ORIGINAL ARTICLE

Monitoring on chemical and biological pollutants in sea waters of central-northern Sardinia

A. PIANA, N. SECHI*, M.D. MASIA, A. AZARA, E. MURESU, A. MAIDA
Institute of Hygiene and Preventive Medicine of the University of Sassari, Sassari, Italy; * Department of Botany and Vegetable Ecology of the University of Sassari, Sassari, Italy

Key words

Sea-waters • Pollutants • North Sardinia

Summary

Introduction. *The aims of this study are to assess the quality of the coastal waters of central-northern Sardinia through data from a monitoring network and to outline maps and experimental models of environmental risk correlated to the presence of chemical and microbiological contaminants. The area studied is the coast between Capo Falcone and the mouth of the river Coghinas, in the northwestern part of the island.*
Methods. *In a first phase, 7 sampling stations of sea water and 1 sampling station of bivalve molluscs (Mytilus galloprovincialis Lam.) were identified. For each transept 3 different collection points at respectively 500, 1000, and 3000 meters from the coast for a total 21 sampling sites were identified. In a second phase, another 7 transepts were identified, 2 of which on the island of Asinara.*
Results. *As regards the microbiological monitoring of the sea water, very low concentrations of Total coliforms, Faecal coliforms and Faecal Streptococci were found and no Salmonella were isolated. Chemical analysis of the waters showed a high constant presence of phenols. In the bivalves we found rather high concentrations of Faecal coliforms without any clear seasonal variation, while no Salmonella was isolated in any of the examined samples.*
Discussion. *The results show that the considered area is not affected by serious pollution processes, thus allowing to express a completely satisfactory judgement on its state of health. However, anthropic pressure in the considered territory is testified by the presence in the water of high concentrations of phenols.*
Conclusions. *The results point out to the necessity of targeted and rational preventive action by means of control and protection measures for environmental ecosytems.*

Introduction

In the past decades, as a result of careless environmental planning, the progressive degradation of the sea environment has been aggravated by continuously increasing industrialisation and urbanisation along the coasts, the expansion of maritime traffic, and the irrational exploitation of natural resources. This aspect is even more evident along the coastal strip, which is particularly vulnerable to changes of a natural and anthropic nature, both because different kinds of new contaminants continuously appear and because fast dilution is less possible. Moreover, chemical contamination today due to industrial waste poses far more complex and more difficult public health problems than those posed by contamination of faecal origin in the past. The usually slow and insidious pathogenetic mechanisms of many of the pathologies caused in man and in the environment by exposition to toxic substances are still unknown today. Moreover, the limit values of the different non-biological polluting agents are not perfectly known.
The main causes of pollution include the disposal of unpurified or insufficiently purified industrial, agricultural, livestock and domestic waste waters, which cause a number of negative phenomena leading to microbiological, chemical, and physical alterations in the marine ecosystem. These and other factors may cause different kinds of problems and damage, such as:

- *infective* problems, mostly deriving from the input of pathogenic agents from urban, hospital, and slaughterhouse wastes, etc.;
- *decompositional*, due to the input into the water body of a large quantity of polluting organic material causing consumption of oxygen and the establishment of processes of anaerobic fermentation;
- determined by the presence of *chemical substances* from the non biodegradable and accumulable processing residues of industrial and handicraft activities (oils, fats, foams), or *toxic substances* (heavy metals, chlorinated hydrocarbons, and compounds of non-biodegradable synthesis);
- *aesthetic*, caused by the presence of materials in suspension or dissolved in water, films of oily substances on the surface and foams, which reduce the dissolved oxygen content. In this context, oil pollution, whose possible sources of dispersion are represented by the industrial petrochemical settlements located along the coasts, or by accidents of passing tankers, is particularly worrying;
- finally, not to be missed is the problem of *dystrophic eutrophication* characterised by an abnormal development of algae due to the presence of an excess of nutrients (nitrogenous and phosphatised substances) mainly from urban wastes, fertilising agents, and detergents. The effects are represented by visible algal blooms, reduction of the

transparency, hyperoxygenation of the surface layers, and anoxia of the deep ones, production of evil smelling and irritant chemical compounds (sulphurated hydrogen, ammonia, methane), reduction of the varieties of species belonging to the highest levels of the food chain, production of mucilage and release of toxins by toxic Dinoflagellates [1, 2].

In the light of the above, it appears clearly visible that important environmental and health implications depend on the quality characteristics of the coastal waters. In particular, the risks to the environment related to the presence in the waters of toxic substances and elements mainly related to anthropic factors and to the environmental deterioration due to chemical and biological pollution are of great interest from the point of view of hygiene and health. These aspects are even more important in Sardinia, where tourism is one of the main economic resources of the island. As a matter of fact, Sardinia has 1896.8 km of coasts accounting for about 23% of the entire Italian coastline. The transparency of its waters, especially on sandy bottoms, are a heritage that must be safeguarded both to protect the health of the population and environment and because it is an important economic resource.

An element of undoubted importance in the identification of a correct "policy" for the protection of the marine ecosystem is certainly the systematic monitoring of the quality of the waters. The more serious and widespread the environmental contamination globally, the more urgent the need to identify the different forms of pollution phenomena in their initial phase in order to act with timely intervention [3].

Based on the above premises, the Institute of Hygiene and Preventive Medicine of the University of Sassari, in collaboration with the Department of Botany and Vegetable Ecology, as part of a joint research Project, carried out according to the provisions of the Ministry of the Environment, targeted to the protection of the seas and in particular to the "*safeguard and protection of the marine coastal environment from pollution and the prevention of adverse effects to the sea resources*" has started a study with the following objectives:

- to assess the quality of the coastal waters of central-northern Sardinia through data from a monitoring network;
- to outline maps and experimental models of environmental risk correlated to the presence of chemical and microbiological contaminants in the waters through the finding of pollutants in relation to the main sources of potential pollution on land.

The environmental data from the monitoring network of the coastal waters of the entire national territory will be put into an Environmental Information System so as to keep the water quality under constant control and follow the dynamics of the phenomena of environmental pollution in real time.

This work reports on the results of the chemical and microbiological monitoring of the waters of the Gulf of Asinara.

Methods

The geographic area studied in this work is the coast between Capo Falcone and the mouth of the river Coghinas, in the northwestern part of the island, for a total area of about 100 km. Within this context, 7 sampling stations (transepts) of sea water 10 miles apart were identified, chosen among those that best represented possible "risk" situations due to the presence of sources of different types of environmental contamination. As a matter of fact several industrial, tourist, livestock and farming settlements, which are not always equipped with appropriate waste treatment systems are in fact present in the sample area. Moreover, a sampling station of bivalve molluscs (*Mytilus galloprovincialis* Lam.), useful bio-indicators of bio-pollution, was identified.

For each transept 3 different collection points at respectively 500, 1000, and 3000 meters from the coast for a total 21 sampling sites were identified.

In a second phase, as a result of the establishment of the Asinara National Park, another 7 transepts were identified, 2 of which on the island of Asinara, at Cala d'Arena and Cala Reale. In order to ensure reproducibility of each sample collection in time, at each sampling point we recorded the place, date, and time of execution, the geographical co-ordinates, the distance from the shore, the bottom depth, the wave height, and the direction and speed of the wind and of the surface current.

Moreover, at each station with a multiparametric probe we recorded the water temperature, salinity and/or conducibility, dissolved oxygen; pH; as well as transparency, colouring; possible presence of tarry residues, and layers of oil.

After sampling, the water and mussel samples were taken in refrigerated bags to the laboratories of the Institute of Hygiene and Preventive Medicine; the water was analysed within 24 hours following the sampling, while the mussels were treated in such a way as to prevent changes in the composition due to drying, evaporation, deterioration, or contamination.

In the laboratory we determined the present parameters in both waters and mussels (waters: *Ammonia, Nitrate, Nitrite, Total Phosphorus, Reactive Phosphorus, Anionic surfactants, Phenols, Tarry residues, Mineral oils, Total coliforms, Fecal coliforms, Fecal streptococci, Salmonella*e; mussels: *Mercury, Cadmium, Organochlorine compounds - DDT, BHC, DDE, Endrin, Lindane - Fecal coliforms, Salmonellae*). For the waters we referred to I.R.S.A. methods and to the D.P.R. (Decree of the President of the Republic) 470/82 relating to bathing waters [4, 5] and further amendments (L. 422/00), while for the bivalves we referred to D.Lvo (Order in Council) 530/92 [6] and to the D.M.S. (Decree of the Minister of Health) dated 31 July 1995 [7].

The analytical data obtained during the monitoring were recorded in databases and processed statistically by specific software for the determination of mean and variability indices.

Results

As regards the microbiological monitoring of the sea water, very low concentrations of *Total coliforms* (T.C.), *Faecal coliforms* (F.C.), and *Faecal Streptococci* (F.S.) were found in the sampling area, with modest increases at the end of the summer season. The highest value found for T.C. was 54 CFU/100 ml, and 12 CFU/100 ml for the F.C., while the F.S. were absent. All found values were well below the limits indicated by DPR 470/82 for the quality of bathing waters. This Decree provides for the following limit values: 2000 T.C./100 ml, 100 F.C./100 ml and 100 F.S./100 ml [4]. In particular, the median values are almost constantly equal to zero. Moreover no *Salmonella* was isolated in any of the examined samples (Fig. 1).

Chemical analysis of the waters showed a high constant presence of *phenols*, whose median value is about double the limit value of 0.05 mg/l fixed by DPR 470/82 on the quality of bathing waters [4] (Fig. 2).

While *surfactants*, *tarry residues*, and *oil layers* are always absent, or below the method's sensitivity threshold. As regards the other examined chemical parameters, which are not even provided for by DPR 470/82, the survey showed presence in low concentrations of *ammoniacal nitrogen*, *nitrous nitrogen*, and *nitric nitrogen*. *Total phosphorus*, for which we point out maximum values of 4.0 mg/l, and to a lesser extent *reactive phosphorus* (maximum observed concentration peak 1.3 mg/l) are worth mentioning as they are present in concentrations which, though not comparable to limit values since there is no specific prescriptive reference, seem to be far higher than those normally found in sea waters, quantified in a range between 0 and 80 μg/l of phosphates [3].

The results obtained in the second phase of the survey, involving 7 transepts, 2 of which near the Island of Asinara, point out low concentrations of bacterial load relating to three indicators of faecal pollution (maximum value 40 CFU/100 ml for T.C. and 66 CFU/100 ml for F.S.) only in the site of Porto Torres alone as regards the microbiological aspect (Fig. 3); while for the chemical aspect, we either found concentrations below the sensitivity threshold for the adopted analytical methods or at any rate always near zero in all the monitored sites (Tab. I).

As regards the aspect relating to the search for microbial pollution indices in the bivalves, we found rather high concentrations of Faecal coliforms (Fig. 5) without any clear seasonal variation [8]. These values are far above the limit of 300 CFU per 100 grams of pulp and intervalvar liquid provided for by the D.Lvo 530/92 [6]. On the other hand, no *Salmonella* was isolated in any of the examined samples.

As regards the analysis of the chemical parameters, the concentrations of trace elements found in the soft parts of the bivalves are the following: between 0.158 and 0.147 ppm with a median value of 0.153 ppm for *Cadmium*, and between 0.005 ppm and 0.028 ppm with a median value of 0.017 ppm for *Mercury* (Fig. 4). It is interesting to note that in our study, unlike others carried out in different parts of Italy [8-14], we did not find any important seasonal differences in the concentrations of the two microelements. As a matter of fact these microelements remain constant also in the reproductive season (spring), which corresponds to the period of greatest body development in mussels.

Fig. 1. Results of the microbiological monitoring of the Asinara Gulf waters.

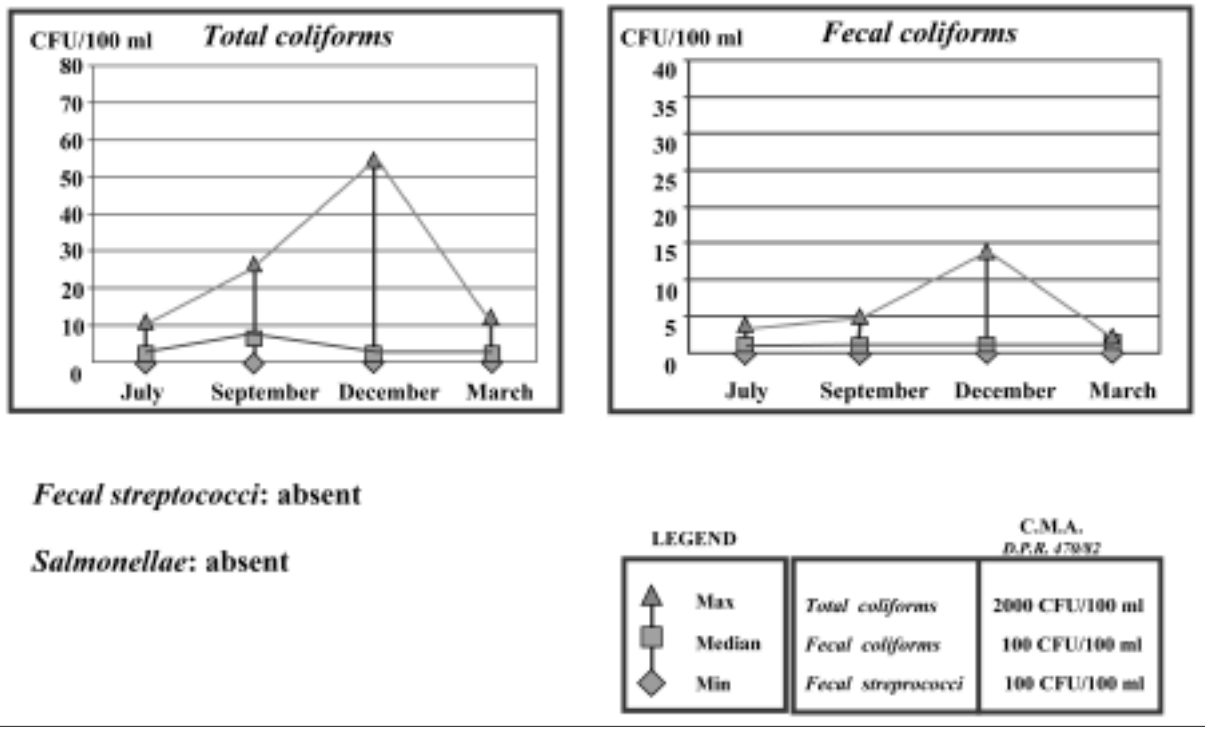


Fig. 2. Results of the chemical monitoring of the Asinara Gulf waters.

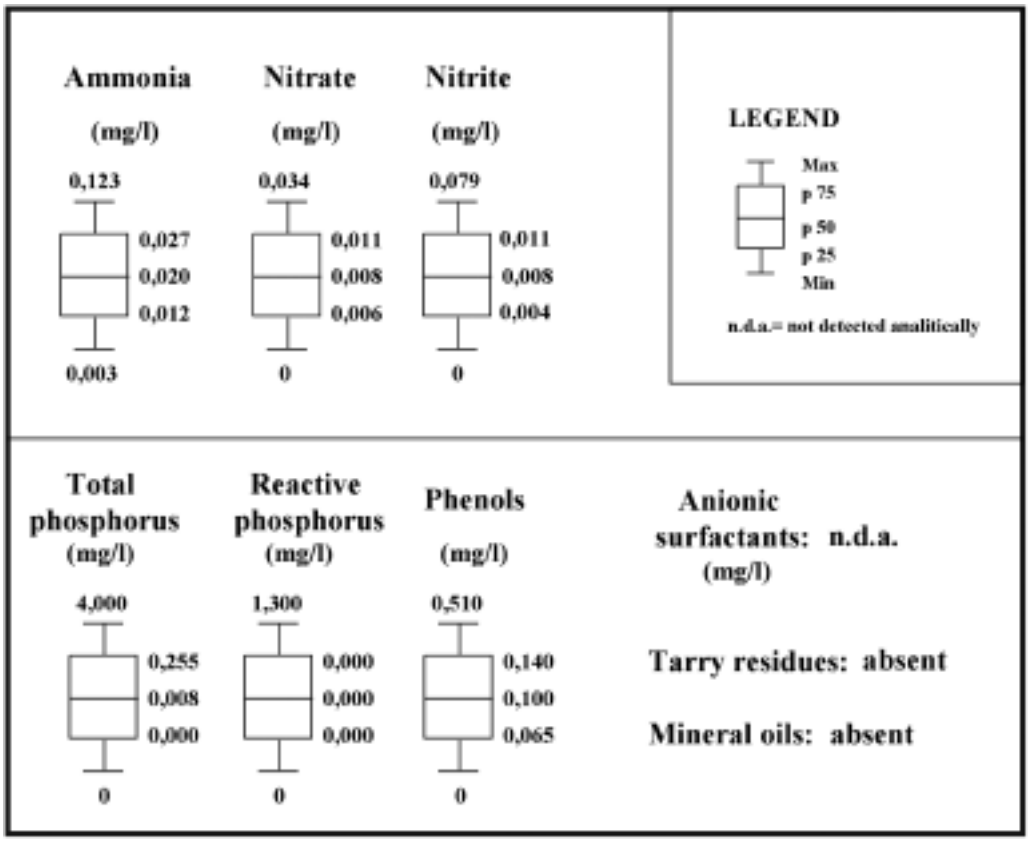
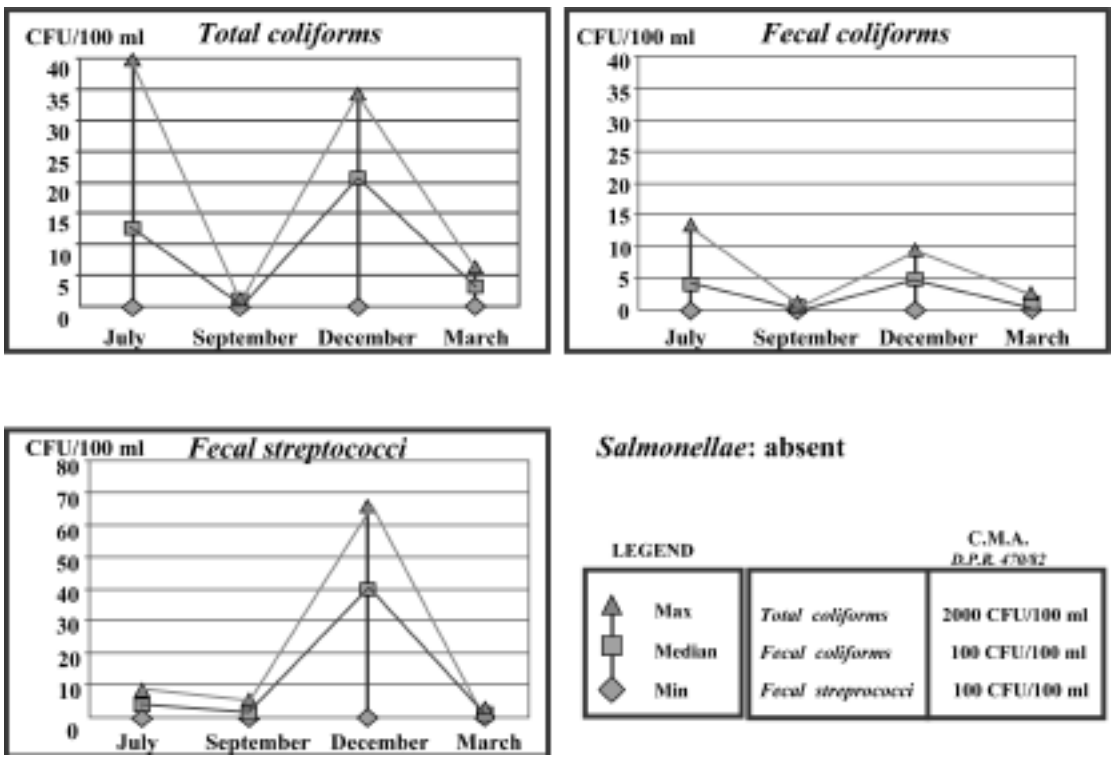


Fig. 3. Results of the microbiological monitoring of Porto Torres site.



Tab. I. Results of the chemical monitoring of the Asinara Gulf waters.(transepts: Porto Torres, Cala Lupo, Cesaraccio, Pazzona, Fiume Santo, Cala D'Arena, Cala Reale).

	Porto Torres			Cala Lupo			Casaraccio			Pazzona			Fiume Santo			Cala d'Arena			Cala reale		
	M	med.	m	M	med.	m	M	med.	m	M	med.	m	M	med.	m	M	med.	m	M	med.	m
Ammonia (mg/l)	0,03	0,004	0	0,01	0,005	0	0,011	0,005	0	0,007	0,005	0	0,009	0,004	0	0,009	0,004	0	0,006	0,003	0
Nitrate (mg/l)	2,38	0,009	0,001	0,18	0,011	0	0,025		0,006	0,003	0,081	0,01	0,003	0,081	0,014	0,002	0,048	0,025	0,002	0,057	0,014
Nitrite (mg/l)	0,081	0,005	0,002	0,03	0,006	0	0,009	0,001	0	0,011	0,005	0,001	0,009	0,003	0,001	0,015	0,003	0	0,023	0,003	0
Total phosphorus (mg/l)	0,039	0,003	0,002		absent		0,019	0,003	0,001	0,025	0,003	0,001	0,155	0,003	0		absent		0,014	0,003	0,001
Reactive phosphorus (mg/l)		absent			absent			absent			absent			absent			absent			absent	
Phenols (mg/l)		absent			absent			absent			absent			absent			absent			absent	
Anionic surfactants (mg/l)		absent			absent			absent			absent			absent			absent			absent	

As regards the results concerning organochlorinated substances with a high molecular weight, DDT, BHC, DDE, Endrin, and Lindane, in all the samplings carried out during the monitoring the concentrations were always below the sensitivity threshold for the analytical methods used.

Discussion

Anthropisation of the coasts together with the relative increase in urban wastes and the use of marine coastal waters for recreational purposes more and more urgently sets the problem of the quality and safeguard of the waters destined to bathing and of the harmful effects they may have on public health. The conservation and protection of the marine environment therefore deserve particular attention, even considering the multiple positive uses they could be turned to: e.g. aesthetic, tourist, recreational, economic, research, and cultural.
Considering these remarks, the results obtained during this survey are based on the following premises:

- the results of the monitoring of the coastal waters of the Gulf of Asinara, even through the use of biological indicators, show that the considered area is not affected by serious pollution processes, thus allowing to express a completely satisfactory judgement on its state of health;
- however anthropic pressure in the considered territory is testified by the presence in the water of high concentrations of phenols, signs of pollution of an industrial origin, and in the mussels by Cadmium and Mercury values, which though present in far lower concentrations than those found on the same kind of bivalves in other localities [9-13], are still characterised by an intrinsic toxicity even at very low concentrations. Moreover, the concentrations of nutrients and in particular those of Total and Reactive Phosphorus are like alarm bells of a latent anthropic pollution which could favour phenomena of eutrophication with severe repercussions on the environment, on public health, and on the economy of our territory.

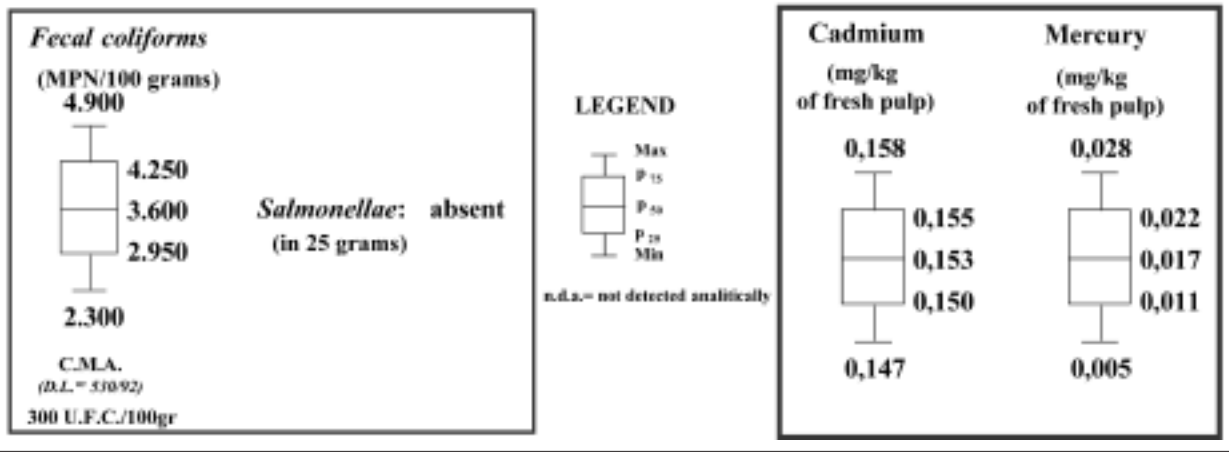
Conclusions

From the viewpoint of limiting the presence of risk factors for public health and the environment, the obtained results point out to the necessity of targeted and rational preventive action by means of control and protection measures for environmental ecosytems, by intervening:

- *upstream*: through the reduction of all pollution sources and the removal of as many discharges of persistent and bioaccumulable toxic substances as possible, thus preferring the use of alternative "clean" productive technologies in view of favouring integration between the environment and economic development;
- *downstream* with the adoption, on the one hand, of appropriate systems of purification and disposal of industrial, domestic, and agricultural wastes capable of curbing contamination, and on the other by favouring the establishment of specially protected areas that play a strategic role in the management of the coastal strip, thus responding to a few priorities for the sustainable development of coastal and marine areas, such as: preserving marine diversity, maintaining the productivity of the ecosystems, contributing to the economic and social welfare of the people thanks to the development of tourism and to the modernisation of infrastructures and services for the territory. From this viewpoint, the establishment of the Natural Park of the Island of Asinara and of that of the Archipelago of La Maddalena represents an appropriate choice for the rational equilibrium between environmental conservation and the development of new economic, cultural, social, urbanistic, scientific, and educational activities.

Therefore the objective of a sensitive improvement of the quality of ecosystems may be pursued and reached through coordinated actions of land recovery, which must be planned and supported by a continuous monitoring of the environment so as to follow and prevent pollution in real time. We should tend to this with immediate, ab-

Fig. 4. Concentrations of faecal pollution indicators, Cadmium and Mercury found in the soft parts of the bivalves.



solute, and constant commitment on the part of Public bodies and with the support of the University in a spirit of collaboration that has allowed to reach in past years a few significant results as regards the environment.
It appears appropriate therefore to point out the unavoidable necessity that this effort should correspond to an equal commitment on the part of the local Administrations of Sardinia as regards legislation, management, and control, and last but not least, a greater awareness of the population towards problems of the territory not only in the form of judgements of its quality, but and especially as an active participation in its protection.

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■ Correspondence: Prof. Andrea Piana,University of Sassari, Institute of Hygiene and Preventive Medicine, via Padre Manzella 4, 07100 Sassari, Italy. Tel. +39 079 228292 – Fax +39 079 228472 – E-mail: piana@ssmain.uniss.it