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Studies on Disposal of Low-Level Radioactive Wastes in Turkey

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STUDIES ON DISPOSAL OF LOW-LEVEL RADIOACTIVE WASTES IN TURKEY

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1. INTRODUCTION

The performance objectives of radioactive waste management include: (a) the protection of the general population from releases of radioactivity, (b) protection of individuals from exposures associated with inadvertent intrusions, (c) protection of individuals during operations, and (d) stability of the disposal site after closure. In order to achieve these objectives, procedures must be established for ensuring compliance with basic radiation protection criteria. Such compliance entails ensuring that population doses are as low as reasonably achievable (ALARA), while maximum individual radiation doses do not exceed regulatory limit values presented in ICRP 26 [1].

The Turkish Government is in the process of planning two nuclear reactors in Turkey. Studies have begun for improved control of low level wastes (LLW) in Turkey before establishment of these reactors. In this study, the PRESTO-II (Prediction of Radiation Exposures from Shallow Trench Operations) computer code [2,3] is used to assess the risk associated with the shallow land disposal of low level waste (LLW) in various sites in Turkey. PRESTO-II is a computer code developed under the United States Environmental Protection Agency, Department of Energy and Nuclear Regulatory Commission funding to evaluate possible health effects from radioactive releases from shallow, radioactive waste disposal trenches and from areas contaminated with operational spillage.

A preliminary simulation using the PRESTO-II computer code has been run for the site in Koteyli, Balikesir, Turkey [4]. 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.

2. DESCRIPTION OF THE MODEL

The PRESTO-II code is a versatile methodology for calculating risks to local and intermediate-range populations resulting from water and airborne transport of radionuclides. The PRESTO-II code tracks radionuclide transport through surface and subsurface pathways and human exposures through external exposure, inhalation, and ingestion. Doses and health risks, both genetic and stochastic, are computed.

The PRESTO-II computer code considers only one scenario per computer run. The scenario to be simulated may be structured by the user by changing values of user-specified parameters such as population size and location, distance of well, percent cap failure, resuspension rate, etc.

The PRESTO-PREP code [5] has also been written to assist the user in preparing PRESTO-II data sets. This code accesses radionuclide data bases to prepare a radionuclide data set in the proper format for reading by PRESTO-II.

The DARTAB code [6] is used by PRESTO-II as a subroutine to combine simulated radionuclide exposure values with dose and health risk factors to produce tabulations of dose and health risk.

3. ENVIRONMENTAL TRANSPORT PATHWAYS

Releases of radionuclides to the environment from nuclear facilities are either waterborne or airborne. Water from precipitation is the primary transport medium for radioactivity from LLW stored in shallow trenches. Radionuclides are transported from the site principally by surface water, groundwater, or windblown dust. 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 or wells. 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. Particulates can deposit on the ground surface or on vegetation through the processes of dry or wet deposition.

PRESTO-II allows the user to select human exposure scenarios including migration of radioactivity from the trench in hydrologic and atmospheric environmental pathways to food and drinking water, the presence of a resident intruder on the site, and farming of the site. Processes considered in calculating individual or population exposure include groundwater overflow and seepage, chemical exchange, trench cap erosion, stream dilution, and resuspension and atmospheric dispersion of contaminated soil followed by inhalation or deposition on crops and land.

4. DATA LIBRARY

There are basically three types of data that are needed to execute PRESTO-II. They are: (1) site-specific and radionuclide-specific data used in the transport section of the code for calculating radionuclide concentrations; (2) data used specifically by DARTAB for creating tabular output; and (3) dosimetric and health effects data.

5. DESCRIPTION OF THE SITES

Because there is no nuclear waste disposal site in Turkey, it is necessary to consider the consequences of waste disposal for sample situations. A sample situation is defined as the combination of a well-characterized waste stream, a specific disposal site and disposal mode, a sample set of site parameters which is used to simulate transport from the disposal site to the population that has potential risk, and a data base of exposure and health risk parameters which is used to evaluate consequences to the population of interest. In this study the Koteyli, Balikesir, site in Turkey is selected as a sample disposal site because of the availability of data which is used to run PRESTO-II. This sample situation was performed using the same radionuclide data set believed representative of the low level waste (LLW) disposal facility in Barnwell, South Carolina, and the results of the simulation have been compared with the results of the Barnwell site.

The Koteyli, Balikesir, site is in the southern Marmara region of Turkey. Precipitation, as snowfall, occurs mostly in the winter with a total mean of 0.723 m/y. The annual average temperature is 14.5°C and maximum annual temperatures is 43.7°C with an annual average relative humidity of 68%. The assumed irrigation rate of this site for farming operating is 0.25 L/m^2-h [8].

The Barnwell low-level radioactive disposal facility is located 8 km west of the town of Barnwell, South Carolina. The climate near Barnwell is relatively mild. The monthly temperatures range from 9°C to 27°C for January and July, respectively. Most of the annual precipitation occurs in the summer with a mean total of 1.13 m/y. Snowfall rarely occurs. The atmosphere around the site is considered to be relatively stable. The assumed irrigation rate for farming operation is 0.02 L/m^2-h [7].

6. METHOD OF SOLUTION

The PRESTO-II code tracks radionuclide transport through surface and subsurface pathways and human exposure modes through external exposure, inhalation, and ingestion. The code allows the user to select human exposure scenarios including migration of radioactivity from trench in hydrologic and atmospheric environmental pathways to food and drinking water and exposure to a resident intruder who lives on and who farms the site. 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 deposition on crops and land. The Dose and Risk Tabulation (DARTAB) [6] computer code is used as a subroutine of PRESTO-II to combine radionuclide exposure rate values with health risk factors to obtain tabulation of dose and risk values.

7. RESULTS AND DISCUSSION

The PRESTO-II computer code has been applied to obtain a preliminary estimate of maximum doses for selected release and exposure scenarios associated with a proposed LLW disposal site in Turkey [8]. Maximum annual exposure results of both Koteyli, Turkey, and Barnwell, South

Carolina, are compared in Table 1. The simulation results are presented in Figures 1-4. Figures 1 and 2 are the graphical representations of 1000-year annual average radionuclide concentrations in leafy vegetables and beef meat due to atmospheric deposition, and Figures 3 and 4 are the graphical representations of radionuclide concentrations in leafy vegetables and beef meat due to irrigation deposition. Using the same radionuclide data set, the Koteyli, Balikesir, Turkey, site annual intake by ingestion is higher than the Barnwell, South Carolina, site; however, values are approximately equal in the case of annual intake by inhalation. The Koteyli, Balikesir, Turkey, site is characterized by a higher irrigation rate than the Barnwell, South Carolina, site. As a result, the pathway of maximum risk is expected to be water-mediated radionuclide migration downward to the aquifer and subsequent horizontal transport to wells or surface seepage points.

It may be misleading, due to some of the arbitrary parameter choices made in describing release scenarios, to generalize about relative consequences of burying wastes in these different geographic regions. Nevertheless, there are lower health risks predicted for the Barnwell site relative to the Koteyli region in Turkey. This conclusion results largely from the assumption that the Koteyli site may eventually be used as farm land. If the Koteyli site were not irrigated, predicted consequences for this site would be lessened.

Results of these simulations suggest that there would be, by comparison to background death rates, little health impact associated with burying these wastes in a low-level disposal area at either site described in this study.

For example, 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 was simulated to be 5.53 10^{-4} deaths/y. By comparison, the current annual death rate from cancer for a representative population of 7033 in the United States is 13 persons [9]. The waste disposal-associated death rate is less than the background cancer death rate by a factor of 4.2 10^{-5} [9].

8. CONCLUSION

Preliminary simulations have been performed of release and transport of radionuclides from a proposed shallow-land radioactive waste disposal site in Turkey. Results of these simulations have been compared to the results of analogous simulations for the Barnwell, South Carolina, site now operating in the United States. Application of a documented methodology and computer code has permitted evaluation of a proposed disposal site by comparison with an operational site using standardized exposure scenarios.

The PRESTO-II methodology was used to obtain a preliminary estimate of maximum doses for selected release and exposure scenarios associated with the proposed shallow land disposal areas in Turkey. Cumulative doses and health risks were calculated for individuals and exposed populations. Such calculations were used to identify nuclides and scenarios that must be considered more carefully. Though no claim is made that this methodology is optimum for, or applicable to, all release scenarios, it is the authors' belief that it can be meaningfully applied to many, if not most, such scenarios.

Simulation results must be regarded as estimates. We have proposed to evaluate the uncertainties associated with the predictions of the PRESTO-II computer code, as functions of the precision with which input variables are known. The PRESTO-II, like any complex computer code, may be misapplied. Misapplication may consist of trying to apply code to examine a site where one or more modelling assumptions are invalid, or 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. Determination of the sensitivity of model results to variations in model input values indicate which parameters need to be known most accurately. The results of these simulations should be useful in providing estimates of consequences of alternative disposal practices. Studies are continuing to analyze other proposed sites in order to compare and evaluate suitable shallow LLW sites in Turkey.

Table 1. Simulated Radionuclide Intake (maximum annual) for Barnwell, South Carolina, and Koteyli, Balikesir, Turkey (pCi/y)

Nuclide	Annual Intake by Ingestion, Barnwell, SC	Annual Intake by Inhalation, Barnwell, SC	Annual Intake by Ingestion, Koteyli, Turkey	Annual Intake by Inhalation, Koteyli, Turkey
^{3}H	1.44 E-10	2.65 E-13	3.79 E-08	6.38 E-13
^{14}C	7.53 E+03	7.85 E-17	1.37 E-05	1.88 E-16
^{54}Mn	1.61 E-08	5.84 E-11	8.81 E-08	2.34 E-11
^{55}Fe	3.96 E-07	6.43 E-10	1.41 E-05	3.09 E-10
^{60}Co	2.00 E-06	4.93 E-09	4.28 E-05	2.41 E-09
^{63}Ni	2.27 E-07	1.87 E-10	5.44 E-06	7.84 E-11
^{65}Zn	1.58 E-08	1.86 E-11	9.09 E-07	1.23 E-11
^{90}Sr	3.97 E-08	2.61 E-11	1.52 E-07	1.61 E-11
^{99}Tc	2.75 E+05	1.66 E-15	8.51 E+06	3.97 E-15
^{109}Cd	1.11 E-11	3.81 E-14	1.31 E-10	3.76 E-14
^{125}Sb	8.75 E-12	2.50 E-14	1.11 E-10	1.26 E-14
^{134}Cs	1.85 E-07	4.44 E-10	3.50 E-06	1.64 E-10
^{137}Cs	2.52 E-06	5.52 E-09	4.54 E-05	2.05 E-09
^{141}Ce	4.08 E-13	2.95 E-15	2.13 E-12	1.10 E-15
^{144}Ce	4.92 E-13	3.85 E-15	2.54 E-12	1.42 E-15
^{210}Pb	1.17 E-10	4.03 E-13	4.59 E-10	1.53 E-13
^{226}Ra	1.05 E-11	1.08 E-14	2.59 E-10	4.38 E-15
^{232}Th	8.44 E-12	2.88 E-14	3.19 E-11	1.06 E-14
^{234}U	1.12 E-11	3.85 E-14	7.11 E-11	2.03 E-14
^{235}U	1.31 E-11	4.49 E-14	7.18 E-11	2.37 E-14
^{236}U	1.88 E-12	6.42 E-15	1.02 E-11	3.39 E-15
^{238}U	1.87 E-12	6.42 E-15	6.32 E-08	2.10 E-11
^{238}Pu	1.42 E-12	3.95 E-15	1.69 E-11	1.47 E-15
^{239}Pu	7.41 E-13	2.01 E-15	9.-2 E-12	7.79 E-16

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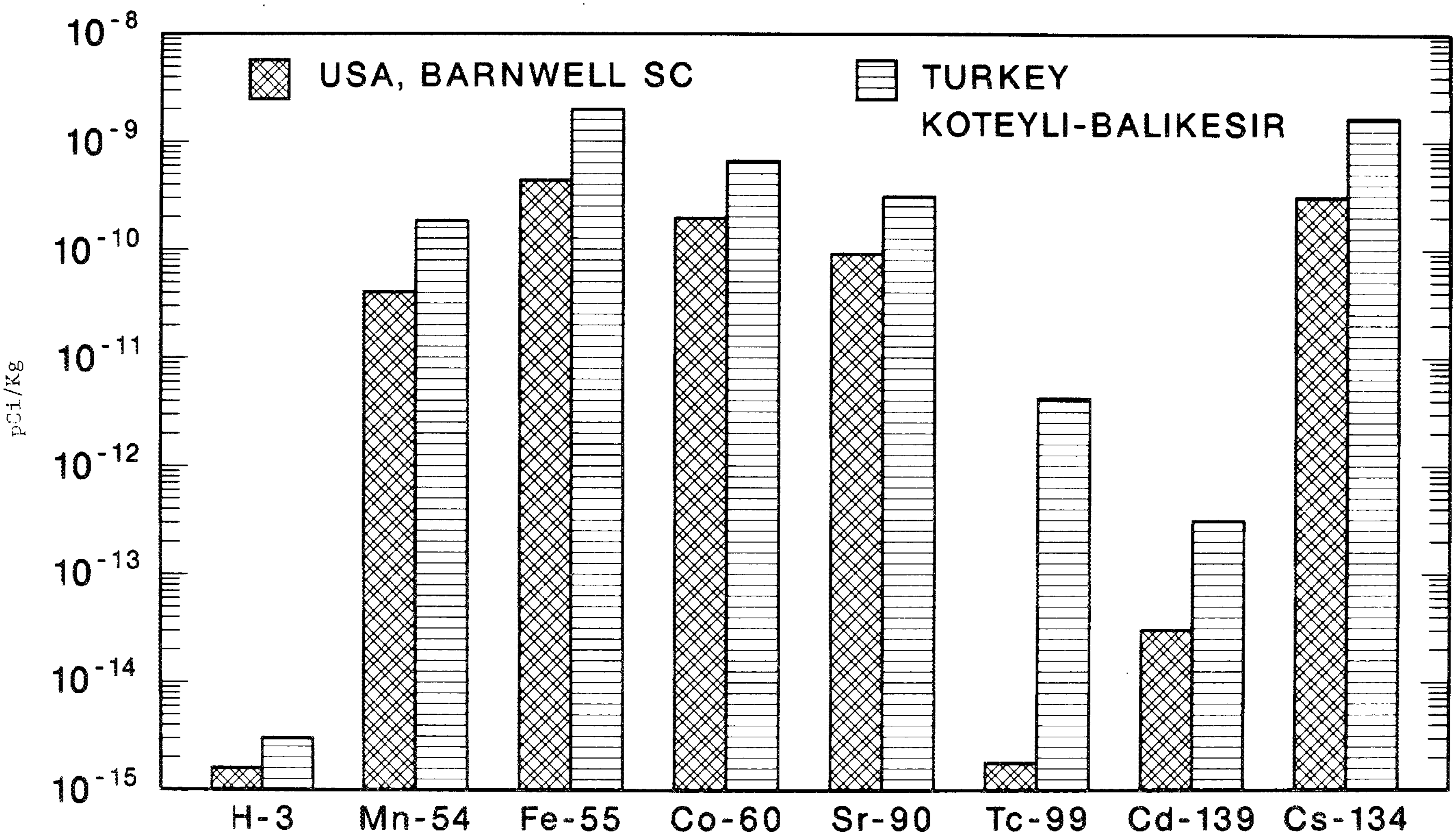

Figure 1. Radionuclide concentration in leafy vegetables due to atmospheric deposition

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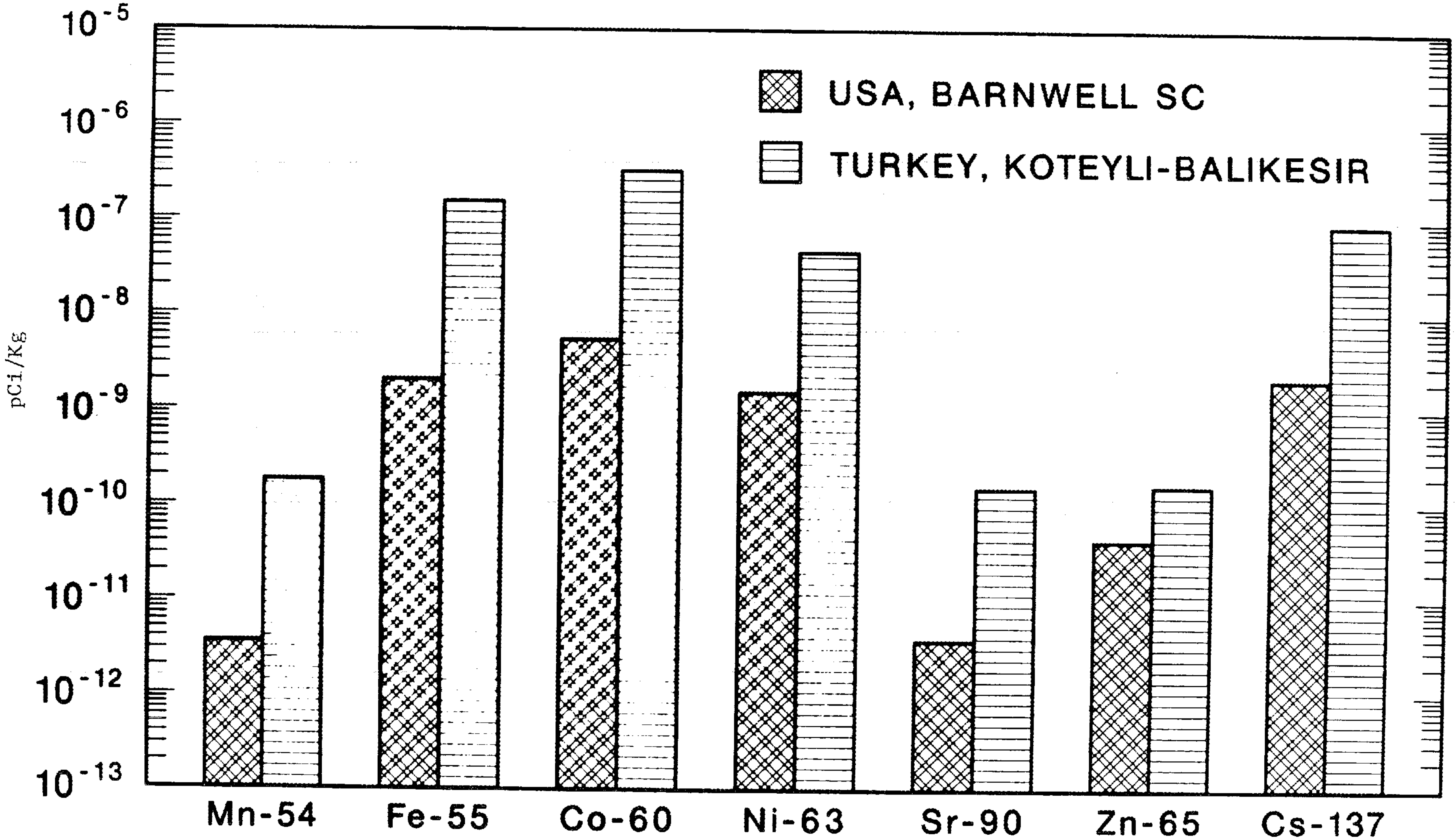

Figure 2. Radionuclide concentration in beef meat due to atmospheric deposition

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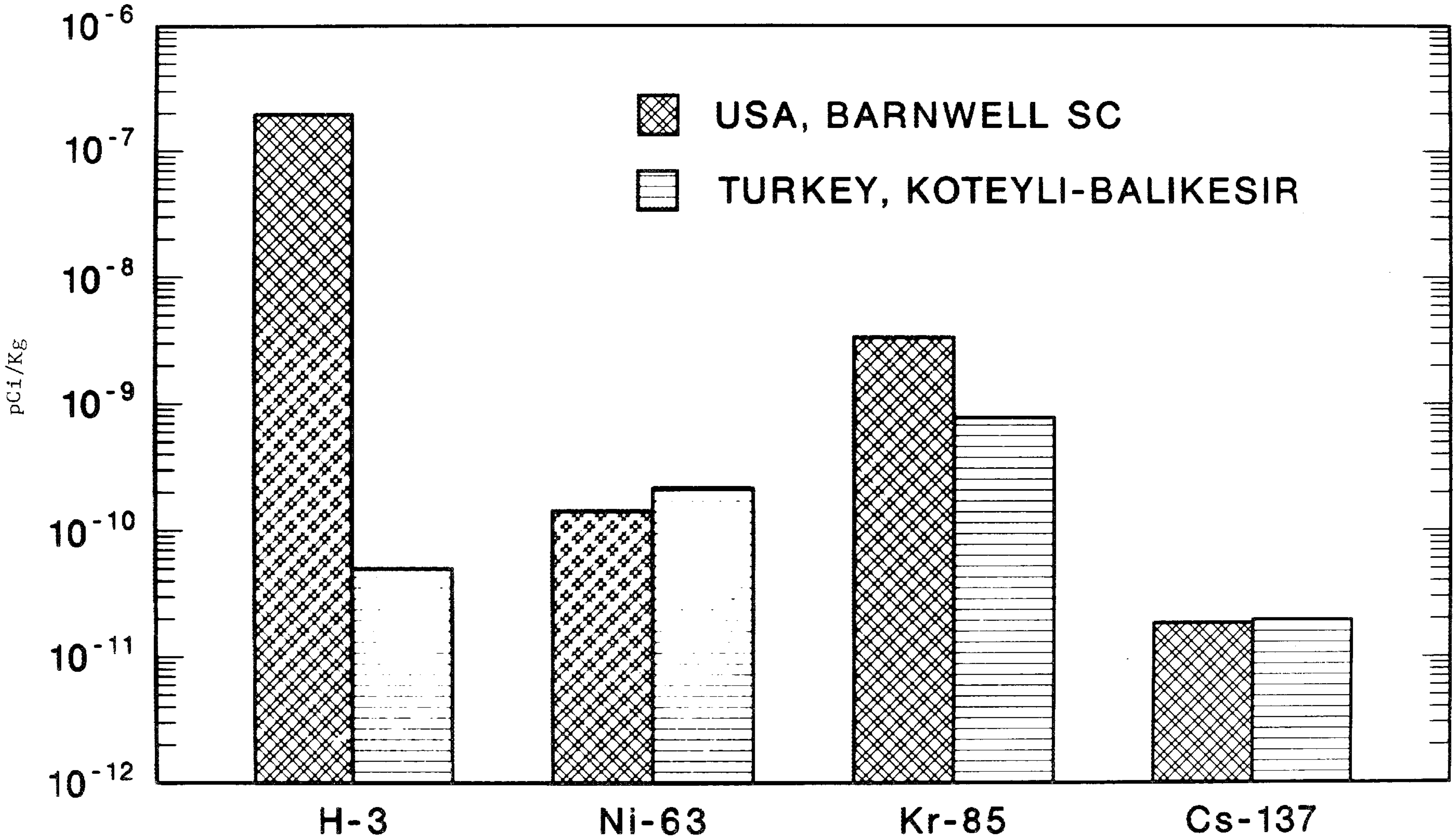

Figure 3. Radionuclide concentrations in beef meat due to irrigation (maximum individual exposure)

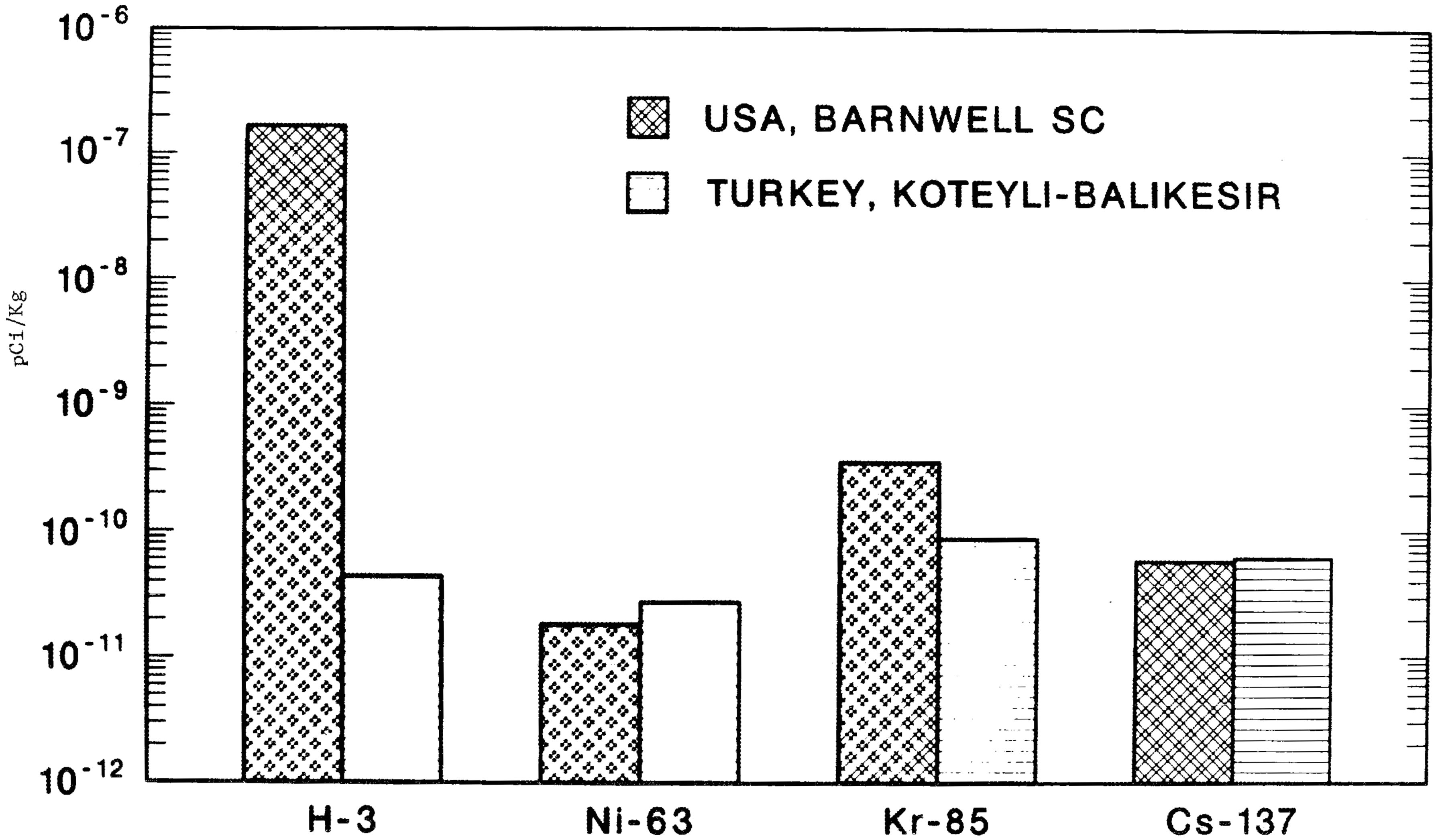

Figure 4. Radionuclide concentrations in cow's milk due to irrigation (maximum individual exposure)

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