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Identifying age measurements distorted by fossil fuel emissions

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Good news for archaeologists and natural scientists! You will be able to continue to use the radiocarbon method as a reliable tool for determining the age of artefacts and sample materials. The reduction of the carbon isotope 14C in the atmosphere accelerated by anthropogenic carbon dioxide emissions and the associated distortion of the radiocarbon age of materials can be precisely identified - by measuring the carbon isotope 13C. This is the result of a study by AWI geoscientist Dr Peter Köhler, which was published today in the journal *Environmental Research Letters*.

For how long will we be able to use our best method for determining the age of organic materials? Archaeologists and natural scientists asked themselves this question about a year ago when it became known that mankind (through its consumption of fossil fuels like coal, oil and natural gas) is changing the carbon isotope balance on Earth to such a degree that the radiocarbon method will generate inaccurate ages within a few decades.

"If the global emissions of fossil carbon dioxide continue to rise in the near future, as is proposed by the business-as-usual scenario of the Intergovernmental Panel on Climate Change, the results of our age readings of new organic material in 2050 will be identical to 1000-year-old samples. In 2150 new samples will appear to be the same age as 3000-year-old carbon, and in extreme cases even the same as 4300-year-old material. This means that fresh samples, for example of a tree felled within the next century, when measured using radiocarbon dating will appear to be the same age as wood that is several thousand years old, " explains Dr Peter Köhler, geoscientist at the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI).

Over the past year, he asked himself the question of whether and how the distorted age of the material can be identified. He found the solution in another carbon isotope. "If we determine the 13C value of the sample as well as using the radiocarbon method, we can find out whether the age is trustworthy. That's because the 13C value tells us whether the carbon of the sample has been affected by fossil carbon dioxide," says Peter Köhler.

Carbon that living organisms ingest through breathing, photosynthesis or with food, contains three different isotopes: the two stable isotopes 12C and 13C as well as the radioactive 14C. The latter is formed through nuclear reactions in the upper layers of the Earth's atmosphere. When an animal or a plant dies, the 14C in the organism's tissue decays at a constant rate. Its half-life is approximately 6000 years.

Scientists take advantage of this fact when they perform radiocarbon dating. The amount of the remaining 14C isotopes in the sample is determined, a ratio to the number of 12C isotopes is established, which in turn is compared with a standard. "The problem we face is that natural gas, oil and coal are so old that their carbon no longer contains any 14C isotopes. When we burn these fossil fuels, we release large amounts of 14C-free carbon into the atmosphere. As a result, the 14C to 12C ratio - similar to an ageing process - becomes smaller, first in the atmosphere and later in all reservoirs it exchanges with. We know this phenomenon as the Suess effect, named after the physicist Hans E. Suess," says Peter Köhler.

The 13C signal identifies the difference

This Suess effect also applies to the 13C isotope - a fact the AWI scientist took advantage of to solve the dating problem. "The burning of oil, coal and gas not only changes the 14C signal in the atmosphere, but also the stable 13C signal. This means: If my measurement shows a distorted 13C signal, then this also tells me that the 14C-based age has been affected by fossil carbon. If, on the other hand, my 13C signal is within the expected range, then the fossil carbon has not had an effect and the 14C dating method shows the correct age," Peter Köhler explains.

In his study, the scientist calculated the 14C Suess effect and the 13C Suess effect up to the year 2500 using the BICYCLE computer model, which simulates the global carbon cycle. His calculations were based on the established emission scenarios of the Intergovernmental Panel on Climate Change. Using further analyses he then tested whether his forecasts still held true if mankind managed to reduce the concentration of carbon dioxide in the atmosphere.

In all scenarios the potential distortion of the dating method could be identified with the 13C Suess effect. Only in areas where exchange with the atmosphere is slow (e.g. the deep Pacific Ocean) is it not possible to clearly identify the distortion using the 13C Suess effect. Further methodological difficulties will also arise if mankind starts at a large scale to remove carbon dioxide from the atmosphere by growing biomass for energy production, then captures the released carbon dioxide during its consumption in power plants and stores it in underground geological formations. This so-called BECCS method has already been implemented on a small scale in some scenarios of the Intergovernmental Panel on Climate Change; however, it is only one of many theoretically conceivable methods to reduce carbon dioxide concentration in the atmosphere.

More information: Peter Köhler, Using the Suess effect on the stable carbon isotope to distinguish the future from the past in radiocarbon, *Environmental Research Letters* (2016). DOI: 10.1088/1748-9326/11/12/124016

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