# Soil contamination with radioactive material and subsequent assessment of ambient dose using PHITS

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## 1. Introduction

Nuclear facilities all have dedicated systems to extract leaked material through dedicated filters before the gas or liquid is vented out of the facility through ventilation and exhaust systems. However, a major accident at one of these facilities, resulting in a large release of material, can have catastrophic consequences.

Radiological accidents, especially nuclear accidents, can release significant amounts of radionuclides, increasing the risk of cancer and the probability of death. Therefore, it is essential to estimate the dose to which the public may be exposed in order to predict and prepare for a hypothetical accident in a potentially dangerous nuclear reactor. [1]

To mitigate radiological effects on local populations, it is important to improve emergency protocols that take into account the location and geographic characteristics of the population. This can be accomplished through measures such as evacuation, shelter-in-place, and resettlement to safer areas."[1]

The effects of radiation exposure from a radioactive material leak have generally been shown to be much greater for women than for men, with a 20-year-old's risk being three times that of a 60-year-old for similar exposure, because the risk depends on the interval between the age of possible exposure and the age of maximum exposure, and the earlier the age of exposure, the shorter the life expectancy into old age [2].

## 2. Methods and Results

### *2.1 Dose Assessment with PHITS*

PHITS is a stochastic Monte Carlo particle transport code written in FORTRAN. PHITS can handle the transport of all particles (atoms, nuclei, neutrons, photons, and electrons) over a wide energy range using several nuclear reaction models and nuclear data libraries. In computational simulations, various quantities such as radiation trajectory lengths and yields can be inferred from the simulation using an implemented estimator function called "tellies" for three-dimensional space. In addition, calculated results can be plotted in 2D and 3D figures and geometries can be set using the ANGEL code. PHITS can be run on almost any computer (Windows, Mac, Linux) using "multipliers" from T-track to built-in (ISO irradiation) or -202 (AP irradiation) doses [3].

### *2.2 Example Contamination Situations*

Radiation dose calculations were based on the assumption that one square centimeter of soil was contaminated with 10 barrels of Am- 241. The contamination radius was assumed to be 1 meter and the contamination depth was assumed to be 3 centimeters below the ground surface.

The calculation of the effective dose by T-track for Am-241 contamination at a concentration of 10 Bq/cm^3 at a depth of 3 cm in soil with a radius of 1 m is shown in Figure 1.

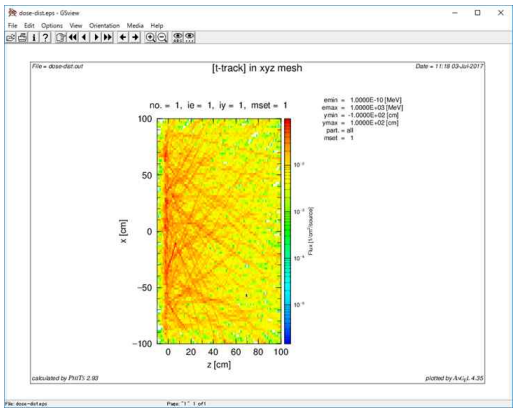


Fig. 1. Effective dose calculation by T-track for Am-241 contamination at 3 cm depth in soil.

Keeping the contamination per unit volume (Bq/cm^3) constant, we saw the change in dose rate when we changed the radius of the contaminant from 1m->3m->9m.

The height of the radiation dose of interest was calculated as the effective dose one meter above the ground.

Also, for Cs-137 contamination, the [T-track] unit in Tally is (particles/cm^2), which can be calculated as (particles/cm^2/second) if using a radiation source. This unit can then be converted to (pSv*cm^2) using a multiplication factor to get the effective dose.

The calculation of the effective dose at 1 meter for Am-241 contamination at a concentration of 10 Bq/cm^3 in 3 cm of soil in a radius of 1 meter is shown in Figure 2.

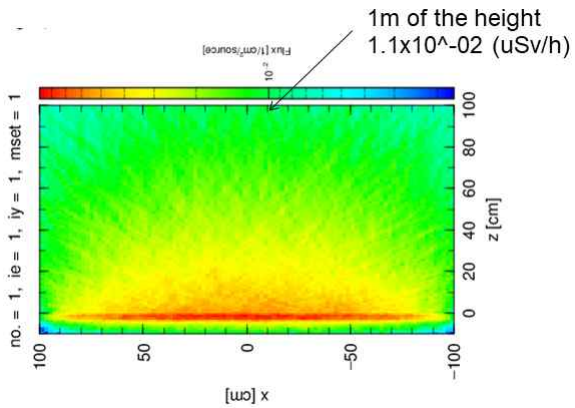


Fig. 2. Effective dose rate 1 meter above the ground.

## 3. Conclusions

In this study, a probabilistic computer simulation code, PHITS, was used to obtain ambient effective dose assessment results from soil contaminated by leakage and spread of radioactive material from a radiological accident.

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