京都大学	博士（工　学）	氏名	PRAPAMON SEEPRASERT
論文題目	The Influence of Soil Fungi on the Sorption of Cesium and Strontium within Organic Layer of Soil（土壌有機層中でのセシウムおよびストロンチウムの収着に及ぼす土壌菌類の影響）		

（論文内容の要旨）

This thesis presents the influence of soil fungi on the sorption of Cesium and Strontium within organic layer of soil, and consists of eight chapters.

Chapter 1: Introduction describes the concept of this research. The research background, topic development and hypothesis are elucidated. In addition, the research objective and scope are provided to clearly understand the state of argument.

Chapter 2: Literature review described the current state of research in the defined area and considers whether there are any closely related areas. In addition, this chapter identifies the gaps in the literature and discusses what is required to attend to those particular research gaps. This chapter outlines the general information followed by the chemical characteristics of Cs and Sr, the fate and transport of both elements in the soil system, and the interaction between the elements and soil microorganisms.

Chapter 3: This chapter elucidates experimental and data interpretation approaches for the isolation and identification of soil fungi. This chapter aims to determine the microorganism community in forest soil and to specify the microorganisms used in this research. Highly sensitive and specific molecular techniques were applied, such as the sequence variability of the internal transcribed spacer (ITS) region of fungi, which is a potentially useful method for rapid and accurate diagnosis of fungal isolation. In the present study, representative fungi were selected and assigned to three genera: *Fusarium*, *Trichoderma*, and *Aspergillus*. C1 shared 98% similarity with the genus *Trichoderma*, D1 shared 97% similarity with the genus *Aspergillus*, and the others shared 78%–91% similarity with the genus *Fusarium*.

Chapter 4: In the previous chapter, the representative soil fungi are described. They are significantly affected when the ambience of their environment changes. Therefore, they should be able to sense and respond to these changes to survive. Beyond some limits, the existence of fungi tends to decrease as a result of inhibition to growth because of toxicity caused by the occurrence of Cs and Sr in the environment. In this chapter, the growth kinetics of the soil fungi affected by two elements Cs and Sr are investigated using statistical evaluation of mathematical models to describe the fungal growth. The inhibitory effects of Cs and Sr on the growth of soil fungi are studied. The study further indicated that Cs exerted significant direct inhibition on the fungi, with an EC_{50} of 80 mM—160 mM, whereas Sr exerted less significant direct inhibition on the fungi, with an EC_{50} of 171 mM—222 mM. However, the natural levels of Cs and Sr in soil were lower than EC_{50} values 600 to 650 times.

Chapter 5: Previous investigators have studied various fungal species to define responsive signaling to the presence of Cs and Sr in the environment. The sorption process mostly influences the fate in the environment of both Cs and Sr. Aims of this chapter are to apply a kinetic model of nonlinear regression for the main purpose of explaining the rate of the sorption process. The kinetic expressions are commonly used. In this chapter, both stable and radioactive isotopes of Cs and Sr are investigated, with experiments performed under various conditions. Therefore, the sorption equilibrium was rapidly reached within 60 min, and no further sorption was observed, even when each of the solutions with the different elements

was mixed for a further 2 h. On the other hand, the experimental data for the radioactive isotopes (^{134}Cs and ^{85}Sr) were better described by the pseudo second-order model, as indicated by the values of the corresponding correlation coefficients.

Chapter 6: This chapter intends to clearly understand how a soil fungi accumulates Cs and Sr as both stable and radioactive isotopes. The Langmuir and Freundlich isotherms are used to describe the sorption characteristics and to quantify the sorption capacity. Batch experiments described in this chapter were performed under various conditions. The results showed that the monolayer sorption capacity for Cs ions was as follows: *Aspergillus* sp. >*Fusarium* sp. >*Trichoderma* sp. and *Fusarium* sp. >*Trichoderma* sp. > *Aspergillus* sp.

Chapter 7: This chapter intends to determine the contribution of microbial activity to the sorption of Cs and Sr in the organic material, which is necessary to compare the non-sterile systems with sterile systems. This chapter highlights the need to develop a new experimental approach to characterize the full potential of soil fungi to accumulate Cs and Sr in the soils. The results for the system inoculated with soil solution to provide the biotic treatment show the percentage of Cs extracted by the mixed cation solution was lower than abiotic system, 15%, 18%, 13%, and 18% of the initial Cs concentration for localities IWT1–IWT4. In the system inoculated with single fungal cultures, approximately 18%–39% of the initial Cs was extracted compared to 28%–50% of the initial Cs extracted from the abiotic system. The treatment inoculated with *Aspergillus* sp. showed a slightly higher ability to retain Cs than those inoculated with *Fusarium* sp. and *Trichoderma* sp. correspond with the result from the previous chapter which shows *Aspergillus* sp. has more ability to adsorb Cs than other genera. However, for Sr in biotic systems only 7%–17% of the initial Sr was extracted, compared to 10%–20% of the initial Sr extracted for the abiotic system. The results for an experimental system comparing biotic and abiotic systems conclusively demonstrate that soil fungi play a role to restrict the mobility of Cs and Sr. In all experiments, the retention of both elements was greater in biotic systems than in abiotic systems. Soil microorganisms especially the saprotrophic fungi make a contribution to influence the retention of Cs and Sr in organic systems and may account in part for the strong, irreversible binding observed in biotic systems. This finding may account for the high level of radioactive Cs and Sr retention in the in situ contaminated site, which cannot be satisfactorily accounted for by physicochemical processes.

Chapter 8: The final chapter summarizes the main finding of the dissertation and the contributions of this study. Moreover, a suggestion for future works is provided.

氏　名	PRAPAMON SEEPRASERT

（論文審査の結果の要旨）

本論文は、土壌中における放射性物質の貯蔵場所としての土壌菌類の役割と、有機土壌系でCsとSrが移動性を保持するための土壌菌類の役割を明らかにしようとしたものである。得られた主な成果は以下のとおりである。

１）土壌腐植中の菌類のいくつかを単離同定することで、森林土壌中で見つかる主な菌類系は木の種類に関係し、本研究で調べたいくつかの土壌系では、主な真菌類はフザリウム属、トリコデルマ属、アスペルギルス属の３種であった。

２）真菌類へのCsとSrの毒性を明らかにするため、成長モデルへの影響を調べた結果、Csは菌類に対し直接的な成長抑制効果を示し、EC50は80-160mMであったが、Srには大きな成長抑制効果はなく、EC50は171-222mMであった。Csの各菌類に対する毒性は、トリコデルマ属種＞アスペルギルス属＞フザリウム属の順となったが、Srの毒性は、フザリウム属種＞アスペルギルス属＞トリコデルマ属と逆になった。

３）収着実験の結果、Csの収着は擬似二次モデルの方が擬似一次モデルよりも良いフィッティング結果を示したが、Srに対しては、逆の結果となった。

４）実験結果から、Csイオンの単分子層収着容量はフザリウム属種＞トリコデルマ属種＞アスペルギルス属の順となったが、Srイオンが系に加えられると、単分子層収着容量は減少した。また、安定同位体を使用して、CsとSr元素濃度を増やした場合、生物学的収着の割合は減少し、収着等温線の平衡プラトー状態にまで達したが、放射性同位元素を用いた低濃度実験では、各元素の生物学的収着の割合は、変化しなかった。

５）一価と二価の陽イオン輸送システムを支配している収着サイトと水素イオンの相互作用のため、低いpHで収着容量が減少するというpHの影響が示された。

以上のように本論文は、原発事故後に問題となる森林土壌中でのCsとSrの挙動における生物学的収着の役割を説明するものであり、今後の放射性物質の環境中挙動解明に大きく貢献するものであって、学術上、実際上寄与するところが少なくない。よって、本論文は博士（工学）の学位論文として価値あるものと認める。また、平成２７年８月２１日、論文内容とそれに関連した事項について試問を行って、申請者が博士後期課程学位取得基準を満たしていることを確認し、合格と認めた。なお、本論文は、京都大学学位規程第１４条第２項に該当するものと判断し、公表に際しては、当該論文の全文に代えてその内容を要約したものとすることを認める。