An Analysis of Maximum Allowable Radiation Levels in Soil: Comparing Risk Models of International and National Agencies – 16306

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ABSTRACT

Setting and complying with an appropriate soil radiation screening level presents a complex problem as there are a multitude of models available based on previous land uses and localities. An in depth analysis of the different maximum allowable concentrations provided by the diverse models has never been conducted before.

This study is a comparison of concentrations of select radionuclides considered acceptable by several national and international agencies. The project focuses on two specific radionuclides of concern Radium 226 and Cesium 137. Each agency's concentrations were derived from its respective model using the residential land use scenario.

The key objectives and benefits of this project include:
1. To facilitate better understanding of each agency's approach to tackling problems of land contamination due to radionuclides.
2. Identify thematic areas for cooperation.
3. Make recommendations on technical and practical issues to the agencies involved.
4. To enhance the dialogue between various international and domestic initiatives concerned with land contamination and regeneration/remediation.

BACKGROUND

Soil is a limited resource, and interestingly one this is vital to the propagation of other natural resources such as forestry and agriculture.

Soil contamination is caused by xenobiotic and naturally occurring chemicals and radionuclides that alter natural soil composition. Although some of the most common contaminants include petroleum hydrocarbons, polynuclear aromatic hydrocarbons, solvents, pesticides, and heavy metals, there is significant concern over radioactive material contaminating soil as well.

The concern over soil contamination stems primarily from health risks, from direct contact with the contaminated soil, vapors from the contaminants, and from secondary contamination of water supplies within and underlying the soil.

The extent of which land is radioactively contaminated is known best in North America and Western Europe. Many countries have national and state agencies that have established a legal framework to identify and remediate this environmental issue. A few of these frameworks will be explored in this paper.

INTRODUCTION

RESRAD is a computer code developed at Argonne National Laboratory for the U.S. Department of Energy to calculate site-specific RESidual RADioactive material guidelines as well as radiation doses and excess lifetime cancer risk to a chronically exposed on-site receptor. A total of nine major exposure pathways are considered in the RESRAD (onsite) code:

- Direct exposure to external radiation from the contamination soil material;
- Internal exposure from inhalation of airborne radionuclides;
- Internal exposure from inhalation of radon progeny; and
- Internal exposure from ingestion of:
    - o Plant foods grown in the contaminated soil and irrigated with contaminated water;
    - o Meat and milk from livestock fed with contaminated fodder and water;
    - o Drinking water from a contaminated well or pond; o Fish from a contaminated pond;
    - o Contaminated soil.

Preliminary Remediation Goals (PRG) and Dose Compliance Concentrations (DCC) Calculators were developed by the U.S. Environmental Protection Agency to set preliminary cleanup goals for a site which has been more extensively evaluated and sampled through a field investigation. It is an Internet based calculator found at: http://epa-prgs.ornl.gov/radionuclides/. In order to set radionuclide-specific preliminary remediation goals in a site-specific context, assessors must answer fundamental questions about the site: information on the radionuclides that are present onsite, the specific contaminated media, land-use assumptions, and the exposure assumptions behind pathways of individual exposure. The calculator provides the ability to modify the standard default exposure parameters to calculate site-specific preliminary remediation goals. The calculator provides default values if specific values have not been determined through site investigation and offers a number of risk assessment scenarios for evaluation. The PRG calculator is also consistent with EPA's recommended model for risk assessment for chemicals in soil, water, and air, the Regional Screening Level (RSL) calculator which may be found at: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm. The Dose Compliance Concentrations (DCC) calculator is similar to the PRG calculator for demonstrating compliance with dose based regulations and located at: http://epa-dccs.ornl.gov/.

RCLEA (The Radioactively Contaminated Land Exposure Assessment Methodology) is DEFRA's (U.K. Government Department for Environment, Food and Rural Affairs) recommended approach for the exposure assessment of a site under the extended Part 2A regime for managing contaminated land in the UK. Information on RCLEA is available on http://www.rclea.info/index.htm. RCLEA calculates potential doses for comparison with UK regulatory criteria. It can also be used to calculate 'Guideline Values' in terms of radionuclide concentrations if reliable measurements are not yet available. In addition to specifying radionuclides present (and concentrations, if

known), initial generic calculations simply provide the user with four basic options to select from:

- Reference land uses, including residential (with or without home-grown vegetables), allotments and commercial/industrial use;
- Building type (timber framed or brick);
- Age of the exposed individual (adult, infant or child); and
- Sex of the exposed individual (male or female).

Bureau of Environmental Radiation of the State of New Jersey provides technical support to the Site Remediation Program. Their Excel based model is called Radioactive Soil Remediation Standards (RaSoRS).

The NCRP (National Council on Radiation Protection and Measurements) published a report entitled, “Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site Specific Studies” (NCRP Report No. 129). It lists screening guidance for over 200 radionuclides with half-lives greater than 30 days. The limits were calculated by dividing 025 mSv by the calculated maximum screening total dose per unit soil concentration in Sieverts.

METHODS

To perform this study, we queried contacts at state and international agencies to develop an understanding of the models they utilize. We also conducted a search of the radiation literature to capture the breadth of radiation dose and risk assessment models to include in this study. After familiarizing ourselves with each of the models, each model was run to produce an output of the highest allowable concentration of Cesium 137 and Radium 226 (plus daughters when available) based on each model’s unique default values.

DATA

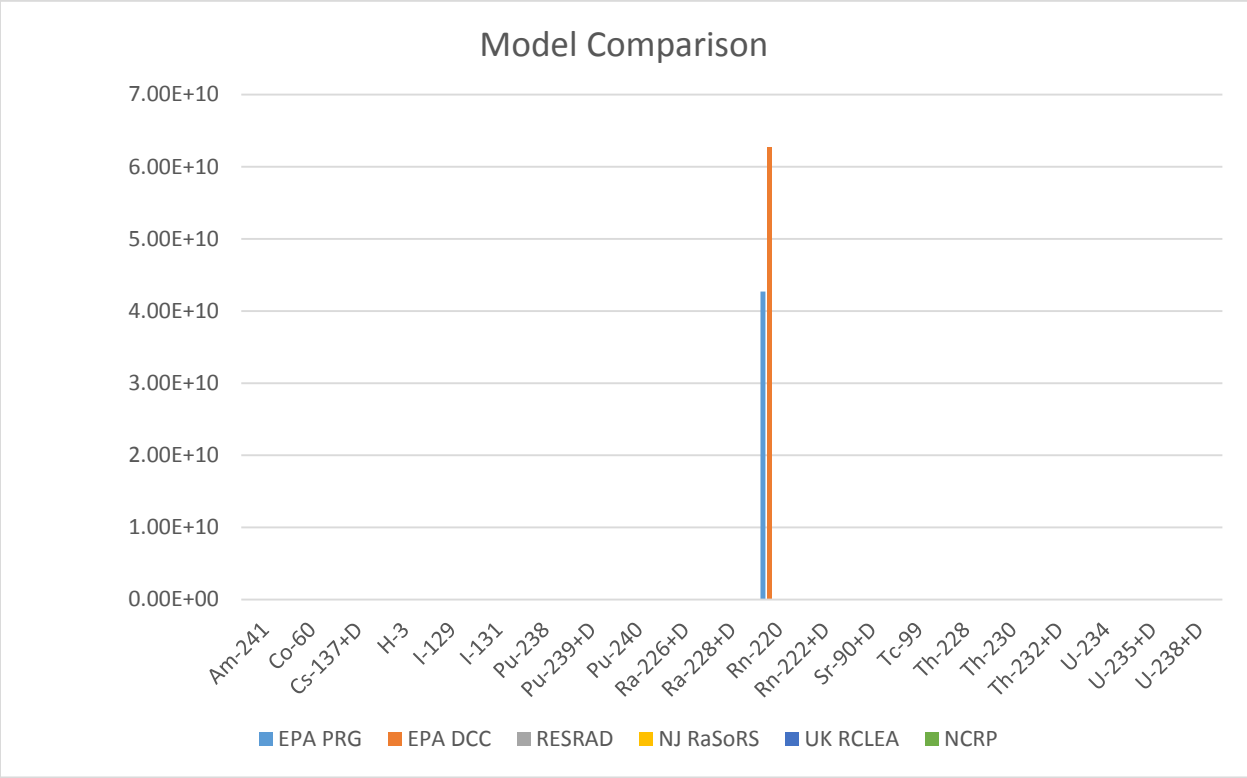

Figure 1. This graph is an overall view when graphing the data. Many of the data points are too close to 0 to be visible in such a macro view.

Models Residential(pCi/g)						
	EPA PRG	EPA DCC	RESRAD	NJ RaSoRS	UK RCLEA	NCRP
Cs-137+D	4.70E+00	9.87E+01	11		1.08E+02	4.05E+00
Ra-226+D	6.43E-01	1.89E+01	0.6	3	2.70E+01	1.11E-01

Table 1. Maximum contamination levels in (pCi/g) of Cesium 137+D and Radium 226+D for each model.

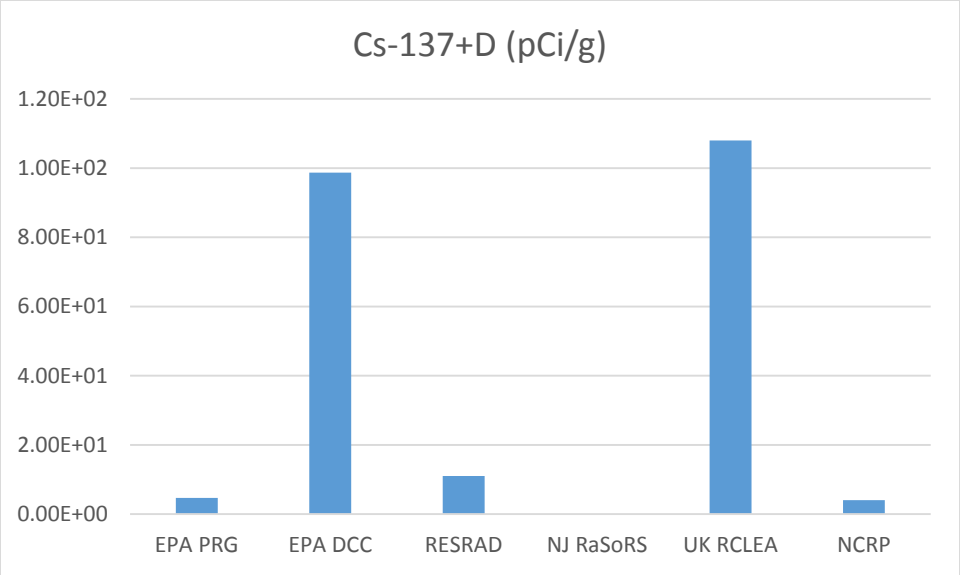

Figure 2. Estimated maximum allowable concentration of Cesium 137 in soil according to various models.

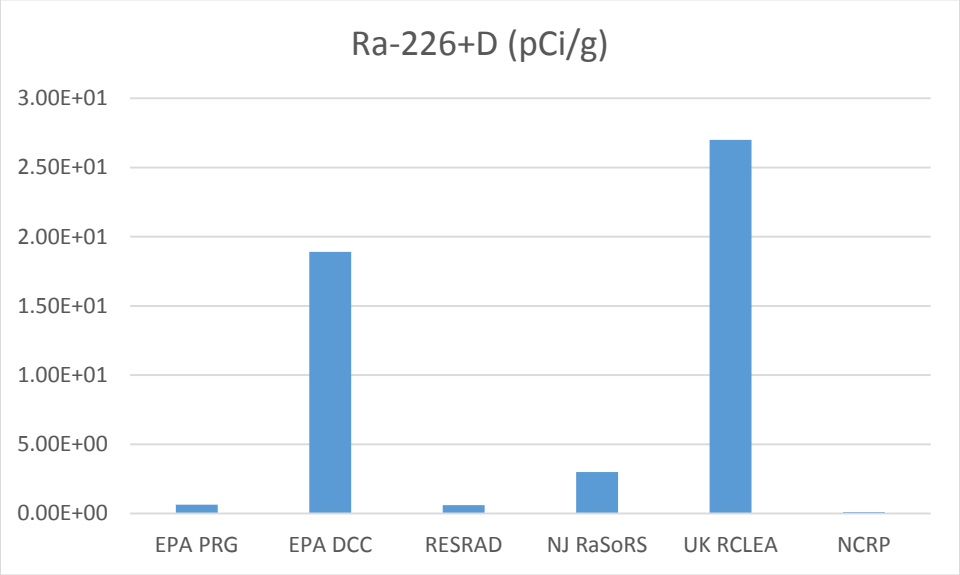

Figure 3. Estimated maximum allowable concentration of Radium 226 in soil according to various models.

DISCUSSION

When comparing the results converted to pCi/g for the two radionuclides, Cesium 137 and Radium 226, one can see that the EPA PRG calculator, RESRAD and the NCRP Screening Guidelines are the most protective and are consistently within one order of magnitude of one another. The RaSoRS maximum allowable concentration

for Radium 226 is also within one order of magnitude as the PRG calculator, RESRAD, and NCRP. It is important to note that the New Jersey RaSoRS model did not include a value for Cesium 137 in the output and therefore shows '0' in the bar graph representation above. Each one of these models takes into account different variables and default parameters.

CONCLUSIONS

In conclusion, the data shows that the six models presented all have a different maximum allowable concentration for each radionuclide. However the only very by zero to two orders of magnitude. Further analysis is warranted to determine the cause of this variance. Such an analysis is beneficial to the US EPA, Department of Energy, NRC, and others, including those whose models were involved in the study to ensure that their risk assessments are in line with one another to ensure achieving the ultimate goal of public health protection.

REFERENCES

Download the risk assessment models at the following links:

PRG Calculator: http://epa-prgs.ornl.gov/cgi-bin/radionuclides/rprg_search

DCC Calculator: http://epa-dccs.ornl.gov/cgi-bin/dose_search

New Jersey RaSoRS: http://www.nj.gov/dep/rpp/rms/rad_cleanups.htm

RCLEA: https://www.gov.uk/government/publications/rclea-software-application (download RCLEA software application)

RESRAD: https://web.evs.anl.gov/resrad/RESRAD_Family/

NCRP soil screening level Guidance.

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