 12).* Particularly, levels of Sn were increased mainly in mussels from the first inlet. It is known that Sn is a component of antifouling paints used for the hull of sea vessels. In fact, the area studied is a harbor area and seat of a naval base of the Italian marine military and its shipyard activities. Higher levels of Hg, Cd, and Pb were observed in *M. galloprovincialis* collected from this area than in samples of the same species collected from other Italian locations *(1, 10, 13)* (Table 3 and Fig. 2). Concentrations of Pb and Sn in our mussel samples were the same order of magnitude as those reported for other locations with intensive harbor activity, such as La Spezia, Piombino and Napoli. As for Cr and Zn, no comparison data were available. In comparison with published data from other Italian coastal areas, the metal concentrations reported here for the Mar Piccolo basin are indicative of a polluted environment. It is believed that the sources of this pollution are anthropogenic influences, such as a higher urbanization of the Ionian Sea shore and greater industrial activity of the eastern coast of Taranto. This area, in fact, includes Ilva, a great iron center, and Agip, an oil refinery, which are the most significant industrial settlements of the Ionian Sea area. The presence of these industries yields a huge amount of particule, which is released directly into the atmosphere as smoke, as well as a great mass of waste. This waste, together with wastewaters from the various processes and treatment installations, is disposed of in a sea area adjacent to Mar Grande. The problems of environmental impact that occur are very complicated because, besides the suspended material, the wastewaters contain toxic pollutants (ammonia, phenols, mineral oils, metals, etc.). The iron industry averages 1,700,000 tonne of waste per year, a fraction of which is toxic and harmful; most of this waste is utilized again, but the rest is discharged. This waste is a source of problems because of the possible release of toxic compounds (polychlorinated biphenyls, asbestos, and metals) into lower strata. As for shipping traffic, besides the marine military base in Mar Piccolo, with its various ship buildings and maintenance and repair facilities, a remarkable amount of harbor activity occurs in Mar Grande; in all, 48% of the movement of goods is related to metallic minerals destined for the siderugical industry, 27% is involves oil and its derivatives, 24% involves solid, combustible minerals (carbon), and 1%

TABLE 2. *Comparison of heavy metal concentrations (mg/kg wet weight, mean ± SD) in* M. galloprovincialis *collected from the first and second inlets of Mar Piccolo (Ionian Sea)*

Location	Hg	Pb	Cd	Cr	Zn	Sn
First inlet (locations 1–6)	0.15 ± 0.07	1.20 ± 0.23	0.69 ± 0.02	0.37 ± 0.18	5.19 ± 0.63	0.60 ± 0.16
Second inlet (locations 7–10)	0.15 ± 0.03	1.17 ± 0.28	0.56 ± 0.12	0.22 ± 0.06	5.10 ± 0.43	0.46 ± 0.01

TABLE 3. *Concentrations of Hg, Cd, and Pb (mean ± SD) in* M. galloprovincialis *from different Italian locations*

Location	Hg (μg/kg)	Cd (mg/kg)	Pb (mg/kg)	Sn (mg/kg)
Genoa	59 ± 37	0.14 ± 0.02	4.98 ± 4.72	
La Spezia	36 ± 9	0.19 ± 0.09	1.53 ± 0.75	0.79
Piombino	33 ± 8	0.14 ± 0.03	2.36 ± 1.31	
Porto S: Stefano	69 ± 16	0.17 ± 0.04	0.91 ± 0.51	
Montecristo	32 ± 5	0.48 ± 0.11	0.60 ± 0.28	
Olbia	12 ± 2	0.06 ± 0.01	0.15 ± 0.06	
Fiumicino	27 ± 6	0.11 ± 0.02	0.56 ± 0.15	
Terracina	19 ± 4	0.09 ± 0.01	0.62 ± 0.24	
Ischia	10 ± 1	0.13 ± 0.02	0.40 ± 0.10	
Naples	32 ± 11	0.15 ± 0.01	1.35 ± 0.77	
Salerno	24 ± 4	0.16 ± 0.01	0.71 ± 0.19	
Vibo Valentia	17 ± 3	0.18 ± 0.02	0.41 ± 0.04	
Gioia Tauro	15 ± 2	0.17 ± 0.02	0.36 ± 0.06	
Palermo	34 ± 7	0.19 ± 0.02	0.38 ± 0.04	
Taranto	43 ± 8	0.15 ± 0.01	0.95 ± 0.27	0.85
S. Maria di Leuca	19 ± 8	0.17 ± 0.03	0.47 ± 0.02	
Brindisi	52 ± 8	0.09 ± 0.01	0.97 ± 0.19	
Bari	16 ± 2	0.13 ± 0.02	0.97 ± 0.16	
Manfredonia	18 ± 2	0.19 ± 0.01	0.41 ± 0.22	
Termoli	18 ± 3	0.15 ± 0.02	0.35 ± 0.03	
S. Benedetto Tronto	15 ± 2	0.16 ± 0.02	0.45 ± 0.02	
Civitanova Marche	15 ± 2	0.22 ± 0.02	0.43 ± 0.02	
Senigallia	20 ± 5	0.34 ± 0.03	0.45 ± 0.02	
Goro	19 ± 7	0.17 ± 0.01	0.44 ± 0.22	
Chioggia	19 ± 6	0.19 ± 0.02	0.41 ± 0.16	
Grado	16 ± 2	0.20 ± 0.02	0.43 ± 0.18	

involves bitumen. Accidental spilling of oil and mineral products into the sea during loading and unloading operations and emission of components of antifouling paints represent the main environmental impacts of these latter activities from vessels. Recent research *(2, 9)* has pointed out that this is a principal source of pollution by organotin compounds of sediments and marine organisms from the Taranto Sea. The values found for Hg, Pb, and Cd indicate that the species under investigation poses no health hazard to consumers because its trace metal contents remain within the permissible range established for safe consumption by humans. Nevertheless, the high values observed, mainly for Pb and Sn, confirm that in sea zones with mussel farming activity, contamination by metallic compounds must not be underestimated.

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