Understanding soil-to-plant uranium transfer and plant adaptation to radionuclide stress

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Introduction:

Environmental contamination by inorganic pollutants is a major challenge to biodiversity and can be a cause of significant organism toxicity [1]. The transfer of pollutants into plants is important as plants underpin all terrestrial food chains. There is also interest in investigating whether bioaccumulation of pollutants into plants has bioremediation potential [1]. Radionuclides, such as uranium and radium, can be a potential risk to ecosystem health because of radioactivity and chemotoxic effects [2]. Understanding the behaviour, mobility and transfer of radionuclides is critical for the development of management strategies for contaminated sites, and is relevant to applications such as nuclear site remediation and disposal of radioactive waste [3]. It is also unclear whether plants can tolerate radionuclide contaminated environments and if so, whether they have adapted tolerance or have constitutive tolerance [2]. The mechanisms underlying the ecological distribution of plant communities in environments contaminated by uranium and radium are poorly studied.

Project Summary:

The project will focus on uranium because of its abundance, its presence at former mining and ore processing sites, and because of the dependency of its environmental mobility on chemical oxidation state [4], but will also consider radium as a bioavailable radionuclide that is often found alongside uranium. This project will build upon data from recent NERC-funded field surveys of two radionuclide contaminated sites in the UK, which identified dominant plant species that were mediating radionuclide bioaccumulation, and which were all associated with arbuscular mycorrhizal (AM) fungi [5]. The first aim of the project is to investigate the role of specific soil chemistry parameters in influencing uranium and radium uptake into plant roots under controlled conditions. The chosen parameters will include soil pH, organic carbon, phosphate, and the abundance of selected essential plant mineral nutrients, as well as the presence or absence of soil microorganisms (bacteria and fungi). Using an appropriate 'model' plant species with known AM fungi association, determined based on the previous survey data, mesocosm experiments will manipulate the soil characteristics either with or without rhizosphere microorganisms to allow quantification of radionuclide uptake. This will be achieved using various analytical tools such as inductively coupled plasma mass spectroscopy and gamma spectroscopy.

The second aim of the project is to investigate radionuclide tolerance in selected plant species to evaluate adaptation traits, with the hypothesis that tolerant plant species that can grow in radionuclide environments will have evolved adaptation. For selected plant species that are able to grow on high uranium and radium soils, physiological parameters will be determined including growth rates, stress physiology (photosynthesis parameters), measurement of radionuclides in plants, fungi and soils, and evaluation of AM fungal association. Growth and stress tolerance will be compared with plants of the same species derived from non-contaminated environments. Stress physiology and radionuclide content will be quantified. This will allow determination of whether specific plant species display adapted or innate tolerance to the radionuclide stress conditions, and allow determination of whether association of symbiotic AM fungi plays an important factor in stress tolerance.

The student will receive training in cross-cutting approaches and skills including plant physiology, microbiology, soil chemistry, and radiochemical spectroscopy techniques, and will work with researchers within the School of Earth and Environmental Sciences in the Michael Smith building and the Williamson Research Centre for Molecular Environmental Science, and the School of Chemistry's Centre for Radiochemistry Research. The research team at Manchester has an excellent track record in environmental radiochemistry, soil ecology and plant physiology. Jon Pittman (primary supervisor) has experience examining responses and roles of metal and radionuclide pollution in plants. He will provide training in plant growth, physiology and some analytical techniques. Co-supervisors Clare Robinson and Gareth Law will provide fungal biology/soil ecology, and radiochemistry analysis expertise, respectively. Access to radionuclide and elemental imaging techniques such as synchrotron X-ray fluorescence imaging and SIMS-based imaging will also be available from collaboration with the Law lab. All the associated labs currently have PhD students and postdoctoral scientists working on related projects and using relevant techniques, and together the labs will provide an excellent training environment for the student to gain a unique set of cutting edge, multidisciplinary skills.

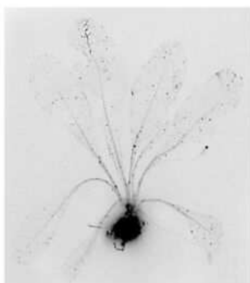

Image 1 – Autoradiograph of radionuclide accumulation into *Primula vulgaris* growing at a uranium mine site.

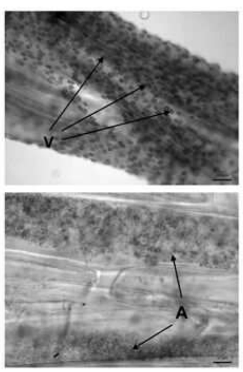

Image 2 Caption – AM fungi structures in plant roots from uranium soils showing fungal vesicles (V) and arbuscles (A).

References

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