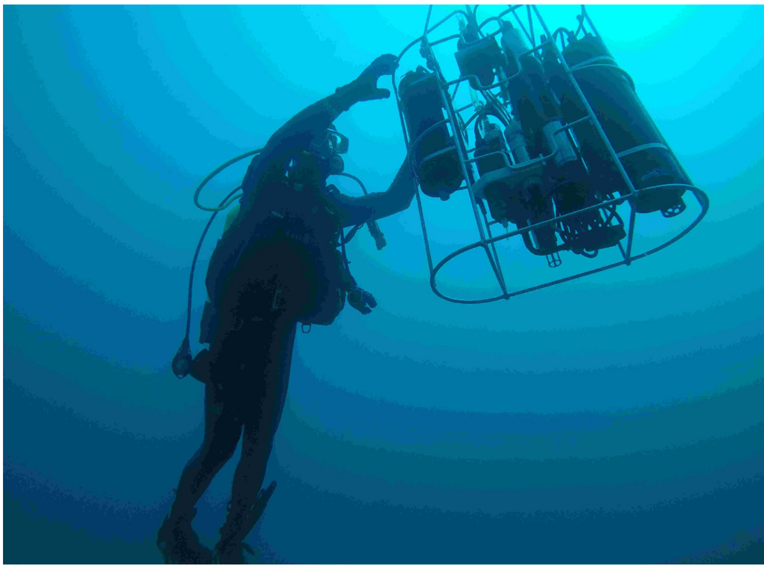
Nuclear and Isotopic Techniques Help Assess Ocean Acidification and Climate Change Impacts

SUMMARY

- The factors that determine climate are complex. Oceans store about one quarter of the carbon dioxide (CO_2) emitted through human activities, and play an important role in limiting impacts of climate change.
- Increasing carbon emissions and rising temperatures are disrupting oceanic processes, with potentially major consequences for marine ecosystems, the global climate, shoreline protection and coastal industries such as fisheries and tourism.
- In order to understand and anticipate potential changes in the climate, it is important to understand the processes involved in the global carbon cycle.
- Increasing levels of CO_2 in the atmosphere cause global warming leading to ocean temperature increase, but also ocean acidification, sometimes referred to as 'the other CO_2 problem' alongside climate change.
- The IAEA supports Member States in using radioisotopes to understand the ocean carbon cycle and the ways ocean acidification can affect the marine environment and critical ecosystem services.



IAEA researchers measure parameters such as sea temperature and salinity to increase their understanding of the global carbon cycle and factors which can impact it.
(Photo: R. Cassi/IAEA)

INTRODUCTION: THE LINK BETWEEN THE OCEANS AND CLIMATE

The global carbon cycle describes the fluxes of carbon between different environmental compartments (atmosphere, ocean, terrestrial biosphere and sediments). This carbon may be for example in the form of carbon dioxide (CO_2) or methane (CH_4), both prominent greenhouse gases. It is essential to quantify these changes and stocks of carbon accurately in order to construct the climate models used to predict the impacts of climate change.

At least one quarter of the CO_2 released into the atmosphere by anthropogenic activities such as the burning of fossil fuels is taken up by the ocean. Some of this CO_2 returns to the atmosphere, and some is exported from surface waters to the deep ocean, where the reservoir of carbon is 50 times larger than that stored in the atmosphere. The ocean provides a vital service to nature through this capacity to regulate atmospheric CO_2 emissions.

A change in fluxes to the ocean carbon pool, such as those caused by human activity, could affect the storage capacity of the ocean, which in turn would have dramatic consequences for atmospheric CO_2 levels. In addition, an increasingly warm and acidified ocean will be unable to absorb the same quantities of CO_2, resulting in higher concentrations of CO_2 remaining in the atmosphere and worsening global warming.

OCEAN ACIDIFICATION

The absorption of CO_2 by the ocean is not without consequences for marine life. It causes ocean acidification: a change in oceanic carbonate chemistry sometimes referred to as the 'other CO_2 problem'. Ocean acidification has emerged as a key global issue in the last decade because of its potential to affect marine organisms and biogeochemical cycles.

Ocean acidification comprises a series of changes to seawater chemistry, such as a decrease in seawater pH level (a measure of acidity/alkalinity), reflecting a shift towards increased acidity. These changes are measurable: average ocean pH levels have decreased by 0.1 since the onset of the Industrial Revolution, which is equivalent to an increase in acidity of 26%. However it is hard to estimate the full impact that ocean acidification will have on marine life. Studies show a wide variety of possible impacts, both positive and negative, and different species show different levels of resilience and adaptability.

Below a certain pH level and the corresponding carbonate concentration, conditions become corrosive to calcium carbonate, which is used by many organisms to build shells and skeletons. Some corals, pteropods (tiny sea snails), bivalve molluscs (like clams and mussels) and calcifying phytoplankton seem to be particularly sensitive to changes in seawater chemistry.

In addition, energy spent overcoming increasingly acidic conditions may reduce the energy available for physiological processes such as reproduction and growth. Scientists at the IAEA Environment Laboratories are using techniques involving radioisotopes to investigate the impacts of ocean acidification and its interaction with other stressors, such as increasing temperatures due to climate change or local stressors like pollutants.

UNDERSTANDING THE IMPACTS OF OCEAN ACIDIFICATION

Nuclear and isotopic techniques are powerful tools for studying ocean acidification and have contributed widely to investigating past changes in ocean acidity and potential impacts on marine organisms. For example, boron isotopes enable scientists to assess past ocean pH levels using corals and fossilized organisms and identify past 'acidification events', with possible correlations with mass extinctions and changes in ecosystem structure.

Nuclear and isotopic techniques can also be used to study the impact of ocean acidification on marine organisms such as corals. Coral reefs host some of the most diverse ecosystems on the planet, yet many corals are very sensitive to variations in their environment and coral reefs are among the most threatened ecosystems in the world.

The IAEA Environment Laboratories conduct research with radioactive isotopes such as calcium-45, which can be used as tracers to examine the growth rates in calcifying organisms such as corals, or mussels and other molluscs, whose skeletons and shells are composed of calcium carbonate. Tracers are also used to determine how ocean acidification is affecting the physiology of other marine organisms, as well as the impact of a combination of stressors, such as ocean acidification, temperature and contaminants.

Because of the potential impacts of ocean acidification on marine environments and ecosystems, the IAEA Environment Laboratories conduct research and support Member States in gaining a better understanding of areas such as the economic implications of ocean acidification for fisheries.

Participants at an OA-ICC training course in China learn how to measure carbonate chemistry to study ocean acidification.
(Photo: V. Shi/Xiamen University, China)

In addition to conducting research, the IAEA laboratories in Monaco host the Ocean Acidification International Coordination Centre (OA-ICC) which fosters global scientific collaboration to support fact-based understanding of the potential impacts of ocean acidification on the marine environment and coastal populations. The Monaco laboratories also build awareness of the ways in which conventional, nuclear and isotopic techniques can be used to understand the effect of changes in seawater chemistry, marine organisms and ecosystems, coupled with other human pressures like overfishing, eutrophication and pollution.

EVALUATING THE OCEAN'S CARBON STORAGE CAPACITY USING NUCLEAR APPLICATIONS

The IAEA Environment Laboratories use radioisotopes to understand the capacity of the ocean to store carbon and the ways in which it might be impacted by changing climate conditions.

The ocean stores carbon primarily through two mechanisms: the solubility pump and the biological carbon pump.

In the solubility pump, CO_2 is transported from the atmosphere into the deep ocean by physical and chemical processes including gas exchange, dissolution and ocean circulation. Through the biological carbon pump, as part of photosynthesis, phytoplankton — microscopic marine plants at the bottom of the oceanic food chain — take up CO_2 in the surface ocean and convert it to particulate and dissolved organic carbon (carbon-containing molecules typically produced by living things). A fraction of this carbon makes its way to the deep ocean, where it is recycled back into inorganic carbon and stored, isolated from the atmosphere.

IAEA BRIEF

A scientist from the IAEA Environment Laboratories takes samples of seawater to study the role of microbes in the ocean carbon cycle. (Photo: R. Hansman/IAEA)

If the biological carbon pump in the ocean were to shut off, atmospheric CO_2 could rise by anything between 200 and 400 parts per million (ppm) above today's levels of 400 ppm, which were reached for the first time in 2015.

The flux of carbon to the deep ocean can be measured directly by collecting sinking particles (living and dead microscopic organisms, faecal matter) in sediment traps, and indirectly using naturally-occurring radioisotopes of thorium and polonium.

These radioisotopes decay at known rates and are used as 'clocks' to determine how quickly carbon-containing particles are sinking. The IAEA Environment Laboratories examine the carbon's fate by using radioisotopes to analyse microbial processes in the deep ocean. Microbes are responsible for the transformation of organic material from sinking particles into inorganic carbon. Both naturally-occurring radiocarbon and radioisotope-labelled tracers can be used to measure these microbial processes in terms of the cycling of carbon in the deep ocean.

The application of these tools in a variety of ocean settings helps to determine the extent of sinking carbon flux across different ecosystems and evaluate its sensitivity to climate change. The IAEA Environment Laboratories participate in research missions around the world to collect samples to measure particle flux, including in the Arctic Ocean, a region which is sensitive to ocean warming, and in oxygen minimum zones such as those off the coasts of Peru and Mauritania. Such zones are predicted to expand under future climate change scenarios.

An understanding of rates of carbon recycling and the conditions that affect it is important for evaluating the deep ocean's capacity to store carbon and the ways that might change in a changing climate and marine environment.

AREAS WHERE MEMBER STATES MAY BENEFIT FROM IAEA ASSISTANCE

1. In examining how nuclear science and technology can contribute to a better understanding of climate change, ocean acidification and their consequences for marine life and coastal industries;

2. In participating in the collaborative research activities of the OA-ICC, which supports effective global cooperation to address the threats to the marine environment from ocean acidification;

3. In collaborating with the IAEA Environment Laboratories in capacity building and training to use nuclear technology to enhance efforts to curb the impacts of ocean acidification.

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