Quantifying moss response to pollution from exposure to increasing levels of copper and uranium using laser induced photoluminescence

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Introduction and Motivation

Moss has long been used in environmental monitoring due to its consistent ability to accumulate trace metals from the atmosphere and from overland runoff (Tremper et al., 2004). The robust and resilient nature of mosses allow them to live in the harshest of conditions and their relatively simple biologic structure and behavior makes them easier to study compared to other vascular plants (Carginale et al., 2004; Berg & Steinnes, 1997; Zvereva & Kozlov, 2011). Mosses offer the opportunity to capture metals downwind or downstream of mining sites, industrial installations, and regions where events release metals. The hindrance in their use has been the ability to detect toxicity and health declines of plants above natural perturbations without physical collection and analysis. This study is a proof of concept in examining measurable impacts of selected metals on moss. It takes advantage of a newly developed laser technology using laser induced fluorescence (LIF) (Misra et al., 2018) to observe biological changes in mosses exposed to metal.

Mission Relevance

The NSSA mission is focused on detection and prevention of the militarization of nuclear weapons. This study will develop a laser induced fluorescence method to detect the biological response of moss after exposure to metals of interest. The method will be developed to quantifiably say whether an area has been exposed to radioisotopes of metals. The end goal of the project is to develop a remote sensing technology to survey areas of interest.

Technical Approach

The project is divided into two parts that focus on creating a replicable methodology to detect moss responses after exposure to uranium and/or cesium. First, we will optimize the response detection using a metal of known biotoxicity (copper). The resulting measurements and observations by fine tuning measurements of color changes will be used to calibrate the laser by determining background variance, setting corresponding detection limits, and documenting response concentrations.

Part 1: Moss Treatment

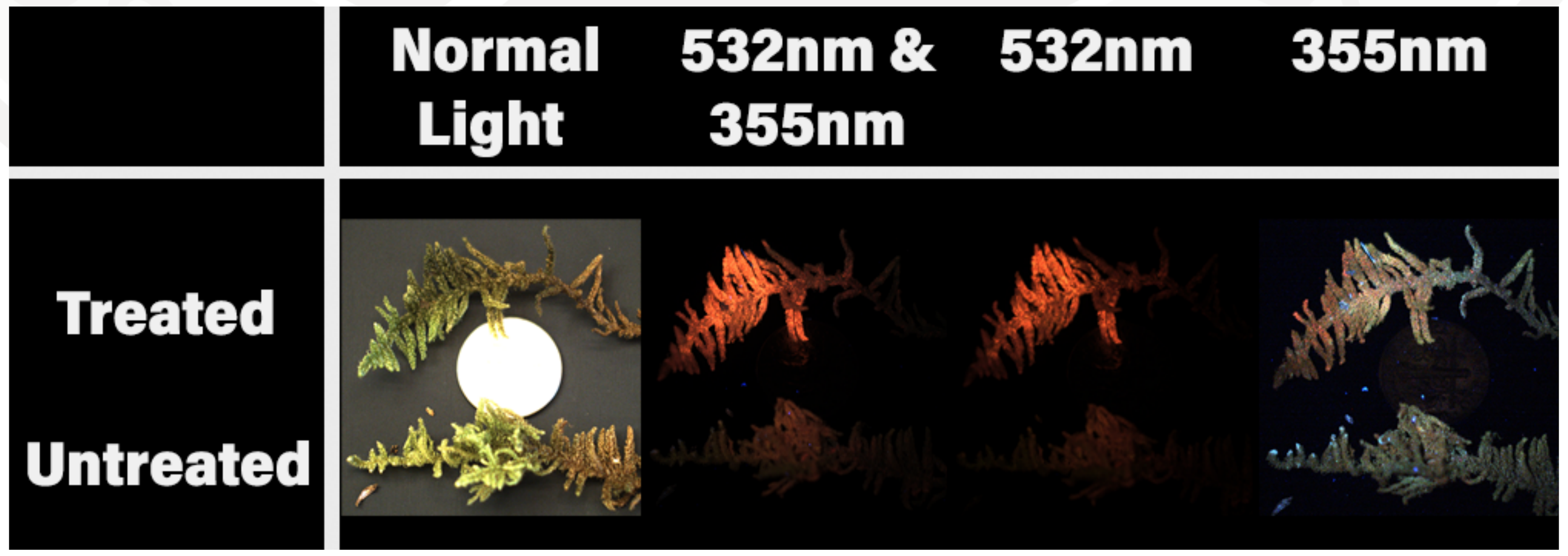
The first phase of the project will be laboratory cultivation and systematic dosing of moss samples with different concentrations of copper. The treatments will be administered over several days and each day the response will be measured using optical as well as destructive methods to determine the absorbed metal levels, changes in chlorophyll composition, and other relevant parameters.

Part 2: Laser Analysis

The optical measurements will quantify the extent and intensity of observed bio-fluorescence changes in the moss as a response to copper. The photographed signal is composed of color changes after exposure due to biological changes resulting from copper uptake. It will be important for the response of cellular death or damage to be documented as it may affect the amount of copper visible under laser induced fluorescence. In order to differentiate such changes, the use of a green laser (532nm) and a UV beam (355nm) help to delineate the pure response of the copper and those sections of the moss specimen with healthy chlorophyll.

Results

Measurements of treated and untreated moss samples clearly identify the area exposed to copper using the 532 and 355 nm lasers. The results show that the laser is viable for identifying the response of moss to copper sulfate exposure, but the quantification of the underlying chemical and biological mechanisms will be investigated further.



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Expected Impact

The application of the laser methodology will be expanded to detecting moss responses to radionuclide exposure and a corresponding quantification method will be developed. Currently, the applied laser can detect changes from as much as 15m away.

MTV Impact

MTV currently supports one graduate student to work on this project as well as collaborations with national labs. The latter include oversight in developing the monitoring technique by Wendy Kuhne. Dr. Kuhne is an expert in the areas of remote sensing and biological indicators and offers potential application of our work at the Savannah River National Laboratory. Other potential collaborations are being developed, for example through Cleat Zeiler from the Nevada National Security Site. Dr. Anupam Misra from UH has been providing laser facilities and expertise.

Conclusion & Next Steps

Copper is only the first step to proving project viability. Testing with uranium will validate the MTV-mission relevance of the methodology. Future work is planned to enhance the laser's capabilities and applications, such as the development of in-situ, microscope, and drone mounted prototypes. Development of the laser data through image processing, data interpretation, and software programing is of greatest importance.

References

- Berg, T., Steinnes E., 1997: Use of mosses (Hylocomium splendens and Pleuroziumschreberi) as biomonitors of heavy metal deposition: from relative to absolute deposition values. *Environmental Pollution* 98.
- Carginale, V., Sorbo, S., Capasso, C., Trinchella, F., Cafiero, G., Basile, A., 2004: Accumulation, localisation, and toxic effects of cadmium in the liverwort Lunularia cruciata. Protoplasma 223.
- Misra, A. K., Acosta-Maeda, T. E., Sandford, M., Gasda, P. J., Porter, J. N., Sharma, S. K., … Egan, M. J. (2018). Standoff Biofinder: powerful search for life instrument for planetary exploration. Lidar Remote Sensing for Environmental Monitoring XVI. doi: 10.1117/12.2324201
- Tremper, A. H., Agneta, M., Burton, S., Higgs, D. E., 2004: Field and laboratory exposures of two moss species to low level metal pollution. *Journal of Atmospheric Chemistry* 49.
- Zvereva, E. L., Kozlov, M. V., 2011: Impacts of industrial polluters on bryophytes: a meta-analysis of observational studies. *Water, Air & Soil Pollution* 218.

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