

# SmartNotes

# QA

## How can stable isotopes be used to trace pollution sources and environmental change?

Protecting our environment from contamination is a global challenge, one that requires international focus and collaboration for our air, water and land resources. The natural and synthetic materials in our air, water and on our land have a fingerprint, a unique chemical signature that allows them to be identified and differentiated from one another. A unique chemical signature that allows this differentiation are the stable isotopes within the polluting material and we refer to this as the Isotope Fingerprint. To visualize this fingerprint, Isotope Ratio Mass Spectrometry (IRMS) is used. The **isotope fingerprint** in natural sample materials is region or process specific, which means that samples can be differentiated based on geographical region (particulate matter in air), botanical origin (organic matter origin and movement) and mineralization processes (breakdown of material in nature). These processes can be routinely traced using **carbon, nitrogen, sulfur, oxygen and hydrogen** isotope fingerprints, providing scope for source identification and tracking changes in our environment on timescales from the present day and into the recent and deep past (Table 1).



**Table 1. Isotope Fingerprints in environmental investigations.**

Isotope fingerprint	What is the biogeochemical interpretation?	What is an example environmental interpretation?	What type of materials can be analyzed?
Carbon	Botanical origin (C <sub>3</sub> , C <sub>4</sub> and CAM photosynthesis)	Fossil fuel burning; Natural fires/ biogenic emissions; Particulate matter source (PM <sub>2.5</sub> to PM <sub>10</sub> ); Mineralization processes	Soils, sediments, water, filters (air and water), gas, biomass.
Nitrogen	Soil processes, fertilizer, trophic level	Particulate matter source (PM <sub>2.5</sub> to PM <sub>10</sub> ); Industrial and vehicle emissions' Fertilizer tracing (nitrate in water)	Soils, sediments, water, filters (air and water), biomass.
Sulfur	Local soil and geology conditions, proximity to shoreline	Particulate matter source (PM <sub>2.5</sub> to PM <sub>10</sub> ); Proxy for natural events and weathering processes; Fertilizer tracing	Soils, sediments, water, filters (air and water), biomass.
Oxygen	Principally related to local-regional rainfall and hence geographical area	Particulate matter source (PM <sub>2.5</sub> to PM <sub>10</sub> ); Fertilizer tracing (nitrate in water)	Soils, sediments, water, filters (air and water), biomass.
Hydrogen	Soil remediation and degradation, sources of atmospheric gases	Biodegradation and pathways of organic contaminants; Source discrimination of fossil fuel	Soils, sediments, gas, biomass.

**Environmental Protection: resolving the problem by tracking the source**

Pollution in our waterways, which affect our drinking water and water resources for arable and pastoral farming, in our air, which affects human and animal health, and our soils, which affect a fundamental aspect of our food supply chain, is a significant and challenging global issue. These issues are complex, and vary in space and time, because the chemical nature, concentration and persistence of pollutants are variable. Globally, environmental protection agencies and governments have enacted and continue to enact legislation and directives that will protect our air, water and land and reduce current and future pollution. This action at the local (country), regional (European Union) and global (United Nations) level has resulted in a long overdue focus on protecting our unique environment by improving its health and cleanliness and the impact on human and animal health.

Pollution can be defined as the introduction of a contaminant to air, water and land systems. Contaminants are largely anthropogenic, meaning they are non-natural, such as emissions from cars and industrial processes, however, they can also be natural, such as sulfate aerosols from sea spray.

Further, pollution sources are categorized as point source or non-point source. Point source pollution means there is an identifiable source, such as factory effluent streams into waterbodies. Non-point source pollution means pollution that derives from many diffuse sources, such as atmospheric deposition, terrestrial run-off from precipitation and spatial differences in drainage, for example. This means pollutants are carried from their source to another location, potentially very far away, and are therefore not necessarily representative of the environment they have been deposited in.

This gives rise to a key and important topic: where does pollution come from and what portion of the pollution is from which source? From this question derives a practical question, which is, how can we trace the pollution and identify the original source? Gaining answers to these questions will allow pollution sources to be identified and inform remedial decisions and processes. Consequently, there is a requirement for a routine, cost-effective analytical solution that can quantify pollution in our environment and identify the source.



### Analytical solution: detecting source using isotope fingerprints

Using **isotope fingerprints**, it is possible to trace the sources of pollution, monitor water and air quality and track environmental change across space and time. Isotope Ratio Mass Spectrometry (IRMS) works by detecting the “isotope fingerprint” of a sample, a unique chemical signature that changes from sample to sample across the environment. There are a number of approaches to processing sample materials for their isotope fingerprint depending on what question is being answered, however, the fundamental process for IRMS is the conversion of a solid or liquid sample to a gas at high temperature. Samples can be introduced for analysis using a number of analytical peripherals, for example an elemental analyzer (EA-IRMS) or using a gas chromatography (GC-IRMS) interface. In the case of EA-IRMS and GC-IRMS, the conversion of the sample to a gas is performed by two processes: combustion and pyrolysis. Combustion, burning the sample at around 1000 °C with oxygen, is used to evolve carbon, nitrogen and sulfur from the sample in the form of N<sub>2</sub>, CO<sub>2</sub> and SO<sub>2</sub>. Pyrolysis, breaking down the sample at

around 1400 °C in a reductive environment, is used to evolve hydrogen and oxygen from the sample, in the form of H<sub>2</sub> and CO. After the gases are produced, they are transferred in a continuous gas flow to a detector that measures the isotope fingerprint of the sample.

Thermo Fisher Scientific provides dedicated Isotope Fingerprinting solutions with a portfolio designed to offer different capabilities and performances, with dedicated features for the coupling to the Thermo Scientific™ IRMS Systems, according to the varying analytical needs of the laboratory working for routine and research pollution source and environmental change applications:

- the Thermo Scientific™ EA IsoLink™ IRMS System, for the analysis of bulk samples
- the Thermo Scientific™ GC IsoLink II™ IRMS System, for analyzing volatile compounds within a bulk sample
- the Thermo Scientific™ LC IsoLink™ IRMS System, for analyzing polar compounds within a bulk sample
- the Thermo Scientific™ GasBench II System, for the analysis of samples in gas form.

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