MONITORING CHEMICAL CONTAMINATION LEVELS IN THE MEDITERRANEAN BASED ON THE USE OF MUSSEL CAGING

Bruno Andral [1] *, Hervé Thébault [2] and Pierre Boissery [3]
[1] LERPAC Ifremer BP 330 83507 La Seyne sur Mer France - bruno.andral@ifremer.fr
[2] IRSN/LERCM Ifremer BP 330 83507 La Seyne sur Mer France
[3] Agence de l'Eau RMC 62, La Canebière 13001 Marseille France

Abstract
A bioindicator monitoring network (RINBIO) was deployed all along the French Mediterranean coast (1,800 km), using man-made cages containing mussels (*Mytilus galloprovincialis*) to assess contamination by heavy metals, persistent organic products and radionuclides. The caging technique compensated for the scarcity of natural shellfish stocks in significant parts of the coast and enabled comparison between sites regardless of their physico-chemical and trophic characteristics. Models linking a biometric parameter from each of 103 mussel samples to pollutant levels make it possible to adjust raw data on contamination for a reference individual, by making a clear distinction between physiological (growth) and environmental factors.
Keywords : Bio-indicators, Coastal Waters, Monitoring, Pollution.

Introduction
Under the aegis of the Water Management Master plan of the French Mediterranean coastal zone and the recent EU Water Framework Directive, a monitoring programme was established to document a coherent and comprehensive overview of the different water masses and inform on progresses towards the achievement of high quality water status. Most monitoring programmes now include the use of biological indicators. In the Mediterranean Sea, the species *Mytilus galloprovincialis* is widespread, but in some locations natural populations are rare or absent. The transplantation method compensated for this scarcity and allows the control of the source, age, and stage of sexual maturity of the samples. Although concentrations measured in the tissue are a function of bioavailable pollutant levels, the bioaccumulation factor depends on mussel growth. Comparison of raw data on tissue concentration between sectors of different trophic potential may be misleading. A biometric parameter representing growth must be used to correct initial data and to produce reliable comparison at a large spatial scale.

Material and Methods
Mediterranean mussels, *Mytilus galloprovincialis*, were transplanted from a unique cultivated population located in a low contamination area and selected in a narrow size range. Mussels were immersed in plastic cages at the end of March and hauled out in July 2003, along 1,800 km of French Mediterranean shoreline, including coastal lagoons. In the open sea, the stations were immersed between 20 m and 30 m in the mean field of dilution of land-based contamination sources. The monitoring network includes 103 transplantation sites and evaluate various trace-contaminant levels: heavy metals, organic pollutants (pesticides, PCBs, PAHs) and radionuclides for which 41 stations were selected. During this sexual resting period, the condition index (CI), defined as the ratio of soft tissue dry weight over shell weight, appears to be a good indicator of growth rate. The use of linear regression analysis for each contaminant statistically infers that tissue concentration under steady state conditions can be a function of the CI. These regression lines allow normalization of the concentrations measured to a reference CI, based on the hypothesis of equal slopes. The contaminants levels are then comparable at a large spatial scale, independently of the trophic conditions prevailing around the sampling sites [1].

Results
The recovery rate of samples is above 98% and mean mortality of mussel is less than 20%. The condition index (CI) ranges from 0.05 to 0.21, growth being greater in samples west of the Rhone river mouth. For each contaminant, adjustment parameters calculated on the basis of the raw data (concentrations per dry weight) allows tdetection of contaminated locations with outlaying values. Cadmium concentrations are in the same order in the open sea and in lagoons (mean value: 1.1 μg g^{-1}), with the exception of one lagoon with concentrations up to 4.5 μg g^{-1} . Mercury background level is stable and below 0.1 μg g^{-1} with high levels in some lagoon (0.15 μg g^{-1}). High concentrations were also observed in the waters of Toulon (0.25 μg g^{-1}). Zinc and copper are stable at about 150 μg g^{-1} and 6 μg g^{-1} respectively with the exception of one lagoon (350 μg g^{-1} and 8 μg g^{-1}). Lead background level is 1.13 μg g^{-1} with extreme values in one lagoon (4.86 μg g^{-1}) and in coastal waters of large urban areas (3.5 μg g^{-1}). Levels of nickel and chromium contamination are equivalent, in lagoon and open sea (1.2 and 1 μg g^{-1}). However, a peak is observed off an old asbestos mine in northwest part of Corsica (3.2 and 3.28 μg g^{-1}). Arsenic concentrations are homogeneous (20 μg g^{-1}). For PCBs, only CBs 138 and 153 were observed at measurable levels; they are uniformly distributed. CB 153 peaks were observed in the waters off Toulon (18 ng g^{-1}), off Marseille (15 ng g^{-1}), and in one lagoon (41.5 ng g^{-1}). DDT contamination peaked in the plume of the Rhône (2.0 ng g^{-1}), but low values were recorded in lagoons. Conversely, the lagoons showed high levels in the by-products of DDT degradation, such as DDE (73.26 ng g^{-1}). Among the PAHs, only fluoranthene is present at measurable levels that fluctuate significantly, with peaks in the Languedocian lagoons, Toulon harbour and the Marseille area (23 ng g^{-1}).
Anthropogenic radionuclides of environmental concern exhibit very low levels in 41 stations along the French Mediterranean coast: ^{137}Cs is the only artificial radionuclide regularly detected in mussels with low and stable values (mean value 0.17 Bq kg^{-1} dry weight corresponding to the baseline levels found in the northwest part of the Mediterranean basin. ^{60}Co is sporadically measured at levels from 0.12 to 0.19 Bq kg^{-1} dry weight. ^{60}Co is clearly originated from releases of nuclear facilities along the Rhone River, and is considered as a reliable tracer to picture the extent of the Rhone river plume along the coast [2].

Discussion and Conclusions
The condition index distribution also provides some clues on the levels of chemical contamination, especially in the case of trace metals and radionucleides. Tissue growth is likely to mask or dilute the levels measured in the case of metals like cadmium, nickel, and chrome, which are essentially present in the structural tissues of mussel. Under these conditions, levels of metals measured in natural populations sampled on the coast are nearly identical to those obtained from transplants of mussels immersed in the open sea. However, the open-sea dilution effect is greater with organic compounds. Levels measured in mussels in artificial stations are much lower than values observed in organisms sampled directly on the coast. This phenomenon may be related to the uptake kinetics of these molecules, which are exclusively accumulated from food, adsorbed on suspended particles and stored in reserve tissues. The transplantation of mussels in caged devices is now a well-tested technique, reliable for large spatial monitoring. The method requires some training of the operating team but could be easily extended to most Mediterranean coastal waters.

References
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