Tracking the impact of plastics pollution on marine life

Fluorescent microplastic beads (in green) can be seen here in the stomachs of Artemia brine shrimp. (The yellow sphere is the light of the microscope used to magnify the specimen.)

Scientists at the International Atomic Energy Agency's ocean labs are using nuclear science to better understand the threat of microplastics.

By Jennet Orayeva

In addition to ocean warming and acidification, our seas and their inhabitants are facing a grave threat from the sustained dumping of plastic debris into the marine environment. Plastic pollution has become one of the most pressing environmental issues today, as it endangers ocean well-being, food safety and quality, and even human health.

Globally, over 250,000 tons of plastic waste have been released into the oceans. These plastic pollutants can vary in size—from macro debris, such as fishing nets and single-use plastic bags, to nano-sized plastic pellets or particles. A secondary, but nevertheless important, consequence of all this plastic in the ocean is the uptake of contaminants by marine organisms. In water, pollutants tend to be attracted to, or attach onto, the surface of plastic particles. By this mechanism, floating marine plastics can collect a cocktail of contaminants and, when mistakenly consumed or ingested by marine biota, affect seafood safety.

While the visible impact of large plastic debris—so-called macroplastics—on marine environments has been well documented, the potential harm caused by microplastics is much less clear. Microplastics originate from the weathering and disintegration of larger plastic debris, from pellets used in plastics manufacturing, and from additives in cleaning and personal care products and synthetic clothing. Specifically made to be resistant, they take a long time to disintegrate and can persist in the environment for more than 100 years.

Over the last decade, the scientific community has been carrying out laboratory and experimental studies to gain a better understanding of the impact of plastic debris on diverse aquatic organisms. Microplastics smaller than 5 millimeters have long been a focus in marine research, but the science has further advanced to quantify microplastic particles smaller than 333 micrometers.

Due to their small size and texture, some plastic particles can be mistaken for plankton and inadvertently consumed by marine animals, such as mussels, shrimp, and fish. Plastic particles, when eaten by animals, can potentially enter their internal organs and interfere with physiological processes by, for example, giving them a false sense of being full. More research is planned to determine what the long-term effect of this would be, and atomic-scale techniques can provide valuable information on the impact of plastics ingestion and the risk to marine organisms and, ultimately, humans.

Nuclear techniques

Pollutants that can attach to plastics include persistent organic pollutants, such as polychlorinated biphenyls (PCBs) and flame retardants, as well as some trace metals, such as mercury and lead. Researchers from the International Atomic Energy Agency's Environment Labora-

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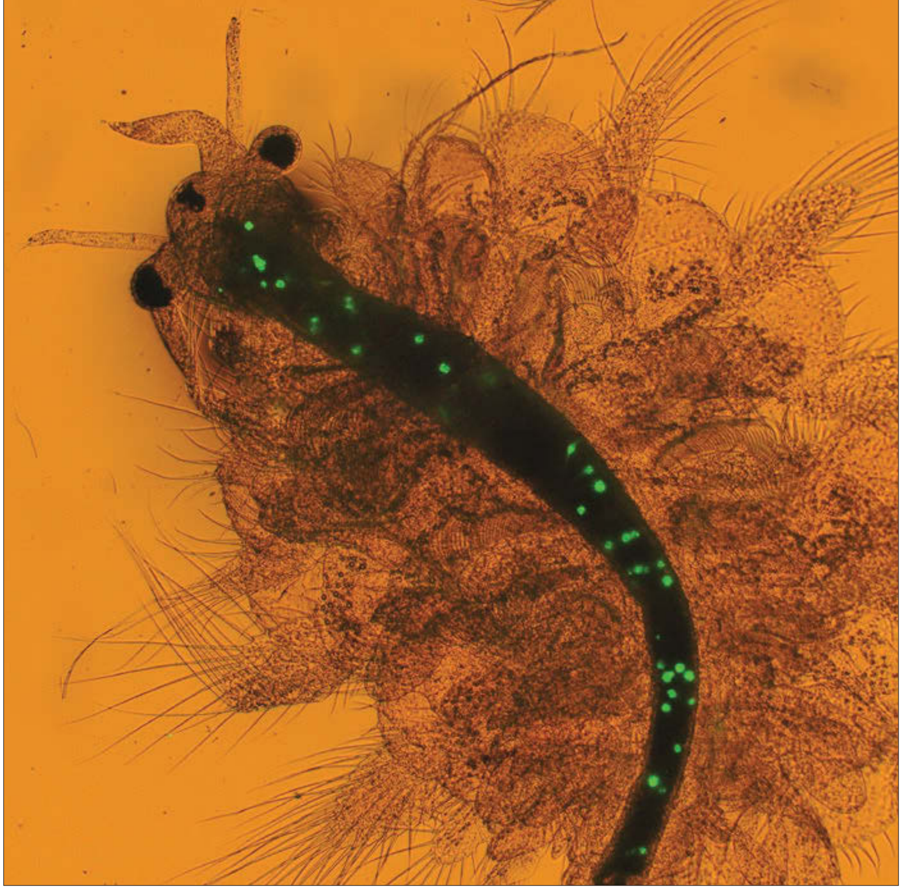

Close-up of an Artemia brine shrimp after having consumed microplastic particles at the IAEA laboratory in Monaco.

tories in Monaco use radioisotopic and other techniques to track and understand how such contaminants affect marine organisms and ecosystems, as well as to see if they can be potentially transferred throughout the food chain. These researchers model realistic scenarios to examine the extent to which microplastics in the environment attract pollutants and how they could act as an additional vector for the transfer of contaminants.

"Nuclear and isotopic techniques have opened a new window that enables us to precisely study the movement and potential impacts of microplastics on aquatic organisms," said Peter Swarzenski, head of the IAEA Radioecology Laboratory in Monaco. "They provide a reliable metric to assess how fragile coastal and marine ecosystems are to the impacts of all this plastic that is unfortunately accumulating in our oceans."

Since 2016, the IAEA Environment Laboratories have been studying the impacts of plastics on marine organisms. Several experiments to assess exposure have been conducted on fish, such as the sea bream, the spiny chromis damselfish, and the convict tang, on corals, such as the smooth cauliflower coral, and on crustaceans, such as the Artemia brine shrimp.

A group of sea bream fish being studied at the IAEA laboratory in Monaco. More research is planned to determine the long-term impact of microplastic consumption on marine life.

Coral nubbins can mistakenly ingest microplastic fragments, which can leach additional contaminants. Using nuclear and isotopic techniques, the IAEA is studying the impact of leaching chemicals from plastics on coral reef environments.

Findings from these studies are used by governments as science-based information for making policy decisions.

The experiments use nuclear research tools called radiotracers—chemical compounds that contain unique radioactive isotopes. Because of the very low-level radiation they emit, these isotopes can be easily tracked as they move through an organism, providing valuable information without harming the target. By using isotopes such as carbon-13, researchers can study how pollutants such as PCBs "attach" themselves to microplastics in the environment and whether they can dissociate, or "detach," from these plastics when ingested by marine animals.

"Radiotracer techniques are widely recognized as the cutting-edge tool of experimental marine ecotoxicology," said Marc Metian, a research scientist at the IAEA's Radioecology Laboratory in Monaco. "These techniques are unique and complementary to the more traditional approaches, such as analytical chemistry or molecular biology. They have been used to study the fate of contaminants or biotoxins in coastal environments, as well as the influence of global stressors such as climate change on marine organisms. They are now important in examining the effect of plastic on aquatic life."

The IAEA applies radiotracers in both laboratory settings and in field work. Laboratory experiments have the advantage of creating simplified and highly controlled replicates of natural ecosystems, where key processes and interactions can be studied uninterruptedly.

Tracing the effects of microplastics in fish

A recent IAEA study monitored the biological impacts of virgin, or uncontaminated, plastic particles (polyethylene microspheres) on sea bream and Artemia brine shrimp. Marine organisms such as these can accumulate microplastic particles in their flesh. People consuming seafood that contains plastics could, in turn, ingest these plastic fragments.

For this experiment, IAEA researchers used nuclear magnetic resonance to determine the abundance of polar metabolites (amino acids, nucleic acids, sugars, and small organic acids that are typically part of primary metabolism) in the brain, liver, and muscles of control and microplastic-exposed sea breams. Carbon-13, nitrogen-14, and nitrogen-15 isotope ratios were also examined to determine whether eating food that contains microplastics can impact these ratios in fish.

The study helped to see how microplastic particles damage the brain and liver cells of sea breams, increasing their mortality. Shortened life spans in key marine organisms make ecosystems more vulnerable to other threats, such as overfishing, climate change, or ocean acidification. Determining marine ecosystem health risks associated with this process of bioaccumulation is an important aspect of the IAEA Environment Laboratories' work. The resulting data can be used by governments to gain new knowledge and to reinforce or adapt seafood safety programs accordingly.

Continued

Understanding the impacts of leaching chemicals from plastics on coral reefs

Another experiment was carried out jointly by the IAEA Laboratories and the Scientific Centre of Monaco to monitor the impacts of leaching chemicals from plastics in corals. Manufactured plastics contain other chemicals and additives, such as brominated flame retardants. With the aging of the plastic or in water, these compounds—or leaching chemicals—are released from the plastic into the wider environment.

Polystyrene is one of the most widely used plastics worldwide, and as a result, one of the most common types of plastic debris found in oceans, coastlines, and beaches. For this study, pieces of beached foam-like plastic macro debris, larger than 2 centimeters, were collected along the French Riviera. They were then analyzed for chemical composition and additives, and corals were exposed to them in order to better understand the impact of leaching chemicals in coral reefs.

The methodology applied used stable isotope labeling detected by mass spectrometry. Contaminants labeled with carbon-13 and hydrogen-2 (deuterium) isotopes helped researchers trace the pathway and effects of leaching chemicals. The results confirmed the accumulation of leached compounds in the corals, indicating that it causes stress to the organisms. More research is needed, however, to fully understand the impact of this stress response. A scientific article about this study will soon be published in the peer-reviewed scientific journal *Marine Pollution Bulletin*.

With studies such as these, the IAEA complements a large body of existing science on environmental plastics. This work is crucial to helping countries monitor marine ecosystems and make informed decisions to control the harmful pollutants that enter the seas.

Sharing knowledge and skills

The IAEA has various mechanisms to carry out research and development activities and to provide assistance to its member states. The agency has a platform—called coordinated research projects, or CRPs—that brings together research institutions from developing and developed member states to collaborate on research projects of common interest. Currently, two ongoing research projects focusing on the behavior and effects of natural and anthropogenic radionuclides as tracers for oceanography studies have gained a high level of interest among countries.

Technical cooperation projects are another major knowledge-transfer medium for the IAEA. A regional project in Latin America is helping countries in the region to collect microplastic samples. Sampling and characterization of plastic debris are crucial for laboratory experiments that can produce accurate monitoring data.

In international forums, IAEA researchers closely engage with many international organizations working on microplastics research, such as the Joint Group of Experts on the Scientific Aspects of Marine Environment Protection and the Food and Agriculture Organization of the United Nations. The IAEA also partnered with the United Nations Environment Programme's Mediterranean Action Plan Programme for the Assessment and Control of Pollution in the Mediterranean Region to provide training courses, proficiency tests, and inter-laboratory comparisons. Through this collaborative effort, laboratories in the Mediterranean region are now equipped with suitable instruments used to determine trace elements and contaminants, as well as to develop a monitoring database for the assessment of marine pollution.

The IAEA Environment Laboratories are located in Monaco and Seibersdorf, Austria. They are unique in the United Nations system, and their work strengthens the capability of countries to develop science-based strategies for the sustainable management of terrestrial, marine, and atmospheric environments. NN