Guide to deploying DGT passive samplers in soils

This is a general guide for deploying DGT passive samplers in soils. It is designed to complement and to be used with the individual guides for each type of devices and set of analytes. Those individual guides are written primary for deployments in solution. However, once the binding gel is retrieved from the DGT passive sampler the subsequent elution and analysis procedures are virtually the same and so those procedures, which are specific to the analysis are not duplicated here.

General considerations

Deployment rationale

Although DGT will work over a range of moisture conditions, it performs optimally in soils that at saturated with water or at the maximum water holding capacity (Hooda et al, 1999). These conditions are best replicated when soils are sampled, air-dried, homogenised and passed through a 2mm sieve. The procedure outlined here was developed as a simple, pragmatic way of using DGT in laboratories under controlled conditions. DGT has on occasion been deployed in-situ in soils, but special procedures are then required to ensure the field conditions are appropriate (Luo et al, 2013, Williams et al, 2012)

Storage

Store the DGT passive samplers in a refrigerator (4°C). The devices are provided in sealed clean plastic bags containing a few drops of 0.01M $NaNO_3$ (or 0.01M NaCl) solution. Do not open them during storage. Check the passive samplers occasionally to make sure they are under moist conditions. Add a few more drops of trace metal clean 0.01M $NaNO_3$ (or 0.01M NaCl) solution if it is necessary. Do not freeze the passive samplers, as performance quality could be affected.

Handling

The main consideration when using DGT passive samplers is to prevent contamination of the sample. Clean handling procedures should be adopted during deployment and recovery of the DGT passive samplers and all subsequent handling during the sample treatment step. Do not touch the white filter at the face of the device and do not let it come into contact with anything else. In general, the highest quality reagents should be used and all equipment and laboratory apparatus cleaned appropriately.

Practical procedures

Soil preparation

Collect soil samples, air dry them and sieve to ≤2 mm. With deionised water, wet them to 100% maximum water holding capacity (MWHC), if known, and mix the soil well to form a smooth paste or slurry. If the MWHC is unknown, add deionised water gradually to the soil while stirring until the soil becomes a smooth paste. Make sure there is no excess water on the soil surface. Equilibrate the soils for 24 hours, loosely covering the container with a plastic plate or sheet to minimise evaporation. For each soil, it is recommended to use 60 g to 80 g dry weight, wet and mix it in a 120 ml plastic pot or a beaker. After 24 hours hydration, divide the soil sample into 3 separate small size petri dishes ready for deployment.

Deployment

Carefully take the soil DGT passive sampler out of the plastic bag. Use a clean spatula to smear a thin layer of the soil paste onto the DGT filter surface. Then gently press the DGT device onto the soil surface, using a twisting motion to ensure there is good contact between the DGT front filter membrane and the soil. Cover the devices and soils loosely using a clean plastic sheet to avoid evaporation.

Although DGT will work over a range of moisture conditions, it performs optimally in soils that are saturated with water or at the maximum water holding capacity (Hooda et al, 1999). These conditions are best replicated when soils are sampled, air-dried, homogenised and passed through a 2mm sieve. The procedure outlined here was developed as a simple, pragmatic way of using DGT in laboratories under controlled conditions. DGT passive samplers have on occasion been deployed in-situ in soils, but special procedures are then required to ensure the field conditions are appropriate (Luo et al, 2013, Williams et al, 2012)

The main consideration when using DGT passive samplers is to prevent contamination of the sample. Clean handling procedures should be adopted during deployment and recovery of the DGT passive samplers and all subsequent handling during the sample treatment step.

Do not touch the white filter at the face of the passive sampler and do not let it come into contact with anything else. In general, the highest quality reagents should be used and all equipment and laboratory apparatus cleaned appropriately.

Record the deployment time to the nearest minute and the temperature of the environment during deployment. If the variation is within ±2°C a mean will suffice.

Retrieval

Remove the DGT passive sampler from the soil, taking care not to touch the face filter membrane. Rinse the DGT device with a wash bottle stream of deionised water and dry obvious surface water with a clean tissue.

Preparation for analysis

To retrieve the binding gel layer after deployment, insert a thick flat head screwdriver (classic heavy duty stubby slotted screwdriver) into the groove on the side of the plastic cap and twist to break the cap at its weak point. Remove the broken cap and then peel off the filter and diffusive gel layer to reveal the bottom binding-gel layer. (If the cap cannot be broken easily using a screwdriver, use clean tweezers to break the white filter membrane directly and pull out the gels from the top). Place the binding-gel layer in a sample tube and add the eluent appropriate to the analyte and type of device used. This can be found in the detailed procedure for the comparable solution device.

Calculation

The mass, M, of analyte accumulated on the binding layer, of volume, V^{bl}, is calculated from the measured concentration of analyte, c_e, in the eluent, of initial volume V_e, remembering to take into account any subsequent dilution. f_e is the elution efficiency.

$$M = \frac{c_e(V^{bl} + V_e)}{f_e}$$

Where c_e is in nmol mL^{-1} or ng mL^{-1}, and V^{bl} and V_e are in mL, M is in nmol or ng. For most devices, the binding gel volume is 0.20 mL.

For the usual set up, if $f_e = 0.9$ and $V_e = 1$ mL, as they are for many metals, M = 1.33 c_e (where c_e is in nmol mL^{-1} or ng mL^{-1}, M is in nmol or ng).

This mass can be used to calculate the mean flux from the soil through the window of the DGT device, of area A_p, for the deployment time, t (in sec). For soil devices A_p is 2.54 cm^2.

$$F = M/ A_p t$$

The DGT equation can be used to calculate the mean concentration at the surface of the device during the deployment time.

$$c_{DGT} = \frac{M\Delta_g}{DA_p t}$$

Δ_g (usually 0.094 cm) is the total thickness of the materials in the diffusion layer (diffusive gel and filter membrane). D (cm^2 s^{-1}) is the diffusion coefficient of analyte in the material diffusion layer for the deployment temperature (see diffusion coefficients). Use recommended units to facilitate easy calculation as shown above.

A key consideration is the meaning of c_{DGT}. Because DGT continually removes analyte, its concentration at the surface of the DGT device may be lowered during the course of the deployment. In some soils the analyte may be continually resupplied to solution from the solid phase. When this effective buffering is substantial, the measured c_{DGT} is close to the concentration measured directly on the soil solution of the hydrated soil, C_{soln}. Comparison of c_{DGT} with measurements of concentrations in soil solution, C_{soln}, can provide information on the dynamics of analyte exchange between soil solution and solid phase. A detailed account of the dynamic processes existing when DGT is deployed in soils can be found in Chapter 7 of the DGT book (see reference below).

References

Diffusive Gradients in Thin-Films for Environmental Measurements, Ed. W. Davison, Cambridge University Press, 2016, Cambridge. Chapters in this book, which are particularly relevant are:

1. Introduction to DGT (covers the basic principles) William Davison and Hao Zhang
2. Principles of measurements in simple solutions (explains procedures for calculations) William Davison and Hao Zhang
3. Diffusion layer properties (provides and critiques diffusion coefficients) William Davison and Hao Zhang
4. Binding layer properties (provides properties including elution efficiencies for a range of binding agents and analytes) William W. Bennett, Maja Arsic, Jared G. Panther, David T. Welsh, and Peter R. Teasdale
7. Principles and applications in soils and sediments (considers the equations and models describing the dynamics) Nik Lehto
8. Measurement at high spatial resolution (describes the evolution and recent developments of high resolution measurements in 1 and 2D) Jakob Santner and Paul N. Williams
10. Practicalities of working with DGT (practical issues such as deployment, quality control and sensitivity) Dianne F. Jolley, Sean Mason, Yue Gao and Hao Zhang

Prime publications for soils:

M. Harper, W. Davison, H. Zhang, H. and W. Tych, Solid phase to solution kinetics in sediments and soils interpreted from DGT measured fluxes, *Geochim. Cosmochim. Acta.* **62**: (1998), 2757-2770.

P. S. Hooda, H. Zhang, W. Davison, A. C. Edwards, Measuring bioavailable trace metals by diffusive gradients in thin films (DGT): soil moisture effects on its performance in soils. *European Journal of Soil Science*, **50**: (1999), 285-294.

J. Luo, H. Zhang, W. Davison, R. G. McLaren, L. M. Clucas, L. Q. Ma and X. Wang, Localised mobilisation of metals, as measured by diffusive gradients in thin-films, in soil historically treated with sewage sludge. *Chemosphere*, **90**: (2013), 464-470.

P. N. Williams, H. Zhang, W. Davison, S. Zhao, Y. Lu, F. Dong, L. Zhang, Q. Pan, Evaluation of in situ DGT measurements for predicting the concentration of Cd in Chinese field-cultivated rice: impact of soil Cd:Zn ratios. *Environmental Science and Technology*, **46**: (2012), 8009-8016.

H. Zhang, F.-J. Zhao, B. Sun, W. Davison, S. McGrath, A new method to measure effective soil solution concentration predicts copper availability to plants. *Environmental Science and Technology*, **35**: (2001), 2602-2607.