The scientific background for the control of coastal eutrophication

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Following any dramatic eutrophication crisis, such as the huge H_2S production by decaying ulvae in Venice lagoon (August 1988) or the extensive formation of mucilage by phytoplankton along the Emilia-Romagna coast in July 1989, the question of scientific recommandations for optimal restoration of eutrophicated waters comes again to the surface, such as a mythic Loch'Ness monster... In fact, a well-documented description of the various stages and consequences of marine eutrophication came out of the previous meetings, workshops or conferences on the subject (*e.g.* for the Mediterranean: the UNEP Workshop at Bologna (Italy), 2-6 March 1987, the International Conference on Marine Coastal Eutrophication at Bologna, 21-24 March 1990, the EEC Workshop on Eutrophication-related phenomena at Roma, 28-30 May 1990...). Despite this scientific knowledge, little improvement seems to have been gained in the control of marine eutrophication, which spreads over increasing areas, according to the growing loadings of nutrients coming from land drainage and urban wastes. At this point, at least two questions arise: 1) Are the scientific programmes really focused on the aspects of the eutrophication phenomenon which are pertinent to its control ? 2) Does a real will exist in the scientific community as well as in the decision-makers sphere to build cost-effective, testable and hence, refutable restoration experiments ?

Concerning the first point, it seems of prime importance to determine which is the most efficient controlling nutrient (*i.e.* the most limiting one) and how much it has to be reduced. As pointed out by several authors (STIRN, 1988; HECKY and KILHAM, 1988), no universal agreement could be reached about the nutrient limiting the marine primary production, in contrast to the inland waters, where phosphorus has been identified. This lack of generality is partly due to the natural heterogeneity of marine waters: for instance, the mean N/P ratio for the whole Mediterranean Sea is significantly higher (19) than in the oceans (≅16). But contradictory and confusing results have been -and are still- reported, due to inappropriate use of N/P ratios in determining the most limiting nutrients: the phytoplankton growth is a dynamic process governed by fluxes of nutrients, not by instantaneous concentrations in surrounding waters. It looks as if the dynamic vision of algal growth gained twenty years ago by the physiologists using chemostats would still be ignored by ecologists working at sea: does a physiologist infer the state of nutrient limitation of his culture from the residual concentrations of nutrients in his chemostat ? As a consequence, it seems important to promote the use of techniques measuring the "point of view" of algae, *i.e.* determination of internal quotas of N and P or bioassays, which are an indirect way of measuring the fluxes of nutrients effectively available to the algae. Supposing that the limiting nutrient could be determined without any doubt, the question remains about how much it is necessary to reduce the loadings to get an appreciable effect on the system. As VOLLENWEIDER pointed out for lakes, the residence time of water in the system is the main parameter controlling the effective transformation of inorganic nutrients into algal living matter, just as in chemostat (DROOP, 1975). Instant is the need for good calculus of residence times in open coastal systems, which requires the determination of the water volume to be considered, as mentioned by LEE and JONES (1981), and a good knowledge of lagrangian residual drift (MENESGUEN and SALOMON, 1988). No reliable estimation of the acceptable level of nutrient loading can be computed without a detailed hydrodynamic background.

The second point is not a scientific one, but a psychological one. On the one hand, scientists too often take refuge behind the argument of freedom and non-profitability of the so-called "fundamental research" to avoid the danger -but also the honor- of deducing from their scientific knowledge clear and operational (*i.e.* quantitative) recommandations. It is a singular paradox that, under the cover of science, a lot of studies precisely avoid the decisive phase of testing (or refuting) their theory by experimenting in the real world, which is the only way to progress in science. On the other hand, it is also quite clear that decision makers, politicians and administrations are not always prepared to agree with scientific results and recommandations which do not fit in their planning. A good example is the controversy on the phosphate loading reductions in coastal areas where nitrogen limitation has undoubtly been established : decision makers argue on the effective role of phosphorus in triggering the eutrophication in inland waters to justify massive dephosphatation of urban sewages in these coastal areas, which is far easier than promoting reduced nitrogen fertilization on the corresponding watersheds (D'ELIA and SANDERS, 1987; MENESGUEN and SALOMON, 1988).

As a conclusion, one can say that a step forward in reducing coastal eutrophication could be obtained if all the partners would first go beyond their own psychological gap, and then bring some technical improvements.

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