INSTRUMENTS

The Delta C mass spectrometer: a pathway to future research

Max Gibbs

Learning to use sophisticated new instruments and seeing the first results can be both exciting and rewarding. Max Gibbs describes his work with one of NIWA's recent acquisitions.

RARELY HAS one instrument the potential to provide the answer to such a wide range of scientific, industrial and medical questions as the new Delta C mass spectrometer now installed and running at NIWA's Greta Point laboratories in Wellington. Although this is the smaller of the two new isotope ratio mass spectrometers purchased by NIWA, the Delta C is designed as a work horse capable of rapidly processing a large number of solid, liquid or gaseous samples to a precision about 10 times better than previous machines in New Zealand, and on a sample size at least 50 times smaller than has ever been possible before in this country.

Challenge

It was my privilege to be first to test and use the Delta C mass spectrometer for research, and to produce a users' manual for this "high-tech" instrumentation. The challenge was laid at a ceremony to mark the commissioning of this new NIWA equipment (see panel). Its big brother, the 252, was already being tested for atmospheric research and, judging by the whoops of joy coming from Dave Lowe (NIWA, Wellington) and his team, it was highly successful ... but that's another story.

Just what is it about isotope ratio mass spectrometry that is so different that allows it to do things that other analytical techniques cannot?

Essentially, these instruments measure the ratio of the naturally occurring stable isotopes in gaseous samples. Unlike unstable (radioactive) isotopes which decay at different rates depending on their half life, stable isotopes do not change in abundance. A change in relative abundance is therefore a function of some process which differentiates between one atomic mass and another of the same element.

For example, terrestrial plants preferentially assimilate the lighter ^{12}C isotope of CO_2 rather than the heavier ^{13}C isotope into their cell structure and this results in a decrease in the ratio ^{13}C:^{12}C in plant material.

In δ-notation (delta-notation), which gives the deviation (per ml) of the isotope ratio of sample relative to that of a mineral standard (known as "PDB"), a negative $\delta^{13}C$ value indicates ^{13}C depletion.

In the aquatic environment, differences in the $\delta^{13}C$ value and also the $\delta^{15}N$ value, obtained from the ^{15}N:^{14}N ratio, can be used to identify the source of phytoplankton, its growth conditions, and even the source of the nutrients used for growth (e.g., riverine or deep ocean upwelling).

The significance of small ratio changes takes on a new perspective when it is considered that those ratios are passed on to the consumers of that primary production. This then allows identification of the food sources of higher life forms. Thus, the analysis of archaeological specimens of skin, feathers or bone can provide information about the diets of specific animals and how that diet has changed with time or in relation to specific events in history such as the European settlement of New Zealand. Even more surprising is that the same technique can be used to estimate the concentrations of greenhouse gases that existed when those animals lived.

In addition to looking at naturally occurring isotope ratios, we can add stable isotopes to a system and use them to study the pathways of uptake and storage within that system.

Experimental application

This latter application was used as the initial test of the Delta C system. In this study, we examined the pathways and transformations of nitrogen within a lake-edge wetland impacted by domestic septic tank effluent. This work was sponsored by Environment Bay of Plenty who are interested in understanding the sources of nutrients to the lakes in their region.

Of particular interest in this study was the fact that nitrogen in the effluent-enriched ground water reaching the wetland was in the ammonium form rather than as nitrate. In the nitrate form,

NIWA's stable isotope ratio mass spectrometers

Extract from news release

(Paul Prince Associates, 19/12/95)

At the official commissioning by Research, Science and Technology Minister, Simon Upton, in December 1995, NIWA's chief executive Paul Hargreaves said the new mass spectrometers provide NIWA's staff and clients with information that can markedly assist in tracking elements such as hydrogen, carbon monoxide, carbon dioxide, nitrogen and oxygen in the atmosphere. He said the equipment is particularly applicable to the agriculture, horticulture, seafood and medical industries.

"For example, the new equipment now gives us the capability to study how the carbon dioxide produced by people is taken up in our oceans, the gases given off by animals, water movement through citrus fruit and the movement of deep ocean water to the surface – which has an effect on fishing industry catches."

"Medical people should also benefit from our spectrometers, through the ability they give us to measure the isotopes which can potentially contribute to identifying bacterial infections, fat malabsorption, the pancreatic function, duodenal and other internal ulcers."

Mr Hargreaves also said that now that the new equipment is installed and running it should be able to assist with early detection of algal blooms through studies of nitrogen and carbon uptake by sea plankton – a technique used for this purpose overseas. "Anything we can contribute to existing knowledge of when algal blooms might occur must be useful to our growing shellfish industry," he added.

"Indeed, our new mass spectrometers offer our scientists the opportunities to take up many new challenges to their ingenuity and come up with better ways of solving current and emerging environmental problems."