研究成果報告会
-ふくしまの環境回復に係るこれまでの取組-
2015年11月9-10日

Calculations of Dose Rate Reductions upon Soil Remediation

Alex Malins ・町田昌彦　システム計算科学センターシミュレーション技術開発室
操上広志・ 北村哲浩　　福島環境安全センター環境動態研究グループ

Overview

Topsoil Stripping
A1: Cover over with clean soil
A2: No covering layer

Soil Layer Interchange
A3: Switch position of topsoil and subsoil layer

Soil Mixing
A4: Mix soil down to set depth with plough or rotovator

Remediating soil contaminated with radioactive fallout, whether from a nuclear reactor accident or test, can lower radiation doses to members of the public. Exposure to fallout radiation can occur internally, by ingestion or inhalation of contamination, or externally, by exposure to *groundshine*.

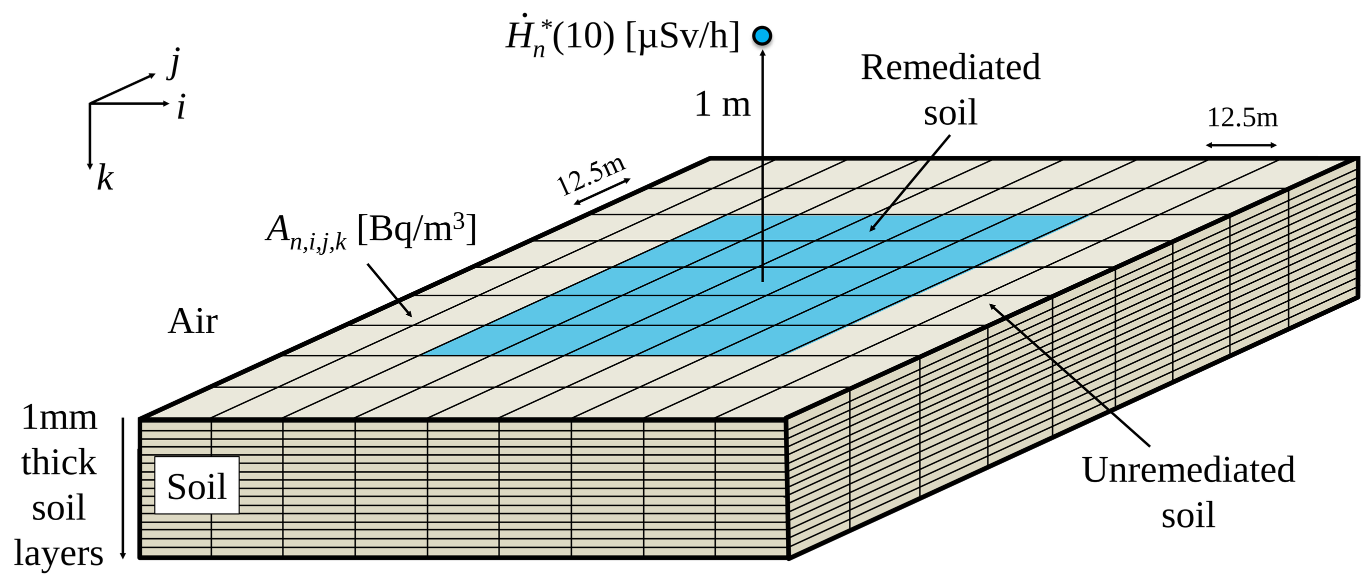
Groundshine is gamma radiation emitted by fallout radionuclides on the ground, e.g. ^{134}Cs, ^{137}Cs etc. within soil. Groundshine contributed to around half of the total doses to the public in the contaminated areas of Belarus, Ukraine and Russia following the 1986 Chernobyl accident. In Fukushima Prefecture, groundshine is the main component of the additional doses from the 2011 Fukushima Daiichi Power Plant accident.

One goal of soil remediation is to lower air dose rates and reduce groundshine exposures. However, remediation is both costly and labour intensive as large areas of land must be remediated to substantially reduce dose rates. It is therefore desirable to optimize the design of remediation activities to maximise dose rate reductions while maintaining cost efficiency.

Purpose

To evaluate how the initial depth distribution of fallout within soil, the depth to which remediation is performed and the size of the remediation plot affect the dose rate reductions achieved by remediation. This information is useful for designing remediation programmes efficiently.

Methods



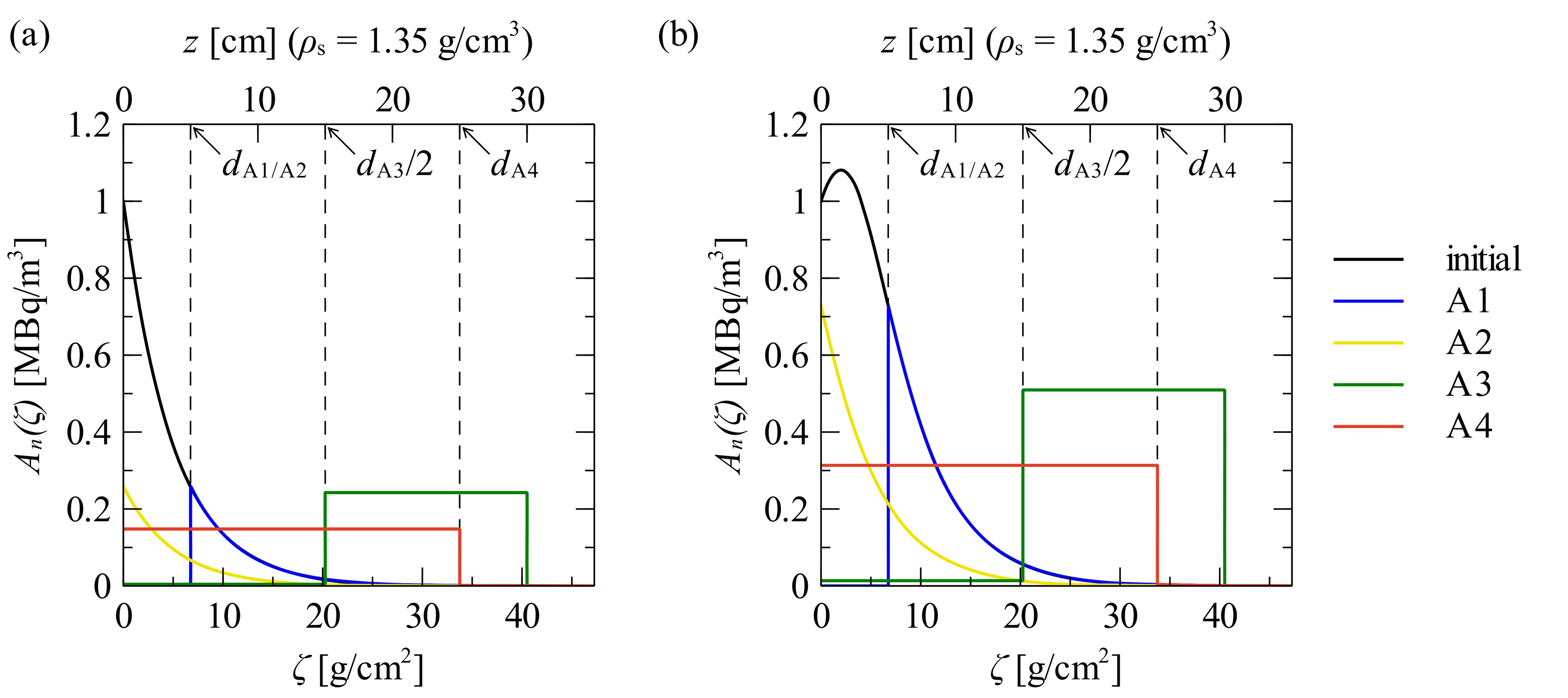
Tool to model ^{134}Cs- & ^{137}Cs-contaminated soil and predict air dose rates

This research employed a tool developed to calculate air dose rates from radiocaesium concentrations in soil. The caesium concentrations can vary both with depth (1mm soil layers), and spatially across the area (12.5x12.5m mesh).

Two initial depth distributions were considered for the radioactivity, based on soil samples from Europe after the Chernobyl accident, and Japan after the Fukushima accident. In one distribution (exponential) the activity concentration decreases continuously with depth. In the other (hyperbolic secant), there is an activity peak below the surface.

The distributions subsequent to remediation by methods A1-A4 are shown below.

Initial Distribution: **Exponential** **Hyperbolic Secant**

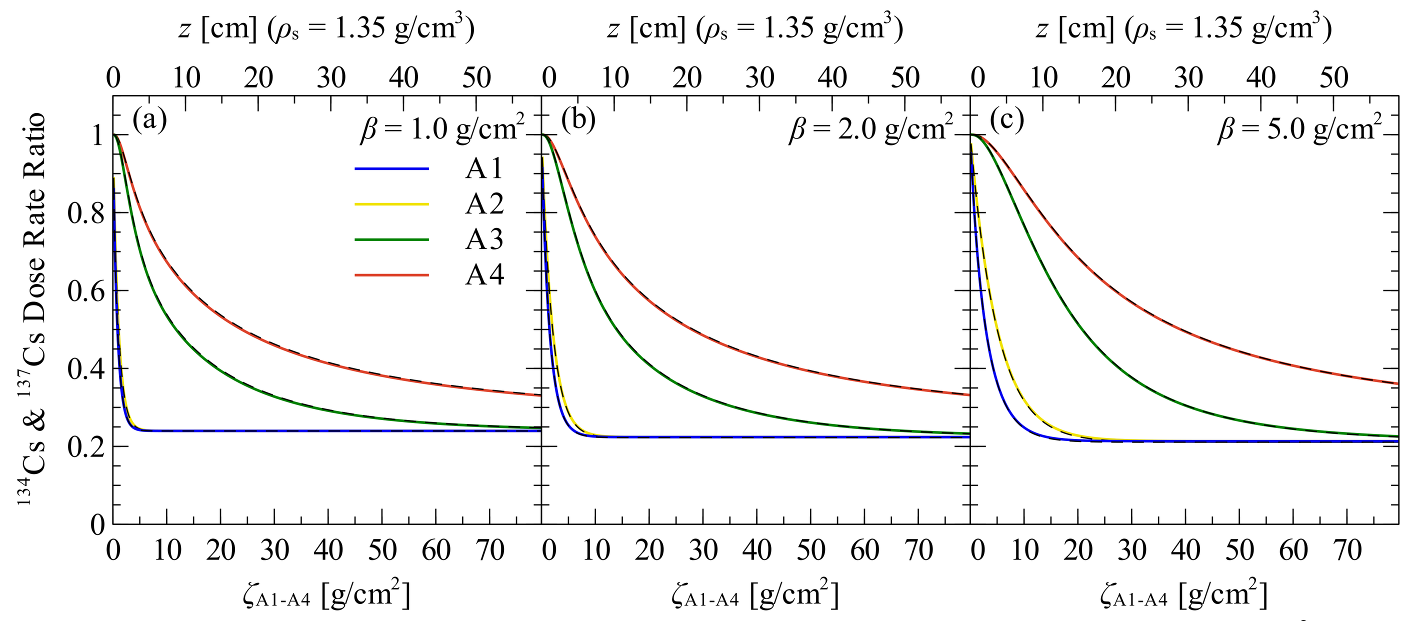


Model for change in radioactivity distribution with depth after remediation

Results

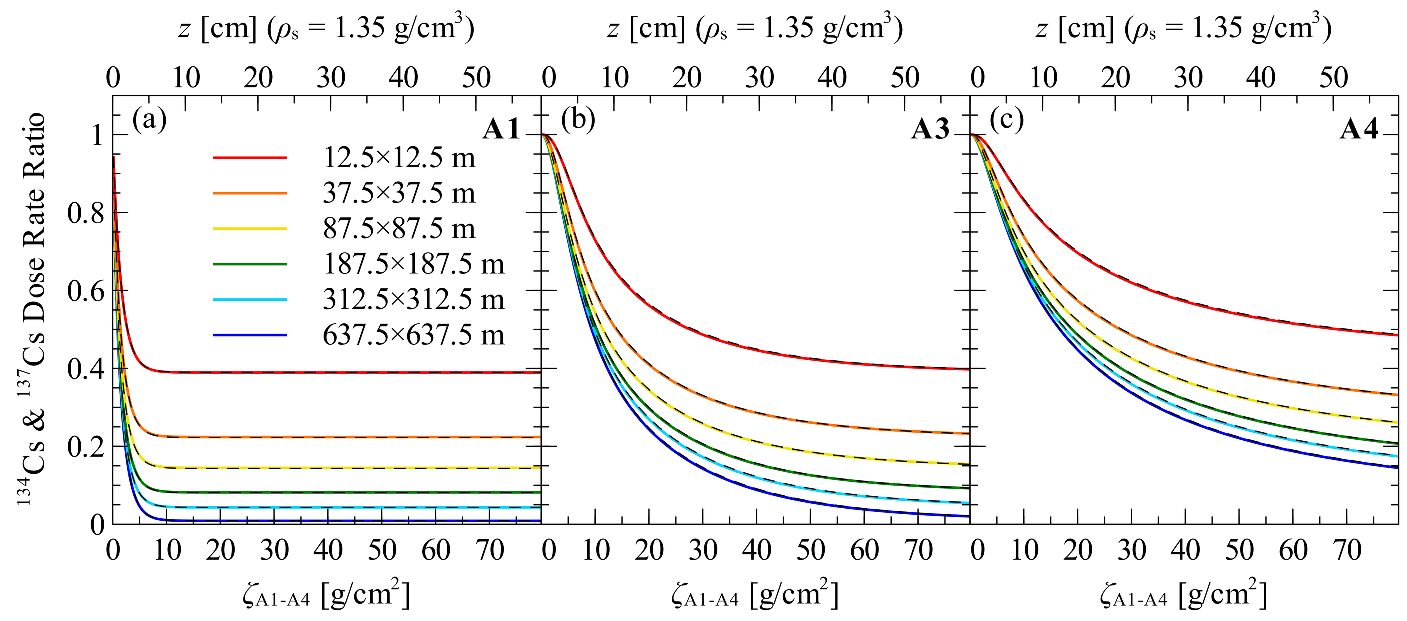
***Dose Rate Ratio*: dose rate after remediation divided by initial dose rate**

Increasing Depth of Remediation:

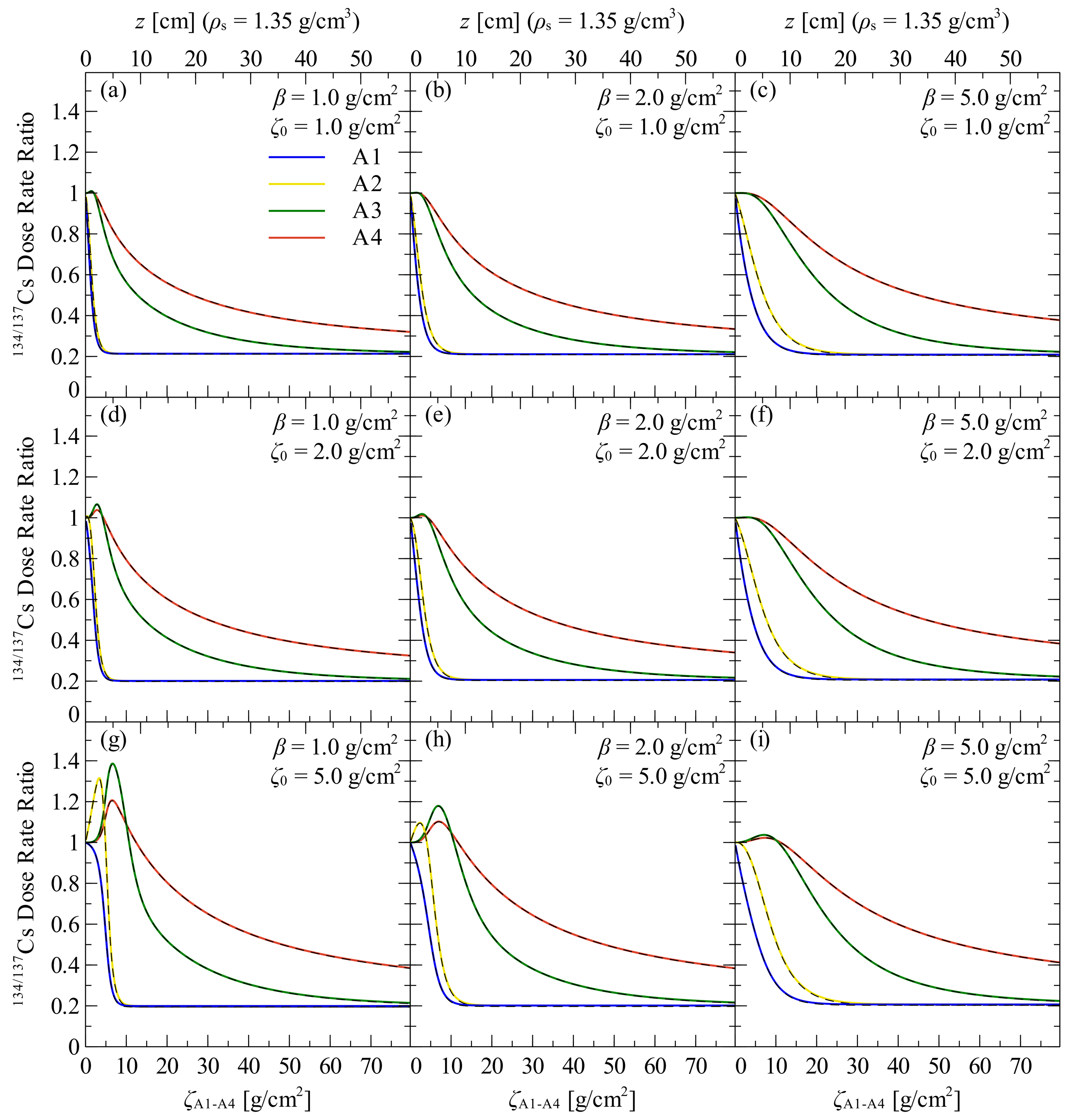


Deeper fallout penetration into soil (larger β in initial distribution)

Increasing Area of Remediated Land:



Initial Hyperbolic Secant Distribution:



Deeper activity peak below the surface (larger β in initial distribution)

Deeper fallout penetration into soil (larger β in initial distribution)

Discussion

- Performance of remediation depends on the initial distribution of radioactivity with depth in soil
- Beneficial to know the initial depth distribution when designing a remediation programme for an area of land in order to remediate efficiently
- Depth to remediate can then be established using calculation tool, thus guarding against over-remediation
- Once soil has been effectively remediated within the remediation zone (shown by plateaus on graphs above), only way to further reduce dose rates is to increase the size of the remediation area
- Other factors also need consideration, such as social, economic and future land use

References:
1. JAEA-Review 2014-051, 2015.
2. Matsuda et al., Journal of Environmental Radioactivity, 139, 427 – 434, 2015.
3. Malins et al., Journal of Environmental Radioactivity, 151, 38 – 49, 2016.
4. Malins et al., *Submitted to* PLOS ONE, 2015.