Background information on stable isotope analyses

1 Purpose and scope

This document provides background information on stable isotope analyses.

2 Associated documents

Physical and chemical assessment: Sampling and preparation for stable isotope analyses of biota and sediment

Refer also to other relevant documents within this manual, which outline methods for:

- sediment sampling
- fish sampling
- macroinvertebrate sampling but **DO NOT preserve the samples with ethanol**
- chlorophyll *a* sampling.

3 Introduction

Isotopes are atoms of the same element, each having a different number of neutrons. Carbon, hydrogen, oxygen, nitrogen and sulphur comprise the bulk of living bodies (along with phosphorus) and all have more than one stable (i.e. non-radioactive) isotope. Stable isotopes occur naturally in the environment and can (amongst other things) be used by aquatic ecologists to track elements such as carbon and nitrogen through a food chain.

Analysis of stable isotopes ratios provide two types of information:

- **fractionation information** – where stable isotopes are fractionated (the ratio of isotopes are changed) through chemical reaction, diffusion or evaporation, and the ratio reflects the reaction, diffusion or evaporation conditions
- **source information** – where stable isotope ratios are used to provide information about origin of a sample (Peterson and Fry, 1987). The source sets an isotopic baseline that can subsequently be shifted by isotopic fractionation.

Stable isotopes can therefore be used in studies of aquatic ecosystems and when investigation surface and groundwater systems to answer questions related to:

- plant and animal ecophysiology
- trophic structure
- energy pathways within ecosystems and at their interfaces (e.g. with terrestrial environments and between freshwater and marine environments)
- hydrology and hydrogeology.

4 Food chains

The use of isotopes to trace nutrient and energy sources and understand trophic interactions depends on variations in isotope ratios in organisms and in their environment. The variation in isotopic ratios of a food source and the consumer of that food source will determine if, how, and when stable isotope techniques may be applied (Michener and Lajtha, 2007), for example:

- The heavier carbon isotope ^{13}C is one of the most effective tracers of organic carbon sources and energy flow in aquatic ecosystems because it does not change much as it is transferred up the food chain, following fixation by plants and undergoes minimal changes during decomposition (Michener and Lajtha, 2007; Tiunov, 2007).
- Sulphur isotopes can also be used for determining food sources, especially in coastal environments or ecosystems with strong gradients in redox conditions (Michener and Lajtha, 2007).
- Nitrogen stable isotopes are a powerful tracer of the nitrogen cycle. The ratio of heavy (^{15}N) to light (^{14}N) nitrogen isotopes changes markedly from food source to consumer and can be used to understand food web interactions in aquatic ecosystems.

5 Hydrology and hydrogeology

Stable isotopes can also be used in hydrology and hydrogeology studies to understand the surface-subsurface water interactions including:

- dominant runoff producing processes
- geographic source of water
- recharge sources or pathways
- the origins of water and solutes and weathering pathways
- flow within and between aquifers and surface waters
- residence time of water in the subsurface (Michener and Lajtha, 2007).

There are many stable isotopes of different elements that may be used in hydrology and hydrogeology studies. Their value to an investigation depends on the purpose of the investigation and the questions it aims to address. When using stable isotopes in hydrology and hydrogeological studies, care should be taken to consider the application of different stable isotopes to the investigation and the ability for particular stable isotopes to address particular issues relevant to the investigation.

6 Sediment source finger-printing

Stable isotopes can also be used in aquatic ecosystem sediment source fingerprinting (Fox 2009; Fox et al. 2010; Laceby et al. 2015; Walling 2013). This involves collecting a sample of the sediment transported or deposited in an aquatic ecosystem and comparing its stable isotope composition with that of potential sediment sources within the catchment area. In this way it is possible to gain information on the relative importance of different potential sediment sources. For example:

- Stable isotopes of carbon and nitrogen, which are linked specifically to the organic fraction of sediment, can discriminate soils from:
    - areas under different vegetation cover (C_3 versus C_4 vegetation)[1]
    - surface soils or from subsurface soils

[1] C_3 and C_4 refers to a certain photosynthetic pathway. Most plants are C_3 plants. C_4 plants include some grasses, sugar cane, maize and sorghum.

    - different nutritional contributions of aquatic organisms to the organic components of the soil (Marwick et al. 2014; Nadelhoffer and Fry 1988; Tiunov 2007).

- Stable isotopes can be used to trace the source of the organic component of suspended sediment and help to identify the source of the sediment (Bellanger et al. 2004; Garzon-Garcia 2014; Gomez et al. 2010; Kao and Liu 2000).

The use of compound-specific isotope analysis (CSIA) of carbon and hydrogen associated with plant fatty acids and long-chain n-alkanes has more recently proven to be useful in discriminating soils from areas under different vegetation (Cooper et al., 2015; Hancock and Revill, 2013).

7 References and additional reading

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