

IMPACT OF ANTHROPOGENIC ACTIVITIES IN THE COASTAL REGION OF THE MEDITERRANEAN SEA

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The coastal region or zone of the Mediterranean is undoubtedly the most wellknown part of it. The beauty and variety of its landscapes have inspired some of the greatest civilisations of mankind, developed a vast number of interesting settlements and were praised by poets and artists throughout history.

As in any other part of the world, the Mediterranean coastal region is the active interface between land and sea. The anthropogenic activities developed in both its terrestrial and marine parts affect the state of the coastal environment as it could be detected and demonstrated through the analysis of a large number of physicochemical and biological parameters of marine coastal waters, sediments and biota.

The Mediterranean coastal region is also the part of the basin which has undergone the most dramatic alterations due to the rapid change of demographic trends, the new socioeconomic conditions prevailing (which favor higher consumption of natural resources) but also due to the new technologies including transport (new roads, new types of ships and therefore new harbors etc).

The resident population of the Mediterranean coastal States almost doubled over the last 40 years, exceeding today 450 millions compared to 246 millions in 1960. In the 1950s the countries of the European coast represented approximately $\frac{2}{3}$ of the total population, while today only $\frac{1}{2}$ of it and, if the current trends continue, only $\frac{1}{3}$ by the year 2025 and $\frac{1}{4}$ in 2050. The pressures exerted to the environment and natural resources (such as freshwater, soils, forests et c), due to that are obvious and are closely linked to "litoralisation" and "urbanisation" phenomena. Apparently, more than 50% (around 25000 km) of its coastline is heavily urbanised, occupied already by concrete and buildings.

The impact of cities and the resident population is amplified significantly by tourism which adds its own pressure of approximately 150 millions of arrivals per year, which are expected to increase significantly in the coming decades. Resident population and tourists produce large amounts of municipal effluents which are collected to a degree higher than 80% to municipal sewer systems. The rest are discharged either directly or indirectly to the sea or to various types of septic tanks and pits. Approximately half of the sewage networks are connected to some kind of wastewater treatment facilities, while the rest are discharged untreated to the sea mainly through large outfalls, which are among the major hotspots around the coast, contributing high loads of organic carbon, (both in dissolved and particulate phase), nutrients and other pollutants. According to a recent survey of WHO/EURO within MED-POL/UNEP Programme, 55% of 545 coastal cities and towns of more than 10000 inhabitants in 19 Mediterranean countries are served by wastewater treatment plants. About 30% of the population of coastal towns is served only by a sewage network. Taking into account that in many cases sewage treatment plants are only

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primary or function improperly (particularly if the resident population doubles or triples during the summer period due to tourism), it becomes apparent that Mediterranean inhabitants and visitors by simply living in the area and using the present infrastructures, have a significant anthropogenic impact on the coastal waters and sediments.

Apart from urban settlements, there are many other pressures. The most common classifications of environmental impacts of anthropogenic activities are made on the basis of (a) the activity / source (eg. urban, agriculture, industrial, aquaculture, mining et c) (b) the pollutant / intervention, irrespective of the source of it (eg. heavy metals, oil, POP et c) or (c) the type of the impact itself and its effect (eg. eutrophication phenomena, anoxia, "red tides" et c), which eventually might be the result of synergetic effect of several pollutants deriving from a variety of sources. All classifications are interlinked and in our brief analysis below we are using a combination of them.

It should be stressed that the analysis of the impacts of various activities in the coastal zone is a very complex and difficult process. The "fingerprints" of the various inputs vary considerably from case to case not only because of the variety of pollutants and sources, but also -and mainly- because of the specificities of the receiving microenvironment and the hydromorphological conditions prevailing.

Therefore, the overall anthropogenic impact upon the coastal region is a mosaic composed by the different types of inputs and mechanisms, some of which are predictable whereas some others might not be. Important features in the Mediterranean picture are the following:

1) The so called "hotspots" connected to permanently observed high concentrations of all kinds of pollutants such as heavy metals, Persistent Organic Pollutants (POPs), Polyaromatic Hydrocarbons, (PAHs) and nutrients from anthropogenic discharges, related to specific and well defined, permanent pollution sources. There are mostly land based, such as major outfalls for domestic sewage, industrial outlets for all kinds of industrial effluents, mine tailings. They may also be activities within the sea such as ports, coastal aquacultures, offshore oil wells etc.

In the vicinity of "hot spots" the concentrations of pollutants in waters and sediments is frequently very high. Study of sediment cores allows us to follow the evolution of the impact of hot spots, which seems to be moderately reduced in the last decade for the majority of industrial sites, due to measures taken and/or the discontinuation of polluting and economically not viable old industrial activities employing obsolete technologies (eg. several shipyards, steel mills, mining activities etc.)

The issue of aquacultures is of somewhat different nature. In one way they correspond to a natural activity similar to that observed in high productivity areas such as lagoons etc, while they could be also compared to land based intensive agricultural activities.

It is noteworthy that in the period 1984 to 1996 the aquaculture production of marine fish increased about 400-fold, mainly due to the development of cage technologies to reach approximately 250.000 tonnes. The production of the same group in brackish waters increased less than 10-fold.

A series of studies, including several of our own team, have shown a wide spectrum of impacts from these activities: from minor alterations to the abiotic characteristics of the water body below the cages (eg dissolved oxygen decrease, increase of organic carbon etc) to major changes (anoxia, significant disturbance of nutrient ratios, accumulation of significant amounts of uneaten food, faeces etc.

forming thick layers of nepheloids which inhibit oxygenation of sediments and result in major alterations of benthic fauna and flora, changes in algal blooms etc. The microbial contamination is also a pressing issue because the extensive use of therapeutic chemicals which have long-term effects on the environment may result in accumulation to benthic species and sediments with unpredictable side impacts.

2) The river mouths and deltas, the coastal lakes, lagoons, wetlands and all types of natural fresh and brackish water discharges which act as “carriers” and bring to the coastal region anthropogenic pollutants, that have entered them at different time and place, eventually long before or in a place far away from the coast.

The contribution in pollutants of the Mediterranean rivers has not been assessed thoroughly until now. It is beyond doubt, however, that rivers draining large catchment areas with agricultural lands, such as the rivers Rhone, Po, Axios, Loudias, Aliakmon and of course the Nile, are the most important point sources of agrochemicals, mostly pesticides in the Mediterranean. Among the pesticides detected are also the “new generation” ones atrazine, simazine, alachlor, molinate and metalochlor which, however, represent only very small percentage (~ 3%) of the quantities applied to cultivated lands. Rivers carry industrial chemicals too, such as polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), solvents and heavy metals (Pb, Zn, Hg, Cu, As). The metal concentrations in Mediterranean rivers are, in general, lower than those of the majority of western European rivers. This is attributed to the result of dilution of anthropogenic heavy metal loads by high levels of suspended solids of low metal content, deriving from soil erosion. The fact that in the last few decades hundreds of reservoirs from the damming of rivers have been created alters in various ways the distribution of metals: in some cases by retaining the sediment-bound metals (so the impact in the river mouth seems diminishing), while in other cases by retaining the low metal particles that “dilute” the anthropogenic load (so the impact in the estuary becomes more visible and the concentrations in the upper layer of sediment columns increase).

Rivers seem to be also major carriers of the radionuclides Cesium-137 and Plutonium-239 and 240 especially in areas where the deposition from the Chernobyl accident was significant (eg. North Adriatic and Liguro-Provençal areas).

3. The “runoff” which is less visible but very important input to the coastal waters, includes not only distinctive freshwater discharges from torrents and streams, but all small non-point discharges entering the sea in fluxes after each rainfall. Runoff carries anthropogenic substances from all types of activities through the washout of rural lands and urban areas. Runoff is a major carrier of pesticides (including insecticides, herbicides and fungicides). Their utilization has increased significantly over the last two decades due to the expansion of intensive agriculture. The largest amounts of active ingredients were applied in the north western part of the Mediterranean (approximately 100.000 tonnes per year in Spain, France and Italy). However high consumptions are noted also in other countries (such as in Turkey, ~35000 t/y) a proportion of which is washed out and carried to the coastal regions by runoff and rivers.

4. A series of anthropogenic activities taking place on the shoreline including constructions, dredgings, land reclamation and expansion into the sea (using eventually mixed mining and/or demolition wastes) or alterations indirectly induced by anthropogenic activities (such as coastal erosion, groundwater or soil salinisation etc).

5. Finally, the proximity of the coastal marine zone to a large number of sources of combustion, both fixed (industrial sources, power generating plants, waste

incinerators etc) and mobile (vehicles), emitting to the atmosphere particules, fumes and gases allow them to be deposited nearshore more than offshore contributing significantly to the overall picture. Considerable loads of lead and several other metals, PAHs, soot and other pollutants found in the coastal regions are of this origin as we have demonstrated also with works of the University of Athens team by coupling and comparing the metal signals and distributions with those of magnetic properties e.g. of magnetically active iron oxides formed during combustion.

A characteristic result of the overlapping of all the aforementioned inputs is the accumulation in a relatively narrow coastal zone of high concentrations of pollutants in seawaters and mainly in sediments where they are removed to a large extent through natural biogeochemical processes among which of paramount importance for the Mediterranean is the fresh-saline water intermixing.

Due to lack of significant tides in the Mediterranean, the intermixing zones are very restricted and the phenomena around the salinity and pH gradients are very intense and localized. It is wellknown that the fresh or low ionic strength runoff is slightly acidic or neutral. When these waters mix with the alkaline marine water, the usually abundant in the region iron ions coprecipitate with other metals and/or with organics forming iron coatings on inorganic particles, colloids and flocks most of which are deposited in rather small distance from the coast.

A series of recent works of our research group in the University of Athens demonstrate the rapid changes in the nature of species with increasing pH and salinity, resulting to distinctly diverse trends: (a) the formation of colloids, flocks and particulate matter rich in iron oxides and coprecipitated trace metals and/or organic matter sinking to the bottom and (b) the desorption of the metal ions from particles and formation of very labile species such as metal ions or metal ion pairs, with chlorides which gradually disperse to the larger water masses offshore. These processes may take place simultaneously or in sequence, in zones very close to the coastline.

The prevailing dynamic physicochemical conditions, the abundance or not of particulate matter or high molecular weight dissolved organic matter etc. govern the removal of pollutants to the sediment or its resuspension and transport of the finest fractions to deeper offshore areas of suitable hydrodynamic conditions, where they settle down and accumulate. It is noteworthy that coastal areas are characterised by high concentrations (more than 200 $\mu\text{M C}$) of dissolved organic matter (DOM), considerably more than the oceanic waters (30-90 $\mu\text{M C}$). Coastal DOM has molecular weights intermediate between those of river waters (usually >1 kDa; >10 kDa) and the oceanic seawaters (<1 kDa). In general, the contribution of the high molecular weight matter decreases from nearshore to offshore and therefore the related impact upon metal speciation also decreases when moving offshore.

From the brief overview given it becomes apparent that, on the one hand, more research and properly targeted monitoring is needed in order to assess better the situation, mechanisms and impact of specific anthropogenic activities in the coastal region of the Mediterranean, while on the other hand concerted and coordinated action is needed to reduce pollution at source and reduce the anthropogenic impact by "assisting nature". Serious strategies are being enacted in the framework of UNEP/MAP and the EU towards this direction. For their success the issue should come higher in the political agenda and citizens should be properly informed and involved.