Long-Term Biomonitoring of Coal Ash Impoundments Using Plants and Unmanned Aerial Vehicle (UAV)-Deployed Remote Imaging Platforms

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Background/Objectives. Coal-fired power plants produce a wide variety of coal combustion residuals (CCR) in their waste streams that are typically disposed of in landfills and surface impoundments. CCR waste streams contain metals and other inorganics that may be persistent, bioaccumulative, or toxic and pose potential human and ecological health risks should leakage or rupture of the impoundment occur. Long-term monitoring of coal ash impoundments is resource-intensive and largely manual, however significant advances in remote imaging using unmanned aerial vehicles (UAVs) are occurring in the precision agriculture domain which can be directly leveraged for more autonomous and efficient long-term risk monitoring of coal ash impoundments (and other contaminated areas). The objective of this study was to investigate the feasibility and value of collecting indicator data for measuring plant responses (chemical and physical) at contaminated sites and inferring changes in site contamination profiles.

Approach/Activities. This study consisted of a comprehensive literature search of indicator, surrogate, and sentinel variables that suggest plant responses to changes in contamination plume dynamics at coal ash impoundments and other contaminated sites, as well as the machine learning algorithms that can deconstruct hyperspectral, multispectral, and infrared imaging data collected from UAVs. Follow-on greenhouse experiments are planned to link precise spectral plant responses to specific contaminants and concentrations and aid in waste management decisions.

Results/Lessons Learned. Using UAVs enabled with hyperspectral, multispectral, or infrared cameras, stress signals from vegetation planted within and surrounding coal ash impoundments can be detected and interpreted using machine learning algorithms to determine whether contamination plume dynamics are changing throughout the impoundment. Even minor shifts in plant reflectance, health, diversity, and density can provide an early warning to site managers that the risk profile of the site is changing. In addition to serving as risk sentinels, these same plants can provide a secondary benefit by stabilizing the soil, thereby slowing the transport of contaminants throughout the impoundment. Biomonitoring of plants using UAVs has the potential to significantly streamline current long-term monitoring methods for coal ash impoundments which are cost-, time-, and labor-intensive. Through extensive literature review, it's been determined that the vegetation indices that appear to be the most informative and feasible for coal ash monitoring is Leaf Chlorophyll Concentration and the Normalized Difference Vegetation Index. These two indices are key indicators of plant health, and can be seen with thermal imagery, multi-spectral imagery, and hyperspectral imagery. It has been overwhelmingly determined that the use of UAVs provides an excellent, cost-effective way to monitor and record plant data aerially. For monitoring plant responses in or on coal ash impoundments, these indices would provide the information needed to determine if plant stress is occurring due to heavy metal contamination.