RADIOTRACERS: ESSENTIAL NUCLEAR TOOLS TO UNDERSTAND OCEANS

Radiotracer studies can be applied in floating or seabed tent structures called mesocosms. This valuable experimental tool allows natural environments to be studied under controlled conditions combining the benefits of lab and field work.
(Photo: Nick Cobbing)

The IAEA's work in helping understand and ultimately protect our oceans depends on nuclear research tools called 'radiotracers'. Radiotracers are chemical compounds that contain unique radioactive isotopes. Isotopes of an element all have the same number of protons in the nucleus, but varying numbers of neutrons. Isotopes are thus forms of a single element with differing mass. When the composition of a nucleus does not change over time, it is considered to be a stable isotope. Unstable, or radioactive, isotopes 'decay' over time. In other words, they transform to another element, or energy status, through a process known as transmutation, in which atomic nuclei (protons and neutrons) emit highly energetic charged and ionizing particles, and/or highly energetic electromagnetic waves, called gamma-ray emission.

Radioecologists routinely introduce tiny quantities of a 'radiotracer', a radioactive isotope, into a complex biological system, for instance, to be able to observe how cells or tissues function. Scientists can identify a radiotracer among all the other natural and almost identical compounds. The radiotracer's unique 'isotopic signature' produces a clearly visible trace as it follows nutrients, energy, or pollutants through an organism, food web or ecosystem. Radiotracers are easy to detect in minute quantities, therefore studies can be conducted without poisoning organisms or ecosystems or affecting the chemistry or fluid dynamics of the system. The IAEA applies radiotracers in both laboratory settings and in field work, each of which has its own strengths. Laboratory based experiments have the advantage of creating simplified and artificial ecosystems in which natural processes and interactions can be studied uninterrupted. Field studies tackle the complex systems of the real world, having the potential to answer questions about a compound's fate, the dynamics between different species, and how compounds attach themselves to sediments and/or are dispersed as pollutants into the environment.

During larger scale field studies, radiotracers are used primarily to reveal the transport processes, dispersion and settling of chemicals in the natural environment. These studies are applied to coastal environments where the extent and effect of sewage and other effluent disposal has been evaluated and scrutinized. In the 1970s, a series of experimental studies conducted on Canadian lake systems, using heavy metal radiotracers (cadmium-109, zinc-65, mercury-203, iron-59, cobalt-60, caesium-134, and selenium-75) and nutrient radiotracers (carbon-14), revealed how tracers are absorbed into sediment and nutrients.

They also showed how contaminants transfer from water and sediments to organisms. From there they enter and move through the food chain. More recently, concerns have been raised over the possible radiological impact such field studies may have had on the environment.

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A non-human biota dose assessment (ERICA assessment tool)[1] of one lake study focused on whether the concentrations of radiotracers used were high enough to have a negative effect on the ecosystem; the results confirmed that doses were below the reference levels established by the International Commission on Radiological Protection. This suggests that it is feasible for radiotracers to be used safely in ecosystem scale studies.

With their limited environmental impact, radiotracers have the potential to be used in a variety of new applications to create a wider awareness of the environment and the challenges it faces. By using carbon-14 or phosphorus-32, it is possible to study nutrient dynamics and acquire a better understanding of the foundations of an ecosystem. Using short-lived analogues of nuclear industry products like caesium-134 and strontium-85, or heavy metal isotopes, radioecologists can examine contaminant accumulation in marine organisms and biomagnification (the cumulative increase in concentration of substances in organisms at successively higher levels of the food chain).

Biomagnification is an important aspect of marine pollution that is particularly worrying for longer living animals like humans. Potential further applications for radiotracers include using them on the nanoscale and labelling organic molecules, such as drugs, to track their behaviour as these molecules interact with organisms, after they are excreted by the human body and pass through sewage systems.

Despite their potential extensive uses, radiotracers do have their limitations, primarily the fact that in order to study some processes the tracers need to be absorbed and dispersed in the environment for several days or longer. In open water environments this can result in a very wide dispersion due to currents, wave action, and migratory animals removing the tracers far from the study area. However, studying some of our most vital marine habitats is not limited by this disruption. Coastal embayment areas, aquaculture farms, coral reefs, and floating or seabed tent structures, may all be used to constrain the movement of organisms and tracers, making them very viable environments for such studies using state-of-the-art nuclear technology.

The latest reports on the state of our oceans are worrying at best. The exploitation of their limited resources, the increase in marine pollution, and destruction of their service providing habitats, is placing a great strain on their organisms. Radiotracers are unique nuclear tools that can be used to study pollution and its transport in coasts and oceans. The IAEA and its partners are striving to make available these nuclear technologies to improve understanding of the health of the oceans, encouraging countries to take practical steps to prevent any further deterioration.

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[1] Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA)—www.erica-tool.com