What Groundwater Tracers to use and why?

A chemical tracer is a substance used to track the progress or history of a natural process.

Some tracers occur naturally and others are introduced experimentally.

A tracer can also acts as a surrogate for a solute or organism of interest.

As hydro/geo/micro subsurface folks, we must ask ourselves what we want to track and what is the best tracer to use keeping in mind:

• Cost
• Detection limits
• Analytical needs
• Reactivity
• What the tracer is actually mimicking
Dissolved tracers

Dissolved gas tracers (He, Ne, Kr)

- SF$_6$
- D$_2$O, I
- H$^{13}$CO$_3^-$
- Br and $^{82}$Br

PIPES

Fluorobenzoates

Chlorofluorocarbons

Purpose

- Groundwater flux and direction
- Preferential flow, matrix diffusion
- Confirming presence of multiphases
- Groundwater dating
Dissolved tracers

Example of dissolved gas tracer in the field each having different diffusion coefficients.

Confirmation of preferential flow coupled with matrix diffusion.
Colloidal tracers

Examples:

• Fluorescent microspheres
• DNA labeled microspheres
• Radiolabeled Fe-oxide particles
• Fe-oxide nanoparticles
• Bacteriaphage
• Eu-tagged bacteria

Microspheres

Tracers of different size

Purpose

• Too large to diffuse into matrix
• Ideal for quantifying advective flow
• Typically reactive, but some get through quickly
• Best when coupled with dissolved tracers
Natural isotopic tracers

Examples:
- $^2\text{H}/^1\text{H}$, $^{18}\text{O}/^{16}\text{O}$, $^3\text{H}/^3\text{He}$
- $^{85}\text{Kr}$
- Radium
- $^{87}\text{Sr}/^{86}\text{Sr}$

- Storm event monitoring, old water/new water.
- Groundwater dating.
- Coupled isotopes approaches help to distinguish groundwater sources.
Dye tracers

Purpose

• Track the migration of surface and groundwater.
• Both reactive and non-reactive; however, non-reactivity must be verified.
• Best when coupled with non-reactive dissolved tracers.

• Rhodamine B and WT
• Uranine (fluorescein)
• Tinopal
• Eosine Y
Novel tracers

*Silicon beads tagged with DNA fragments*

More than a trillion DNA tags are available.

Therein lies a key strength of the technology: It allows production of virtually unlimited numbers of tracers that behave identically but that are easily distinguished because each DNA tag naturally pairs with complementary DNA fragments of a known sequence.
Novel tracers

**Diatom proteins**

Proteins extracted from common diatom species

Proteins used to develop monoclonal antibodies and accompanying enzyme immunoassays (Walker, 1996) that will facilitate the identification and quantification of the proteins in ground water.

Uses advanced cellular, biochemical, and immunological techniques for assessing ground water/surface water interactions.
Novel tracers

**Ice-nucleating bacteria**

Certain bacteria can serve as nuclei that initiate the formation of ice in supercooled water (ice-nucleating active Pseudomonas)

Super duper low detection limits.

I think they are sticky to the subsurface media...however, some might get through thus providing advective fluxes in heterogeneous media.
Short-lived Radioactive Tracers

Both reactive and non-reactive.

Ideal surrogates.

Regulatory acceptance for injection into groundwater may be tough, especially in California.

Very low detection limits.