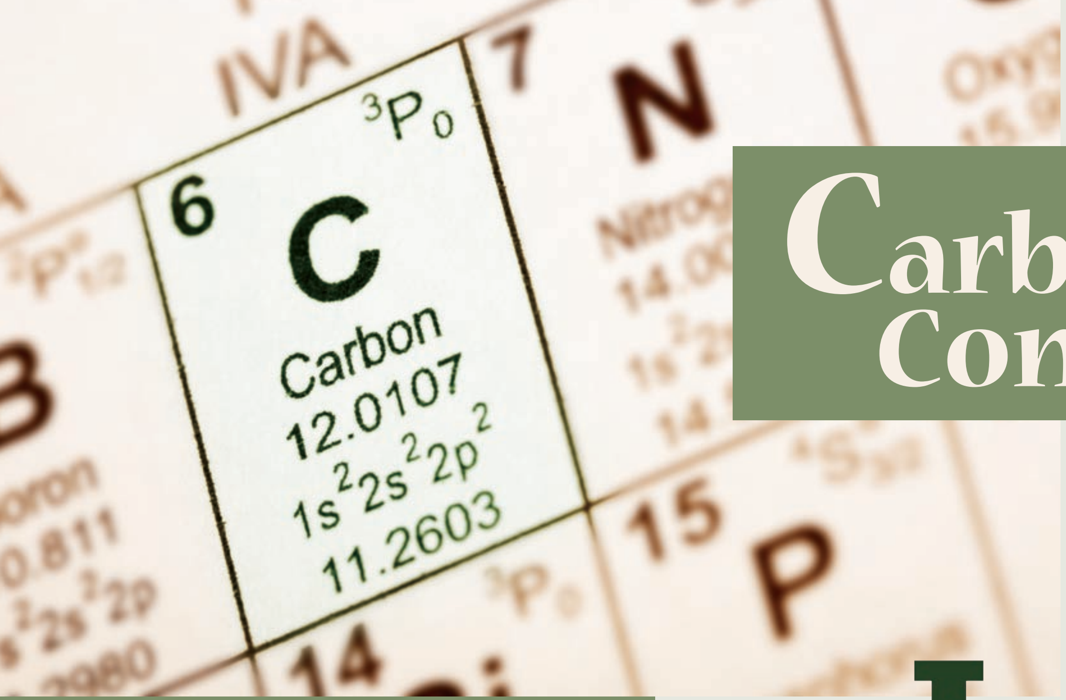
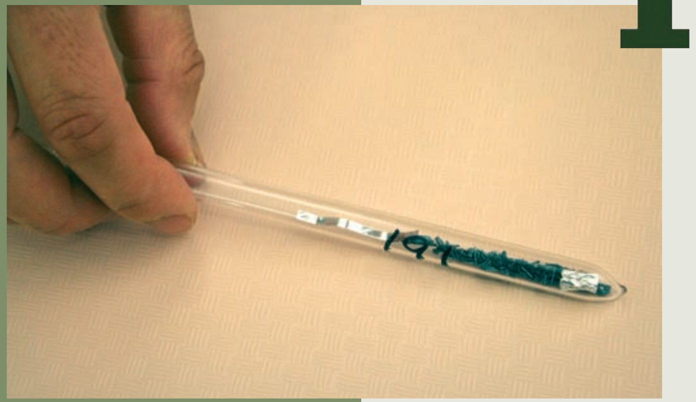


The Carbon Connection:

Understanding Organic Carbon in Decomposition

By Kelly Hong



> “One nature of research is that it keeps you constantly aware of how little you know”

It’s in our pizzas, our plastic water bottles, our diamond rings, our skateboards and clock radios. It’s in our hair, our bones, our breath, even in our very DNA. It’s in the water we drink, the air we exhale, and the earth we build our houses on. “It” is carbon, one of the essential building blocks of all life and the basis of life itself. This chemical element bonds to itself and many other elements to form the world around us.

Organic carbon is a type of carbon created by living creatures. It forms the basic compounds that all life is made of, cycling through the environment and making up a vital part in the cycle of life and death. Yet scientists know very little about how organic carbon transforms as it travels through the decomposition process. What happens to these molecules is the focus of the research being led by Dr. Tomoko Komada, marine biogeochemist at the Romberg Tiburon Center, SF State’s marine laboratory.

When an organism dies, it gradually decomposes. Most of the organic carbon in its body breaks down and transforms into carbon dioxide, which disperses into the atmosphere, and into the waters and sediments of the world’s oceans. But a tiny fraction of that organic carbon is left over. It mixes with other leftovers, eventually collecting into large leftover organic carbon reservoirs concentrated in ocean waters and sediments. Where is all this carbon coming from and when will it turn into carbon dioxide and make its way back into the life cycle? “We are missing a big component of the carbon cycle in the ocean.” explains Komada. “I am interested in understanding why we have all this old carbon in the ocean and how organic carbon is transformed once it is no longer a part of living tissue.” Komada’s research will shed more light on exactly what happens to this leftover organic carbon and how it is transformed during the decomposition cycle.

To understand how carbon cycles in the ocean, one can imagine the ocean as being like a huge bowl of soup. Floating in the soup are many spices swirling around in the bowl. Some of them fall to the bottom and collect along the sides of the bowl. Organic carbon in the ocean acts just like these spices. It floats around the ocean, drifts down onto the ocean floor and collects in sediments along river banks and estuaries. But the organic carbon swirling in the ocean is a huge collective mass - a lot of which doesn’t seem to be going anywhere any day soon. It’s not being eaten by microorganisms and turned into carbon dioxide (a process similar to how we eat food and part of that food is turned into the carbon dioxide we exhale). It just cycles around the oceans growing old. And the ocean is full of this very old organic carbon.

Carbon is naturally found in three different general types: organic, inorganic and elemental form. Organic carbon is found in all living organisms, and is synonymous with organic matter. It forms the backbone of all organic compounds on Earth and is extremely diverse. It is found in any soft biological tissue, living or dead, from a dog’s ear to a decaying leaf to human skin. The inorganic carbon in our environment is mostly carbon dioxide (created when we breathe, turning organic carbon into carbon dioxide) and carbonate minerals such as the shells of many marine organisms. Elemental carbon is pure carbon. Diamonds and graphite, a grayish soft mineral often used in lead pencils, are examples of elemental

(left) Glass vials are carefully cleaned for sample storage. Plastic is avoided as much as possible to minimize organic matter contamination.

(top right) A sediment core collected from the Santa Monica Basin aboard the R/V Point Sur. Cores are transported to a refrigerated van within minutes of recovery.

(second from top, right) Setting up the multicorer for the next deployment.

(third from top, right) Deploying the multicorer. Multicorers are capable of collecting cores from the seafloor with minimum disturbance to the sediment-water interface.
shipboard photos courtesy of Dr. Komada

(far left) Dried sediment sample sealed inside an evacuated quartz tube along with elemental silver and copper oxide. The tube is combusted, and the carbon dioxide is isolated and analyzed for carbon isotope ratios.

Komada's fascination with carbon cycles and the decomposition cycle itself stems from an early childhood memory.

Carbon itself can be very flexible. It can cycle back and forth through organic and inorganic forms as easily as water transforms from liquid, to solid, to gas. Both inorganic and organic carbon can also exist in either particulate or dissolved states. The difference between these two states is size. "Dissolved" is defined as anything that can pass through a 0.2 mircon filter (2 tenths of one thousandths of a millimeter). "Particulate" is that which does not. Carbon transforms through these two different forms primarily via biological activity. For example, photosynthesis turns dissolved inorganic carbon into particulate organic carbon. Enzymes produced by microbes break down particulate organic carbon into smaller dissolved organic carbon. But in the end, organic carbon must always turn into carbon dioxide in order to finish its cycle through the decomposition process. How long it takes carbon to transform and flow through these different forms and the time it stays in each form varies. Our oceans are filled with carbon cycling through these different forms.

(top right) Dr. Sabrina Crispo, postdoctoral associate, making ampoules for storing porewater dissolved inorganic carbon samples.

(two instruments) A high-temperature-combustion analyzer (top) and an elemental analyzer (bottom) are used routinely to determine organic carbon concentrations in aqueous and solid samples, respectively.

Organic carbon in the ocean is like diluted soup and most of it is found in dissolved, not particulate form. The deeper you venture into the ocean the older the dissolved organic carbon is. How it got there and what happens to it is the big question in Komada's field of marine biogeochemistry. There are numerous hypotheses as to what happens to the dissolved organic carbon. But scientists speculate that some of it is slowly eaten by organisms or degraded by sunlight.

Komada's most recent projects focus on understanding the complex process of how organic carbon transforms as it collects and leaves marine sediments. By studying the carbon in these sediments she will determine whether or not marine sediments are one of the sources of all the old dissolved organic carbon we see in the ocean. By better understanding how dissolved organic carbon changes as it moves through sediments, Komada can learn more about the nature of dissolved organic carbon itself. Her hypothesis is that the dissolved organic carbon in the sediments will be a mix of "resistant" (very stable and doesn't break down easily or very fast) and "labile" (more delicate and breaks down easier and faster) components. If Komada's research is successful it may help answer the question of why there is so much old dissolved organic carbon in the ocean.

In order to test her hypothesis, Komada is collecting sediment samples from San Francisco Bay and off the coast of California, then analyzing them to find out just how much resistant and labile organic carbon they contain. To do this Komada is extracting the carbon from her sediment samples and analyzing the abundance of the isotope ^{14}C. This will help her figure out how old the organic carbon molecules are, since as time passes the isotope ^{14}C naturally decays. In living tissue, that decay is balanced by a constant intake of ^{14}C from the atmosphere, but in dead tissue there is only decay. So scientists use isotope ^{14}C like a clock to determine how long is has been since the organic carbon was no longer part of living tissue. The older the organic carbon, the less ^{14}C it has. Resistant carbon that is slow to breakdown will most likely be the oldest because it sits in the sediments the longest. And labile carbon will be the newest in age because it is prone to turning into carbon dioxide. "My samples are a mix of substances that came from different sources," says Komada. "By using ^{14}C and doing balance calculations I can calculate what fraction of the dissolved organic carbon is a mix of old and new."

Each of Komada's organic carbon samples is dried, powdered, and vacuum sealed in quartz tubes, then placed in a muffle furnace (a large hot oven) where the entire sample is burned into gas form. Each gas filled tube is placed on a vacuum line (a spider web maze of glass tubes used to separate and isolate gasses) which separates out all the different gasses the sample is made up of until only carbon dioxide is left. Then Komada sends a portion of the carbon dioxide gas to an Accelerator Mass Spectrometry facility. There it is turned into graphite and loaded into an Accelerator Mass Spectrometer. This large U-shaped machine will analyze the carbon turned graphite and determine how much of the rare ^{14}C isotope it contains. Another portion of the carbon dioxide gas is also analyzed in an isotope ratio mass spectrometer. This machine will analyze the carbon turned graphite and determine how much of the rare ^{13}C isotope it contains. The amount of ^{14}C and ^{13}C isotopes in the carbon dioxide sample will give Komada clues about the origins and ages of the organic carbon. Komada then takes these results and looks at the distribution of the carbon isotopes (^{14}C and ^{13}C) and does some calculations.

"It's hard to get something out of just one sample so it's usually a series of samples and you are looking for trends over space or time," she says.

For a subject so complex and detailed one wonders how Komada broke into it in the first place. "I enjoy the fact that I get to work on topics that have fascinated me thorough most of my life," she says. "When I was in graduate school [at Rutgers University] I happened to come across a professor looking at carbon cycling in marine environments and was attracted to her type of research."

Komada was born in Japan but came to America in 1996 to pursue her research and earned her PhD in New Jersey at Rutgers University. Part of her thesis focused on studying how dissolved organic carbon cycles through organic-rich, estuarine sediments. "This is a very budding field–there's hardly any data on this topic. Understanding how organic carbon cycles in mud, especially DOC [dissolved organic carbon] in mud, is very complex," Komada explains. Soon after finishing her doctorate she moved to Southern California, where she did her post doctoral work at the University of California, Irvine. Komada now works on her current decomposition research at the Romberg Tiburon Center.

Dr. Tomoko Komada

Komada's fascination with carbon cycles and the decomposition cycle itself stems from an early childhood memory. When she was about five, she came across a picture in a newspaper. "There is a plant growing out of the ground and there is an animal eating the plant and some other animal eating that animal," Komada says.

"And there is a bird of prey flying in the sky, clearly at the top of the food chain. You see that the bird later dies and falls next to the plant. The plant then draws nutrients out of the decaying bird to grow. I recall being amazed that such a cycle exists. The image stuck with me and I still remember it to this day," she says.

Komada hopes to complete her current research project in two years, and then pursue new questions that need to be answered. "If you're doing active research you should be doing something for which people don't have an answer. Otherwise, why do it?" says Komada. As she works in her lab she analyzes each of her samples much like a crime scene investigator goes about analyzing crucial fragments of evidence. She is methodical, precise, and always aware that no matter how insignificant her experiment might seem it may very well provide a clue that could one day impact how we view and influence the environment.

"One nature of research is that it keeps you constantly aware of how little you know," Komada says. ❦