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Test abnormalities in benthic foraminifera and heavy metal pollution at the Goro lagoon (Italy): a multi-year history

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Heavy metal pollution, a phenomenon causing deleterious effects on ecosystems and markedly increased over the last few decades, is believed to induce abnormalities in benthic foraminiferal tests as well as changes in abundance and taxonomical composition, size variation, and structural modification of assemblages. Accordingly, the occurrence and abundance of deformed tests might represent a powerful, easy/inexpensive bioindicator of trace metal pollution. However, response to pollutants has not always been easily distinguished from response to 'natural' variations of environmental parameters. High proportion of abnormal tests may result as well from extreme environmental conditions or from rapid changes in environmental parameters as salinity or pH.

The Goro coastal lagoon, located in the south of the Po River Delta (northern Italy) is a dynamic ecosystems, characterized by highly variable salinity and temperature gradients, extremely interesting from a naturalistic, ecological and scientific point of view. Furthermore, this area plays a significant role for the human community due to the prosperous and massive molluscan and fishing exploitation and commerce. This environment, however, is also very sensitive to the stress exerted by human activities that may affect and damage its ecological equilibrium. Considering their limited dimensions (26 Km^2) and shallow depth (mean depth 1.5 m), the Goro Lagoon is a perfect natural laboratory for a continuous biomonitoring testing the ecosystem health.

The possible relationships between the occurrence and quantity of abnormal tests in living benthic foraminifera (Rosa Bengala stained) and the heavy pollution have been investigated at the Goro Lagoon through diverse samplings during different years (2003, 2005, 2006), analyzing in the same samples the concentration of twenty trace

metals, by using standard laboratory methods of X-Radion Fluorescence.

The biocenosis proved to be substantially unchanged in its main components thorough the years and includes a low-diversity (eight species maximum) assemblages composed by three dominant opportunist species, typical of unstable environments, such as *Haynesina germanica, Ammonia tepida* and *Cribroelphidium gunteri.* The extraordinary ecological tolerance of these species enables them to tolerate extreme conditions even if producing morphological abnormalities. In fact, abnormal specimens are always present even if with different percentages varying from station to station reaching generally the maximum values in the central-northern part of the lagoon characterized by muddy sediments. The maximum percentage is also highly variable up to 100% of living forms (year 2005). Reduced size of one or more chambers, aberrant chamber shape, distorted or twisted chamber arrangement, change in coiling, twinning, abnormally protruding chambers are the identified malformations.

The comparison with a previous study performed in 1997 in the Goro Lagoon (Coccioni 2000; Environmental Micropaleontology, 15, 71-103, Kluwer Academic/Plenum Publishers, New York) shows that the heavy metal concentrations is slightly decreased in 2003 and also the percentage of deformed benthic foraminiferal tests is reduced proportionally. All these lines of evidences encourage the use of benthic foraminifera for the pollution monitoring. Conversely, this proportion has not been respected in 2005, when the percentage of deformed test is extremely high. The data on salinity and Ph suggest to excluding a natural origin of the devastating amount of deformations. Possible explanations of this apparent contradiction are: 1) the heavy metal/s responsible of test malformations have not been included in the analysis (e.g. Hg, As); 2) other pollutants (e. g., medicines, pesticides) may have caused these deleterious effects on benthic foraminifera; 3) benthic species have developed a hypersensitivity to the pollution through the years.

This long-term analysis reveals unexpected results and supports the importance of the continuous biomonitoring in natural environments coupled with laboratory analysis in order to be confident in applying foraminiferal abnormalities as a biomarker for evaluating spatial and temporal trends in heavy metal contamination.

This study is part of a long-term integrated (University of Ferrara, ENEA, Ferrara Province) program for pollution monitoring at the Goro Lagoon and belongs to the *ForamLag Scientific Project* aimed to study the response of foraminifera to contaminants.