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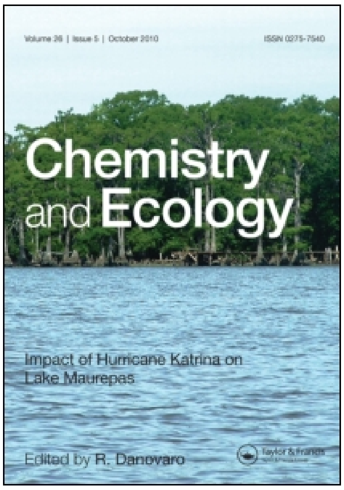

Chemistry and Ecology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455114

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To cite this Article Goldberg, Edward D.(1995) 'The Health of the Oceans - A 1994 Update', Chemistry and Ecology, 10: 1, 3 — 8
To link to this Article: DOI: 10.1080/02757549508035325
URL: http://dx.doi.org/10.1080/02757549508035325

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Chemistry and Ecology, 1995, Vol. 10, pp. 3–8
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THE HEALTH OF THE OCEANS – A 1994 UPDATE

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(Received 4 March 1994)

Three collectives of substances – plastics, plant nutrients, biotoxins – are candidates for monitoring programmes that could keep track of the quality of ocean waters for vital life processes. All three are not subject to systematic surveillance at present. They are each characterized by long residence times in the marine environment, by increasing influx, and by growing evidence of their deleterious impacts on living systems.

KEY WORDS: plastics, plant nutrients, toxins, marine ecosystems, human health

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INTRODUCTION

In 1976 I attempted to identify the challenges to the quality of the oceans as a consequence of human activities (Goldberg, 1976). This exercise has been repeated several times since then, the latest in 1990 (GESAMP, 1990). Over the past forty years many marine pollution problems have been investigated and addressed. Some polluting substances have been brought under control, such as tributyl tin, DDT and methyl mercury. Monitoring programmes have been initiated and pursued to ascertain whether or not pollutant levels in the marine environment are increasing. Some substances identified as potential pollutants, such as some metals, have turned out to be benign (Goldberg, 1992) and are no longer of serious concern.

Perspectives on marine environmental quality and the gravity of potential problems change year by year. Our concern is shifting from those that are immediately evident to those damaging in the long term. For example, the impact of eutrophication in many coastal waters may be measurable only in time periods of decades, while the discharge of a toxic waste may cause immediate and drastic acute effects, such as a fish kill.

In addition, our ability to analyze smaller and smaller amounts of substances are improving. Two decades ago, measurements in the nanomolar range were made with difficulty; today they are commonplace and can be undertaken in many laboratories. Furthermore, very subtle changes in the make-up and functioning of marine organisms and communities suggest that some ecosystems may be under stress. Some problems may even be understandable at the molecular or genetic level.

Herein I will consider several potential and real marine pollution problems, some receiving only limited or no serious attention; there are commonalities between them. The substances are appearing in the marine environment in increasing amounts and frequency; they are persistent and are shown to have detrimental effects on the vitality of the marine ecosystem.

PLASTICS

The litter so evident on beaches of the world has its origins in shipbourne waste as well on land from recreational activities, and domestic and industrial discharges. About eighty percent or so of this material is plastic, which, for all practical purposes, is not naturally degraded. The so-called biodegradable plastics constitute only a minute fraction of these discards. These materials may remain on the beaches for many months before becoming accommodated in the surface waters or in the sediments. Freshly discarded plastics are buoyant but quickly accumulate an organic coating which is associated with shells, sand or other debris and may also be colonized by epifauna. With the consequential increased density, they may sink to abyssal depths or to the sea floor. They can also be transported far from the site of their introduction by winds and ocean currents, and reach remote, even polar, regions (GESAMP, 1990).

The increase in beach-stranded litter over time is well-documented. For example, in the remote Inaccessible Island of the Tristan de Cunha, South Atlantic, there has been an almost five-fold increase between 1984 and 1990 (Ryan and Moloney, 1993). Eighty percent of the litter was plastic, with most identifiable items coming from South America some 3000 km distant. The annual accumulation of debris on thirty-six beaches at seven U.S. national parks increased significantly in the years 1989 to 1991 (Cole *et al.*, 1992); plastics constituted ninety-two percent of the materials. The US/EPA Harbor Survey programme found >90% of floating debris was plastic, including plastic pellets in eleven metropolitan areas (Redford *et al.*, 1992).

There are many types and classes of plastic materials: bottles, fishing lines, pellets used as the feedstock for plastics manufacture, six-pack yokes, bags, ropes and netting, footwear and straps. Their size ranges from millimetres or less, to metres. As they are virtually non-degradable, they will remain in the marine environment for a long time.

The actual and potential impacts of the plastic debris will occur on beaches, in surface waters and in the sediments. They will tend to accumulate in the benthos and their long-term effects there can be disastrous. Perhaps one of the most worrisome impacts is their continued accumulation to the extent that they can inhibit gas exchange between the overlying waters and the pore waters of the sediments. Further they provide a habitat for unwelcome opportunistic organisms. In either case, the plastic accumulation can seriously interfere with the normal functioning of the benthic ecosystem. In principle, anoxic conditions can develop below the plastic debris and this will lead to a change in the make-up of the assemblage of organisms. Periodic monitoring should be undertaken to determine the extent of bottom coverage by plastics in coastal areas receiving high inputs of litter, e.g., recreational beaches and sewage discharge areas, with the aim of measuring the extent, and amounts and types, of plastic and other debris on the sea floor. Several monitoring options are available: photographic, diving or submersible surveys and trawls. All are costly and can sample only a small part of an affected area. Trawl surveys appear to be the least expensive (Ribic *et al.*, 1992). Simultaneously, research to understand the dynamics of change in benthic ecosystems covered by plastic debris should be initiated.

Plastics are also hazardous to the lives of birds, fish, turtles and cetaceans through entanglement. They also interfere with metabolic processes through their ingestion – plastic fragments are often misidentified as food items and appear to block the digestive tract (Quayle, 1992). The ingestion of smaller pelleted plastic materials replaces the natural diet and can lead to starvation.

Man is also affected, sometimes colliding with plastic debris when swimming or diving. Plastics also interfere with the operation of boats and ships through

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entanglement of lines and sheets in propellers, with the intake of materials in pumped sea water often critical for cooling as at coastal power stations, and in the operation of fishing gear. The simultaneous capture and unwanted association of discarded plastic materials in the fishing catch require time-consuming sorting and result in economic loss. Finally, plastics are universally judged as aesthetically unpleasing.

EUTROPHICATION

The over-fertilization of coastal waters through the entry of plant nutrients – nitrogen, phosphorus, silicon and carbon – has resulted in a worldwide increase in biomass, in a greater degree of anoxia than in the past, and in alteration of community structure. These impacts have been seen in semi-enclosed estuaries and seas such as Chesapeake Bay, New York Bight, Southern and Northern Californian coasts, Kaneohe Bay (Hawaii), the Baltic, Oslofjord, the North Sea, the Adriatic Sea, the Black Sea, Omura Bay (Japan), among others.

Some long-term records illustrate the progressive trend towards anoxia. For example, the annual minimum oxygen concentrations in the bottom waters of fourteen coastal stations off Sweden have continuously decreased from the early 1950s and 1960s through to 1984 (Rosenberg, 1990). Rosenberg attributes these to large-scale eutrophication. He takes them to be a warning signal of potential resource losses, such as commercial fish and shellfish, unless the inputs of plant nutrients from domestic wastes and agriculture is reduced. There have been significant reductions in the extent of the benthic fauna. Similarly MONITOR (1985) has data for Landsort Deep since 1891 and shows progressive decline of oxygen and increasing incidence of anoxic conditions and production of H_2S.

The progressive development of eutrophication can take place over time periods of decades and perhaps longer, periods not usually covered by sustained surveillance programmes. Further, the spatial dimensions can extend to thousands of kilometres. If monitoring programmes are to be initiated, commitment for long-time periods and large study areas are necessary. According to participants in a Marine Board of the U.S. National Research Council Workshop (Stony Brook, New York, April 1991) extensive measurements must be included. These would distinguish any new eutrophication monitoring programmes from past surveillance efforts. In order that relevant and essential data can be gathered economically, novel methods will be needed, possibly employing satellites and buoys. The development of instruments that can monitor a range of relevant chemical and physical parameters continuously is essential.

Priority for monitoring sites could be drawn from areas with large urban populations, extensive agricultural activities, and/or valuable commercial fisheries. The programme should encompass chemical, physical and biological measurements to ascertain whether or not there are unequivocal changes in the chemical make-up of waters of the euphotic zone and the benthos and changes in the structure of marine communities. Measurements might include the following: chemical – nutrients, dissolved oxygen, chlorophyll; biological – primary production, phytoplankton species, bacterial mass and production, benthic respiration, water column respiration; physical – current speeds and directions, tides, density field, light field, vertical particle flux.

The haunting possibility of continuous changes in marine ecosystems that could result from initial alterations of the structure of the planktonic food base by eutrophication must be assessed continually. The formulation of an economic and rational programme needs to have this as its goal.

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BIOTOXINS, PATHOGENS, ALIEN ORGANISMS

If potential human mortality is used as an index of unacceptable marine pollution, toxic substances generated by marine organisms rank high. Some notorious substances bring about paralytic shellfish poisoning (PSP). The recently identified domoic acid, found in pennate diatoms, has been identified in episodes on both coasts of North America. Other substances are known to lead to morbidities such as diarrhoeic shellfish poisoning (DSP), and neurotoxic shellfish poisoning (NSP). For example, increased frequency and intensity of toxic organisms are reported for Australian waters, especially for species with PSP. In 1980 two deaths occurred and there have been others since, but none before (Hallegraff, 1987). In 1986, fifteen shellfish farms had to be shut down due to high levels of the toxin and subsequent closures of five farms were imposed in 1987.

A recent workshop (IOC, 1987), which reviewed evidence of plankton blooms and red tides throughout the world, concluded that the phenomena are global and appear to be increasing in both extent and frequency. Although primary concern is for human health jeopardized by consumption of toxic substances generated by red tide organisms and accumulated by filter feeders, the impact on shellfish and fin-fish resources, both natural and farmed, also has serious consequences. For example, red tides with *Chattonella antiquau* have caused massive kills of farmed fish, mostly yellowtail, in the Seto Inland Sea of Japan (IOC, 1987). Similar events occurred in Antifer, France (near Le Havre), where the entire stock of a maricultured fish perished after a red-tide event dominated by *Exuvialola*, with one toxin being PSP (Jenkenson, 1987). Clearly, the increasing intensity and frequency of red tides can bring about untold economic losses to fish farmers.

A recent addition to the collective of harmful marine algae is the pennate diatom *Pseudonitzschia* sp., some of which produce the toxin domoic acid. This was identified in 1987 as the cause of poisoning episodes in the Gulf of St. Lawrence, leading to both illness and deaths (Smith, 1993). In subsequent blooms, a non-toxic form of the diatom was found. Both forms are common in coastal waters in both southern and northern hemispheres. Domoic acid travels up the food chain and is not unexpectedly accumulated by mussels. It has been found in Dungeness crabs from Washington and Oregon States in 1991. Brown pelicans and cormorants which had ingested anchovies were apparently killed by the toxin (Garrison and Waltz, 1993). Domoic acid is a neurotoxin for man, leading to headaches, confusion and loss of memory.

The transport of toxic organisms from one port to another often takes place via the ballast waters of ships, adding a new dimension to the problem. For example, of the eighty cargo ships entering Australian ports, six were found to contain cysts of the toxic dinoflagellates *Alexandrium cutinella* and *A. tamarense* (Hallegraff and Bolch, 1991). Blooms of these organisms occurred in Australian waters where the organisms had not been seen previously.

PERSPECTIVE

The measurement of potential marine pollutants will reflect conventional wisdom about the changing nature of the oceans. Several interesting twists are emerging. The impact on public health was the initial concern in many marine pollution studies. Strategies to control the levels of artificial radionuclides in sea water and in marine

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organisms at levels that would protect the most exposed individual were developed in the United Kingdom in the early 1950s. These were translated into regulations to control releases from nuclear installations and to minimize risk for effective protection of the public.

In subsequent years, greater attention was directed to minimizing disturbances to ecosystems. The control of uses and management of tributyl tin and pesticides such as DDT and dieldrin have reduced damage to marine organisms and birds. But now the protection of humans from consumption of marine toxins, especially those accumulated in filter-feeding organisms, demands a new sense of direction, or perhaps redirection.

Figure Professor Edward Goldberg addressing 2IOPS participants at a dinner hosted by Professor Jiaji Zhou in the Summer Palace, Beijing.

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Experience with metals suggest that maricultured organisms may provide the most accessible and suitable sentinels of polluting conditions; the pens for culturing marine species are usually placed in coastal waters. Evidence that the health of exposed organisms has been affected is attributable to exposure of mussels to methyl mercury in Minimata Bay, Japan, of oysters to copper ion Chesapeake Bay, USA and Taiwan, and of oysters and marine snails to tributyl tin in Baie d'Archachon in France. With increasing mariculture throughout the world, perhaps systematic surveillance of the vitality of these organisms would provide an effective assessment of the quality of their ambient waters.

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