8–8 Detailed Simulation of Transfer of Radioactivity in Land Surface Ecosystems

— Development of Nuclide Transport Model for Atmosphere-Vegetation-Soil System —

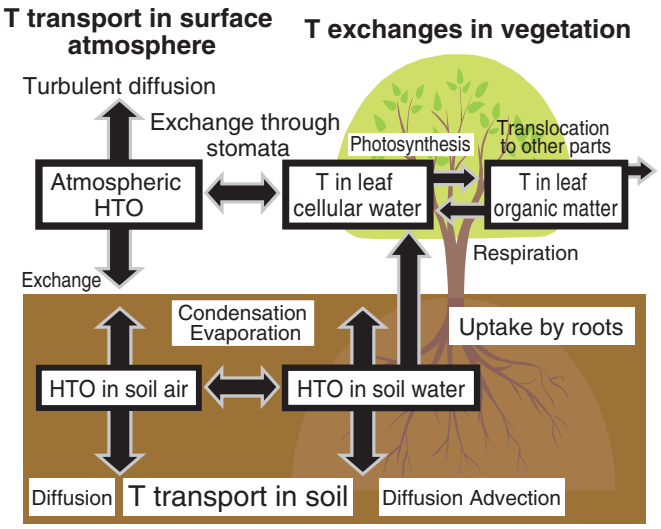

Fig.8-21 T transports and exchanges considered in the developed model
The model simulates the transport of HTO in a multilayered atmosphere and soil, and exchanges of T in vegetation, by considering the water and CO_2 cycles.

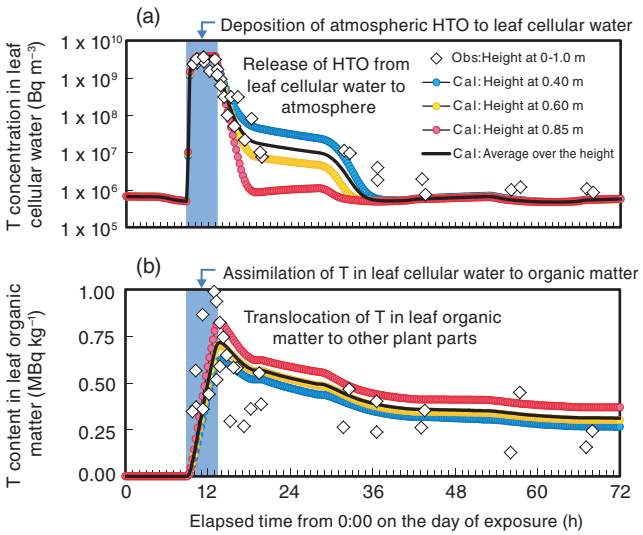

Fig.8-22 Reconstruction simulation of experiment in which grape plants were exposed to atmospheric HTO vapor
(a) The model simulates well the changes in T concentration in leaf cellular water due to deposition of atmospheric HTO during exposure (indicated by hatch marks) and release of HTO from the leaf cellular water after exposure. (b) The model also successfully predicts changes in T content of leaf organic matter that are caused by assimilation of leaf cellular water T by photosynthesis and translocation of T in the leaf organic matter.

Tritium (^{3}H, T) and radiocarbon (^{14}C) are important radionuclides in the assessment of the radiological impact to the public of nuclear industries because of the long half-lives of T (12 years) and ^{14}C (5730 years) and the biological importance of hydrogen and carbon in all life forms. T and ^{14}C are discharged through the operation of nuclear power plants and fuel reprocessing plants; in the natural environment, T and ^{14}C exist mainly in the form of tritiated water (HTO) and $^{14}CO_2$, respectively. Thus, the discharged T and ^{14}C are soon incorporated into the water and C cycles in the surrounding environment and are assimilated to vegetation as organic matter. The assimilated T and ^{14}C eventually deliver a dose to the public through ingestion pathways; therefore, the transfer of T and ^{14}C in land surface ecosystems should be precisely predicted to assess the dose due to nuclear facilities. However, models that dynamically consider the water and CO_2 cycles and the resultant T and ^{14}C transfer within a land surface ecosystem have not been developed; thus, assessments of the T and ^{14}C-derived dose have contained a range of uncertainties.

We developed a model that predicts the transfer of T and ^{14}C in a land surface ecosystem in detail. The dynamics of T (Fig.8-21) and ^{14}C in the surface ecosystem are modeled, and the modeled T and ^{14}C dynamics are incorporated into a land–surface water and CO_2 transport model (SOLVEG-II, developed by the Japan Atomic Energy Agency). The developed model successfully predicted the accumulation of T (Fig.8-22) and ^{14}C in leaves on plants exposed to HTO or $^{14}CO_2$.

For a comprehensive understanding of the land surface T and ^{14}C cycle, we then performed a range of numerical experiments using the model. The results demonstrated that during atmospheric T deposition to the soil, the loadings of HTO to the leaf cellular water due to root uptake of soil HTO significantly control the T concentration in the leaf cellular water, and hence the T content in leaf organic matter. Our results also quantified the increase in the ^{14}C content of vegetation due to below-ground $^{14}CO_2$ production caused by decomposition of ^{14}C-containing soil organic matter originating from ^{14}C-containing plant litter. Clearly, the model can be used to clarify the role or importance of each elemental process in the entire land surface T and ^{14}C cycle; this useful information cannot be obtained from field observations or laboratory experiments.

As a more practical application of the model, we are now investigating the transfer of T and $^{14}CO_2$ discharged at a nuclear facility over the surrounding land surface ecosystems through a simulation coupling the developed model and an atmospheric dispersion model.

Reference

Ota, M. et al., Importance of Root HTO Uptake in Controlling Land–Surface Tritium Dynamics after An–Acute HT Deposition: A Numerical Experiment, Journal of Environmental Radioactivity, vol.109, 2012, p.94–102.