Uranium Uptake for *Capsicum Annuum* in Various Growing Conditions

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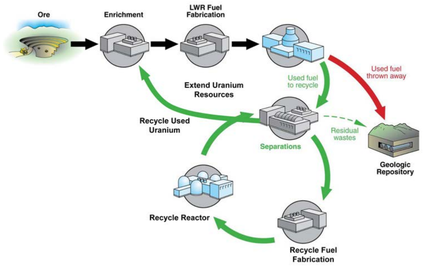
Abstract

Uranium is naturally radioactive and commonly found in water, soil, and rock. It can occur in elevated concentrations due to the presence of ore bearing bodies and be concentrated through human activities. This thesis focuses on uranium uptake for *Capsicum annuum* for three growing conditions. These include a set of plants grown in hydroponic systems, and two traditionally grown, one with a single acute spike and the other with constant contamination. In addition to the dose scenarios there are two controls, a hydroponic and a traditionally grown. The commercially grown pepper plants were cropped to remove mature seed pods. The plants were then allowed to grow (uncontaminated) until new peppers were just forming. At that point, uranium as uranyl acetate was added. Uranyl acetate was dissolved in water to a concentration of 50 µg/mL for the hydroponic and the constant contamination group. The one-time spike contained the same amount of uranium as the total constant contamination traditionally grown plants, but applied in one application such that concentration was 700 g/mL applied in 50 mL. The peppers collected prior and post contamination were analyzed using neutron activation analysis (NAA). Uranium concentration ratios (soil to plant) were developed for the different growing conditions. While uranium concentrations were larger in traditionally contaminated plants than hydroponic systems, uranium concentrations in soils were larger than in hydroton; thus, concentration ratios for hydroponic systems were larger than traditionally contaminated systems.

Introduction

Uranium is of interest due to its ability to fission and the large amounts of energy produced during fission, which can be used in a nuclear reactor to produce steam and thus electricity. Of the naturally occurring Uranium isotopes, U-235 is of interest in nuclear reactors due to its ability to fission with thermal neutrons. For use in reactors, Uranium needs to be transformed into a useful form; this process, also known as the nuclear fuel cycle. During the various steps in the nuclear fuel cycle, there is waste produced that contains uranium and other radioactive materials. After contamination, the radionuclide will transport through its surroundings, such as surrounding soil or nearby water bodies.



When a radionuclide is present in soil and a plant is growing there, a portion of the radionuclide will be absorbed into the plant. To describe how the radionuclide will transport, concentration ratios are calculated.

$$CR = \frac{Concentration\ in\ Plant}{Concentration\ in\ Soil}$$

These concentration ratios are tabulated and used in radiological transport codes .

Materials and Methods

Plants were grown in the Nuclear Engineering and Radiation Health Physics (NERHP) due to the use of radioactive materials in the experiment.

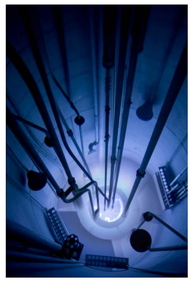
- Three growing conditions were chosen:
  1. Hydroponic
  2. Constant Contamination
  3. One-time Spike
- A concentration of 50 µg/mL uranium for hydroponic and constant contamination.
- A concentration of 700 µg/mL uranium for one-time spike.

Prior to contamination, existing peppers were clipped for analysis. Contamination continued for 34 days. The following steps were taken for analysis:

1. Samples were dried
2. Pepper samples were ground using SPEX Sample Prep Mixer/Mill 8000M
3. Hydroton samples were ground by hand
4. Samples were encapsulated in a 2/5 dram vial and then encapsulated in a 2 dram vial
5. Standards and Reference Material were prepared and encapsulated
6. Samples were irradiated in the OSU TRIGA Reactor
7. Analysis was performed using HPGe for Np-239's 106.1 and 277.6 keV peaks

Neutron Activation Analysis

Since uranium is an alpha emitter, it cannot be measured using conventional detectors. Instead, neutron activation analysis needs to be performed. As the sample is present in the reactor, there will be a decrease in uranium atoms due to absorption of neutrons and being fissioned and a proportional increase in daughter atoms. It is thus desired to measure a daughter product of uranium that undergoes radioactive decay that can be measured using conventional detectors. One such interaction is the absorption of a neutron from U-238, resulting in the following decay chain:



$$^{238}_{92}U(n,\gamma)^{239}_{92}U \xrightarrow{\beta^-} ^{239}_{93}Np \xrightarrow{\beta^-} ^{239}_{94}Pu \xrightarrow{\alpha} ^{235}_{92}U$$

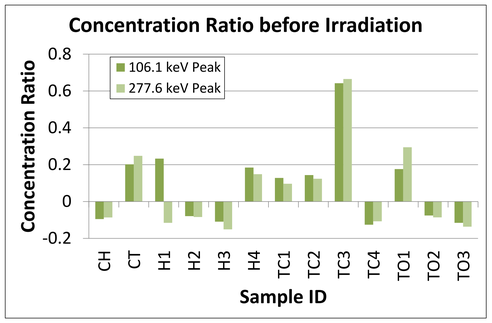
In this decay chain, the nuclide of interest is Np-239. As Np-239 decays it emits a beta particle as well as several gammas. In this analysis, the gammas of energies 106.1 and 277.8 keV are of interest. These gammas can be detected using a High Purity Germanium (HPGe) Detector. The actual activity of the sample can be calculate using standards that are irradiated with the samples in the group.

A standard is also irradiated that has a known weight of Uranium. Given the irradiation facility and irradiation time, there will be an expected activity of the sample. This expected activity is compared to the actual activity, such that:

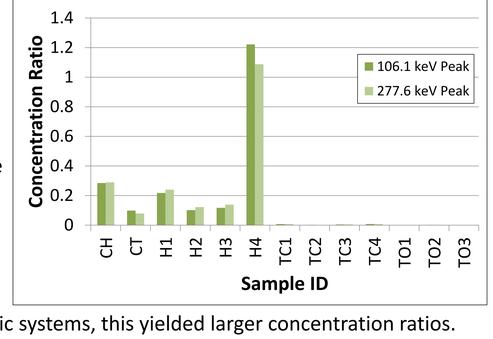
$$Weight\ of\ U\ in\ sample = \frac{(Counts\ of\ Np239 - Background\ Counts)_{sample}}{\left(\frac{Counts\ of\ Np239 - Background\ Counts}{Weight\ U}\right)_{standard}}$$

Results

The uptake of uranium into pepper plants before contamination was measured. In these cases, Uranium content averaged between 0.5 to 1.7 ppm. The resulting pepper plant uptake was up to 0.4 ppm. Negative values on the graph indicate that values were below detectability limits. One thing to note is that the pepper plants were most likely grown for a longer period that the 34 day period of this study: starting as seed and progressing to mature pepper plants. This would have caused a larger uptake of uranium over the plant's cumulative life.



After uranium contamination, uranium content in soils varied from 350 to 460 ppm for constant contamination, 560 to 860 ppm for one-time spike, and only 2 to 2.5 ppm for hydroponic systems. While the pepper concentrations were more comparable, varying between 0.25 and 0.07 ppm. However, due to the smaller concentrations in the hydroton of the hydroponic systems, this yielded larger concentration ratios.



Conclusions

While uranium uptake into the plant was comparable for each condition, the uranium uptake into the hydroton for the hydroponic systems was considerably less, yielding a lower concentration ratio. This could be due to the larger amounts of drainage in the hydroponic system or due to the inherent properties of the hydroton. This suggests that for hydroponic systems, the concentration ratio may not be appropriate for comparison with traditional systems.

Sponsor

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