THE ESTABLISHMENT OF COMPUTER CODES FOR RADIOLOGICAL ASSESSMENT ON LLW FINAL DISPOSAL IN TAIWAN

Ching-Chong Yang
CTCI Corporation
Taipei, Taiwan, R.O.C 10661

Huan-Tong Chen, Chein-Liang Shih
Institute of Nuclear Energy Research
Lung-Tan, Taiwan, R.O.C. 32500

Chiun-Shin Yeh, Chiao-Ming Tsai
Radwaste Administration, ROCAEC
Taipei, Taiwan, R.O.C. 10772

ABSTRACT

For final shallow land disposal of Low Level Waste (LLW) in Taiwan, an effort was initiated to establish the evaluation codes for the needs of environmental impact analysis. The objective of the computer codes is to set up generic radiological standards for future evaluation on 10 CFR Part 61 "Licensing Requirements for Land Disposal of Radioactive Wastes".

In determining long-term influences resulting from radiological impacts of LLW at disposal sites there are at least three quantifiable impact measures selected for calculation: dose to members of the public (individual and population), occupational exposures and costs. We will first focus on the radiological impacts by processing the LLW under the circumstances which already exist in Taiwan. The computer codes are from INTRUDE, INVERSI and INVERSW of NUREG-0782 (1), OPTIONR and GRWATRR of NUREG-0945 (2). They are both installed in FACOM-M200 and IBM PC/AT systems of Institute of Nuclear Energy Research (INER).

The systematic analysis of the computer codes depends not only on the data bases supported by NUREG/CR-1759--" Data Base for Radioactive Waste Management, Volume 3, Impact Analysis Methodology Report" but also the information collected from the different exposure scenarios and pathways. The sensitivity study is also performed to assure the long-term stability and security for needs of determining performance objectives.

INTRODUCTION

From the first operation of experimental reactor at National Tsing Hua University in April 1961, the radioactive wastes began to be generated. Until Dec. 1986, it's estimated that there are 70,000 drums of waste produced from industry, hospital, research institution and nuclear power plant, etc. Due to about 20 years interim storage period of Low-Level Waste (LLW) in Lan-Yu of Taiwan , the final disposal of LLW has become more important and must be designed detailed in advance to fulfill the future licensing requirements. The safety and radiological impacts should be confirmed before getting the proper operating licenses.

The Radwaste Administration (RWA) of ROCAEC was established in 1982 and responsible for storage and disposal of LLW. And the INER Staff have proposed an overall scope for disposing the LLW (3). Each phase has been carefully arranged since last year. There are three principal purposes for the scope developed:

- Establish general requirements for the progress of whole disposal plan of LLW.
- Establish the logic consequences of each step to combine all the available resources and to provide abundant information which have been collected.
- Establish the administrative and procedural requirements which ROCAEC will follow in licensing the land disposal of LLW.

For most of the LLW which is generated in Taiwan, the disposal process consists of three steps: processing and packaging; transport; and disposal. Therefore, for the establishment of computer codes, the exposure scenarios and pathways should be revised in detail according to the natural and special environments in Taiwan. The computer codes are installed in IBM PC/AT system in order to make more efficient and rapid evaluation.

The sensitivity study will be performed by considering the variance of important parameters such as retardation factor, percolation-infiltration factor and dispersion factor, etc. The disposal technology can be improved by better analysis of engineering or natural barriers to prevent and to restrict the long time release of radioactive waste.

EXPOSURE SCENARIOS AND PATHWAYS SELECTION

Pathway Analysis

To fulfill the licensing requirements of LLW shallow land disposal sites in Taiwan, the selection of long-term radioactive exposure scenarios is necessary. In this study the selecting procedures are not only based upon NUREG-0945 but also referred to the special cultural and geological circumstances in Taiwan.

Each scenario consists of complicated exposure pathways and such combination represents a complex series of interactions which are influenced by specific parameters such as waste properties, disposal characteristics, and operational procedures. Due to the possible transportation of radionuclides in the future, the potential exposure pathways can be generalized into following groups:

- Human Intrusion

Construction

Agriculture

Discovery

Deep Drilling

Touring

- Influences from surface and ground-water

Direct Radiation

Ingestion by all possible pathways

Inhalation from evaporation of contaminated surface water

- Erosions

Erosion by wind

Erosion by rain

Erosion by living creatures

By comparing and combining all the potential exposure pathways in Taiwan, a diagram of exposure pathways can be represented in Fig. 1. This diagram includes both the scenarios shown in NUREG-0945 Appendix C and the different environments such as sea water contamination, concentrated population, ...etc. It can predict nearly all the potential exposure pathways as possible.

To consider the carriers of radioactive materials, the radiological consequences can be simplified and summarized as follows:

- From Air

Inhalation of the contaminated air

Direct gamma exposure from the contaminated air

Ingestion of all the food products contaminated by air

- From Soil

Inhalation of the resuspended dust from ground surface

Direct gamma exposure from the deposited dust

Ingestion of all the food products contaminated by soil

- From Water (Including sea water)

Direct gamma exposure directly from water

Consumption of contaminated water or food products which contaminated by water

The possible exposure uptake pathways can be described in Table I and the structure includes important events within our imagination.

Pathway Dose Conversion Factors (PDCFs)

The concepts of PDCFs developed in NUREG-0782 can really simplify the complicated exposure events and perform radiological impacts. Since the sea water pathways are added in leaching and migration scenario, the model should be revised to acccord with the existing circumstances in Taiwan. The surrounding sea is considered as a volume source for diving and half-volume source for boating or other activities above sea. This combination helps to provide conservative guidelines for an island which is occupied by concentrated population and owns valuable ocean resources. Each PDCF represents an identical combination of uptake pathways (Table I). The effort of grouping pathway components facilitates the development and use of computer code to calculate the total PDCFs.

In order to calculate PDCFs, some radionuclide independent parameters are being utilized. These parameters have been experienced a broad survey that the values exist in Taiwan are quite different from which in U.S. and Japan (Table II). They are introduced to the computer program as the input parameters. Thus the calculating procedures help to obtain more practical and useful PDCFs values applied in dose estimation.

PDCFs are sets of grouping parameters of basic Dose Conversion Factors (DCFs). They contribute the generalized but rather reasonable operating processes for dose impacts simulation. It is multiplied by the radionuclide concentrations at the biota access locations (Ca) to obtain the human exposures.

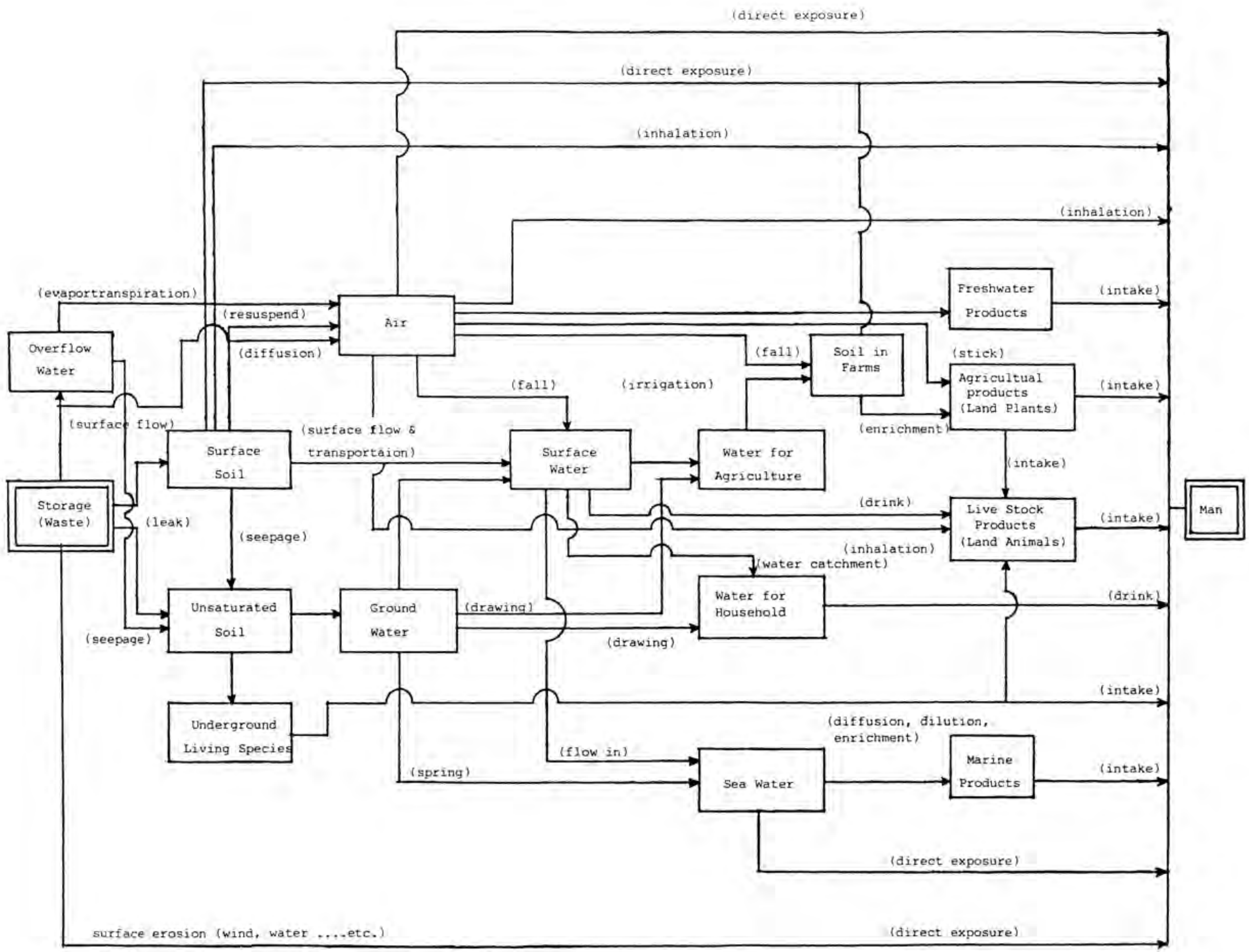

Fig. 1. Modified Exosure Pathways Undertaken for Assessment (4).

TABLE I

Details of Uptake Pathways (1)

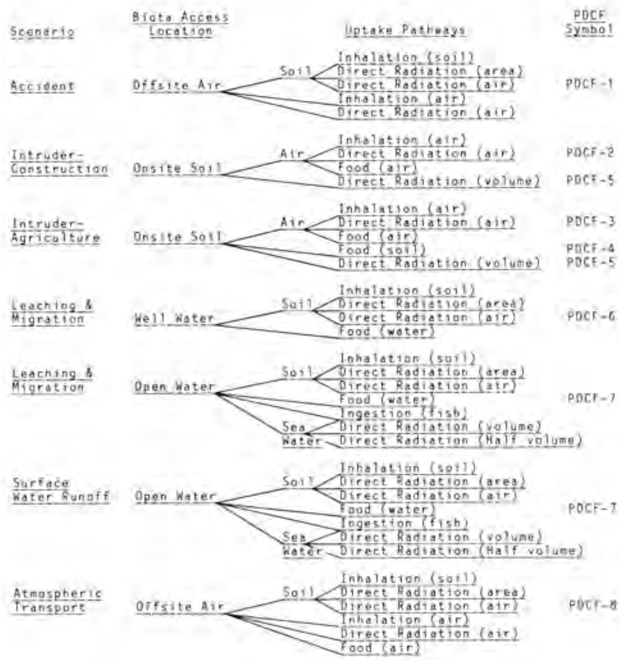

TABLE II

Parameters Adopted for Calculation (5)

Definition	USA	TAIWAN	JAPAN
Crop Yield per unit area	1 kg/m**2	1.08	23
Soil Density	1600 kg/m**3	1600	2630
Consumption of plants by man	190 kg/year	129	36.5
Consumption of plants by animals	50 kg/day	45	
Consumption of animals by man	95 kg/year	51.7	
Consumption of milk by man	0.3 l/day	0.1	0.6
Consumption of water by beef cattle	50 l/day	36	
Consumption of water by milk cows	60 l/day	45	
Consumption of water by man	370 l/year	370	
Consumption of fish by man	6.9 kg/year	35.1	73
Consumption of seafood by man	1.0 kg/year	28.0	21.9
Resuspension factor	8.5E-9 1/m		1.0E-7
Inhalation rate of man	8.0E+3 m**3/year	6200	7300
Areal mass available for resuspension (top 1 cm of soil)	16 kg/m**2		
The fraction of initial activity deposited as fallout or contaminated water that is retained by foliage	0.25		
Irrigation rate	3.7E-3 m**3/m**2-day	1.43E-3	2.1E-3
Fraction of activity deposited on foliage removed per unit time by weathering mechanisms	4.83E-2 1/day		
Fraction of activity deposited in the root zone removed per unit time	7.6E-4 1/day		
Settling velocity for elements			
other than iodine	8.0E-4 m/sec		
for iodines	1.0E-2 m/sec		
Mass of soil in root zone	240 kg/m**2		450

ESTABLISHMENT OF COMPUTER CODES

Program Survey

To provide quantitative measurements about the radiological impacts for licensing requirements, the development of computer codes is necessary for assessing needs. The basic computer programs are derived from NUREG-0782 (INTRUDE, INVERSI and INVERSW) and NUREG-0945 (GRWATRR, OPTIONR). We install all the program sources and data files directly in FACOM-M200 system for dose and cost estimation. Then we transfer all the computer programs to IBM PC/AT system. Sources are revised and some important parameters are adapted in accordance with the future environments in Taiwan.

The long-term performance of disposal system is emphasized in the impact analysis performed in the environmental impact assessment. The long-term performance may be quantified through potential radiological impacts and long- term socioeconomic impacts. Program for calculating PDCFs is also installed in IBM PC/AT system and separated into two options. One is for interactive operation if special or modified dose conversion factors are provided. The other is for reading a data file which includes all the basic dose conversion factors.

Program Function

There are six program sources (INTRUDE, GRWATRR, OPTIONR, INVERSI, INVERSW and PDCF) utilized for dose impact analysis. The structure is shown in Fig. 2 and functions of the first five programs are described as follows:

- INTRUDE:

There are four basic scenarios considered for potential intruder exposure. They are defined as intruder-construction, intruder-discovery,intruder-agriculture and intruder-well. The intruder-well scenario will be considered in GRWATRR code. INTRUDE program performs the radiation estimation for potential exposures accepted by inadvertent intruders and provides the ICRP weighted exposure as an indicative of the total impact of exposure.

- GRWATRR:

There are four basic scenarios considered for exposure from potential ground-water migration. They are defined as boundary-well , intruder-well,population-well and population-surface water. GRWATRR program performs an assessment of the impacts from ground-water migration of radionuclides.This code calculates human organ doses as a function of time after closure of the disposal facility.

- OPTIONR:

The previous two codes, INTRUDE and GRWATRR, concentrate on the long-term radiological impacts. OPTIONR program can perform all the impact measures other than intruder and ground-water impacts. The land use, energy consumption and cost evaluation are also achieved in this program analysis.

- INVERSI:

This program performs the evaluation of the maximum average concentrations of intruder scenario. It is used to calculate the maximum exposure limits under appropriate radiological guidelines and various disposal technology indices.

- INVERSW:

This program performs the evaluation of the maximum average inventories of ground-water scenarios. It is also used to calculate the maximum exposure limits under various geological circumstances such as different percolation and retardation characteristics.

CASE STUDY AND SENTIVITY ANALYSIS

Case Study

The purpose of case study is to ensure long-term safety and environmental protection and to minimize the degree of social commitment in the shallow land disposal of LLW. In evaluating the level of safety which should be achieved, the following components need to be identified:

- Protection of occupationally exposed workers and the public during disposal processes
- Long-term environmental protection
- Protection of an inadvertent intruder
- Long-term commitment of social and natural resources

The results of case study may provide a simple but correct prediction of doses received under specific disposal conditions. In response to the simplified evaluation here, four cases according to NUREG-0945 are also chosen for numerical analysis as representatives:

- Base case (B)
- No action case (N)
- Part 61 case (P)
- Upper bound case (U)

The geological environment is based upon the rainy site with sandy soil and faster ground-water velocity. This condition will make better approximation since it's similar to the environmental properties in Taiwan. The calculation results not only provide the radiological dose impacts but also offer a reference tool for setting up the ideal dose

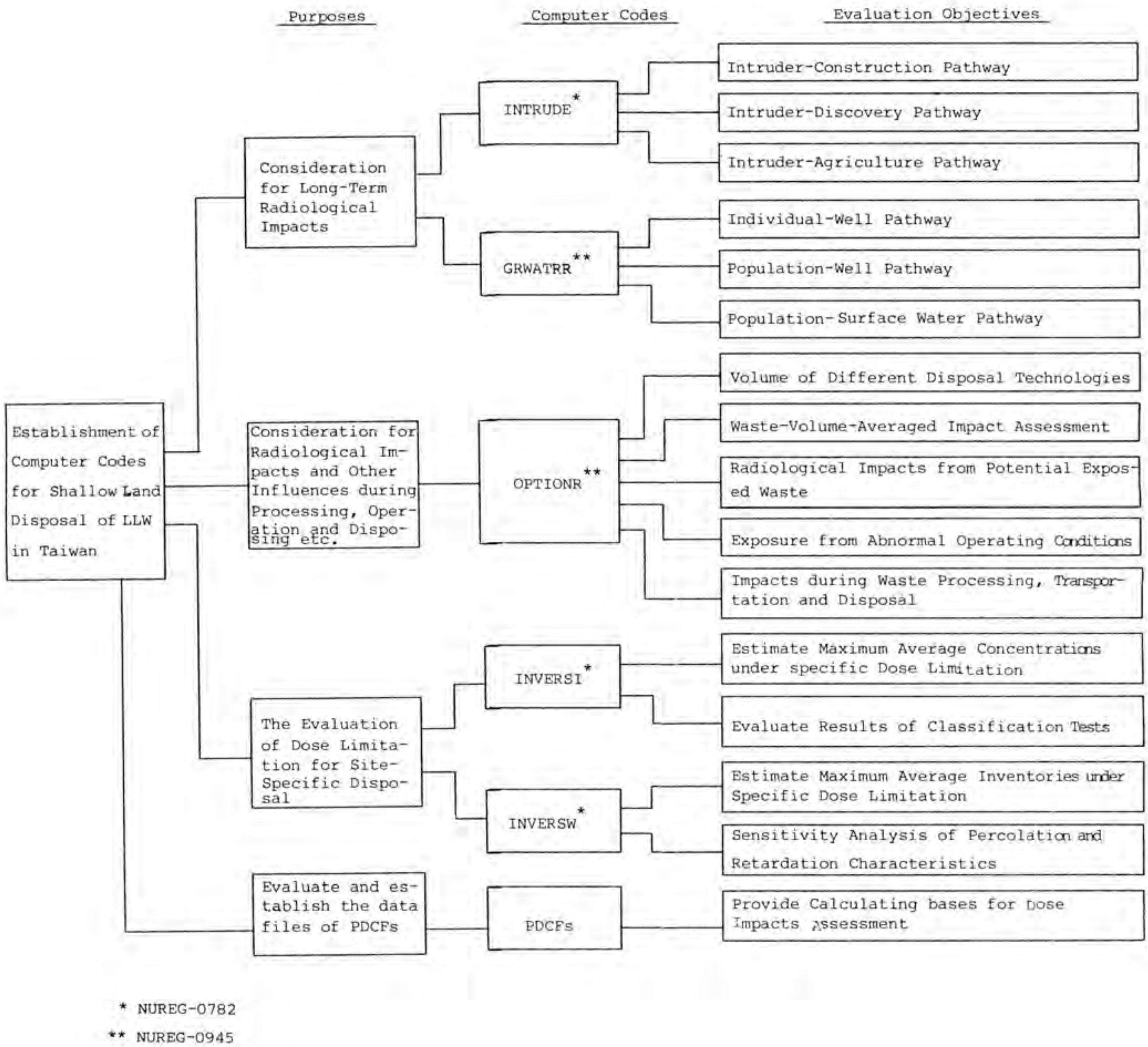

Fig. 2. Structure of Computer Codes.

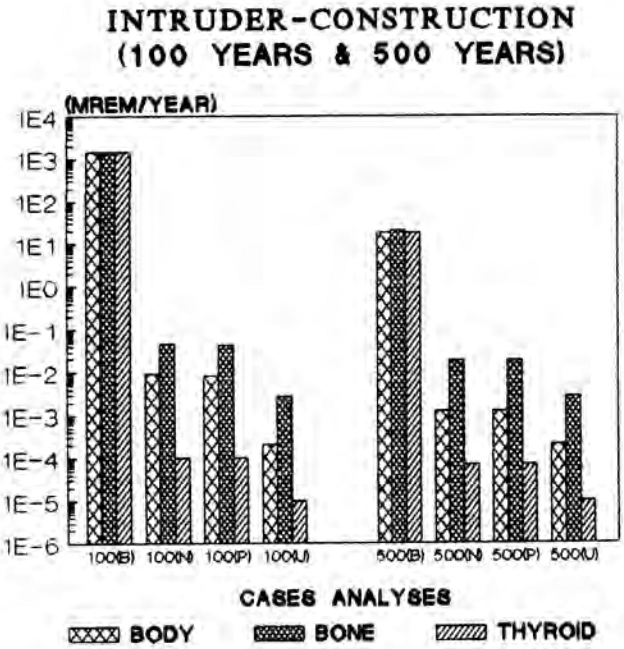

Fig. 3. Dose Distributions for Intruder-Cosntruction.

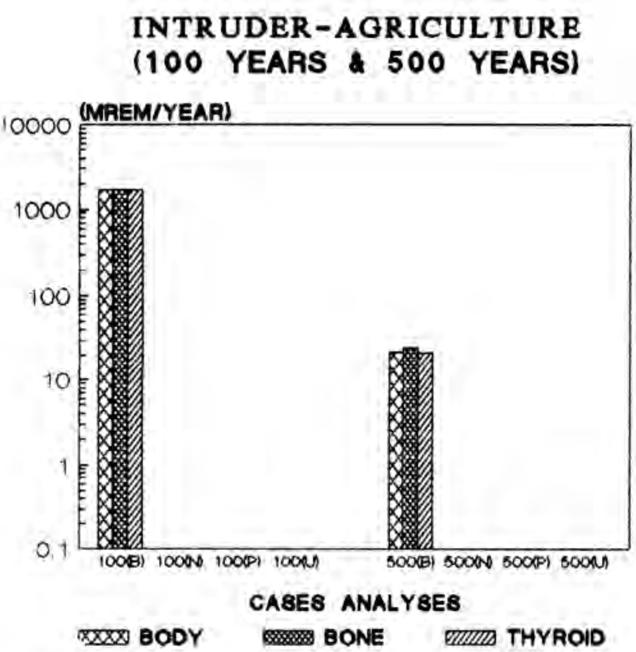

Fig. 4. Dose Distributions for Intruder-Agriculture.

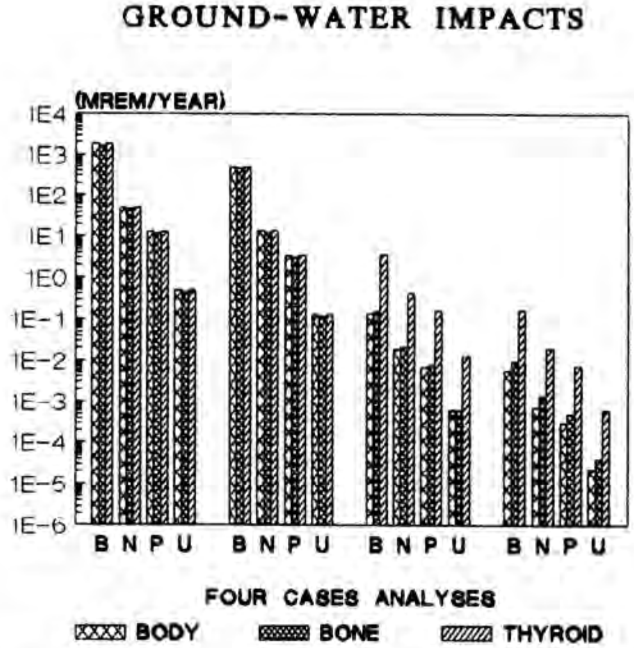

Fig. 5. Dose Distributions for Ground-Water Impacts.

limitations. For long-term exposures, intruder and ground-water impacts are important for assessment. Three organs are chosen for evaluation because the accumulated doses are significant. The institutional control times for intruder dose calculation are selected as 100 years and 500 years.

The dose distributions of intruder and ground-water are shown in Fig. 3, Fig. 4 and Fig. 5. The general explanations of the four cases analysed are described as follows:

- Intruder-Construction:

The exposure doses of different cases are primarily based upon the various disposal technology indices. For base case, institutional control periods of 100 years and 500 years may result in different order of received doses.But for upper bound case, they almost result in same exposure doses. From the three chosen organs, doses accepted by bone may cause higher impacts than others.

- Intruder-Agriculture:

The only difference is that the contact with waste disposal cell is less than that of intruder-construction scenario. This condition causes the relatively low radiological impacts for no action case, part 61 case and upper bound case.

- Ground-water Impacts:
- Four scenarios-Intruder well, Boundary well, Population well and Surface water are considered

in the calculating procedures. For base case and no action case, the maximum exposure doses occur in 40 year and 70 year of the disposal site. For the part 61 case and upper bound case, the maximum exposure doses occur in 6000 year and 10000 year. The high doses to thyroid in comparison with doses to body and bone are principally due to migration of I-129.

- Sensitivity Analysis

Sensitivity analysis is a methodology which involves perturbing each parameter of a model by a small amount while leaving all other parameters at selected values. Those have the greatest influence on the prediction values are chosen as the sensitive parameters for evaluation . A sensitivity analysis can be performed by considering the maximum, minimum and middle value of each possible parameter. The Sensitivity Index (S) is defined by Eq. (1) (6):

$$S = 1\text{-}Cmin/Cmax \quad (1)$$

where Cmin and Cmax represent the maximum and minimum values of computer outputs. For the analysis of sensitivity parameters in Taiwan, several important items are first considered. The results of primary sensitivity analysis are shown in Table III.

CONCLUSIONS

For the establishment of future disposal site, the computer codes for radiological assessment on LLW final disposal are important. The generic standards for disposal site evaluation are determined by the information provided by the computer analyses. Modification of exposure scenarios, installation of proper computer programs and determination of special cultural and geological circumstances in Taiwan will provide a sound basis for development of the sophisticated disposal concepts and technologies in the future.

The purpose of setting up computer codes in IBM PC/AT system is to obtain rapid estimation of radiological and socioeconomic impacts. The sensitivity analysis will continue in order to decide the important parameters for future disposal of LLW in Taiwan.

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TABLE III

Ranking of Input Parameters by Using Sensitivity Index

Parameters	Ranking order	Sensitivity index (x1.E-3)	The Most sensitive organ
FMF (C-14)	1	927.67	body
RET (Ni-59&Co-60)	2	890.51	thyroid
PRC	3	872.67	bone
FMF (H-3)	4	727.75	lung
RET (Sr-90)	5	688.44	thyroid
BAS	6	688.19	thyroid
FMF (Pu-239)	7	657.69	bone
RET (C-14)	8	649.41	lung
FMF (Sr-90)	9	647.81	bone
RET (H-3)	10	635.59	kidney
TTM	11	629.49	bone
RET (Cs-137)	12	592.42	thyroid
FMF (Am-241)	13	569.80	kidney
QFC	14	526.31	body
RET (Tc-99&I-129)	15	481.39	lung
FMF (U-238)	16	445.54	bone
FMF (Cs-137)	17	321.77	liver
FMF (Tc-99&I-129)	18	223.50	G-I tract
TPC	19	66.50	liver

Notes:
BAS: Waste radionuclide concentration
PRC: Percolating infiltration
TTM: Ground-water travel time
QFC: Dilution factor
TPC: Peclet number
RET: Radionuclide retardation coefficient
FMF: Radionuclide leachate partition ratio

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