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EVALUATION OF PROPOSED SHALLOW-LAND BURIAL SITES USING THE PRESTO-II METHODOLOGY AND CODE+

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ABSTRACT

PRESTO-II (Prediction of Radiation Effects from Shallow Trench Operations) is a computer code designed to evaluate possible doses and risks (health effects) from shallow-land burial sites. The model is intended to serve as a non-site-specific screening model for assessing radionuclide transport, ensuing exposure, and health impacts to a static local population for a 1000-year period following the end of disposal operations. Human exposure scenarios include normal releases (including leaching and operational spillage), human intrusion, and limited site farming or reclamation. Pathways and processes of transport from the trench to an individual or population include ground-water transport, overland flow, erosion, surface water dilution, suspension, atmospheric transport and deposition, inhalation, external exposure, and ingestion of contaminated beef, milk, crops, and water. The proposed waste disposal area in Koteyli, Balikesir, Turkey, has been evaluated using the PRESTO-II methodology. The results have been compared to those obtained for the Barnwell, South Carolina, site. Dose estimates for both sites are below regulatory limits, for the release and exposure scenarios considered. The doses for the sites are comparable, with slightly higher estimates obtained for the Turkish site.

INTRODUCTION

The Turkish Government is in the process of planning two nuclear reactors in Turkey. Studies have begun to develop for improved control of low level wastes (LLW) in Turkey before establishments of these reactors. In this study, the PRESTO-II (Prediction of Radiation Exposures from Shallow Trench Operations) computer code [(1)] is used to assess the risk associated with the shallow-land disposal of low level radioactive waste (LLW) in various sites in Turkey. PRESTO-II is a computer code designed for the evaluation of possible health effects from shallow-land burial of radioactive wastes.

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A preliminary simulation using the PRESTO-II computer code has been run for the site in Koteyli-Balikesir, Turkey [2]. This example simulation was performed using the same radionuclide data set believed representative of the LLW disposal facility in Barnwell, South Carolina. Site environmental variables were selected to typify credible worst case exposure scenarios. Radionuclide inventories are primarily based on estimated waste composition rather than measured values.

THE PRESTO-II METHODOLOGY

PRESTO-II is intended to serve as a non-site-specific screening model for assessing radionuclide transport, ensuing exposure, and health impacts to a static local population for a 1000-year period following the end of disposal operations. Human exposure scenarios include normal releases (including leaching and operational spillage), human intrusion, and limited site farming or reclamation. Pathways and processes of transit from the trench to an individual or population include ground-water transport, overland flow, erosion, surface water dilution, suspension, atmospheric transport, deposition, inhalation, external exposure, and ingestion of contaminated beef, milk, crops, and water.

The PRESTO-II methodology and code have been well-documented. A code listing and example input for each of three example sites has been published [3], together with a sample run. The code uses the 1981 version of the RADRISK data set [4,5]. The code has also been made available through the Radiation Shielding and Information Center (RSIC) in Oak Ridge, Tennessee. One component of the PRESTO-II code is the DARTAB model, which has been separately documented [6], and which is designed to generate dose and risk tables for specific individuals, organs, and exposure modes.

The PRESTO-II code tracks radionuclide transport through surface and subsurface pathways and human exposures through external exposure, inhalation, and ingestion, with a resolution of 1 year (some processes are simulated with higher temporal resolution, and the results applied within portions of the code having a 1 year resolution). The methodology is mechanistic, and physical transport processes are modeled separately and in detail. Valid results require adequate knowledge of site variables. Source terms are initial radionuclide distributions in the atmosphere, streams, land surfaces, and in subsurface trenches. Human exposure scenarios include migration of radioactivity from the trench in hydrologic and atmospheric environmental pathways to food and drinking water. At-risk individuals and populations include those ingesting contaminated on-site or off-site food and water, breathing contaminated off-site or on-site air, undergoing external exposure to ground surface contamination, or living in an on-site basement.

Water, principally from precipitation, is often a primary transport medium for radioactivity from LLW stored in shallow trenches. Precipitation or irrigation water falling on the waste disposal site may either infiltrate the soil or trench cap, run off the surface, or evaporate, and radionuclides may be transported from a LLW disposal trench by groundwater or by precipitation runoff. Runoff also causes erosion of the soil surface and erodes the trench cap. Water percolating downward through the trench to the subtrench soil zone may ultimately enter an aquifer. Radionuclides that finally reach the aquifer will generally be transported more slowly than the characteristic flow velocity of water in the aquifer because the radionuclides interact with the solid materials in the aquifer. Some of the radionuclides which enter the aquifer may eventually reach irrigation or drinking wells or surface streams. Contaminated water from the trench may overflow onto the surface soil. Once overflow has occurred, radionuclides may be transported by runoff water to nearby streams and become available for human consumption via irrigation, drinking, or other ingestion exposure modes. Humans may also be exposed to radionuclides transported from LLW sites by atmospheric processes.

Atmospheric transport processes are included in the PRESTO-II methodology. Radionuclides left on the soil surface by trench overflow, by spillage during disposal operations, or by complete removal of the trench cap may be suspended in the atmosphere and transported downwind where they may be inhaled or deposited on vegetation and soil. In the case of deposition, the radioactivity may produce external exposure to humans or may enter into the food chain and result in radioactivity in crops, meat, and milk. For atmospheric transport calculations, the total population is assumed to reside within the same 22.5-degree sector. User-specified parameters give the fraction of the year that the wind blows into that sector. A user option allows the results of the atmospheric dispersion calculation in the code to be replaced by an externally-calculated dispersion coefficient which considers several population centers.

Processes considered in calculating individual or population exposure include: groundwater transport, precipitation runoff, trench water overflow and seepage, chemical exchange, trench cap erosion, stream dilution, and resuspension and atmospheric dispersion of contaminated soil followed by inhalation or oral and external exposure subsequent to deposition on crops and land.

The termination of LLW disposal operations (as associated with final trench closure) is the starting time for the total assessment period considered by the code. The user specifies the total length of the assessment period, from 1 to 1000 years. The health effects for a user-specified length of time within this assessment period are calculated. The averaging time for health effects can be as short as any single year of the assessment period or as long as the entire assessment period. The maximum concentration of each radionuclide and the year of this maximum for each of the four major exposure pathways for each nuclide is calculated. The initiation time and period for mechanical suspension of the surface soil by farming is specified by the user. The user can also specify the time at which the trench cap begins to fail and the temporal profile of this failure, which results in exposure of the trench contents. The primary code time step is fixed at one year, while the printout interval is user-specified.

The resident intruder scenario assumes that an intruder digs into the disposal trench while building a residence. The individual will receive external exposure to the buried radionuclides due to time spent in the basement of the residence, which is assumed to have walls made of trench material. The user-specified length of residency, time in the assessment period when the residence is first occupied, and the composition of the initial trench inventory will all contribute to the dose from external exposure.

Farming the site after loss of institutional control is treated as a separate intrusion scenario. By farming the site a farmer will be affected by most of the hydrologic and atmospheric transport processes described above. In contrast to an off-site population, however, a larger portion of the farmer's food may consist of crops grown in the contaminated zone near the trench. The water used by the farmer for irrigation, drinking, and livestock may be taken from directly beneath the trench or from a nearby stream and thus contain a much higher concentration of radioactivity than water used by the off-site population. The farming process may also mechanically suspend contaminated soil in the atmosphere. Such mechanical suspension may impact both the farmer and a downwind population.

Annual-average concentrations of each radionuclide in environmental media (such as well water or the atmosphere) over the assessment period are used to calculate radionuclide concentrations in foodstuffs. Foodstuff information and human ingestion and breathing rates are utilized to calculate the annual average radionuclide intake per individual in the population by ingestion and inhalation. These intake data are used by the exposure and risk submodels to estimate dose rate and health risk. Each member of the population is assumed to eat the same quantities of food (vegetables, beef, and milk). These foods are assumed produced on the same fields and spray irrigated with contaminated water. Contaminated water is assumed drunk by beef and dairy cattle. The code user may independently specify the fractions of water taken from wells or streams and used for human consumption, for irrigation, or for livestock consumption. The health risk estimation methodology assumes that each member of the population is a member of a cohort that is exposed to constant, annual-averaged radionuclide concentration levels. The PRESTO-II model is most appropriately used as a screening model, and site-specific codes should be considered in cases where PRESTO-II numerical results fall close to reference values used for decision making.

The code contains algorithms to track both radionuclide amounts and radionuclide concentrations in well water. This approach permits the code to correctly conserve radionuclide mass. Radionuclides are first withdrawn from the well for human ingestion in an amount appropriate to the number of exposed persons specified, and remaining radionuclides may be withdrawn to be used for irrigating crops and watering livestock. A second reason to account for both amount and concentration of radionuclides at the well is to insure that the amount withdrawn at the well (based on the calculated concentration at the well) does not exceed the amount available. As a result of this calculation, the dose and risk calculated for a single individual may exceed the dose and risk calculated for individual members of a large population taking water from a well.

PRESTO-II, like any complex computer code, may be misapplied. Misapplication may consist of trying to apply the code to examine a site where one or more modeling assumptions are invalid, or of choosing values of input parameters that do not accurately reflect variables such as radionuclide inventory, site meteorology, surface and subsurface hydrology and geology, and future population demographics. One serious misapplication of the PRESTO-II methodology would be use of carelessly-chosen k_d values to determine hydrologic transport. Element-specific values of k_d vary widely as sites, chemical forms, and other waste components are changed. Futhermore, site climate and usage may change significantly with time, and predictions based on expected usage 1000y in the future contain considerable uncertainty.

Some release and transport scenarios, such as those necessary to consider major meteorological changes, mining of the trench contents, in-situ combustion of trench wastes, and intrusion and radionuclide transport by burrowing animals or plant roots, are not considered in the PRESTO-II model and code. The user must make significant changes to the code and the input data in order to consider those scenarios. If such mechanisms are added to a version of the PRESTO-II model, the authors of this report would appreciate being informed, and will consider adding these capabilities to their version of the code for future distribution.

RESULTS AND DISCUSSION

Table 1 summarizes the simulation results of the dose and health effects for Barnwell site and Koteyli site associated with the radionuclide data set believed representative of the LLW disposal facility in Barnwell, South Carolina. These simulation results must be generally regarded as estimates based on the assumptions about waste stream composition, disposal methodology, and site geography. The simulation results presented in Table 1 indicate that relative human radiological impacts for these sites vary according to the relative gross radioactivity of the streams, since most health effects are due to ingestion of surface water. Lower consequences are predicted for the Barnwell, South Carolina site, relative to the Koteyli, Turkey site but this conclusion results largely from the assumption that the Koteyli, Turkey site may eventually be used for farm land. If the Koteyli, Turkey site were not irrigated, predicted consequences for this site would be considerably lessened.

Table 1. Summary of lifetime fatal cancer risk and health effects for the Barnwell and Koteyli sites associated with the radionuclide data set believed representative of the LLW disposal facility in Barnwell, South Carolina

	Koteyli	Barnwell
Lifetime fatal cancer risk	$1.68\ 10^{-4}$	$5.6\ 10^{-6}$
Health Effects (Deaths/y)	$2.04\ 10^{-2}$	$5.53\ 10^{-4}$

The sum of all radiological impacts from exposure of the local population of 7033 persons to contaminants in all low-level waste disposal areas near Barnwell is $5.53\ 10^{-4}$ deaths/y. By comparison, the current annual death rate from cancer for a representative population of 7033 is 13 persons [7]. The waste disposal-associated death rate is less than the background cancer death rate by a factor of $4.2\ 10^{-5}$.

CONCLUSIONS

Preliminary simulations have been performed of release and transport of radionuclides from a proposed low-level radioactive waste disposal site in Turkey. We expect that the results of such simulations will be useful in providing estimates of the consequences of alternative disposal sites and practices.

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