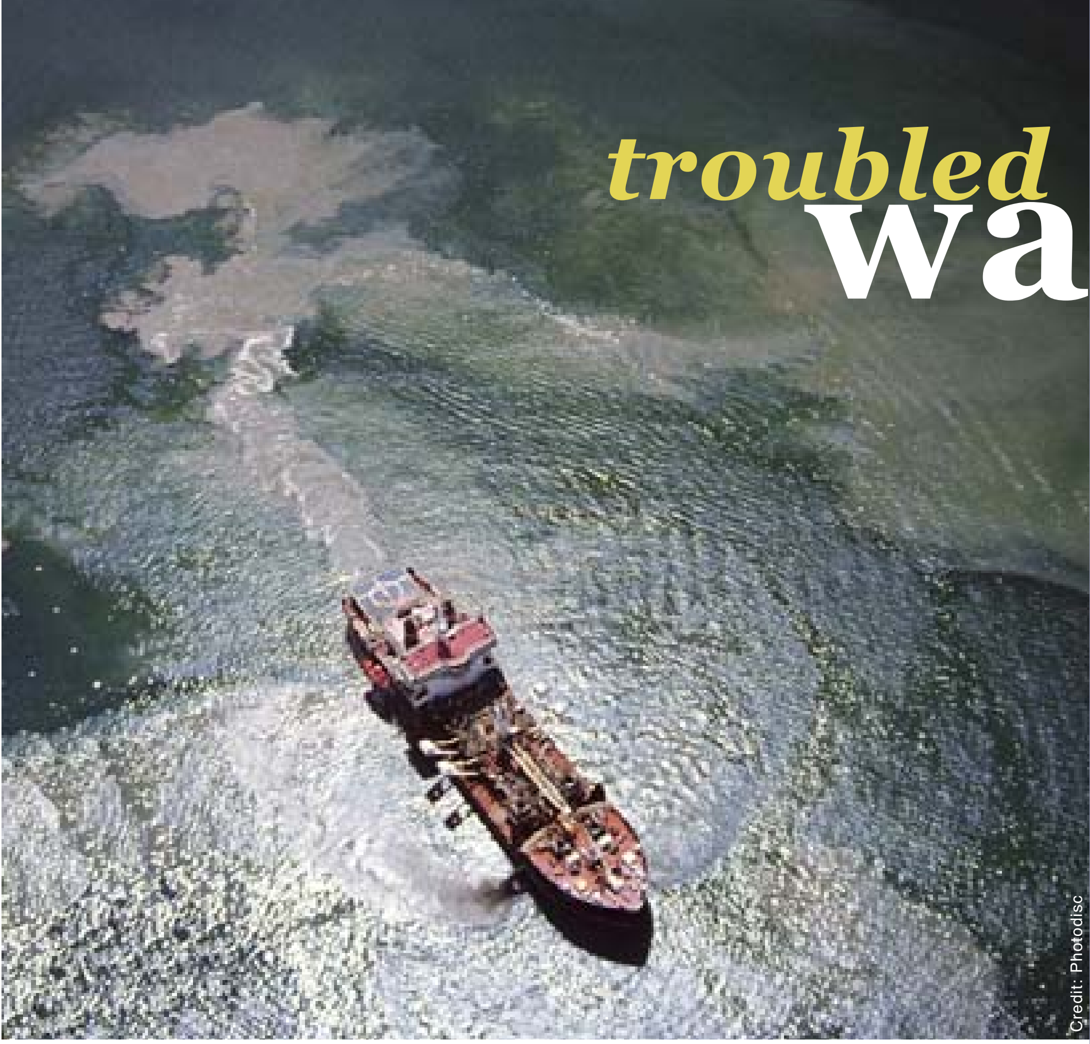

troubled waters

Human activity is polluting the marine environment and the economic livelihoods of millions who fish the seas. Science can help change the picture.

THE FUTURE OF THE OCEANS

by Alasdair D. McIntyre

The Past

"**Most things became exhausted with promiscuous use. This is not the case with the sea**." When Hugo Grotius, the famous Dutch jurist, made that remark in 1609 he was encapsulating a view of the oceans with which most would have agreed at the time. It was thought that the size and depth and mobility of the seas made them invulnerable to any effects of human activities. Yet, as early as the 11th Century, the Basques, on the Atlantic coasts of France and Spain, were killing so many whales that the stocks were soon depleted — a fate that eventually overtook other whale species around the world. This warning was disregarded. Large marine mammals were seen to be uniquely vulnerable and until the late 1800s, it was thought that marine fish stocks would never be affected in the same way. Eventually, however, fishermen began to note reduced catches, while simultaneously the expanding world population put increased pressure on fish stocks. Disturbingly, the advance of technology added to this pressure as improved boats and better trawls made fishing for bottom-living species more efficient. Pelagic fish, like herring and mackerel, traditionally difficult to locate, were also under attack as the introduction of acoustic fish-finding devices, and of huge purse seines, made it possible to detect and sweep up every shoal, so no fish on the continental shelves were safe. For a time it seemed that fast-swimming migratory species in the open sea, particularly tuna, salmon and squid, would evade capture, but the development of fine nylon drift nets, hung as curtains across hundreds of kilometres of ocean, closed that catching gap and all marine species were exposed to excessive fishing.

Although for centuries it was recognised that humans could influence marine living resources through fishing, any suggestion that other activities might alter the basic properties of the oceans was not taken seriously. This view, however, was shattered in the early 1950s with the testing of nuclear weapons in the atmosphere — one consequence of which was the fall-out of artificial radionuclides that were detected on the oceans' surface. While the concentrations were not sufficient to damage biota, their presence demonstrated incontrovertibly that humans could unwittingly alter ocean chemistry. This was rapidly confirmed over the next decade or so by a diversity of further events.

In the early 1950s, an effluent released into the sea from a factory in Minamata, Japan contaminated fish with mercury causing the deaths of local consumers. This event drew attention to the risks of marine disposal of metal-rich wastes and highlighted potential problems of other metals — particularly cadmium, lead and copper.

Sewage and urban waste-water from the local population constitute another discharge that was routinely piped untreated on to the coast posing health hazards due to the pathogens carried in the sewage. It contaminates seafood that accumulates human pathogens causing hepatitis, cholera and a range of gastro-enteric diseases. Recreational users of the coast are also at risk from contaminated seawater. Swimmers, wind surfers, water skiers, and even those using beaches for relaxation can be affected by minor illnesses. The need for proper treatment and disposal of sewage is now widely recognised, and, in some countries, monitoring of shell-fisheries and bathing water is mandatory.

In addition, since sewage is high in nutrients, it can lead to over-fertilisation of plants. This eutrophication produces excessive blooms of seaweeds on the shore and of phytoplankton in the water column. When these plants decay, it results in the accumulation of large volumes of sludge on beaches, damaging amenities and tourism. Meanwhile, their bacterial decomposition depletes the water of oxygen causing the deaths of marine organisms. Additionally, some phytoplankton species are toxic and there has been a dramatic recent increase in harmful algal blooms (*see box: Shell Shock*). The problem of eutrophication is further exacerbated by nutrients in land run-off from agriculture and intensive stock rearing. Even though monitoring programmes are routine in many countries, these problems cause global economic losses and human deaths.

Metals and nutrients occur naturally in seawater and, if the concentration is not excessive, organisms should be able to live with them. However, synthetic organic compounds constitute a very different class of

Shell Shock

Bolinao, Philippines — Suddenly, in the early days of February 2002, milkfish started floating to the surface of the clouded ocean waters. Hundreds of tonnes of milkfish (locally known as bangus) valued at millions of dollars were dying in their cages and traps, and beginning to decompose *en masse* on local beaches. The coastal town of Bolinao in western Luzon—one of the principal sources of fresh seafood for Metro Manila—was rapidly turning from prosperity to an economic and environmental disaster area.

"We knew that the heavy concentration of aquaculture in the area made it extremely vulnerable to an algal bloom at some point," says Professor Rhodora Azanza of the Marine Science Institute of the University of the Philippines (UPMSI). "But the severity and magnitude of the fish kill was nearly unprecedented, and the nature of the phytoplankton bloom causing all the damage remained a mystery."

It was critically important to find out. Some algal blooms are laden with a toxin that can concentrate in mussels, clams, and other shellfish and be lethal to consumers. Scientists call these varieties Harmful Algal Blooms (HABs). One health condition they can cause is paralytic shellfish poisoning (PSP), characterized by death from respiratory arrest. Dr. Azanza and her team at UPMSI went to work quickly analyzing water and shellfish samples in their laboratory in Quezon City. Within days, and thanks to a powerful microscope provided by the IAEA, they informed the concerned public that a phytoplankton, Prorocentrum minimum, was the source of the bloom. While it had killed a lot of fish, it posed no toxic danger to humans.

While the news was good, the incident points to a much more extensive set of environmental problems that are not about to go away. With more than 7,000 islands spread across thousands of square kilometres of tropical seas, the Philippines is a fisherman's wonderland—and an ideal location for aquaculture, the cultivation of seafood in artificial environments.

But along with the growth of coastal aquaculture over the past two decades, the incidence of "red tides" like the one in Bolinao and toxic algal blooms causing PSP have been on a rapid rise. There are now 17 coastal areas across the country that are known to have been affected by an algal agent known as Pyrodinium bahamense var. compressum, and some 1,800 cases of PSP have been reported and over 110 deaths over the period.

The government agency in charge of tracking HABs is the Philippine Bureau of Fisheries and Aquatic Resources (BFAR), which has established monitoring stations across much of the country and a central laboratory to conduct toxic testing of water and shellfish. According to BFAR's senior aquaculturist, Fe Bajarias, "Our labs are constantly monitoring to ensure safety for the public. While our warning system is working, our methods of testing and analysis would benefit from more advanced knowledge and testing technologies."

BFAR's shellfish testing laboratories were relying on using live mice – an inaccurate, time-consuming and inhumane methodology. However, since 1997, an IAEA Technical Cooperation project has been working to transfer a more scientifically advanced and precise method—the receptor binding assay technology—to assist the government in evaluating shellfish toxins resulting from increasingly frequent toxic "red tides."

Researcher Iris Baula of the Marine Sciences Institute gathers water samples in Manila Bay using equipment supplied by the IAEA. The Institute is tracking the history of algal bloom incidences in the Bay in order to better forecast and prevent new occurrences.
(Credit: Kinley/IAEA)

The nuclear techniques rapidly detect toxicity in marine foods contaminated with toxins produced by harmful algal blooms. The new testing method gives the maritime industry greater certainty that the algal bloom outbreak is genuine, before they are forced to close-up shop. One immediate result would be more timely and accurate warnings to seafood consumers which should help reduce the number of food poisonings from algal blooms. It also comes as a relief to sea towns and villages hit by job layoffs and tourist slumps every time there is an algal bloom scare.

The Philippine Nuclear Research Institute (PNRI) and UPMSI have been making excellent progress in adopting the new method and are already providing backup testing and analysis for the conventional laboratories operated by BFAR. "Within a few years, we expect that the nuclear technique will assume the lead role in ensuring safety for the public, " says Professor Azanza.

— by David Kinley, IAEA Division of Public Information.

Read more about this and other IAEA Technical Cooperation projects in *Science Serving People, Technical Cooperation for Development*, accessible on the IAEA WorldAtom website at: http://www.iaea.org/worldatom/Press/Booklets/Ssp/algal.html

pollutant and, in the 1960s, were a significant addition to the list of problems. Residues of pesticides, particularly DDT and industrial chemicals such as PCBs, began to appear in the environment. These chemicals are toxic, highly persistent and fat-soluble, which means build up in the tissues of animals. They are passed up the food chain and accumulate in and cause damage to top predators like marine mammals and sea birds. A more recently identified threat came from another synthetic organic compound, tributyl tin (TBT), a constituent of paint used to protect ships' hulls and other underwater structures from fouling organisms. TBT was found to impact non-target animals, devastating populations of marine snails by causing sex change, and more importantly from the commercial point of view, producing shell-thickening in oysters thereby reducing the fishery.

Plastics, another group of synthetic organic compounds, have significant impact on the oceans. The increasing replacement of natural materials with synthetics for many types of manufactured goods has resulted in the proliferation of light, persistent debris in the form of fishing nets, straps, bands, containers, sheeting and even fine particles that float in the sea. Although chemically inert, this debris interferes with, and often kills, marine life and causes major amenity deterioration on beaches.

Oil is another contaminant that came to the fore in the 1960s. Oil has been a problem since the time it was first used as fuel for ships but in the early days the issue was operational discharges of wastes, including bilge and tank washings. However, as oil was increasingly transported as cargo rather than just in ships' bunkers, and as the size of tankers grew, so did the fear of wrecks. Alarm mounted in the 1960s with the building of very large crude carriers. And, in 1967 when the "Torrey Canyon" ran aground in the English Channel releasing 100,000 tonnes of crude oil, these fears were validated. This was only the first of many large spills, forcing us to confront an entirely new situation. Fortunately, learning was rapid. Initially, industrial detergents were used on the slicks but these were more toxic than the oil itself and were replaced by sophisticated chemical dispersants with different formulations tailored to the type of oil. Also, environmentalists devised and tested a variety of alternative approaches to clean-up. But perhaps even more relevant, it was recognised that the prime requirement was to prevent accidents from occurring. Governments in several countries extensively examined the whole issue of the safety of ships at sea. Official inquiries focused on accidents at sea and made recommendations on such basic matters as the design, structure, crew and route of ships.

While the transport of oil at sea is of major concern, the offshore production of gas and oil poses environmental threats that are quite independent of shipping and occur at every stage of the operation. In the exploratory phase, seismic surveys can damage marine mammals and disturb migration and shoaling of fish. Once production starts there are the possibilities of spills and blowouts from platforms, discharges of drilling muds, chemicals and production water as well as accidents to pipelines.

In addition to the discharge of potentially polluting chemicals to the oceans, the input of organisms is attracting attention. There are several ways by which humans can transfer non-indigenous species from one ecosystem to another. These include transport on vessel hulls, intentional and unintentional release via aquaculture and movement through connecting waterways. But today the most frequent mechanism is in ships' ballast water and it is estimated that as many as 7,000 different species are carried around the world in this way every day. When discharged into new habitats, these exotic species may survive, disrupting the native ecology, impacting economic activities, and even affecting human health. Indeed, invasive marine species are now regarded as one of the major threats to the world's oceans and the International Maritime Organization (IMO) is engaged in an extensive programme of study, in collaboration with other international agencies, particularly the Global Environment Facility (GEF) and United Nations Development Programme (UNDP), to address the problem.

Coastal development is another human activity causing direct consequences to the marine environment. Building harbours and industrial installations and constructing hotels, marinas and other tourist facilities require draining wetlands and concreting the coastline. This type of "development" triggers the destruction of natural habitats and the loss of nursery grounds for fish. In the Mediterranean, nearly half of the Spanish coast is now affected by tourist construction, while on the French Riviera, and around Alexandria, Athens, Istanbul and Naples, much of the coast is already developed. Similar construction is underway in the Caribbean and other attractive tourist regions. As well as changes at the land/sea interface, activities in the hinterland, sometimes hundreds of kilometres from the sea, can be detrimental to the coast.

The manipulation of hydrological cycles by dams and irrigation schemes can alter the hydrographic regimes in estuaries, increasing the salinity of normally brackish waters and reducing the sediment input. The opposite effect is created by land use practices such as deforestation which can result in soil erosion and consequent silting up of marine habitats where the biota have evolved in clear water and so require low turbidity for survival.

The Present

In assessing the state of the ocean today, it is useful to think in terms of its general condition and consider its living resources. The good news is that the waters of the open ocean are in reasonable chemical health. They receive contaminant inputs from two major sources — the atmosphere and shipping. Atmospheric input is a diverse mixture of all the pollutants already mentioned which mingle in the air carried around the world, and eventually fall out by wet or dry deposition. However, due to dilution and the long residence time often associated with atmospheric transport, the oceanic fallout, although measurable, leads to only low concentrations in surface waters so that significant impacts on marine biota are not detected. The shipping input is more concentrated, but is confined to traffic lanes, and tends to be rapidly dispersed and diluted — although persistent materials that float, like plastics and tar balls, can be carried great distances and accumulate on beaches. Fortunately, shipping issues are well addressed by the IMO and in particular with reference to pollution by the MARPOL 73/78 Convention, which is a dynamic instrument evolving to meet new situations.

In contrast to the open ocean, the coastal zones of the world present a very different picture. As most of the polluting inputs come from the continental landmasses, near-shore areas are significantly at risk, and the adjacent shelf seas are also threatened. Degradation is particularly acute in estuaries where industry is concentrated and in coastal areas where major rivers carry wastes from the hinterland to the sea. Semi-enclosed bays that have extensive urban or farming hinterland, and are poorly flushed by the open ocean, are also highly vulnerable.

As for the living resources, in spite of earlier fears, marine pollution has not been the threat that was feared. Indeed, the danger to them is more direct — the impact of excessive exploitation. The decline of catches of the preferred species, and the collapse of important stocks is now all too clear, and fishing communities are under great pressure. Today, of the major fish stocks throughout the world, 47% are fully exploited, 18% are over-fished, and 9% are depleted.

The Future

In the light of this review, what can we say about the future of the oceans? One issue closely watched is global climate change. The major drivers of this are thought to be anthropogenic carbon dioxide and aerosols released by humans into the air. Climate warming will cause ocean temperatures to rise and its volume to expand, as well as melting of land-based ice that will add fresh water to the oceans. As a consequence, the sea level will rise. Unfortunately, we do not yet have sufficient understanding of the many processes at work in the ocean-atmosphere system to make accurate predictions about the physical changes that will certainly occur — nor can we be clear about the biological effects of changes in level and temperature of the oceans. One major question is how to distinguish between natural variability in the oceans and change caused by human activities. Researchers are intensively seeking answers to this and other relevant questions.

Although climate change for the moment is an imponderable, what we can evaluate about the state of marine pollution is more optimistic. The rise of public awareness is most encouraging, demonstrated not least by the widespread support for environmental non-government organisations such as World Wildlife Fund (WWF), Friends of the Earth and Greenpeace. Thanks to their efforts, industry and governments are increasingly aware of the need to take account of environmental issues. Witness the fact that the annual report of every oil and gas company these days includes a major section on this topic. In general, the future looks promising if only because consciousness of the need to improve the condition of the seas is firmly reflected in numerous international treaties and agreements. These may not all be globally ratified, but the framework is in place. In addition, regular so-called environmental summits occur and while they can be criticised for not being entirely effective, they do focus attention on the important topics and stimulate government action.

One aspect of real concern is the future of fisheries. Clearly fish, unlike oil, have the potential to constitute a sustainable resource if properly managed. It is generally agreed that a reduction in fishing effort is essential to ensure sustainable fish stocks. And, and last, it is recognised that stocks must be managed not species-by-species or fishery-by-fishery, but in the context of whole ecosystems. However only fishermen and politicians can take the required action. Unfortunately most fishermen do not address the question adequately. They are unwilling to look ahead and seem unable to appreciate that short-term profit equals long-term destruction. The central problem is that most politicians have not, so far, been effective in persuading the fishermen who are their constituents. The science is now available to provide the necessary advice to management. Also, it is essential to involve the fishing industry in management decisions and to take proper account of socio-economic aspects. Thus, while all the elements for good management are in place, it is by no means clear today that the necessary action will be taken to ensure sustainable fisheries. However, there are some hopeful signs. Public awareness of the problem is increasing and politicians do seem to be backing action, albeit reluctantly. This is reflected in the recommendations from the recent Johannesburg Summit on Sustainable Development that called for the restoration of the world's heavily depleted fish stocks by the year 2015. This may be unattainable, but it is worth aiming for the target.

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Tapping Ocean Water

Designers of nuclear power plants are more closely eyeing the developing world by crafting reactors that can serve a dual purpose — to produce electricity and economically turn seawater into fresh drinking water. The twin production system is known as “nuclear desalination”.

Economics holds the key to the future of nuclear desalination, experts say, with advanced reactor designs now promising reduced costs in turning seawater into freshwater. For developing countries facing water crises, it is a major drawing card.

The technology of desalination — or desalting seawater — is not new. Over the past fifty years, its use has grown, particularly in the Middle East and North Africa, where freshwater is scarce. More than 7000 desalination facilities are operating worldwide. The facilities are energy intensive, and usually draw the steam or electricity they need from conventional fossil-fueled plants. But as environmental concerns grow over greenhouse gas emissions, other cleaner sources of energy are being sought.

The technology of coupling nuclear energy and desalination plants already has taken hold in Japan and Kazakhstan, where commercial facilities have been operating since the 1970s.

At an international conference on nuclear desalination, held in Morocco in late 2002, specialists from more than 35 countries assessed global developments, including the prospects for nuclear plants. Participants heard that advanced High-Temperature Gas-Cooled Reactor designs were a competitive, safe and cleaner alternative to conventional fossil-fueled plants. As well as generating electricity, when coupled with a desalination facility the reactors could produce freshwater for about a dollar for two cubic meters.

India aims to have its demonstration desalination plant being built at Kalpakkam in the southeast of the country operating in 2003. The jury is still out on its cost effectiveness, as it uses an older model heavy water reactor. It will, however, provide training and research in finding solutions to the freshwater shortages facing the people of southern India.

The IAEA’s Mr. Mabrouk Methnani, a technical officer in the IAEA Section on Nuclear Power Technology Development, said in the past, designers of nuclear reactors did not account for the developing world. “No emphasis was made to coupling a desalination unit with the reactor. The picture is changing, with small and medium reactors being developed for this purpose,” he said.

The conference was told that Pakistan intends to tackle its freshwater shortages using nuclear desalination, with plans to have a facility operating by 2005. The IAEA has been requested to provide technical assistance, as it has done with India.

The conference was organized by two non-governmental organizations — the World Council of Nuclear Workers (WONUC) and the Moroccan Association of Nuclear Engineers (AIGAM) — with the IAEA and the World Water Council playing cooperative roles. At the conference, Agency experts hosted a day-long session on “Advances in Nuclear Desalination”. The session was largely technical in nature, emphasizing technology features, including design, coupling, economics and safety aspects of nuclear desalination plants. Many authors referred to the IAEA programme known as DEEP — which stands for the Desalination Economic Evaluation Programme — as their main tool for analyzing nuclear desalination and called for further development of it. DEEP is the only existing tool that provides initial estimates of the costs of nuclear desalination verses conventional desalination.

For more information, visit the IAEA’s web pages at http://www.iaea.org/programmes/ne/nenp/nptds/ndesal/index.htm