HUMAN PERTURBATIONS

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Summary

For millennia, humans have been making great use of the oceans in a variety of ways. First and foremost is as a habitat, with over half of the world's population now living within 100 km of the coastline and most urban areas having concurrently developed along the coasts largely on account of their access to transportation: quays and wharves have been erected for ships to be tied up, ports and shipping channels have been dredged for the purpose of navigation. Levies, meanwhile, have been imposed to support all of these facilities.

Along with the use of the ocean space, large chunks of wetlands and shallow shelves have been 'reclaimed', transforming them into such facilities and amenities as industrial sites, settlements, airports, military bases and recreation centers, or simply for use as dumping sites. With this has come a price: the discharge of domestic and industrial effluents as well as agricultural wastes, all being cast off into the coastal oceans. Added to this are thermal effluents from power plants, which add heat, frequently unwanted, and radionuclides - again thoughtlessly discharged into the coastal environment (see *Natural and Anthropogenic Radionuclides*).

It goes without saying, therefore, that marine pollution is most severe in the coastal zones. The following sections discuss trace metals, pesticides and organic compounds, while making reference to current efforts being made towards international collaborations for marine pollution mitigation and control. (see *Non Radioactive Ocean Pollution; Ocean Regeneration*). This section presents the less noted, but more widespread, problems with regard to nutrients and carbon dioxide, by presenting an overview of what is known about the distribution of carbon and associated biogenic elements (namely, nitrogen, phosphorus and silicon) in the oceans. The penetration of anthropogenic CO_2 in to coastal areas and oceans is also described.

Anthropogenic CO_2 has penetrated below the thermocline everywhere in the Atlantic, but to a much greater extent on its western side. Evidence of this is that the deepest penetration of excess CO_2 in the Atlantic is found in the northwest region, where excess CO_2 actually reaches the sea floor. Other than this, the deepest excess CO_2 penetration occurs near 40°S. In contrast, winter surface sea ice coverage and intensive upwelling of old Circumpolar Deep Water (CDW) in the Weddell Sea in the Atlantic east of the Antarctic Peninsula prevent excess CO_2 from moving freely across the air-sea boundary or from being advected downward. As a result, little excess CO_2 is found below 200 m in the Weddell Gyre.

The major difference between the Atlantic Ocean and the Pacific is that excess CO_2 does not penetrate much deeper than the permanent thermocline in the Pacific Ocean except in the Sea of Japan. Overall, excess CO_2 penetrates to a shallower depth in the Equatorial Pacific than in the Atlantic, with the shallowest penetration outside of the Southern Ocean, in fact, occurring in the eastern Equatorial region where excess CO_2 only penetrates to 400 m or less. Very much like the trend in the Weddell Sea, in the region around 65°S, intensive upwelling prevents excess CO_2 from reaching more than the 200 meter depth. It appears, however, that penetration may extend as deep as 800 m in the western Pacific. Excess CO_2 penetrates even deeper in areas farther south, and reaches more than 1 000 m off Cape Adare at the northwest corner of the Ross Sea in the Pacific along the coast of Antarctica. The deepest excess CO_2 penetration in the South Pacific occurs around 45°S near the Subantarctic Mode Water. The deepest penetration in the North Pacific occurs in the confluence, or joining point, of the Kuroshio and Oyashio Currents where the North Pacific Intermediate Water (NPIW) originates.

No deep excess CO_2 penetration can be found in the northern part of the Indian Ocean, except in the Red Sea because there is no bottom water formation in the North Indian Ocean. The major difference between the Indian and the Pacific Ocean is that excess CO_2 penetrates much deeper in the Equatorial Indian Ocean, perhaps because of weaker upwelling relative to that in the Pacific Ocean.

In the following sections, Asian marginal seas in the Northwest Pacific Ocean are presented in the form of case studies. Recent shelf-related studies indicate that the eutrophication-derived carbon deposits on continental margins and in marginal seas may not account for the missing anthropogenic CO_2. Nevertheless, the marginal seas do serve as important links in the global carbon cycle.

Deep marginal seas, which have larger bodies of water, especially those with deep water formation, may be non-negligible sinks for excess CO_2. It is estimated that seawater in the marginal seas in the North Pacific alone may have taken up over 1 Gt (10^{15} g) of excess carbon, including 0.19±0.05 Gt for the Bering Sea, 0.31±0.05 Gt for the Sea of Japan, 0.07±0.02 Gt for the East China and Yellow Seas and 0.50±0.1 Gt for the South China Sea

More importantly, high latitude marginal seas, such as the Okhotsk Sea and the Bering Sea, may act as "conveyer belts" in exporting excess CO_2 to the North Pacific Intermediate Water. The upward migration of calcite and aragonite saturation horizons may also make the shelf deposits on the Okhotsk and Bering Seas more susceptible to dissolution, which would neutralize excess CO_2.

1. Introduction

In this section, we shall first present an overview of the impact of human perturbations on marine coastal areas; this will then be followed by a brief discussion of the influences of such disturbances on the atmosphere. To start with, the marine environment is a highly fragile one because of the wide variety of foreign material that is continuously introduced into it both intentionally and unintentionally. Simply stated, the marine environment has, in some areas, become a mere receptacle for untreated sewage, oil and industrial wastes, fertilizers and pesticides.

The major threats to the marine environment come from the land, with the most serious sources of pollution being nutrients, products linked with microbial activity and pesticides used in agriculture. Pollution from hydrocarbons and the dumping of toxic products is generally less severe. Although industrial wastes can sometimes have an adverse effect locally, they are by and large less important on the grand scale than other substances which reach the sea from several different sources.

To be more specific, what the coastal and continental shelf zones suffer from most is the effect of riverine inputs into the sea. In the open oceans, these waters are constantly dispersed by currents, which automatically reduces the threat of contamination. In contrast, danger from the potential toxicity of various sediments is surely reinforced when these elements are trapped in coastal systems, such as estuaries, deltas and coastal lagoons, whose fragility is much greater and whose survival is more prone to abrupt and irreversible destruction than the open oceans.

Although pollutants from natural sources inflict great harm on marine organisms like fish all over the world, there are so many more problems. The overexploitation of marine flora and fauna is another problem. The eradication of marine mammals, the destruction of the sea bed by trawling, the loss of the fauna of coral reefs, the overdevelopment of the coasts, the demise of fish breeding areas and the dumping of toxic wastes provide further evidence of the misuse and abuse of the seas today. According to the International Maritime Organization, 23 countries or regions issued 1,208 permits to allow for sea disposal and incineration in 1997. The People's Republic of China (PRC) ranked number 1 in terms of the number of permits with 538, followed by the United Kingdom (182), Hong Kong (126), Canada (91), Norway (66) and the United States (56). The PRC and Hong Kong also ranked first and second, respectively, with regard to the total amount of material cast off, with about 65×10^6 tons and 29×10^6 tons, respectively, most of it being dredged and excavated material and construction waste. Other countries dumped wastes from food and beverage processing, those from the textile industry, fish wastes, explosives, vessels, as well as bark and chips. However, even the most unexpected is thrown away. To cite a prime example, the PRC issued 14 permits to dump human remains.

Having briefly taken a look at the extent of human disturbances on the marine environment, we now turn to the impact of such perturbations on the atmosphere. Although carbon dioxide constitutes only a small percentage (0.036 percent) of the atmospheric composition, it is an essential and beneficial compound for life, and changes in its concentration, be they intentional or not, obviously have serious, long-lasting effects on the global thermal regime, and on the totality of life as we know it today. For this reason, the impact of changing atmospheric conditions has been studied as far back as recorded history. The importance of carbon dioxide is nothing new. On the contrary, from a historical perspective, as early as 1827, French mathematician and physicist, J.B.J. Fourier (1768-1830), claimed that the atmosphere acts like "the glass of a hothouse, because it lets through the light rays of the sun but retains the dark rays from the ground". Soon after, British physicist, John Tyndall (1820-1893), noted that the elemental gases, hydrogen, oxygen and nitrogen mixed in the atmosphere, have much less absorptive and radiative capacity than do the compound gases. Hence, he was convinced that air was a mixture and not a compound. His experiments showed that compounds in the air, such as "carbonic acid" (the nineteenth century term for carbon dioxide) or nitrous oxide, have absorptive and radiative powers much greater than air or the elemental gases alone. He demonstrated that, at certain pressures, absorption by "carbonic acid" was about 150 times greater than that of oxygen on its own.

J. Tyndall reported that various scientists, including Swiss linguist, F. De Saussure (1857-1913), and J.B.J. Fourier, regarded, "...the interception of the terrestrial rays as exercising the most important influence on climate." Tyndall firmly believed that the compound gases augment "the differential action" between the heat coming from the sun to the Earth and the heat radiating from the Earth into space. This led him to the conclusion that, "It is not, therefore, necessary to assume alterations in the density and height of the atmosphere to account for different amounts of heat being preserved on the Earth at different times; a slight change in its variable constituents would suffice for this. Such changes in fact may have produced all the mutations of climate which the research of geologists reveals - the extent alone of the operation remaining doubtful."

As far back as 1896, the distinguished Swedish chemist, S. A. Arrhenius (1859-1927), predicted that increases in CO_2 in the atmosphere would warm the Earth by as much as 9^{o}C if the CO_2 level of his day were to triple. He calculated that this 9^{o}C warmer temperature was what was found in the balmy Tertiary Arctic regions. By the same token, for the Ice Age temperatures to prevail between the 40th and 50th parallels, he reckoned, the CO_2 level would have to sink to 55-62 percent of the level of his day, which translates to a 4-5^{o}C drop in temperature. Well-known American geologist and proponent of the principle of multiple working hypotheses, T.C. Chamberlin (1843-1928), proposed alternative ideas that variations in climate, such as the advent of glaciation, could have been triggered by geologic processes that altered the carbon dioxide concentration in the atmosphere. Though there are some differences in these theories, they all emphasize the important effect CO_2 has on climate variations.

Since those early astute observations, much research has been conducted to investigate whether an increase in CO_2 causes what is known as the "greenhouse effect." The radiating spectrum from the 6 000 K sun peaks in the visible range (about 0.55m), while radiation from the ~300 K Earth peaks at 11 m, in the infrared. The difference in these wavelengths is fundamental to the understanding of the greenhouse effect. CO_2 and other gases, such as methane, chlorofluorocarbons, nitrous oxide and water vapor, allow the visible or near-visible radiation spectrum of the sun to penetrate to the Earth, thereby warming it. These same gases, however, block the reradiation of the infrared rays from the Earth back to space by absorbing them. As such, the gases act as a blanket for the Earth to keep its warmth. Any imbalance between the incoming and outgoing radiation would of course cause the Earth to become warmer, with higher average temperatures.

The greenhouse effect has been the subject of deep concern for scientists, economists, politicians and the public at large. Their concern is partly generated from the knowledge that the continuous increase in atmospheric CO_2 content has been largely caused by the burning of fossil fuels and the large-scale clearing of forests, activities that are deeply rooted human means of survival and are the very foundation of modern industrial society. Meanwhile, still many others are still not aware that 'development' very often goes hand-in-hand with excess CO_2.

The oceans act as a sink for excess CO_2 in the atmosphere although at present it is unlikely that they can remove such an excess at a rate that can keep up with the extent and speed of perturbations caused by Humans. In other words, it is hoped that the CO_2 increase does not affect life on Earth too drastically. Aggravating the whole dilemma has been the constant rise in population, particularly in developing countries, and the need to cultivate more and more farmland by deforestation in order to feed the growing population. As also mentioned earlier, the growing population is settling in, developing and altering our marine coastal areas. At the same time, in spite of conservationists' efforts, people living in highly industrialized nations are not likely to lower their standard of living or 'quality of life' substantially, so it is not expected that fuel consumption will decrease either. Many symposia and conferences have been held to evaluate and seek solutions to the questions of both CO_2 and marine coastal area. Experts in various fields have debated the issues at social, scientific and even political gatherings, which has resulted in the publication of numerous books, articles and reports. Related readioactive and non-radioactive marine pollution is discussed in *Natural and Anthropogenic Radionuclides*; *Non-radioactive Ocean Pollution*. What follows is a description of human perturbations as concerns nutrients and carbon dioxide.

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Biographical Sketch

Prof. Chen-Tung Arthur Chen was born in Changhwa, Taiwan, on 22 April 1949, Prof. Chen-Tung Arthur Chen, his wife and two daughters are currently residing in Kaohsiung, where he has been Professor at the Institute of Marine Geology and Chemistry since 1986. After receiving his B.Sc. degree in Chemical Engineering from National Taiwan University in 1970, Prof. Chen was awarded his Ph.D. degree in Chemical Oceanography from the University of Miami in 1977. In the same year, he was appointed Assistant Professor in the College of Marine Sciences of Oregon State University, where he was later promoted to Associate Professor in 1981. He served as Visiting Professor at National Sun Yat-Sen University (NSYSU) in Kaohsiung, Taiwan, and as Chargé de Recherche (CNRS), Université Pierre et Marie Curie in Paris during 1984-1985. During this period, he founded the Institute of Marine Geology at NSYSU, and served as its director until 1989 when he was made Dean of the College of Marine Sciences, a position he held until 1992.

Prof. Chen has sat on numerous international committees, including the Scientific Committee on Oceanic Research and the World Ocean Circulation Experiment. He also served as one of the executives of the Scientific Steering Committee of the Joint Global Ocean Flux Study (JGOFS) between 1992–1995. Just prior to that, he had helped to form the Joint JGOFS / LOICZ Marginal Seas Task Team in 1991, and served as its chairman until 1995. Prof. Chen is at present one of the editors of Oceanography Journal and associate editor of Marine Chemistry. Besides having more than 150 of his own scientific papers published, Professor Chen was awarded the highly-coveted Biowako Prize for Ecology from Japan in 1997.