Determining Transfer Factors of Non-Human Biota

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Summary

This paper investigates transfer factors of analytes through multiple pathways into the food chain of humans, resulting in radioactive exposure and dose. Non-human biotas were submerged in a liquid medium that contained analyte representing common radioactive effluent after a release (Cesium and Potassium). These plants were later checked for any uptake of analyte. The transfer factors were found to be in order of 10E-3 with minimal errors. This transfer factor analysis was encouraging and through a need of experimentally determined transfer factors, a study was setup that included plants and analyte in hypothetical environmental situations.

1. Introduction

The transport of radionuclides from source to receptor is vital for dosimetry studies. Throughout the years, nuclear operations and events such as nuclear weapons testing, radioactive waste storage and disposal, and accidents at nuclear power generating stations have created an increase in awareness of the potential effects caused by radioactive releases. In order to understand the effects of the radioactive releases on organisms, a pathway that exposes humans to radionuclides through ingestion of non-human biota was examined.

Radiological releases to the air may be dispersed by wet or dry deposition (wind or rain) via a plume. During wet deposition, the contents of the plume are deposited through rainout or washout onto surfaces such as soil, and migrate through the soil via water transport. During dry deposition, the plume directly deposits on the soil surface via gravitational settling or inertial impaction. Both types of dispersion, wet and dry, expose the non-human biota which can absorb the radionuclides. Accumulation of these radionuclides within the non-human biota will travel through the food chain, and eventually reach humans.

The focus of these experiments is to study the ecological transfer of nuclides in specific non-human biota and determine whether maximum uptake of the contaminants will occur in a water medium between the biota and the analyte.

The scope of this report is to briefly outline the importance of transfer factors, and pathway analysis with regards to non-human biota. In addition, it will identify the materials and apparatus used throughout the course of the experiment, and the experimental procedures used to collect data.

2. Background

A transfer factor is the ratio between the concentration of nuclides in an environment and the concentration of nuclides that is being absorbed by the organism in that environment. Transfer factors are determined by the relationship in Equation 1.

$$K = \frac{\text{Concentration in Biota } \left(\frac{Bq}{kg}\right)}{\text{Concentration in Surrounding Media } \left(\frac{Bq}{kg}\right)} \quad (1)$$

Transfer factors are useful since they can be utilized to evaluate the effectiveness of countermeasures applied to reduce impacts of accidental releases of radionuclides and to predict future releases from waste repositories [1]. The data that is being used today relies heavily on data obtained from literature [1].

ICRP Publication 114 [2] and IAEA Technical Reports Series no. 472 are documents in which approximations are acquired from tabulated transfer factors. Sensitivity analysis reveals that uncertainties in the concentration ratios are the key parameters leading to inconsistencies in dose rate estimates for non-human biota [3]. Therefore, it is necessary to determine transfer factors for non-human biota in order to achieve better accuracy. Non-human biota of concern includes flora such as wild grass, trees, herbs and field crops and fauna such as cows, pigs, chicken, deer, and other animals consumed by humans.

In regards to the CSA compartmental transfer-model [4], it is important to consider pathways through vegetative soil, forage and crops since they represent a release scenario that could result in an internal dose to humans. Therefore, by understanding the transport of nuclides, this project could be beneficial for predicting the amount of contaminants transferred at each compartment. The transfer diagram suggests that forage, crops and animal products are located at a lower trophic level; therefore, if ingested by humans, there is a possibility of bioaccumulation through ingestion. By determining the transfer factors, a more accurate prediction of doses to biota will be sought.

3. Methodology

3.1 Apparatus set-up

This experiment was designed to provide optimum condition for analyte uptake in order to determine the maximum uptake a plant may experience. Therefore a setup where the biota was immersed in water provided the best conditions. The biota used is the parsley plant, which is an herb, and therefore a biota of interest. The analytes used in this experiment included caesium and potassium (both stable isotopes). A setup where beakers with 40 g/L of analyte concentration were used to immerse the root of the parsley plants and a stirred and non-stirred apparatus was set-up for each analyte. Magnetic stirrers were used for the stirred beakers.
The setup, shown in Figure 1, included a light bulb fixture configured directly above the plants; hence, the light source was situated 13.75 inches from the top of the stir plates. The light source worked in conjunction with a timer that allowed for the plants to get 8 hours of light source per day for the weeklong experiment.

Figure 1: Experimental setup of water immersed parsley

3.2 Detection

Upon the completion of the experiment, the dried plants were grinded using a mortar and pestle. The process of determining transfer factors between the biota and the medium in which it was planted within was separated in two X-ray fluorescence (XRF) sections. Primarily using the XRF machine, the ground and dried plant was analyzed for the amount of nuclide it absorbed in the submersed duration. Additionally, the amount of analyte within the water was also measured through the use of a water filter. These two XRF results were given in the units of PPM (parts per million) and were subsequently normalized to their respective weights, and the quotient of the two was found to be the transfer factor in the units of grams/grams.

4. Experimental Results

Table 1: Water-Immersed Parsley Transfer Factors with Respective Errors

Chemical	Transfer Factor (g/g)	Error %	Error +/-
CH_3CO_2K – not stirred	3.16E-03	2.48%	7.85E-05
CH_3CO_2K – stirred	5.76E-03	2.84%	1.63E-04
CsCl - Not Stirred With Chemical	3.05E-04	3.61%	1.10E-05
CsCl - Stirred With Chemical	3.13E-03	3.66%	1.15E-04
No Chemical – Heavy Nuclide Analysis	0	-	-
No Chemical – Light Nuclide Analysis	0	-	-

Table 1 shows the results gained from analysis for the transfer factors for parsley plant submersed in solutions that contained potassium acetate, cesium chloride and no analyte at all. The transfer factors shown are to order of approximately 10E-3. The errors associated with transfer factors consist of detection and statistical errors.

5. Discussion

The results displayed in Table 1 show the amount of uptake of the parsley plant with respect to the analyte concentration in the medium it was dispersed within. In the case of an event where a measured value for the amount of analyte within a medium was available, the maximum uptake was calculated from the product of the transfer factor and the measured value. Using calculated uptake values, dose calculations can be made for various non-human organisms or for humans using an environmental transfer model.

Conversely, the transfer factors are expected to be lower for soil since the plants are not constantly immersed in the analyte in this scenario. However, these transfer factors for soil are not clearly defined in literature; there is a need for experiments to determine them. Since the presented experiments show valid results, a basis was formed for future studies where a wider variety of plants and analytes can be used in a soil medium.

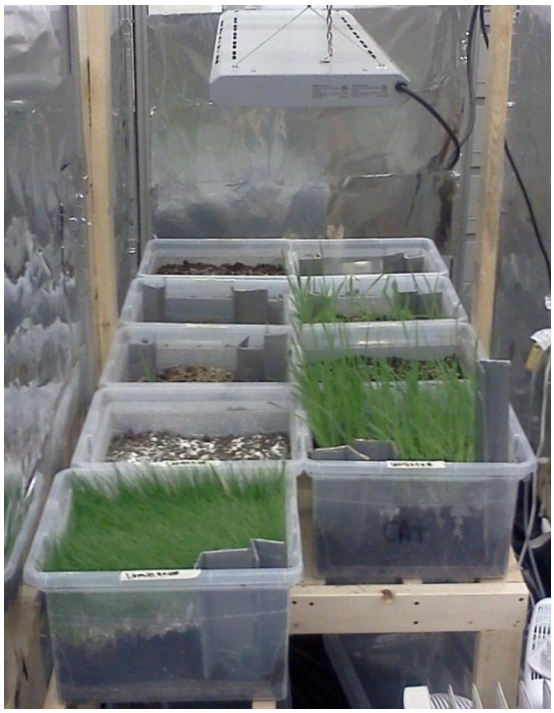

Figure 2: Experimental setup of non-human biota that is planted in soil

The current setup for obtaining soil transfer factors contains cesium, potassium, and lanthanum as analytes and cat grass and lawn grass as non-human biotas in a soil medium. With this setup, the uptake of a soil immersed plant can be measured with respect to time. This is done by taking samples on a weekly basis from each respective plant. Therefore the final results will yield a graphical function/correlation that can relate the uptake within the plant (the transfer factor) to the amount of analyte it was submersed within and the amount of time it remained there.

6. Works Cited

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